AGRO-ECOLOGICAL RANGELAND CONDITION ASSESSMENT OF EXTENSIVE LAND-REFORM PASTORAL FARMING SITES IN THE BLOEMFONTEIN MAGISTERIAL AREA POST TWO WET SEASONS PRECEDED BY DROUGHT

By

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DECLARATION

I, Thabiso Emmanuel Mokhesengoane, declare that the thesis hereby submitted by me for the PHILOSOPHIAE DOCTOR (SUSTAINABLE AGRICULTURE) degree at the University of the Free State is my own independent work and has not previously been submitted by me at another university/faculty.

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Thabiso Emmanuel Mokhesengoane Date

DEDICATION

I dedicate this work to my late grandparents Mr. Sello John and Mrs. Tselane Selina Mokhesengoane who were passionate about education.

ACKNOWLEDGEMENTS

To my supervisors, I reiterate the words of Sir Isaac Newton “Indeed if I have seen further in life, it is because I stood on the shoulders of the giants”. To my mother Palesa Pretty “Ausi Ma-Thabiso” thank you for not giving up on me even though I gave you so many reasons to do so. To my family, my wife Lesimole “Mpai” and the boys Kananelo and Thabiso Junior thank you for your understanding, unwavering support and for always being my pillars of strength during tough times. Last but not least, a big thank you to Bloemfontein land-reform farmers for their participation in this research project. To Almighty God be the glory.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANC	African National Congress.
ANOVA	Analysis of Variance
C	Carbon
Ca	Calcium
CEC	Cation Exchange Capacity
CH_4	Methane
CO_2	Carbon dioxide
DAFF	Department of Agriculture, Forestry & Fisheries
DLA	Department of Land Affairs
DREA	Department of Rural Economy and Agriculture
EA	Exchangeable acidity
EC	Electrical Conductivity
EIV	Ecological Index Value
FAO	Food and Agriculture Organization
H_2O	Water
Ha	Hectare
K	Potassium
KCl	Potassium Chloride
LRAD	Land Redistribution for Agricultural Development.
LSUs	Large Stock Units
Mg	Magnesium
N_2O	Nitrous oxide
Na	Sodium
P	Phosphorus

PLAS	Proactive Land Acquisition Strategy.
SADC	Southern African Development Community
SAR	Sodium Adsorption Ratio
SDGs	Sustainable Development Goals
SLAG	Settlement /Land Acquisition Grant
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
T. Triandra	*Themeda triandra.*
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
WSWB	Willing seller- Willing buyer.
Zn	Zinc

ABSTRACT

The study aimed to provide holistic guidance for future sustainable livestock production in the semi-arid rangelands of the Bloemfontein magisterial area for extensive land reform livestock farmers. It aimed to compare rangeland condition per land reform farm and between land reform farms, and to establish correlations between rangeland condition, soil chemical properties and managerial inputs on sampled land reform farms. The study also aimed to use land reform livestock farmers' decisions on livestock stocking rates to establish their production efficiency and to establish correlations between rangeland condition and soil carbon. Nine extensive land-reform livestock farms out of a total of twenty-nine land-reform farms which participated in the stocking rate study during the 2018/2019 drought were sampled using a non-probability snowball sampling procedure. A multi-methodological approach, namely, qualitative and quantitative methodologies, was employed to investigate the research topic. Structured questionnaires were used to determine profiles of rangeland managers, farm management information, and sound sustainable livestock management information, including current stocking rates on all nine sampled farms. The rangeland degradation gradient method for the semi-arid rangelands of the central Free State province region was used to determine rangelands condition scores together with the wheel point apparatus tool on two camps of each sampled farm. Soil samples were taken from each camp at the beginning of the rangeland condition assessment transect line, in the middle and end, at 20 cm depth, using the soil auger tool. The descriptive statistics, average scores, and standard deviations were calculated using analysis of variance (ANOVA), Pearson correlation, and t-tests to compare the average values. Statistical Package for Social Science (SPSS) version 28 was used to analyse quantitative data. Metabolic body weights were used to calculate large stock units. The study recorded a significant relationship ($p < 0.05$) between soil carbon (C) and rangeland condition, with three times more C on a good rangeland condition score of >60% when compared to a poor rangeland condition score of <20%. A strong relationship ($p < 0.05$) was also found between a production plan and higher average rangeland condition scores. However, no significant relationship ($p > 0.05$) was found between other soil chemical properties and rangeland condition, except for the positive trends recorded on soil phosphorus

(P) and soil pH levels and a significant relationship between soil carbon (C) and rangeland condition. On the other hand, no relationship ($p > 0.05$) was found between rangeland condition scores and other variables. The highest average rangeland condition score was 77%, and the minimum average rangeland condition score recorded amongst farms was 21%. Thus, the study concludes that the implementation of science-based knowledge on both stocking rates and rangeland management for extensive land-reform livestock farmers in the Bloemfontein magisterial area is paramount and valuable for climate change impacts mitigation and sustainable livestock productivity. Furthermore, the study recommends investigating carbon market participation as an incentive for farmers to implement sustainable ecological practices and the practicality of incorporating variable stocking rates into extensive livestock management systems.

Keywords: Rangelands assessment, Land-reform, Extensive pastoral farms.

CHAPTER 1
INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 INTRODUCTION

Rangelands are generally defined as parts of the world where wildlife and domestic livestock graze on the natural vegetation (Squires, 2010; Craggs, 2017). However, according to Shackleton et al. (2001) and Dovie et al. (2002), rangelands also play an important role as the source of other natural resources, which include fuel wood, thatching grass, wild fruits, edible herbs and medicinal plants and all these are harvested for both household use and sale. Since it is clear that these rangelands have constantly been subjected to one form of management system or another, the importance of sustainable rangeland management practices for sustainable pastoral farming cannot be over-emphasized.

“Pastoralism is defined as a production system in which 50% or more of the household gross income is derived from livestock or livestock-related activities” (Niamir-Fuller, 1998). Thus, pastoralism is a science of raising livestock, particularly small ruminants, cattle and camels as a primary means of survival.

Extensive pastoral/livestock farming systems are standard in Africa's vast open arid and semi-arid rangelands. A distinctive feature of these ecosystems is the variable annual average rainfall precipitation rate, leading to the differences in rangeland characteristics due to differences in water resource distributions. The latter led to the development of different rangeland management systems by pastoralists, which are custom-made for each geographical region, as the pastoralists adapt to trends such as new economic opportunities and utilization of the modern means of livestock farming (DREA, 2010). The following facts have greatly influenced the socioeconomic importance of extensive pastoral farming in Africa:

- Pastoral areas occupy about 43% of Africa’s land mass, albeit with significant variations between countries (FAO, 2018).
- Livestock or livestock-related economic activities contribute at least 5 to 100 per cent of the total GDP and cover 15 to 40 per cent of the added value in agriculture within the dry lands of Sub-Saharan Africa (De Haan, 2016).

- In general, pastoral areas are less suitable for crop husbandry, and livestock production remains the most viable opportunity to harness scarce biomass resources (Coppock et al., 2017).
- Over and above, there is clear evidence of rangeland degradation in recent years, resulting from human activities such as fuel wood collection and crop farming in the marginal areas (UNEP, 2000), including extensive livestock farming activities.

Nonetheless, according to Child and Frasler (1992) and Mitchell (2000), these grassland ecosystem areas cover 40-50% of the world's surface area, and Egoh et al. (2011) further confirmed that the grassland is home to approximately one billion people around the globe. However, the United Nations Convention to Combat Desertification identified rangeland degradation in arid and semi-arid grassland regions as a global phenomenon (UNCCD, 1995). The White Paper on Agricultural Policy (1984) pointed out that the South African natural rangelands are deteriorating tremendously (Du Toit et al., 1991). Thus, the deteriorating state of the natural rangelands can be attributed to human and non-human parameters. Essential human parameters, amongst others, include imprudent rangelands management practices such as higher or lower animal stocking rates; both extremes are detrimental to rangelands sustainability (Mokhesengoane et al., 2021), as they lead to over-utilization and underutilization of grazeable materials, and thus impacting rangelands species composition negatively. In contrast, non-human parameters include wildlife grass species preferences in unprotected rangelands and natural disasters such as droughts.

However, even though livestock production is central to the livelihood development of rural and farming communities, the implementation of research results regarding rangeland management and climatic variations is minimal, especially for the emerging livestock farmer's sector. This is despite the essential inarguable negative impacts of imprudent rangeland management practices and, to an extent, the effect of long-term climatic variations translating into droughts. The rangeland and forage science literature, thus, consistently agree that below-average annual rainfall impacts on rangelands cannot be attributed to the single below-average rainfall season but to preceding seasons thereof (Mokhesengoane et al., 2021).

Furthermore, Harper (1967) highlighted that in ecosystems with a recurrence of natural hazards such as droughts, populations and farmers are likelier to spend most of their time recovering from the hazard. The economic impact of droughts on productivity at the farm level leads to drastically reduced returns on investment, which poses a severe threat to the development of emerging livestock farmers' livelihoods (Van der Westhuizen et al., 2020). In recent years, this reality has become evident on grassland biome extensive livestock farmers, including semi-arid rangelands livestock farmers in the Bloemfontein Magisterial area in the central Free State province of South Africa.

Benkenstein (2017) highlighted that the recent droughts, which lasted for almost a decade in South Africa, are comparable in intensity with the most devastating catastrophic droughts human nature has experienced in the past fifty years. This predicament requires good rangeland management practices from extensive livestock farmers to effectively support natural adaptation of the semi-arid rangeland vegetation to maintain sustainable rangeland productivity. Thus, Iglesias et al. (2016) indicated that the continued vulnerability of poorly managed natural vegetation for extensive livestock grazing systems in semi-arid regions leads to negative socio-economic impacts. In addition, Fereja (2017) highlighted that increased pressure on natural resources due to the exponential human population growth and livestock numbers, coupled with poor rangeland management practices, worsens the intensity of land degradation. On the other hand, urbanization exacerbated by increased shelter needs for human beings as a result of population growth, expansion of cultivation fields and excessive defoliation, as well as livestock trampling impact, leads to the inability of rangelands to withstand the extreme climatic variations and natural hazards.

The world's exponential population growth is also emphasized by the United Nations (UN) as cited by the Food and Agriculture Organization (FAO) (2014), anticipating a sharp positive trajectory on global population growth from 7.2 billion to 9.3 billion in the year 2050. Furthermore, the latest Statistics South Africa Report confirms a population growth from approximately 54 million to 62 million people. In this regard, the importance of the Sustainable Development Goals (SDGs) document, which advocates for zero hunger and sustainable livelihoods through decent job opportunities, cannot be over-emphasized. Agriculture, particularly the livestock sector, becomes a critical role player in this regard, as it currently supports livelihoods development for millions of poor people in developing countries (Swanepoel et al., 2010), including South Africa. The sector caters for sustainable livelihood development and sustenance through its daily economic activities, ranging from primary livestock production, livestock transportation in between livestock farms and to different livestock marketing destinations such as livestock auctions, feedlots and abattoirs both nationally and internationally (Chaminuka et al., 2014). During climate change, the agricultural sector must increase productivity to support the increasing dietary demands of the growing population trends sustainably.

Nonetheless, it must be borne in mind that prudent rangeland management practices are paramount in ensuring sustainable and increased livestock productivity during this unprecedented climate change era. This will counteract climatic variation impacts leading to droughts with discrete developmental stages in nature, which are characterised by non-tangible structural evidence. The phenomenon is, thus, exacerbated in intensity by the frequency of incidences, which too often render the rural extensive livestock farming communities incapable of recovering from the devastating catastrophic impacts. Thus, Peshawar et al. (2017) reported that the re-occurrence of below-average rainfall incidents exposes farming communities to the irreversible risk of livelihood losses. Furthermore, Mathbout et al. (2018) confirmed that below-average rainfall and poor rangeland management practices have catastrophic consequences on agricultural productivity, ecological productivity, and cultural, social, and economic sustainability in many climatic regions dependent on rainfall. Implementing rangeland management practices that ensure the improvement of rangelands, mitigate the negative effects of droughts and increase productivity essential for the livestock industry. According to a study by Van der Westhuizen et al. (2020), livestock production increased during drought season with sustainable rangeland management practices compared to no rangeland management practices during a regular rainfall season.

According to Jones et al. (1990) and Davis-Reddy and Vincent (2017), the drought phenomenon is defined as a continuous period of extremely dry and hot weather characterised by a poor precipitation rate (Dai, 2011). Wardeh (1999) and Hao and Singh (2015), defined drought as a temporary recurrent phenomenon or an extended rainfall deficiency period in a geographical region. This yearly or seasonal dry spell phenomenon, influenced by climatic variation in arid or semi-arid zones, often negatively impacts poorly managed natural rangelands and livestock productivity. As the quality of rangeland resources and forage declines, livestock's vulnerability to diseases increases tremendously, leading to high livestock mortalities

(Mokhesengoane et al., 2021). Other scholars, such as Harrison and Shackleton (1999), have identified the African grasslands as highly resilient due to their ability to recover post-exposure to intensive grazing. Hence, in rangeland and forage science, resilient grasslands can recover and function efficiently by providing fodder, regardless of disturbances (Abel & Langston, 2001). Nonetheless, the opposing argument presented by Danckwerts and Stuart-Hill (1988), stated that the rapid recovery ability of semi-arid grasslands highly depends on sufficient grazing withdrawal periods post below-average rainfall reoccurrences. In addition, O'Connor (1995) highlights that the recovery ability of rangelands is highly dependent on the history of natural rangeland utilization, including grazing management practices employed before the onset of drought and during the drought period.

According to Bosch and Tainton (1988), the Karoo, Grasslands and Savanna biomes cover eighty-five per cent of the land surfaces in South Africa. As a result, they are the most essential areas for livestock production systems. Nonetheless, the grassland biome remains the most significant part of South Africa's beef-producing areas (Van Niekerk, 1996). The land cover type of the grasslands gives the grassland biome the advantage of being more suitable for livestock farming with specific reference to cattle and sheep compared to other biomes. However, Avenant (2019) highlighted that one-third of a grassland biome has already been transformed into other land uses such as cultivation and mining. Future rangeland degradations in the grassland biome as a result of imprudent grazing management practices, coupled with the catastrophic impact of the inevitable future drought occurrences, can profoundly impede the productive ability of the grassland biome.

According to Vogel (1994) and Hoffmann et al. (2001), the research literature, government policies and legislation have pointed out the relationship between climatic variations, rangeland management and desertification. Irrespective of the latter, the South African government is still reluctant to invest money in climate change impacts research, resulting in limited knowledge in the management of climate variation impacts. Furthermore, Avenant (2019) reported that the grassland biome of South Africa covers 32 534 079 ha (Hectares), of which available livestock grazing area is 21 560 559 ha grazed by 3 934 838 LSU heads. Meanwhile, in the Free State province, the grassland area amounts to 12 982 516 ha with an available grazing area of 8 538 734 ha grazed by 1 333 815 LSU heads. Despite the latter, the grassland biome remains more prone to the threat of rangeland degradation due to unsustainable rangeland management practices, including overgrazing and not having sufficient resting periods. Natural disasters, especially droughts and inappropriate land use practices, may exacerbate rangeland degradation.

Nonetheless, there is an increasing research interest by the scientific community on rangelands due to their ability to sequester carbon, as they cover approximately 30% of the ice-free global land surface (FAO, 2009). The latter seeks to reduce the rapidly disruptive greenhouse gases such as carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O concentration in the atmosphere, leading to global warming. According to IPCC (2007,2013) and MacCarthy and Zougmore (2018), the major contributors to increased atmospheric greenhouse gas concentrations are pastoralism, deforestation, crop farming, land use change, and industrial developments. However, according to Mgalula et al. (2021), restoration of degraded agricultural lands and improved rangeland management practices can significantly enhance carbon sequestration, which to an extent confirms the crucial contribution that can be made by good rangeland management practices in reducing greenhouse gas concentration in the atmosphere and related global warming risks. Rangelands are mainly utilized for livestock grazing purposes. Thus, if prudent grazing management practices are correctly followed, they can assist the root systems of grasses and shrubs to increase carbon C storage in the soil (Ma & Coppock, 2012).

Over and above rangeland scientists recommend that to ensure efficient and sustainable utilization of rangelands, stocking rates must always be below or at least equal to the grazing capacity of the natural veld when rangeland is in pristine condition.

However, the support from the department of agriculture and advisory services is central to land reform farmers' development. According to Bembridge (1990), agricultural extension is a crucial field addressing many social and economic farming-related aspects in rural communities. Furthermore, Zwane (2012) confirmed that agricultural extension, as a profession, has a role to play in rural development. However, despite all these, a study by Conrandie (2016) reported a knowledge deficit of 30% and 35%, respectively, in livestock husbandry and rangeland management on newly appointed agricultural extension professionals. These manifestations threaten the sustainability of livestock productivity, mostly on farms dependent on agricultural extension and related support services for guidance, namely extensive land-reform livestock farms, communal farms and commonages.

1.2 BACKGROUND OF THE STUDY

The inability of emerging livestock farmers to implement sustainable rangeland management practices leads to rangeland degradation and subsequent ripple effects on emerging livestock farmers' sustainable livelihood development. On the other hand, long-term impacts of climate variations defined as droughts in successive dry years (Bounejmate et al., 2004), combined with poor rangeland management, increasing fodder shortages and rangeland degradation intensity. According to Ndandani (2016), approximately twenty-five per cent of land owned by government and rural communities in South Africa is degraded. It is all the latter factors and urbanization due to population growth coupled with the reoccurrence of the inevitable El Niño/La Niño induced climatic variations of the recent years in South Africa, Free State Province and Bloemfontein geographical region in particular, that to an extent aggravates the inability of degraded rangelands to support sustainable extensive livestock farming activities and subsequently food security.

Maré and Willemse (2016) recorded an enormous catastrophic loss of 40,000 heads of livestock in Kwazulu-Natal due to poor rangelands management and below-average rainfall-induced challenges. At the same time, Mokhesengoane (2020) recorded an average devastating loss of 142.2 LSUs (Large Stock Units) amongst land reform farmers in the Bloemfontein area from October 2018 to January 2019. These mortalities increase drastically as farmers overgraze (Mokhesengoane et al., 2021). Poor rangeland management practices and below-average annual rainfall drastically reduce the ability of rangeland productivity and subsequently lead to increased susceptibility of livestock to diseases, which leads to low reproductive ability caused by a deficit in livestock dietary needs.

Excessive imprudent grazing practices and consecutive years of below-average rainfall, as observed by the researcher over the years of experience in the study area, affect the ability of rangeland plants to regrow the leafy area, which is crucial for photosynthesis and related processes leading to gradual change in rangeland composition. Herbivory, below-average rainfall and poor rangeland management decisions have profound underlying effects on rangeland composition and vegetation production (O'Connor, 1995). Thus, Naidoo et al. (2013) highlighted the immediate need for Southern African Development Community (SADC) region countries to prioritize rangeland management practices, which will mitigate the impacts of climate variability and, therefore, support rangelands in this region to be resilient against climatic variations. However, with sustainable rangeland practises, Van der Westhuizen et al. (2020) demonstrated that the impact of climatic variability could not only be mitigated, but livestock production levels could also be high during periods of below-average rainfall when good rangeland management practices are applied.

During 2014/2015, the Southern African regions were affected by the El Niño event, and the impact became intense in 2015/2016 (Benkenstein, 2017). According to Rembold et al. (2016), the El Niño impact became evident when the first summer rains were delayed for several months. The rainfall remained significantly below average, with extremely high summer temperatures recorded.

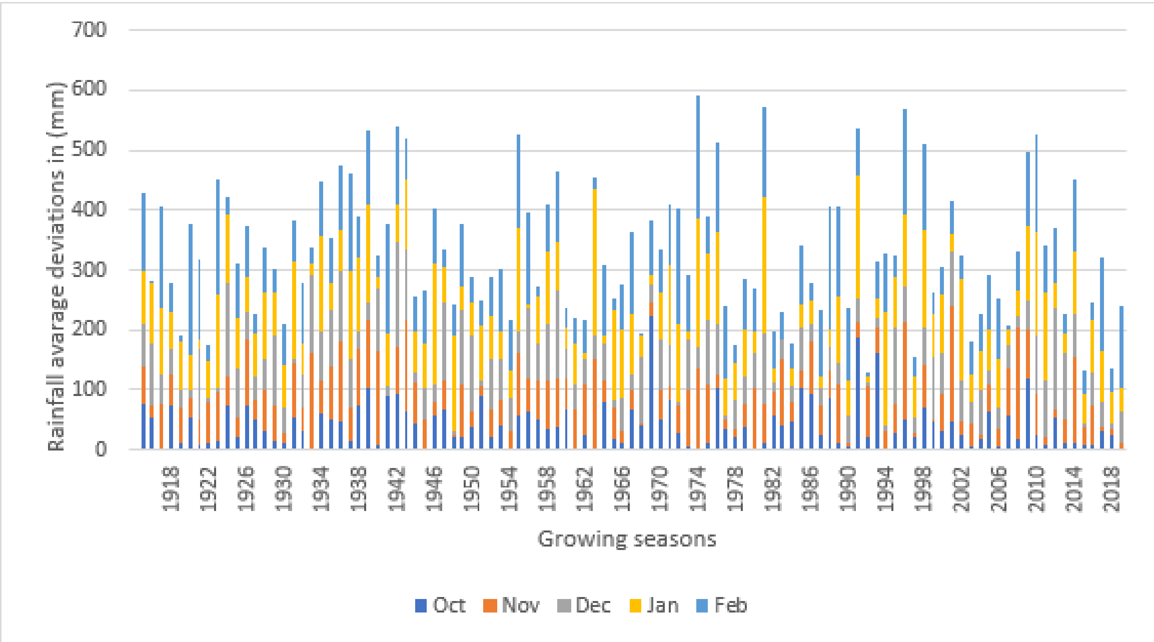

Figure 1.1: Bloemfontein rainfall differences report for hundred years from 1 October to 28 February (South African Weather Services (SAWS) long term data)

1.3 RESEARCH MOTIVATION

According to Bodner and Robles (2017), rangeland and forage scientists worldwide have highlighted several rapid rangeland species compositional changes in the significant grassland biomes. These changes are attributed to the combined effect of intensive defoliation by livestock and wildlife, fire and below-average annual rainfall incidents leading to invasion by exotic species and shrub encroachment. Hence, Vetter (2005) emphasized that the sustainability of rangelands in Africa and other regions is an excellent concern in rangeland management dialogues. However, O'Connor et al. (2010) indicated that a research review in South Africa failed to find a study that specifically investigated livestock management variables on plant species composition. Nonetheless, O'Connor et al. (2011) researched these variables in the sourveld of the grassland biome in Kwazulu Natal province, and their findings were that the increase in the proportion of sheep to cattle in the rangelands led to a long term decrease in forbs richness and subsequently the reduction of total species richness in general.

The recent occurrence of El Niño incidents in 2014-2016, experienced across South African summer rainfall geographical regions worsened by poor management practices on rangelands, had catastrophic impacts on most of the country's rangeland resources (Baundoin et al., 2017). There is also further confirmation that below average annual rainfall impacts exacerbated by poor rangeland management practices were not only responsible for high wildlife and livestock mortalities in South Africa. Thus, they were equally responsible for the noticeable changes in rangeland species composition (Baudoin et al., 2017; Swemmer et al., 2018).

Nevertheless, grass species diversity loss on the herbaceous layer is the worst impact of persistent imprudent animal stocking rates, poor rangelands management decisions and below-average annual rainfall on the grasslands. Overgrazing and underutilization of grazeable natural vegetation are significant rangeland degradation drivers in the grasslands (Du Toit & Cumming, 1999). The South African arid and semi-arid rangelands are susceptible to re-occurrence of drought incidents (Vetter, 2009). With the climate change phenomenon, drought impacts are more likely to create a favourable environment for rangelands with severe species composition loss in the next decade. Human factors such as rangeland management impact environmental pollution based on natural vegetation assessment research, which becomes critical (Zhou et al., 2018).

According to Kauffman et al. (1997), rangeland degradation impacts biotic sustainability badly and reduces the various future utilizations of rangeland ecosystems. Degradation of rangelands is "the retrogression of vegetative cover leading to surface layer exposure to wind and soil erosion by washing away the organic compositions that give vigour to plants' development" (Solomon, 2003). Thus, Fynn and O'Connor (2000) highlighted that intensive grazing during droughts substantially declines perennial grass species such as *Themeda triandra* in the semi-arid grasslands. On the other hand, there is limited research highlighting the relationship between rangeland condition, soil chemical properties and soil pH levels, apart from the findings of a study done by Kotzé (2015) in the eastern part of Bloemfontein which investigated the concentration of these soil chemical properties at different soil depths under different rangeland management systems.

Due to the world population growth and the shift from nomadic livestock farming to a more relaxed livestock farming fixed to an area, Squires (2010) indicated that many land-use methodologies and strategies are irrelevant due to new economic and political trends.

Furthermore, Grobler et al. (2014) suggested that the South African livestock sector's self-sufficiency can be achieved by increasing the average calving rate and the beef production off-take, mainly in the communal and emerging sectors. The latter will be impossible without prudent and sound rangeland management practices, which ensure both production efficiency and sustainability of the rangeland's ecosystem and, to an extent, mitigation of catastrophic below-average rainfall impacts on rangelands.

1.4 RESEARCH AIM

To provide holistic guidance for future sustainable livestock production in the semi-arid rangelands of Bloemfontein magisterial area for land-reform farmers.

1.5 RESEARCH OBJECTIVES

1. To investigate land-reform livestock farmers' decisions on management to establish their production efficiency.
2. To compare rangeland condition per land-reform farm and between land-reform farms.

3. To establish correlations between rangeland condition, soil chemical properties and managerial inputs on the sampled land-reform farms.
4. To establish a correlation between rangeland condition and soil carbon content.

1.6 RESEARCH QUESTIONS

1. What holistic management guidance can be provided to extensive land-reform livestock farmers in the semi-arid rangelands, which will lead to sustainable livestock productivity during this unprecedented climate change era?
2. Does extensive land-reform livestock farmers' management decisions influence their production efficiency?
3. What are the similarities between rangeland conditions per farm and between different land-reform farms?
4. Does a correlation exist between rangeland's condition and soil chemical properties?
5. Does a correlation exist between soil carbon and rangeland conditions?

1.7 HYPOTHESIS

This study hypothesizes that poor rangeland management implicates rangeland degradation with lower condition scores, influencing soils and production levels and increasing the negative impacts of drought and global warming.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

According to FAO (2013), the grasslands cover an estimated surface of seventy per cent of the global agricultural area, which accounts for twenty-six per cent of the total global land area. Nonetheless, the world's rangelands are subjected to active management practices based on several methods and challenges Snyman (2009), and the South African grassland biome is no exception, particularly the Bloemfontein area in the central Free State.

Research in the development of agro-ecological rangeland condition assessment techniques has always been a priority for rangeland scientists in the last sixty years (Bosch & Taiton, 1988); to monitor rangeland condition and to quantify forage production, the rangelands can offer livestock grazing. Over the past years, techniques have focused on benchmarks, ecological indexes, key species, and degradation of gradient rangeland condition assessment methods (Friedel, 1991). Finally, in 2003, Van der Westhuizen (2003) developed an objective rangeland degradation gradient method for the semi-arid rangelands of the central Free State province region in the grassland biome of South Africa.

2.2 RANGELANDS MANAGEMENT

According to Tefera et al. (2010), communal and commercial rangeland management systems are the most common systems utilized for extensive pastoral farming.

However, the natural rangeland production hindrances, such as poor rangeland management, namely, overstocking and understocking, as well as water balance and nutrient availability, were identified in these systems. Thus, the ecological sensitivity of semi-arid rangelands continuously increases their susceptibility to excessive grazing pressures, leading to rapid deterioration of these rangelands if not correctly managed (Van der Westhuizen et al., 1999).

Despite this, SANBI (2014) discovered that pastoralists often manage livestock with the intent to achieve production goals only and not to maintain the rangeland's ecosystem. This is why Van der Westhuizen et al. (2018) reiterated that optimization of long-term forage production quality needs rangeland deterioration prevention through good rangeland management practices.

According to Bosch and Taiton (1988), rangelands utilization history and climatic variation information are very crucial for rangeland management planning, rangeland improvement, animal species choice and the number of animals the rangeland can support since the livestock production systems differ according to vegetation nature. Solomon et al. (2006) also reported that climatic variations coupled with improper grazing adversely affect the composition and quantity of grasses in the seed bank.

In summary, Van Der Westhuizen et al. (2018) classified South African extensive grazing management into three categories: communal production, with no land ownership and poor farming infrastructure maintenance. Thus, continuous grazing is commonly used. The authors described the second grazing management category as primarily used by emerging livestock farmers, who graduated from communal farms and varies from constant grazing to two, three, and four-camp systems, with visible signs of rangelands degradation. The third category is commercial production, characterised by well-maintained critical livestock farming infrastructure (water reticulation and well-fenced-off and divided grazing camps). As a result, a multi grazing camp system is used.

Nevertheless, according to Allsopp et al. (2007), the intentions to promote ethical livestock farming and rangeland management practices amongst smallholder emerging and communal farmers have failed drastically in Africa. This is partly because of non-compliance to ecological carrying capacities in arid and semi-arid regions.

Nonetheless, the South African agricultural sector originated from a demise that agricultural input support programs initiated by the government were mainly intended for large-scale and commercial farmers focussing on productivity and contributing to the gross agriculture income. Thus extending the minimum to no support at all for smallholder emerging farmers and communal farmers (Vetter, 2003). Despite this, the researcher, over the years of experience, has observed that agricultural support extended to land-reform and communal farmers by the current government during natural disasters such as droughts is in contrast with ethical rangeland management practices, since farmers with more livestock numbers receive more assistance as opposed to those with fewer livestock numbers, without careful considerations of farmers grazing area sizes. However, too often than not, as highlighted by Salomon (2011), these efforts ignore sustainable rangeland utilization goals and sustainable livestock productivity goals by farmers, jeopardizing future livestock reproductive performance and quality of weaner animals produced from extensive livestock farming systems.

2.3 GRASSLANDS VEGETATION

The Grassland biome of South Africa, as a significant resource for livestock production, covers parts of the Free State, Kwazulu Natal, Eastern Cape, Mpumalanga Provinces and parts of the Mountain Kingdom of Lesotho (LandCover 2013/14 Data Set, 2015).

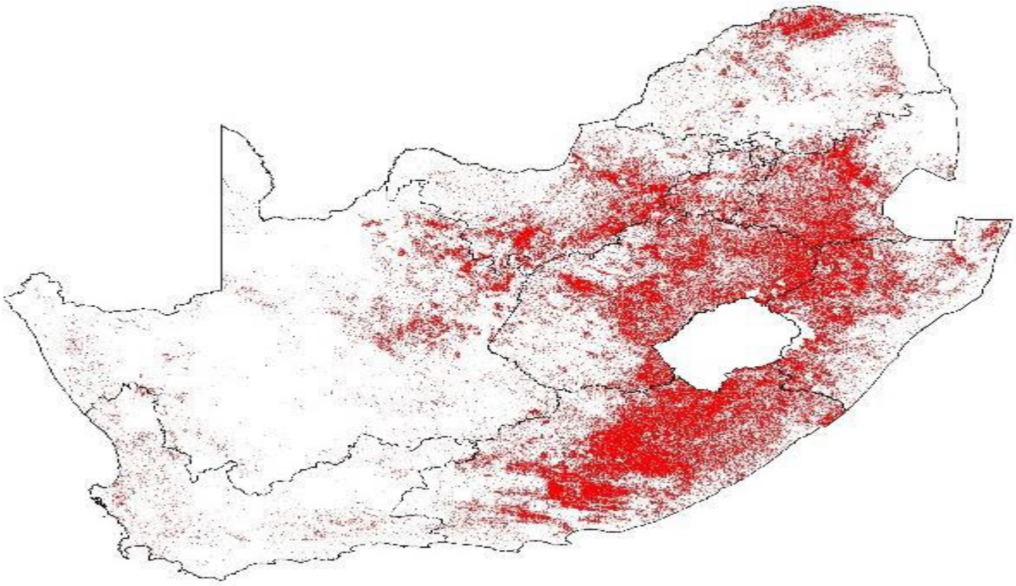

Figure 2.1: South African grasslands biome map (LandCover 2013/14 Data Set, 2015)

Vast differences in annual average rainfall characterise these grasslands. As a result, they are dominated by sourveld grass types in the higher annual rainfall areas and sweetveld grass types in the lower annual rainfall areas (Naidoo et al., 2013). The dominant grass species used as rangeland condition indicators are *Themeda triadra* (climax) for good rangeland condition score, *Eragrostis* (sub-climax) species for average rangeland condition score as well as *Aristida* species and *Cynodon dactylon* (pioneers) for abysmal rangeland condition score (Van der Westhuizen, 2003).

Natural vegetation for livestock grazing in Bloemfontein is described as sweet grass veld of the grassland biome, with *Themeda triandra* as the most distinctive and well-distributed grass species, followed by the *Eragrostis* grass species (Acocks, 1988; Van der Westhuizen, 2003). Trees are extremely limited in plain topography variations, but dense stands can occur in vlei areas and hill variations. Prudent veld management is essential to maintain the rangeland condition on an optimal positive trajectory to ensure sustainable livestock production. The distinctive characteristic of Bloemfontein rangeland sweet veld type of grasslands, with that of the sour veld type of the grassland biome, is low annual average rainfall leading to constant palatability with low carrying capacity, when compared to the sour veld with decreasing palatability as it grows with high carrying capacity, due to higher annual average rainfall (Tainton, 1999).

Nonetheless, “the grassland biome remains the greater part of South Africa’s beef-producing areas as highlighted” (Van Niekerk, 1996). This is despite the observations by Musemwa et al. (2012), who suggested that livestock farming is not the key enterprise in the emerging and communal farming categories compared to other agricultural enterprises in different biomes. However, the suitability of the grassland biome for extensive livestock farming activities is inarguable.

2.4 LIVESTOCK REPRODUCTION PERFORMANCE

Over the years of experience, the researcher observed that Bloemfontein's extensive land-reform livestock beneficiary farmers mostly come from communal livestock farming systems, which are characterised by poor application of grazing management systems, high land degradation incidents and low calving rates of 35% and below as reported in the South African livestock structured survey conducted by (Scholtz & Bester, 2010). Furthermore, Nkadimeng et al. (2022) reported the average reproductive performance of smallholder cattle farmers in South Africa as 50% pregnancy rate less 12% of losses, indicating an average calving rate of 38%. These low calving rates are comparable to the average 32% calving rate of land-reform livestock farmers in Bloemfontein in the central Free State province of South Africa, reported during the 2018/2019 drought in a stocking rate study conducted by (Mokhesengoane et al., 2021).

The latter emanates from high stocking rates and ineffective rangeland management, which yields poor reproductive performance, low growth rates and take-off (quantity of meat produced over time) due to the lengthy periods it will take for animals to be marketable.

Thus, these low calving rates are also comparable to the results of a research trial conducted by Van der Westhuizen et al. (2020) at the Glen experimental farm in Bloemfontein, which recorded a 32% calving rate with minimal to no rangeland management effort during drought. These low calving rates negatively reflect on the livestock production efficiency of the Bloemfontein land-reform farmers' group, threatening the sustainability of their livestock farming operations.

Nevertheless, these low calving rates can be attributed to a range of interlinked livestock production factors: animal nutrition, animal breeding and animal disease control, with management as a core factor or at the centre of sustainable livestock productivity. However, sustainable livestock production management must also include ecological sustainability by preventing rangeland degradation under variable climatic conditions (Dankwerts & Tainton, 1996; Van der Westhuizen et al., 2018).

2.5 LAND DEGRADATION

According to Mani et al. (2021), land degradation is a worldwide challenge with adverse effects on ecosystem functioning and livelihood development. However, the total size estimates of degraded lands worldwide are uncertain (Gibbs and Salmon, 2015). In South Africa, land degradation is rife, which was confirmed by approximately 60% of degraded lands (UN Environment Programme, 1997). Thus, in their research projects, Stocking and Murnaghan (2001) have identified inappropriate land management, wrong technology, exponential population growth, poverty and decisions of social and political formations as key human factors related to land degradation. Nonetheless, other studies presented a different viewpoint by highlighting that land degradation can occur independently from human activities but worsen with poor rangeland management practices. It was further confirmed by

Darkoh (2009) that land degradation and overgrazing are considered among the key environmental challenges in South Africa.

On the other hand, Belsky and Blumenthal (1997) indicated that livestock activities, namely grazing and trampling, affect plant species composition directly, even though the severity of the impacts differs according to animal distribution and density. Since plant species vary significantly in their palatability and response to grazing pressures, species composition can be used to indicate rangeland conditions (Abule et al., 2007).

According to Oztas et al. *(*2003) and Maki et al. (2007), changes in vegetation structure, composition and productivity occur due to changes in grazing pressure. Increased livestock grazing pressure increases palatable plant species' susceptibility to heavy grazing and livestock trampling impact. The latter is evident by bare patches near water troughs and livestock feeding points, leading to the disappearance of *Decreaser* plant species as they are replaced by *Increaser* or Invader plant species as reported by (Sisay & Baars, 2002).

Thus, Abule et al. (2007) indicated that biomass production can be utilized to determine the quantity of available forage for animal grazing.

2.6 CLIMATE VARIATION

The South African grassland biome’s climate is typical of the sub-tropical semi-arid environment, which is characterized by sweltering summers and cold dry winters, with the mean minimum temperatures ranging from minus nine degrees Celsius in winter to the mean maximum of thirty-nine degrees Celsius in summer (J. Van den Berg, personal communication, August 29, 2022) Annual average rainfall in Bloemfontein is 556 mm and the substantial amount of this rains fall during summer months (ISCW-databank, 2018).

Hence, the Grassland biome is generally classified as an arid to semi-arid region receiving an average rainfall of 500 mm or less per annum, which applies to approximately 65% of the grasslands (Snyman, 1998). Due to low annual average rainfall and high temperatures, the grasslands are more prone to periodic climatic variations.

Nevertheless, rainfall has apparent effects on herbaceous productivity, and as a result, rainfall timing is essential for rangeland recovery post-defoliation and exposure to variable climatic conditions. Rangeland's growth in the central Free State increases tremendously from November to February as days are longer and nights are shorter during this period. However, Fynn et al. (2000) indicated that the importance of rainfall on veld compositional change cannot be attributed to the single rainfall season but also the preceding seasons.

Bloemfontein respectively received below-average rainfall from October to February in 2016/2017, 2017/2018 and 2018/2019. As a result, livestock productivity was severely impacted. Thus, Dzama (2016) indicated that the 2015/2016 El Niño induced droughts compelled Lesotho, Swaziland, Namibia, Malawi and Zimbabwe to declare a state of drought emergency nationally, whilst two of the SADC countries, namely South Africa and Mozambique, declared drought emergencies partially.

However, the researcher also became cognizant of the fact that in a natural weather pattern environment, El Niño events precede LA Niña events, which is the total opposite as LA Niña is characterised by above-average annual rainfall leading to flooding and freezing winter temperatures (Sazib et al., 2020).

Thus, Van Der Westhuizen (2006) reported that an average of approximately sixty-two per cent contribution to rangeland production occurs during these five months. However, this process heavily depends on adequate rains from August to October, ending the dormant winter period with shorter days and longer nights.

Nonetheless, climatologists have already predicted a sharp increase in the climatic extremes and severity in the twenty-first century in both arid and semi-arid regions (South African Weather Services). However, Keshavarz et al. (2017) highlighted that these occurrences will severely impact rangeland's sustainability. Thus, sound and appropriate rangeland management practices will be imperative in minimizing the anticipated negative impacts.

2.7 SOIL PROPERTIES

In South Africa, more emphasis is placed on the impacts of rangeland management practices on livestock performance and forage production. However, less emphasis is given to the effects of grazing practices on soil properties (Snyman & Du Preez, 2005; Du Toit et al., 2009).

Nevertheless, soil is the most essential resource for ecosystem functioning. It is equally crucial for both physical and chemical soil properties, which give vigour and are necessary for healthy flora production in the ecosystem. Apart from its significant role in livestock production, this ecosystem flora also prevents soil erosion and thus further prevents degradation of these ecosystems. According to Greenwood et al. (2001), above-ground vegetation loss by intensive grazing on rangelands and soil macro-pores loss tremendously increase the water runoff rate. Chen et al. (2008) also indicated that the loss of vegetation cover might lead to changes in the soil P transformation, resulting in changes in plants' P needs and soil’s physical, chemical and biological properties. The intensity will, however, depend on the soil texture form being the proportional representative of clay, sand, and silt. According to Pei et al. (2008), overgrazing of rangelands is responsible for a significant decrease in soil chemical, physical, and biological properties. Nonetheless, Derner and Schuman (2007) attested that the carbon sequestration process is critical for rangeland health maintenance and rehabilitation, as it enhances the improved soil structure, nutrient cycling, and general soil quality and ultimately reduces soil erosion since it increases soil water retention capacity and thus limit water run-off.

Kotzé (2015) provided empirical evidence showing that grazing directly impacts soil properties such as organic C, extractable P, exchangeable Ca and Mg, in research trials conducted in the grasslands and the savannah biome, respectively. The study furthermore highlighted that some soil properties are more sensitive to rangeland condition degradation than others (e.g. POM and soil aggregates). These soil properties are also essential for the resilience of rangelands to degradation. The trampling impact of livestock on rangelands exacerbated by overgrazing leads to the removal of vegetation cover, thus rendering the soil properties susceptible to being washed away during heavy rains. Thus, Fernandez-Giminez and Allen-Diaz (2001) confirmed that most changes in soil properties and nutrients occur in the livestock watering points and supplementary feeding areas due to the impact of livestock trampling.

2.8 POLICY

Greenberg (2010) criticised the South African national government for failing to prioritise agriculture since the advent of democracy, citing a low budget of below two per cent of the national budget allocation to national and provincial agriculture departments even though significant but not satisfactory budget allocation adjustments have been made to date.

This ignites serious concerns, especially when the world will be ushering in a new era of climate change, in which scientists have already predicted inevitably above-average rainfall patterns and above-maximum average temperatures, translating to more floods and drought incidents re-occurrences. Central to the latter situation is the exponential growth in the human population, as highlighted by forever rising food and fuel prices, abrupt changes in the political arena, and the absence of clear policy direction to unlock land reform challenges, which contributes immensely to the underdevelopment of drought and climate change impacts mitigation strategies in the South African arid and semi-arid rangelands (Vetter, 2009).

Thus, Van der Westhuizen et al. (2018) indicated that successive droughts reduce perennial plant cover and subsequently decrease the number of animals the natural veld can support under normal circumstances.

Despite the regulatory framework provided by the policy, which seeks to create an enabling environment by steering the government investment such as human resources and finance for implementation and research priorities articulation as highlighted by Lahiff (2006) and Vetter's (2013) argument is aligned to that of Hall and Clife (2009) highlighting that government's targets for agricultural land redistribution and to improve both food security and rural livelihoods have not been realised despite land-reform programs enjoying political support.

2.9 SOUTH AFRICAN LAND-REFORM HISTORY

In South Africa, Land reform aspired to address more than 350 years of race–based colonization and dispossession as part of the transition agenda to a democratic society (Olive et al., 2017). This programme in South Africa emanates from the election manifesto of the African National Congress (ANC) as a build-up to the first democratic elections held in 1994, leading to the advent of democracy. The main objective of this programme was to redress the injustices of the apartheid system by securing tenure, generating employment, increasing rural incomes, supplying residential and agricultural land for historically disadvantaged individuals and increasing agricultural productivity. As a result based on the mandate in the constitution land reform in South Africa has three pillars, namely; restitution, tenure reform, and redistribution. The pillars involve returning land or providing other compensation to persons or communities who were dispossessed of property after 1913 due to racially discriminatory laws or practices (ANC, 1994).

The techniques employed by the government to realize land redistribution were based mainly on the operation of the existing land market. Amongst other measures the government can explore is land expropriation without compensation, even though it has not been utilized widely thus far. South African government's role has always been limited to support through provisional grants to assist people who cannot enter the land market to buy their own property. The willing seller –willing buyer (WSWB) concept slowly entered the discourse in the South African land reform issue during 1993-1996 as a reflection of the ANC's fast shift in economic thinking from the nationalist agenda to the neoliberal agenda (Lahiff, 2006).

Exhaustive, extensive consultative efforts by the new Department of Land Affairs (DLA) within South Africa and international advisers pointed to a new policy direction, which was outlined in the 1997 White paper on South African Land Policy, leading to market-based approach and particularly the WSWB concept as the cornerstone of land reform policy (World Bank 1994; Williams 1996; Hall et al., 2003;). The South African Constitution did not guide the approach. Still, it was a policy choice to keep up with emerging international trends and the macroeconomic strategy (the Growth, Employment, and Redistribution strategy) adopted by the ANC in 1996.

In 2000, the Settlement /Land Acquisition Grant (SLAG) was rolled out, prioritizing citizens living in abject poverty with a maximum monthly household income of R1, 500 to qualify for the R16,000 grant. Even though success was realized in this regard, it was widely criticized for clustering too many poor people on one commercial farm without the necessary skills and resources to make those farms productive. The SLAG program was then effectively replaced by a program referred to as Land Redistribution for Agricultural Development (LRAD) in 2001, which was introduced with a clear objective to advance commercially focused agriculture but alleged to cater for other farming groups such as commonage farmers. The new policy offered higher grants paid to individuals rather than households; it also used loans financed through institutions, such as the state-owned Land Bank, to supplement the grant. LRAD offered a single unified grant support system which allowed beneficiaries to access money on a sliding scale ranging from R20, 000 to R100, 000 (T. Kuduga, personal communication, May 20, 2023). The applicants had to bring their contribution to qualify. However, their contribution was not limited to cash since the beneficiaries' labour was also accepted to replace monetary contribution. To qualify for the minimum grant of R20, 000 the beneficiary was supposed to contribute R 5,000 in cash or as labour. Provincial land reform offices provided the LRAD grants as per the agency contract with the DLA, and the grant was then paid out through the Land Bank. The LRAD program's land acquisition approach retained the market-based, demand-led approach of the previous policies.

As of 2006, the government became proactive and started buying land on the market without identifying potential beneficiaries prior to land purchasing. Most redistribution projects have involved groups of applicants pooling their grant allocation to buy formerly white-owned farms to pursue commercial agriculture. The focus on group projects led to mostly the small size of the available grant relative to the size and cost of the typical agricultural holding and many more challenges associated with the subdivision of land.

Most of the rural communities viewed redistribution as a means to expand their existing communal landholding, and they also favoured collective ownership. According to van den Brink et al. (2007), LRAD farmers made smaller groups comprising extended family groups due to the increased availability of financing in the form of grants and credit. However, it later came to the realization of the South African government that conflicts were rife amongst these groups, and as a result, they later sold these farms back to their previous white owners since they had title deeds. Thus, the government resolved to implement the Proactive Land Acquisition Strategy (PLAS) for agricultural land redistribution. In this program, land ownership lies solemnly with the state and the beneficiaries are given thirty-year lease agreements with an option to buy. It also allows the government to prematurely terminate the contract with the beneficiary through its provincial subsidiaries if the land is not utilized fully for agricultural purposes.

Despite all the efforts, the production levels of most land-reform farmers in South Africa are not satisfactory (Shabangu et al., 2021). This can be attributed to the socio-economic status of land-reform beneficiaries, incomprehensible government support channelled towards land-reform farmers and the sentimental values some land-reform farmers attach to livestock.

Nonetheless, according to Sikwela et al. (2018), land reform in South Africa remains critical to unlocking social and economic transformation and bringing about true reconciliation between different ethnic groups. Due to the nature of the grassland biome ecosystem, land reform farmers in the grassland biome are mostly extensive livestock farmers. Thus, rangeland management is critical for successful livestock farming in this biome.

2.10 CONCLUSION

According to Van der Westhuizen (2003), *Themeda triandra* in the grassland biome rangelands is critical for the proper functioning of the ecosystems. For this reason and many other ecological benefits, Van der Westhuizen et al. (1999) identified Themeda triandra as the most important grass species as a rangeland condition indicator and the grassland's essential livestock diet composition. Nonetheless, proper rangeland management practices are paramount for maintaining these ecosystems and ensuring their sustainable contribution to livestock productivity.

The recent reoccurrences of below-average rainfall incidents in these ecosystems, perpetuated by climate variations, is evidence enough that rangeland management is the only and most important variable a farmer or rangeland manager can control. Thus, Van der Westhuizen et al. (2020) highlighted that livestock production efficiency can be achieved with proper veld management and without production licks supplementation since many studies have already identified adverse impacts of livestock production licks supplementation on the soil chemical and physical properties (Van der Westhuizen et al., 2020; Owens et al., 2021).

Over the past three to four decades, scholars have been in disagreement about the climate change reality's impacts, intensity and anticipated effects on agricultural productivity over time, with some arguing that climate change reality was too often cited out of context, blown out of proportion, loosely used and often mistaken for normal weather patterns, Benestad et al. (2015), these authors reviewed a total of thirty-eight scientific publications disputing climate change reality. The latter is appropriated to have resulted in the reluctance in agricultural policy formulation by governments, specifically rangeland protection policies. However, the government has a crucial role in ensuring agricultural policy development and creating an enabling environment for such policies and sustainability of the agricultural sector to decrease food insecurity as the population grows.

Even though the South African government does assist farmers during natural disasters such as floods and droughts as per the South African Disaster Management Act 57 of 2002 (as amended, Act 16 of 2015), it is imperative to highlight that the due diligence process before the natural disaster declaration which might lead to government support through reliefs in the form of either livestock feed, medication, seeds, fertilizers and water infrastructure upgrades is lengthy and thus rangeland management and proper stocking rates are paramount at farm level to eliminate livestock losses.

CHAPTER 3
MATERIALS AND METHODS

3.1 STUDY AREA/LOCATION

The study was conducted in the Bloemfontein magisterial area situated in the semi-arid region of South Africa, lying at an altitude of 1.395 metres above sea level. According to Acock's (1988) classification, Bloemfontein is within the grassland biome with *Themeda triandra* as the most distinctive and well-distributed grass species amongst other perennial grasses for livestock grazing (Van der Westuizen, 2003).

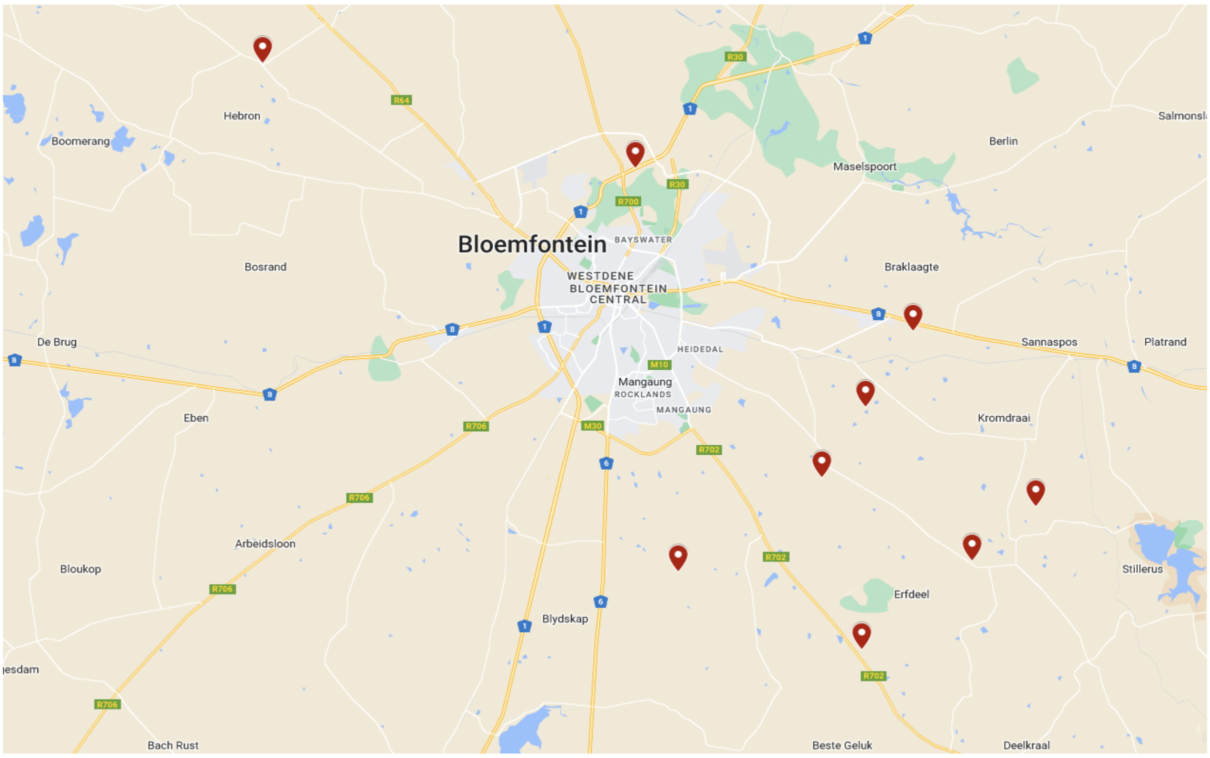

Figure 3.1: Bloemfontein magisterial area map highlighting the position of studied farms (Available:https://www.google.com/maps/place/Bloemfontein)

The topography of Bloemfontein is characterised by the scarcity of trees in the plain variations, with dense stands found in hill variations and shallow minor lake areas.

According to Van der Westhuizen (1994) and Van der Westhuizen et al. (1999), *Themeda triandra* is a crucial significant species in this vegetation type; thus, the species is not only of ecological importance in the study area but also an excellent rangeland condition indicator (r2 = 0.99). *Themeda triandra* is the most important grass species in the central Free State's extensive livestock diet composition (Van der Westhuizen et al., 2001).

According to Van Weshuizen et al. (1999), *Themeda triandra* and *Eragrostis chloromelas* are dominant grass species for veld in reasonable rangeland conditions, with scores of 50% and more. In contrast, *Themeda triandra* dominates the veld with an excellent rangeland condition score of 90% and more. However, with degradation, *Themeda triandra* as climax species becomes the first grass species to be replaced by *Eragrostis chloromelas as sub-climax,* followed by *Aristida bipartitah* as pioneer grass species*.* Nonetheless, *Themeda triandra* also occurs in poor rangeland conditions with a score of 30%; however, it is not the dominant grass species*.*

The Department of Agriculture and Rural Development (2003) recommended 6ha per LSU head animal stocking rate for the Bloemfontein semi-arid rangeland geographical region. However, as rangeland conditions deteriorate due to unsustainable rangeland management practices, grazing capacity decreases tremendously in the semi-arid region of the central Free State. Thus, rangeland managers and other key agricultural role players in this region must understand that these animal stocking rate recommendations are for the natural veld in good condition. Nonetheless, in practice, rangeland managers must interpret these recommendations with the natural forage scarcity periods and natural disaster occurrences such as droughts.

However, according to Chaichi et al. (2005), the soil form and veld management practices influence grass species re-establishment and root development in the rangelands. This is why soil water retention capacity is essential for rangeland's sustainability and establishment. Nevertheless, MacVicar et al. (1977) described Bloemfontein soil form as dominated by Milkwood, Arcadia and Valsrivier, with more than 35% clay.

3.2 RESEARCH METHODOLOGY

Brannen (1992) provides the following distinctive criticism for qualitative and quantitative research methodologies: quantitative methodology assumes a broader world perspective, whereas qualitative methods take a narrow view of the world. Although qualitative methodology assumes a narrow perspective, it produces an objective analysis of biological processes indispensable for research purposes. Thus, the two methodologies will be employed together in this study to strike a balance between the inefficiencies of each and for a practical holistic research problem approach.

Quantitative methodology was employed to question the hypothetical statement of this study by establishing the technical knowledge of rangeland managers, current stocking rates, and grazing camps' utilization history in the sampled sites. In contrast, qualitative methodology was used to test this study's hypothetical statement by establishing a basis for rangeland degradation and rangeland changes comparison on the nine sampled sites. Creswell (2013) confirmed this mixed methods approach for effective cross-checking of results by utilising different techniques to ensure a holistic research problem approach and objectivity.

3.3 RESEARCH INSTRUMENTS

Structured questionnaires were used to determine profiles of rangeland managers, current stocking rates and grazing camps utilization history and management for the nine sampled farmers. The Wheel Point Apparatus Field Method by Tidmarsh and Havenga (1955) was used to identify and determine grass species composition on two managed grazing camps per farm identified by the farmer, researcher and rangeland scientist; soil samples from each sampled site were collected with a soil auger, from a 20 cm layer for comprehensive soil laboratory tests of the following soil chemical properties electrical conductivity (EC), sodium adsorption ratio (SAR), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), zinc (Zn), soil organic matter (SOM), soil carbon (Co), soil pH using potassium chloride (KCl) method instead of water (H_2O), phosphorus (P) using P-Bray 1 method. To determine soil texture, three fractions, namely clay, silt and sand, were used (The Non-Affiliated Soil Analysis Work Committee, 1990). The grass species were categorized according to their classes' *Climax, sub-climax* and pioneer to determine the greater class proportionality to identify the rangeland condition per grazing camp per sampled farm. The results were then used to compare rangeland conditions on the sampled camps per farm and between farms.

3.4 SAMPLING PROCEDURE

Nine extensive land reform livestock farming sites out of a total of twenty-nine land reform farms which participated in the stocking rate study during the 2018/2019 drought were sampled using a snowball sampling procedure (Bhattacherjee, 2012), starting with the perceived group leader within the stocking rate study sampled group. Each farmer was requested to identify from a land-reform farmers group one farmer they perceive to be generally a good livestock farmer in their category. Although this technique could be biased regarding the selection of farmers with better livestock skills, it was used to allow farmers to be involved in the selection process from already scientifically selected participants. This technique is, however, also subjective in the sampling process of farmers and will probably not represent a random selection of farmers over the range of different stocking rates and management skills, therefore not representative of varying levels of farm management but instead focus on some of the best livestock farmers according to perceptions of the other Bloemfontein land-reform beneficiary farmers. Nevertheless, the risk of bias is low when snowball sampling procedure is employed on a homogeneous population.

3.5 SAMPLE

Nine extensive land reform livestock farming sites out of twenty-nine land reform farms that participated in the stocking rate study during 2018/2019 drought were sampled using a snowball sampling procedure, starting with the perceived group leader within the sampled group. Each farmer was requested to identify from a land-reform farmers group one farmer they perceive to be generally a good livestock farmer in their category. The snowball sampling procedure was used to eliminate the unforeseen biases from the researcher's side and ensure objectivity in the study's outcome. Financial implications informed the sample size for this study since the researcher financed the data collection process.

3.6 DATA COLLECTION

Structured questionnaires (see appendix A) were completed in an interview with each sampled site rangeland manager/farmer to establish their rangeland management, technical knowledge, literacy level and demographic information.

During the interview, the researcher gave a detailed explanation of the exercise to the farmers. The researcher then poses questions as they are captured on the structured questionnaire and records the rangeland manager's responses. The narrative data captured contributes to the achievement of the main objective of this study.

During September and October 2021, the agro-ecological veld condition assessment was conducted in all nine sampled farms, using the wheel point apparatus method, as confirmed to present an acceptable level of accuracy and repeatability by (Walker, 1970; Sykes et al., 1983). During agro-ecological veld condition assessment, abundance data were collected by recording the nearest plant for 100 points per camp. A maximum of 100 points were taken per two camps of all sampled farms to determine rangeland condition percentage scores (Frequency = No of plants/ total count x 100) using the objective rangeland degradation gradient method developed by (Van der Westhuizen, 2003) for the semi-arid rangelands of the central Free State province region in the grassland biome of South Africa.

Big bare patches around watering points and feeding areas were purposely avoided. Independent soil samples were taken from each sampled camp per farm at the beginning of the rangeland condition assessment transect line, in the middle and end, for soil chemical and physical properties analysis. Soil auger was utilized to take soil samples at 20cm deep. Thus, Van der Westhuizen et al. (2005) emphasised that a periodical objective assessment of rangeland conditions is essential to monitor rangeland condition trends. Furthermore, Foster (2015) further confirmed that the success rate and reliability of rangeland condition assessment results rely entirely on the experience and vegetation knowledge of the individual undertaking the assessment. Thus, the researcher was closely supervised during the ecological rangeland condition assessment on each sampled farm for the reliability of the data collected by Dr H.C Van der Westhuizen, a Professional Rangeland and Forage scientist with more than thirty years of practical experience in this field (see Appendix B).

3.7 DATA ANALYSIS

Statistical analyses were performed on all variables. The descriptive statistics, means and standard deviations were calculated for comparison purposes, and analysis of variance (ANOVA) was also used to compare the average values. Metabolic body weights were used to calculate large stock units (LSU) (Meissner et al., 1983). Rangeland conditions were determined for every camp using the indicator species technique developed and tested against a degradation gradient technique specifically for this vegetation type (Van der Westhuizen, 2003). All soil chemical analyses were performed and done according to (The Non-Affiliated Soil Analysis Work Committee 1990): soil pH was measured using potassium chloride (KCl) and plant-available P using P-Bray 1 method (The Non-Affiliated Soil Analysis Work Committee 1990). The quantitative data was analysed using the Statistical Package for Social Science (SPSS) version 28 for descriptive analysis.

3.8 ETHICAL CONSIDERATIONS

The researcher considered the ethical research conduct protocol of the University of the Free State in conducting this research by seeking and obtaining ethical clearance from the university's ethical clearance committee on general human ethics protocol (**UFS-HSD2021/1018/21**) and environmental and biosafety research ethics committee (**UFS-ESD2021/0123/01**) respectively, prior data collection (see appendix C). The ethical clearances are attached to the appendix list of this research report.

The researcher further stated that the data would be used discretely without divulging respondent information. Thus, the data cannot be traced to a farmer or farm. The data will also be stored following each ethical clearance committee's data storage requirements. Furthermore, the study followed the required academic standards by properly citing all the materials used in the study and the material authors in the reference list.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 PARTICIPANTS OVERVIEW

The sampled extensive livestock farms are approximately 50km around Bloemfontein city, as shown in Figure 3.1. The farm owners' literacy level differs significantly, ranging from Standard 4, the minimum highest standard passed, to a university master's degree, the highest qualification obtained. Nonetheless, neither of the farmers had a formal qualification in the agricultural field. The average age of the sampled farmers was 53 years, comparable to the findings of Mokhesengoane (2020). More than half of the group regarding gender representation were men, with only two women and one person aged less than 35 years. Thus, this sample group is consistent with the general perception that the South African agricultural sector is male-dominated.

Furthermore, it correlates with the findings of Anyanwu (1992) that younger South African men have little to no interest in the agricultural sector. For this reason, most of them, from farms or rural communities, go to big cities nationwide to look for glamorous lives and jobs to sustain their livelihoods. All the sampled farms have been active extensive livestock farms under the same management for over a decade, and all have extensive commercial livestock farming history before 1994.

4.2 SPECIFIC INDIVIDUAL PARTICIPANT NARRATIVE

4.2.1 Participant 1

The farmer had a total farm size of 2484 ha, of which the total portion available for livestock grazing was 1880 ha. The total Large Stock Units kept for extensive farming purposes were 157.81 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 62% and 61%, respectively, with the average rangeland condition score of 61.5%. The farmer had no grazing management system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the *Eragrostis chloromelas*. The total calving rate of 28% and the average weaning weight of 192kg at roughly six to seven months of age were recorded on this farm. The farmer followed a prescribed animal health program for the area but did not follow a breeding season and had no production plan. The farmer supplied seasonal production licks to livestock as well as salt blocks. The highest education level recorded for the farmer was matric, and the farmer's trusted agricultural information source was only the informal mentorship arrangement with the neighbouring farmers.

4.2.1.1 Production level

A low yearly calving rate of 28% was recorded, with pre-weaning annual mortality of 15 calves and yearly mortality of 18 LSUs recorded on matured livestock. The average weight of weaners recorded over time was 192kg, and this farm recorded an exceptionally low stocking rate of almost below 50%, resulting in an additional substantial loss of income.

4.2.1.2 Financial implications

Under- and overstocking is neither beneficial to the ecological sustainability nor the profitability of extensive livestock farming enterprises (Mokhesengoane et al., 2021). Thus, based on the beef average weaner price of October 2021 of R39.50 (see appendix E) and the average class C2/C3 beef carcass price of R45.11/kg, the farmer lost R 113 760 of the potential weaner income and R 194 875.2, respectively on matured cow slaughter income.

4.2.2 Participant 2

The farmer had a total farm size of 516 ha, of which the total portion available for livestock grazing was 376 ha. The total Large Stock Units kept for extensive farming were 66.19 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 19% and 56%, respectively, with the average rangeland condition score of 38%. The big difference in rangeland condition is because one survey was executed on old arable lands. The farmer, however, identified this camp because it was regularly grazed. The farmer was using a rotational grazing system for effective rangeland management. *Eragrostis chloromelas* was the most prevalent grass species identified during the rangeland condition assessment, followed by *Themeda triandra* and annual herbs on the old arable lands. The total calving rate of 85% and the average weaning weight of 186kg at roughly six to seven months of age were recorded on this farm. The farmer did not follow a prescribed animal health program and the breeding season for the area but had a production plan. The farmer supplied no seasonal production licks to LSUs kept on the farm but instead, provided salt blocks. The highest education level recorded for the farmer was matric, and the farmer's trusted agricultural information sources were internet, government agricultural extension and private agricultural extension support. Stock theft is a significant problem in this area, and the farmer kraals livestock every evening.

4.2.2.1 Production level

A high yearly calving rate of 85% was recorded, while no yearly pre-weaning mortality was recorded on this farm, with mortality of 2 LSUs recorded for matured livestock only. The average weight of weaners recorded over time was 186kg. The insignificant stocking rate, compared to the area carrying capacity norm of 6ha/LSU, was also recorded on this farm.

4.2.2.2 Financial implications

Proper stocking rates are essential for the sustainability of rangeland ecosystems and efficient livestock productivity. Thus, based on the average class C2/C3 beef carcass price of R 45.11 in the central Free State. The farmer lost R 21 652.8 of potential matured cow slaughter income.

4.2.3 Participant 3

The farmer had a total farm size of 260 ha, of which the total portion available for livestock grazing was 252 ha. The total Large Stock Units kept for extensive farming purposes were 83.48 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 49% and 54%, respectively, with the average rangeland condition score of 52%. The farmer was using a rotational grazing system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the annual pioneer *Chloris virgate.* The total calving rate of 68% and the average weaning weight of 210kg at roughly six to seven months of age were recorded on this farm. The farmer followed a prescribed breeding season and the animal health program for the area and had a production plan. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was a university master's degree, and the farmer's trusted agricultural information sources were the Internet and government agricultural extension support.

4.2.3.1 Production level

A yearly calving rate of 68% was recorded with pre-weaning annual mortality of two calves, while no loss was recorded on matured livestock. The average weight of weaners recorded over time was 210kg, and an exceptionally high stocking rate of slightly above 50% was recorded on this farm, exerting enormous pressure on the rangeland ecosystem. The increased occurrence of *C. virgata* and the high levels of phosphate in the top soils confirm the overstocking and pressure on the rangeland. According to Van der Westhuizen et al. (1999), the fast-growing annual *C. virgata* is an indicator of rangeland degradation, while the increase of phosphate (P) in the topsoil is the dominant soil indicator for rangeland degradation for this vegetation type (Van der Westhuizen, 2003; Van der Westhuizen et al. 2021).

4.2.3.2 Financial implications

Overstocking contributes immensely to rangeland ecosystem degradation and, as a result, threatens the sustainability of extensive livestock farming enterprises. Thus, based on the average weaner price of beef in October 2021 of R39.50 in the central Free State. The farmer lost R 16 590 of the potential weaner's income.

4.2.4 Participant 4

The farmer had a total farm size of 214 ha, of which the total portion available for livestock grazing was 180 ha. The total Large Stock Units kept for extensive farming purposes were 31.12 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 81% and 73%, respectively, with the average rangeland condition score of 77%. The farmer was using a rotational grazing system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the *Eragrostis chloromelas* grasses. The total calving rate of 15% and the average weaning weight of 183kg at roughly six to seven months of age were recorded on this farm. The farmer followed a prescribed breeding season and the area's animal health program and had a production plan. The farmer supplied no seasonal production licks to LSUs kept on the farm; instead, the farmer provided the livestock with only salt blocks. The highest education level recorded for the farmer was Standard 4, and the farmer's trusted agricultural information sources were informal mentorship arrangements with the neighbour and government agricultural extension support.

4.2.4.1 Production level

A very low yearly calving rate of 15% and no yearly mortalities were recorded on this farm. However, the average weight of weaners recorded over time was 183kg, and the stocking rate was roughly consistent with the area norm of 6ha/LSU, which was also recorded on this farm. The partially dysfunctional bull was the major contributor to low production levels/calving rate, which the farmer only noticed towards the end of the mating season.

4.2.4.2 Financial implications

The effects of proper stocking rates have a bearing benefit on the sustainability of the rangeland ecosystem and the efficiency and sustainability of extensive livestock farming enterprises. Thus, it cannot be over-emphasized. No losses were recorded on this farm as there were no mortalities recorded. However, the farmer lost over 50% of the potential weaners' income due to a partially dysfunctional bull.

4.2.5 Participant 5

The farmer had a total farm size of 342 ha, of which the total portion available for livestock grazing was 320 ha. The total Large Stock Units kept for extensive farming purposes were 8.79 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 27 % and 25%, respectively, with the average rangeland condition score of 26%. The farmer was using a rotational grazing system for effective rangeland management. *Eragrostis chloromelas* was the most prevalent grass species identified during the rangeland condition assessment, followed by Themeda triandra, which had less than 13%. The total calving rate of 82% and the average weaning weight of 197kg at roughly six to seven months of age were recorded on this farm. The farmer did not follow a prescribed animal health program but followed the area's breeding season and had no production plan. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was matric, and the farmer’s trusted agricultural information sources were government agricultural extension and private agricultural extension support.

4.2.5.1 Production level

A high yearly calving rate of 82% was recorded, with pre-weaning annual mortality of one calve and yearly mortality of two LSUs recorded on matured livestock. The average weight of weaners recorded over time was 197kg, and an exceptionally low stocking rate of significantly below 50% was also recorded on this farm, resulting in an additional substantial loss of income. The low stocking rate was confirmed because the rangeland is underutilized, with high fodder production and organic material. Stock theft is, however, a significant problem in this area, hampering production levels. And according to the farmer, about 40 cattle were lost in 2017 due to rife stock theft.

4.2.5.2 Financial implications

Under- and overstocking is neither beneficial to the ecological sustainability nor the profitability of the extensive livestock farming enterprises. Thus, based on the beef average weaner price of October 2021 of R39.50 and the average class C2/C3 beef carcass price of R45.11 in the central Free State. The farmer lost R 7 781.5 of the potential weaners income and R 21 652,8 on matured cow slaughter income.

4.2.6 Participant 6

The farmer had a total farm size of 339 ha, of which the total portion available for livestock grazing was 300 ha. The big difference in rangeland condition between the two camps was that one survey was done in a camp closest to the farmhouse per the farmers' recommendation. The total Large Stock Units kept for extensive farming purposes were 69 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 67% and 27%, respectively, with the average rangeland condition score of 47%. The farmer was using a rotational grazing system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the *Aristida bipartita* for the camp in a 67% rangeland condition.

In contrast, *Aristida bipartita* dominated the home camp, followed by *Eragrostis chloromelas*. The total calving rate of 67% and the average weaning weight of 205kg at roughly six to seven months of age were recorded on this farm. The farmer followed a prescribed animal health program and the breeding season for the area but did not have a production plan. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was Standard 4, and the farmer's trusted agricultural information source was only an informal mentorship arrangement with the neighbouring farmers.

4.2.6.1 Production level

A yearly % calving rate of 67% was recorded, with yearly pre-weaning mortality of two calves and yearly mortality of one LSU recorded on matured livestock. The average weight of weaners recorded over time was 205kg, and a higher stocking rate was recorded on this farm compared to the area's 6ha/LSU carrying capacity norm.

4.2.6.2 Financial implications

Overstocking contributes immensely to rangeland ecosystem degradation and, as a result, threatens the sustainability of extensive livestock farming enterprises. Thus, based on the beef average weaner price of October 2021 of R39.50 and the average class C2/C3 beef carcass price of R45.11 in the central Free State. The farmer lost

R16 195 of the potential weaners' income and R 10 826.4 on matured cow slaughter income.

4.2.7 Participant 7

The farmer had a total farm size of 1574 ha, of which the total portion available for livestock grazing was 1420 ha. The total Large Stock Units kept for extensive farming purposes were 222.29 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 48% and 55%, respectively, with the average rangeland condition score of 52%. The farmer was using a rotational grazing system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the *Eragrostis chlomorelas*. The total calving rate of 16% and the average weaning weight of 192kg at roughly six to seven months of age were recorded on this farm. The farmer did not follow a prescribed animal health program and the area's breeding season and had no production plan. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was Standard 6, and the farmer’s trusted agricultural information source was only government agricultural extension support.

4.2.7.1 Production level

A low yearly calving rate of 16% was recorded with pre-weaning annual mortality of 20 calves and yearly mortality of six LSUs recorded on matured livestock. The average weight of weaners recorded over time was 192kg. A slightly lower stocking rate was recorded on this farm compared to the 6ha/LSU carrying capacity norm, resulting in an additional loss of income.

4.2.7.2 Financial implications

Under- and overstocking is neither beneficial to the ecological sustainability nor the profitability of the extensive livestock farming enterprises. Thus, based on the beef average weaner price of October 2021 of R39.50 and the average class C2/C3 beef carcass price of R45.1 in the central Free State. The farmer lost R 151 680 of the potential weaners' income and R64 958.4 on matured cow slaughter income, respectively.

4.2.8 Participant 8

The farmer had a total farm size of 1064 ha, of which the total portion available for livestock grazing was 360 ha. The total Large Stock Units kept for extensive farming purposes were 150.11 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 28% and 14%, respectively, with the average rangeland condition score of 21%. The farmer was using a rotational grazing system for effective rangeland management. *Aristida biparitita* and *Cynodon dactylon* pioneer species were the most prevalent grass species identified during the rangeland condition assessment, followed by the *Eragrostis Chlomorelas.* The total calving rate of 14% and the average weaning weight of 228kg at roughly six to seven months of age were recorded on this farm. The farmer did not have a production plan but followed a prescribed animal health program and the breeding season for the area. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was a university B-tech degree, and the farmer’s trusted agricultural information sources were informal mentorship arrangements with the neighbours, government agricultural extension and private extension support.

4.2.8.1 Production level

A low yearly calving rate of 14% was recorded, with neither yearly pre-weaning mortality on calves nor yearly mortality on matured livestock. The average weight of weaners recorded over time was 228kg, and an exceptionally high stocking rate of almost more than 100% was recorded on this farm, compared to 6ha/LSU on the natural veld. Thus, this placed enormous pressure on natural vegetation despite the availability of maize residues on 350ha of the total arable land on this farm. The abundance of pioneer grass species on this farm, as opposed to climax and sub-climax grass species, confirms poor rangeland management despite the availability of crop residues and further demonstrates inefficiency in the utilization of rangeland resources for extensive livestock farming purposes.

4.2.8.2 Financial implications

Poor rangeland management practices such as overstocking are detrimental to the natural grazing veld and thus threaten the sustainability of the extensive livestock enterprises. No losses were recorded on this farm as there were no mortalities recorded. However, this farm's extensive livestock farming enterprise is inefficient and cannot survive without crop residue supplementation.

4.2.9 Participant 9

The farmer had a total farm size of 942 ha, of which the total portion available for livestock grazing was 905 ha. The total Large Stock Units kept for extensive farming purposes were 78.58 LSUs. Rangeland condition scores recorded for this farm post rangeland condition assessment were 62% and 49%, respectively, with the average rangeland condition score of 55.5%. The farmer was using a rotational grazing system for effective rangeland management. *Themeda triandra* was the most prevalent grass species identified during the rangeland condition assessment, followed by the *Eragrostis chlomorelas.* The total calving rate of 99% and the average weaning weight of 208kg at roughly six to seven months of age were recorded on this farm. The farmer did not have a production plan or follow a prescribed animal health program and the breeding season for the area. The farmer supplied seasonal production licks to LSUs kept on the farm and the salt blocks. The highest education level recorded for the farmer was matric. The farmers' trusted agricultural information sources were informal mentorship arrangements with the neighbours, government agricultural extension, and private extension support.

4.2.9.1 Production level

A high yearly calving rate of 99% was recorded with pre-weaning annual mortality of 2 calves, and no yearly mortality was recorded on matured livestock. The average weight of weaners recorded over time was 208 kg, and this farm recorded an exceptionally low stocking rate of almost below 50%, resulting in an additional substantial loss of income.

4.2.9.2 Financial implications

Under- and overstocking is neither beneficial to the ecological sustainability nor the profitability of the extensive livestock farming enterprises. Thus, based on the average weaner price of beef in October 2021 of R39.50 in the central Free State. The farmer lost R16.432 of the potential weaner's income.

4.3 COLLECTIVE SYNOPSIS OF PARTICIPANTS' PRODUCTION LEVELS ANALYSIS

A minimum of 14% calving rate and 183kg weaning weight, an average of 53% calving rate and 200kg weaning weight and a maximum of 99% calving rate and 228kg weaning weight were recorded, respectively. Nonetheless, according to Zantsi et al. (2021), the general average land reform livestock productivity in South Africa is closer to that of commercial farmers when compared to the average crop production, suggesting that land reform livestock farmers can achieve commercial livestock production levels much more manageable with appropriate support and resources.

Despite data for this study being collected at the beginning of the calving season, generally prudent livestock management skills amongst extensive land-reform livestock farmers are concerning. Over and understocking incidents recorded confirms: the absence of grazing management systems, breeding plans, livestock disease prevention measures, mortalities, low calving rates, and spurious high calving rates recorded. Scholtz and Bester (2010) recorded very low calving rates for emerging livestock farmers sector in South Africa, comparable to 32% calving rate recorded in a research trial by Van der Westhuizen et al. (2020) conducted at Glen experimental farm north of Bloemfontein without rangeland management inputs, as well as that of Mokhesengoane et al. (2021) recorded during droughts amongst land-reform farmers in Bloemfontein.

According to Van der Westhuizen (2003), grazing capacity in the study area for rangelands at 50% of condition score is approximately 9.5 ha/LSU for small stock and 8 ha/LSU for cattle. However, the findings of this study are inconsistent with the recommendations of Van der Westhuizen (2003), even though both studies took place in the same study area. These discrepancies are detrimental to proper ecosystem functioning, environmental sustainability and subsequently sustainable livestock production and, thus, threaten livelihood development and food security.

4.4 RESULTS AND DISCUSSIONS

The following statistical analyses and figures represent the managerial decisions of the sampled Bloemfontein land-reform extensive pastoral farmers and their impacts on rangeland condition scores and soil chemical and physical properties. These statistical analyses also seek to achieve the objectives of this study, namely, to provide holistic guidance for future sustainable livestock production in the semi-arid rangelands of Bloemfontein magisterial area for land-reform farmers, to establish correlations between rangeland condition, soil chemical properties and managerial inputs on the sampled land-reform farms., to compare rangeland condition per land reform farm and between land reform farms and, use land-reform livestock farmers' decisions on animal stocking rates to establish their production efficiency and to establish a correlation between soil carbon and rangeland condition.

4.4.1 Variations in land size, utilization and minimum and maximum stocking rates for sampled extensive land-reform livestock farmers

Table 4.1: Descriptive statistical analyses regarding the total farm size, grazing area and arable land

	Total farm size (ha)	Grazing area (ha)	Arable land (ha)
Mean	859,44	671,67	186,67
95% Confidence Interval for Mean Lower Bound	274,62	208,65	-20,63
Upper Bound	1444,27	1134,69	393,96
5% Trimmed Mean	805,05	631,85	168,52
Mode	214[a]	180[a]	0[a]
Median	516,00	360,00	30,00
Variance	578865,78	362848,00	72725,75
Std. Deviation	760,83	602,37	269,68
Minimum	214,00	180,00	0,00

Maximum	2484,00	1880,00	700,00

The mean grazing area was 671, 67 ± 602,37ha, with a minimum of 180ha (Table 4.1) grazed by 31.12 LSUs, with an average rangeland condition score of 77% and a maximum rangeland condition score of 81%. The maximum of 1880ha (Table 4.1) grazed by 139.33 LSUs, with an average rangeland condition score of 61.5% and a maximum rangeland condition score of 62%. According to the Department of Agriculture (2003), the stocking rate norm for the study area is 6ha/LSU. Thus, stocking rates for the minimum grazing area were statistically insignificant, whereas stocking rates for the maximum grazing area were below 50% of the grazing area's total capacity, which is inconsistent with good rangeland management practices. Thus, Mokhesengoane et al. (2021) emphasised that farmers must constantly balance their natural grazing resources and livestock numbers.

The mean arable land was 186,67 ± 269,68ha, with a minimum of 0ha and a maximum of 700ha (Table 1). Only 33.3% of the sampled farmers' group had a crop on their arable lands, which could be used as a residue for livestock grazing. In contrast, other arable lands were not planted for successive years preceding this study, including the farm with the minimum grazing area and the farm with the maximum grazing area. Nonetheless, the standard deviation indicated that grazing hectares within the group were more spread out in numbers. Thus, these standard deviations illustrate vast statistical dispersion amongst the sampled group in total farm size, grazing area and arable land. Only 350ha of the maximum arable land in this study had a crop residue. Considering the latter variables, it can be confirmed that the sampled group was heterogeneous.

4.4.2 Variations in rangeland condition scores, including the average, minimum and maximum scores for sampled extensive land-reform livestock farmers

Table 4.2: Descriptive statistics of rangeland condition scores

	Rangeland condition scores
Mean	50,28%

95% Confidence Interval for Mean Lower Bound	40,34%
Upper Bound	60,22%
5% Trimmed Mean	50,59%
Mode	49,00%[a]
Median	54,50%
Variance	399,389
Std. Deviation	19,985%
Minimum	14%
Maximum	81%

The mean rangeland condition score was 50,28 ± 19,99%, with a minimum of 14% rangeland condition score and a maximum of 81% rangeland condition score (Table 4.2). The average rangeland condition score concedes with that of Van der Westhuizen (2003), which was confirmed to be moderate with an estimated carrying capacity of 8 ha/LSU for cattle and 9.5 ha/LSU for sheep, respectively for the central Free State area. Nevertheless, the farm with the minimum rangeland condition score had the most crop residues in the sampled group, contrary to the farm with the maximum rangeland condition score with no crop residues. The standard deviation for rangeland condition scores also indicated the vast differences amongst farms.

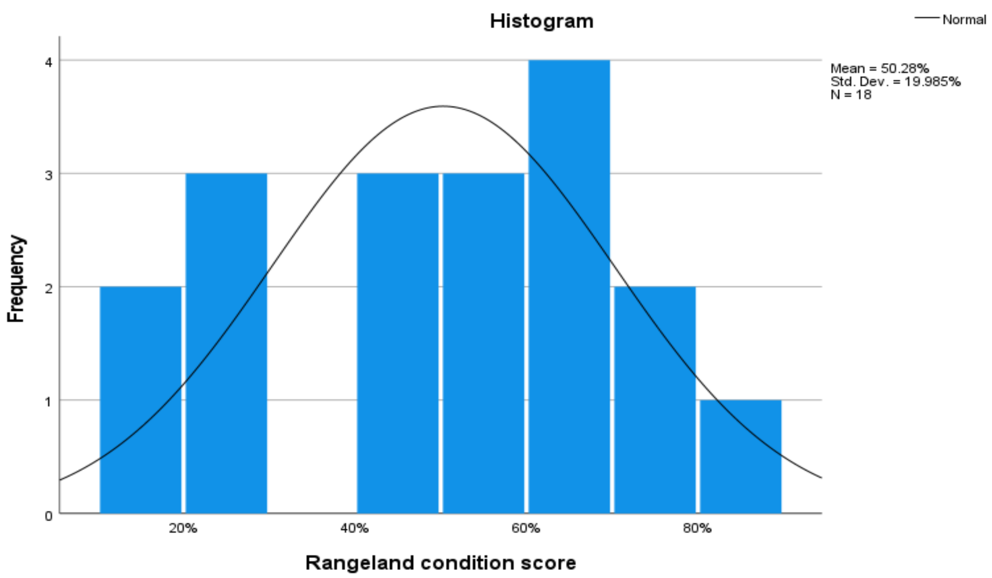

Figure 4.1: Histogram of rangeland condition scores on land-reform farms

Despite the 50, 28% moderate average rangeland condition scores as reported in (Table 4.2) above, a significant proportion of sampled land-reform farms had average rangeland condition scores of below 50% (Figure 4.1) without crop residues, and this clearly threatens sustainable extensive livestock productivity in this land-reform farms and will result in a loss of income and subsequently lead to poor quality meat produce in the long run.

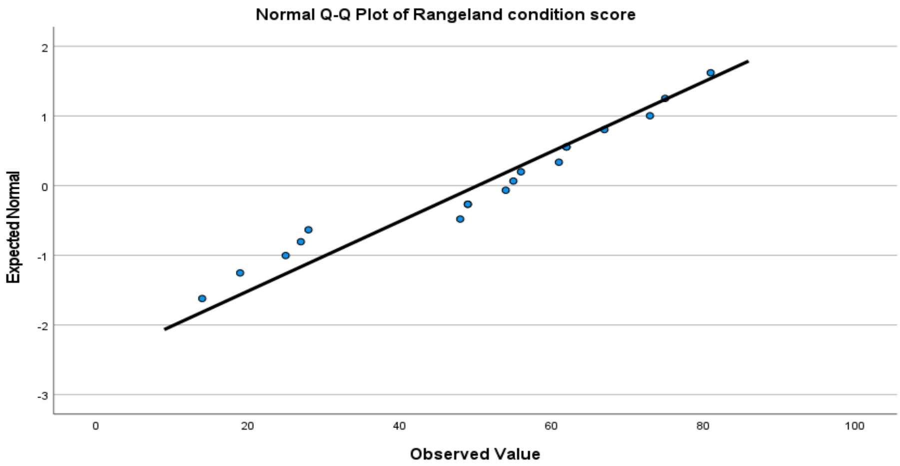

Figure 4.2: Normal Q-Q plot of rangeland condition scores on different land reform farms illustrating normal distribution

4.4.3 Variations in soil pH (KCl) distributions represented by the mean, std. deviations, minimum and maximum compared with rangeland condition scores among the camps

Table 4.3: Descriptive statistical analyses of soil pH (KCl)

	pH (KCl)
Mean	5,356
95% Confidence Interval for Mean Lower Bound	4,917
Upper Bound	5,794
5% Trimmed Mean	5,284
Mode	4,6[a]
Median	5,000
Variance	0,779
Std. Deviation	0,8827
Minimum	4,5

Maximum	7,5

The mean soil pH recorded between all camps was 5,3 with 0,88KCl std deviation with a minimum soil pH of 4,5KCl (Table 4.3) on the rangeland condition score of 54% and a maximum soil pH of 7,5KCl on the rangeland condition score of 56%. Nonetheless, although no significant differences exist between the rangeland scores for the minimum and the maximum soil pH recorded between camps, there is a trend between the rangeland condition score and pH levels.

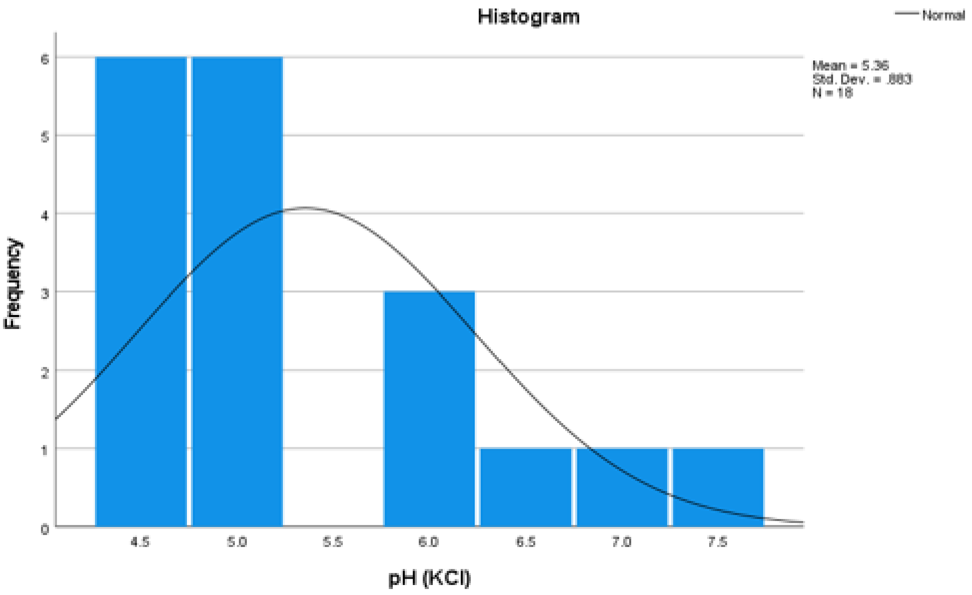

Figure 4.3: Histogram of soil pH (KCl)

The minimum soil pH was strongly acidic, whereas the maximum soil pH was neutral, whereas the average recorded soil pH was also acidic. The standard deviation illustrated a vast difference between the pH of all sampled camps (Figure 4.3).

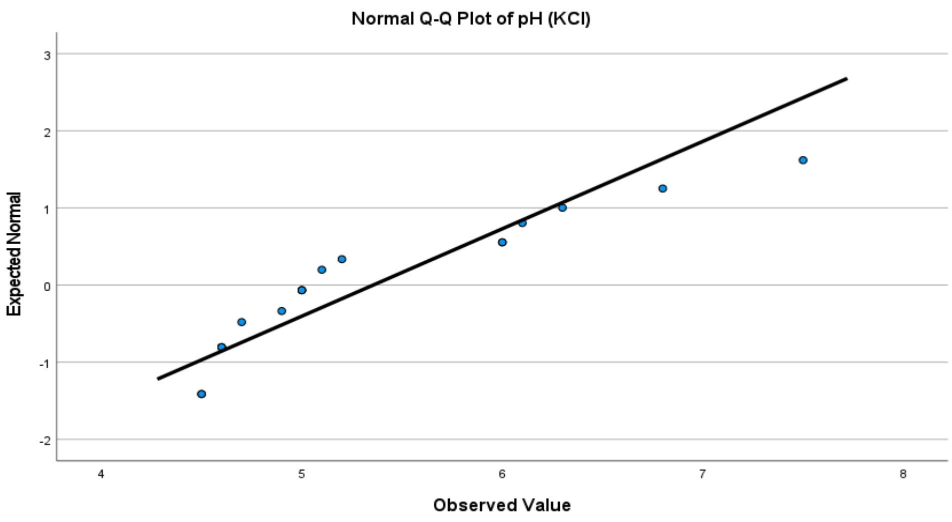

Figure 4.4: Q-Q plot confirming slightly uneven soil pH (KCl) level distribution amongst camps

4.4.4 Variations in chemical soil properties distribution represented by the mean, std. deviation, maximum and minimum concentration

Table 4.4: Soil chemical properties

	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	S (mg/kg)	Na (mg/kg)
Mean	3,483	418,161	1586,222	424,694	103,597	20,583
95% Confidence Interval for Mean Lower Bound	1,958	343,836	1006,224	309,638	65,524	9,925
Upper Bound	5,009	492,487	2166,221	539,751	141,669	31,242
5% Trimmed Mean	3,137	414,523	1527,247	415,516	98,182	18,304
Mode	1,20	151,2[a]	409,0[a]	136,2[a]	1,3[a]	0,9[a]
Median	2,750	392,900	1283,500	368,750	87,525	12,150
Variance	9,413	22338,777	1360308,536	53530,924	5861,498	459,400
Std. Deviation	3,0681	149,4616	1166,3227	231,3675	76,5604	21,4336
Minimum	0,8	151,2	409,0	136,2	0,9	1,3
Maximum	12,4	750,6	3825,0	878,4	303,8	80,9

4.4.4.1 Phosphorus

The mean P was 3,48 with 3,07mg/kg std deviation, a minimum P of 0,8mg/kg and a maximum P of 12,4mg/kg (Table 4.4), which is comparable with 12,8mg/kg P recorded by Kotzé (2015) in the Thaba Nchu nature reserve with poor rangeland condition, used as a control plot and statistically insignificant to 10.5mg/kg recorded on a commercial farm with good rangeland condition in the same study area in the same depth of 0-5cm in the central Free State province, whereas there were no comparable records on the soil samples taken on 10-20cm depth (Table 4.4).

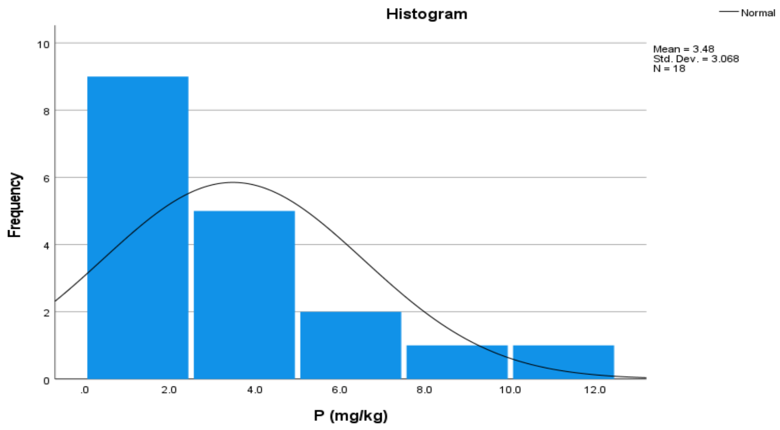

Figure 4.5: The Histogram of soil Phosphorus on different land-reform farms

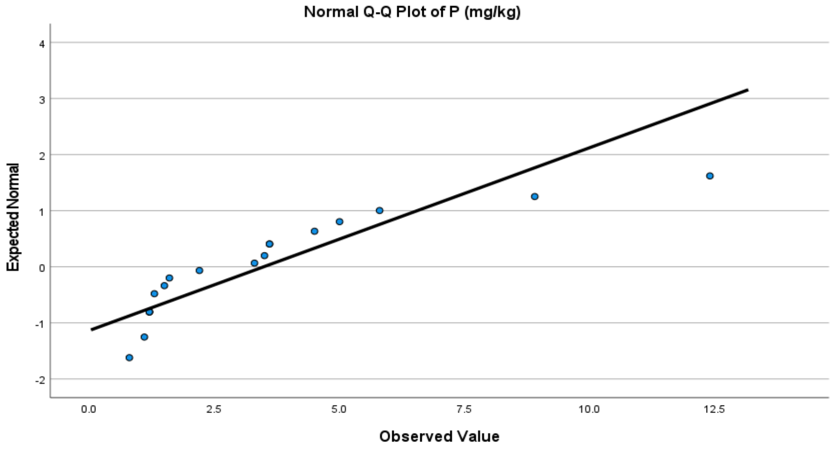

Figure 4.6: Q-Q Plot of Soil Phosphorus on different land reform farms confirming slightly abnormal distribution

4.4.4.2 Potassium

The mean K was 418,16 with 149,46mg/kg std deviation, the minimum K of 151,2mg/kg and the maximum K of 750,6mg/kg (Table 4.4), incomparable with all results of Kotzé (2015) in different farming categories and soil depths.

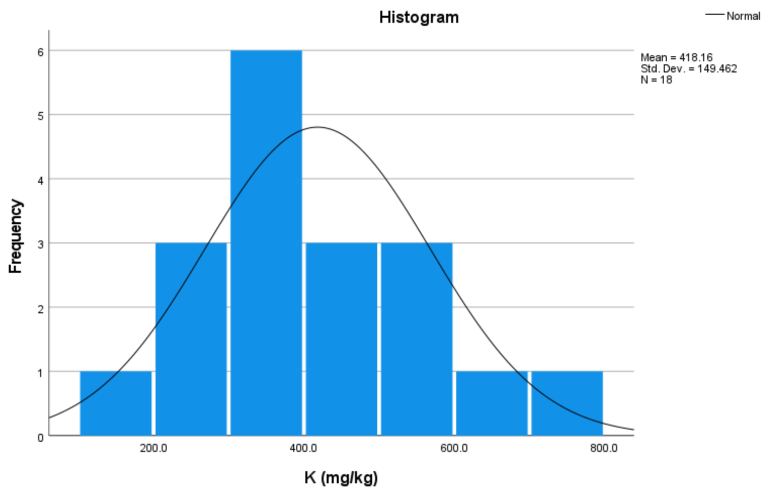

Figure 4.7: Histogram of soil potassium on different land reform farms

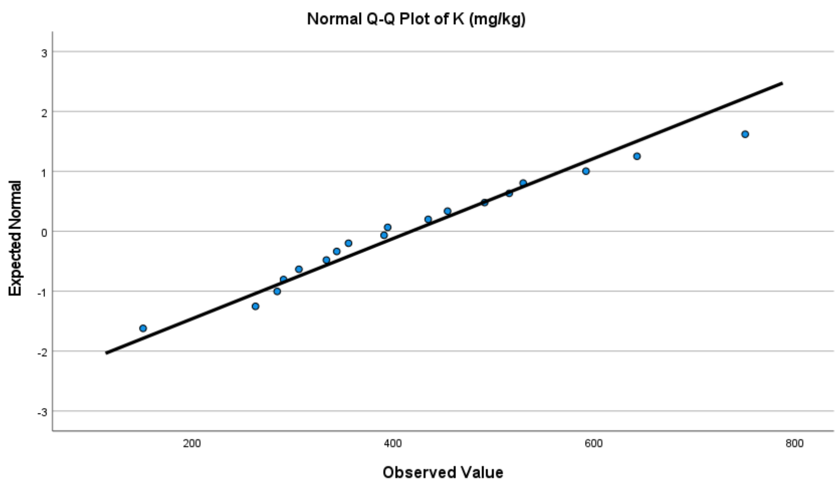

Figure 4.8: Q-Q plot of soil potassium on different land-reform farms confirming normal distribution

4.4.4.3 Calcium

The mean Ca was 1586,22 with 1166,32mg/kg std deviation, a minimum Ca of 409,0mg/kg and a maximum Ca of 3825,0mg/kg (Table 4), which is the highest when compared with the results of Kotzé (2015) of soil samples taken in all farm categories including the control farm at different soil depths ranging from 0-5cm minimum and 10-20cm maximum depth.

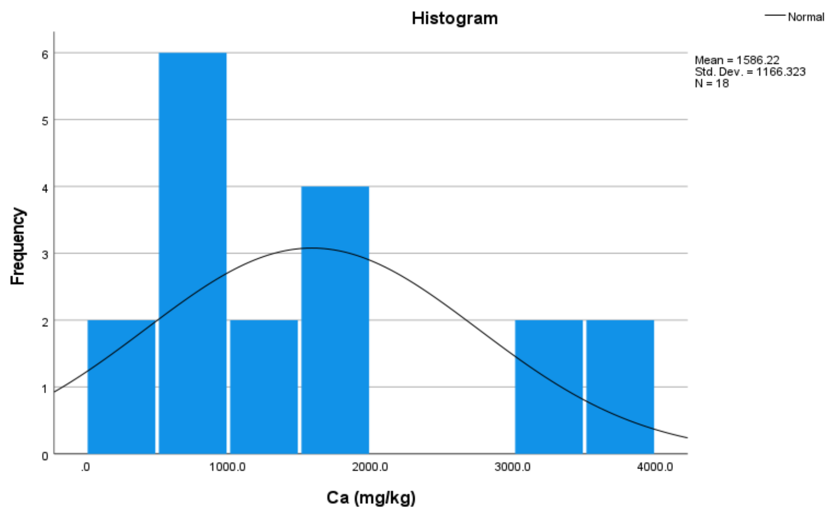

Figure 4.9: Histogram of soil calcium on different land reform farms

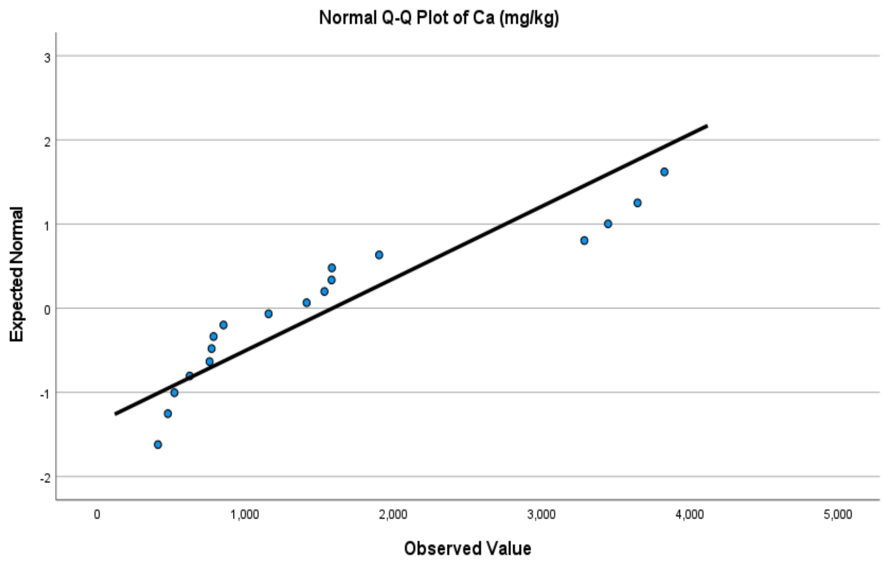

Figure 4.10: Q-Q plot of soil calcium on different land-reform farms confirming the fairly abnormal distribution

4.4.4.4 Magnesium

The mean Mg was 424,69 with 231,37mg/kg std deviation, the minimum Mg of 136,2mg/kg and the maximum Mg of 878,4mg/kg (Table 4.4) only comparable to 875mg/kg recorded on a commercial farm with a good rangeland condition in the same study of Kotzé (2015) on the soil depth of 10-20cm.

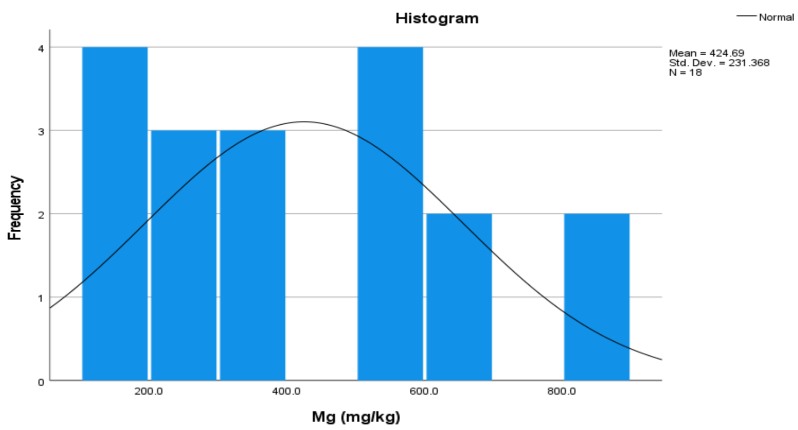

Figure 4.11: Histogram of soil magnesium on different land-reform farms

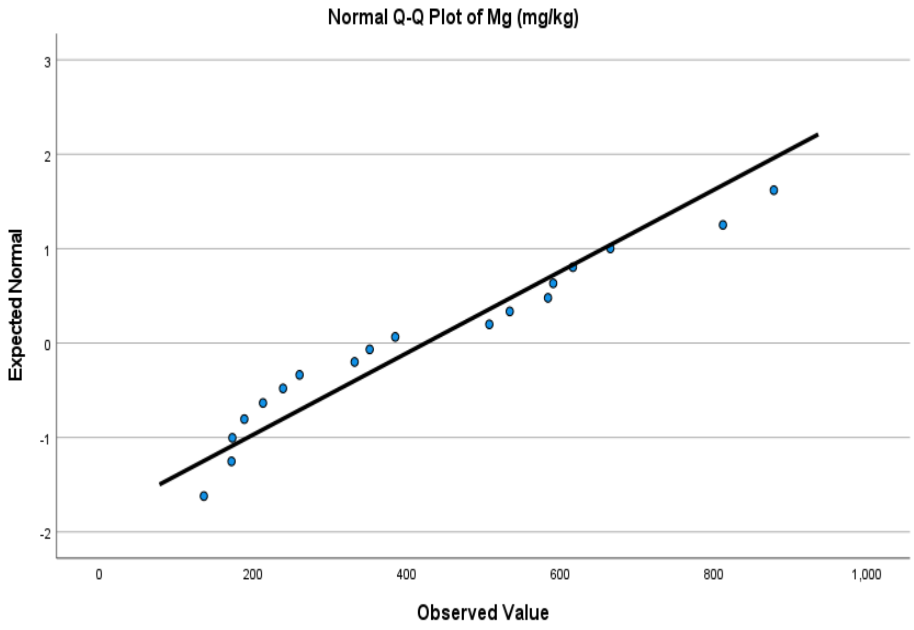

Figure 4.12: Q-Q plot of soil magnesium on different land-reform farms confirming relatively normal distribution

4.4.4.5 Sodium

The mean Na was 20,58 with 21,43mg/kg std deviation, the minimum Na of 1,3mg/kg and the maximum Na of 80,9mg/kg (Table 4.4) only comparable to the maximum of 100mg/kg recorded for a land-reform farm with moderate rangeland condition at the soil sample depth of 10-20cm in the study of (Kotzé, 2015). Lastly, the mean S was 103,60 with 76,56mg/kg std deviation, the minimum S of 0,9mg/kg and the maximum S of 303,8mg/kg.

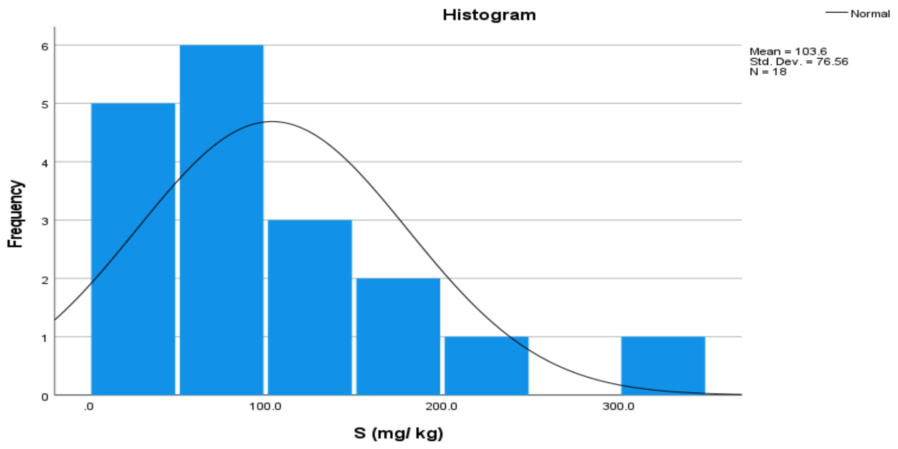

Figure 4.13: 19 Histogram of sodium on different land-form farms

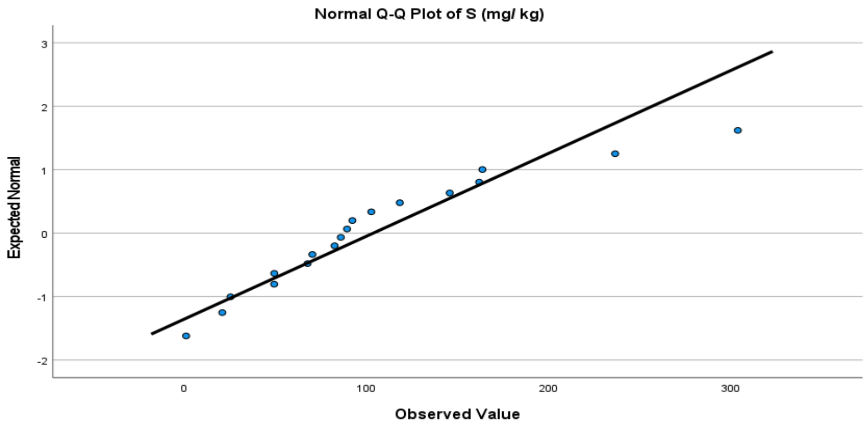

Figure 4.14: Q-Q plot of sodium distribution on different land-reform farms illustrating a slightly abnormal distribution

4.4.4.6 Soil carbon

Novara et al. (2014) highlighted that soil C content in semi-arid environments can increase with the fast growth and adaptability of the natural vegetation (see Table 4.5 below). The natural rangelands are essential in the carbon sequestration process, as they absorb the atmospheric carbon dioxide during the photosynthesis process and transport it through the root systems to be stored in the soil as C, which gives vigour to the soil structure amongst other increasing soil macro pores increasing substrate and energy to support soil microbial activity leading to storage of organic Ca, P and other related soil nutrients. Thus, the maintenance of rangelands through prudent management and proper stocking rates increases the potential of the soil to store more

C and, as a result, mitigates the effects of climate change (Fynn et al., 2009). The average C of 2.17 ± 1.065 was recorded (Figure 4.15) below.

Table 4.5: Topsoil carbon content (%) for different rangelands condition classes

Rangelands condition	**Abysmal (≤ 20 %)**	**Poor to Moderate (21 - 60 %)**	**Good (> 60 %)**
Carbon content ± SD (%)	$1.0^{a} \pm 0.43$	$1.9^{a} \pm 0.73$	$3.1^{b} \pm 1.08$

[a, b, c, d] – Values (mean ± SD) within a column followed by different superscript letters are significantly different ($p < 0.05$), SD = Standard deviation.

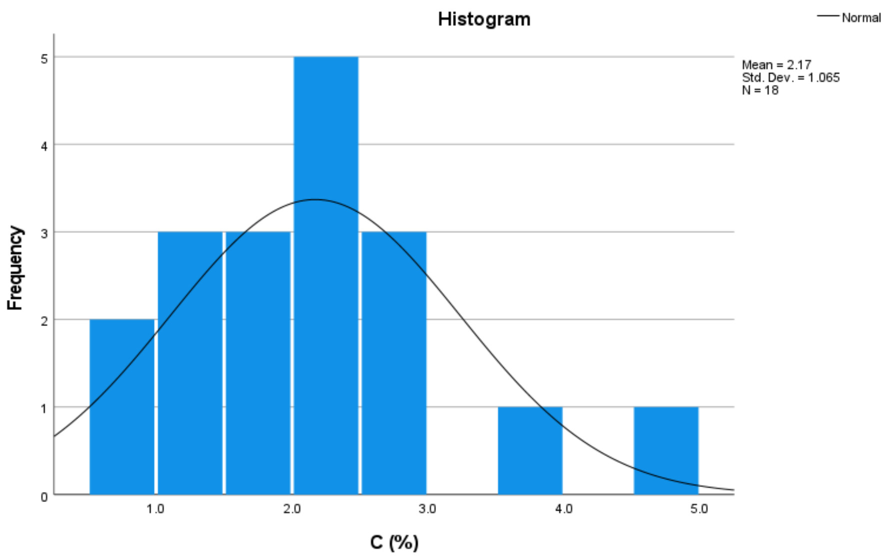

Figure 4.15: Histogram of soil carbon illustrating normal distribution

These results illustrate contrasting findings with that of Kotzé (2015) by highlighting comparable maximum soil P at different soil depths in the grasslands of the central Free State, secondly by highlighting incomparable maximum soil K and Ca at different soil depths and by highlighting comparable maximum soil Mg and Na increasing with the soil depth as per the findings of Kotzé (2015). However, even though the results of Kotzé (2015) strongly associated the maximum concentration of these soil chemical properties with the rangelands ranging from moderate to good condition, this was not evident in this study as there were no significant differences in the concentration of these soil chemical properties between the different camps of different farms with lowest rangeland condition scores and highest rangeland condition scores recorded, except for soil carbon content which increased three times more on good rangelands condition with score of 60 % and more. Furthermore, the study also recorded a trend between soil pH and rangeland condition and a trend between soil P content and rangeland condition.

4.4.5 Variations in Exchangeable Acidity (EA), Cations Exchange Capacity (CEC) and Electrical Conductivity (EC), represented by the mean, std. deviation, maximum and minimum concentration

Table 4.6: EA, CEC and EC

	EA	CEC (cmolckg-1)	EC (mS/m)
Mean	0,149	12,721	11,611
95% Confidence Interval for Mean Lower Bound	0,038	9,029	6,850
Upper Bound	0,260	16,412	16,372
5% Trimmed Mean	0,135	12,310	10,335
Mode	0,000	4,4[a]	6,50
Median	0,000	11,555	7,750
Variance	0,050	55,112	91,653
Std. Deviation	0,2240	7,4237	9,5735
Minimum	0,0	4,4	4,5
Maximum	0,5	28,4	41,7

Soils can hold only a certain quantity of nutrients. This amount varies with the soil type: sandy soils hold less than clay soils. Negatively charged colloids of clay and organic matter hold positively charged nutrients (cations such as Na, K, Mg, Ca, and ammonium). If there are too many cations for the colloids to hold, the rest stay in solution and drain away with the water. The mean EA was 0,15 ± 0,22 with a minimum of 0,0 and a maximum of 0,5The mean CEC was 12,72 ± 7,42cmolckg-1 with a minimum of 4,4cmolckg-1 (Table 4.6), indicating a good potential for essential soil chemical properties maintenance being Ca, Mg and P as well as the physical soil properties. A maximum of 28,4cmolckg-1 was found on the camps with the highest clay content soils recorded. The mean EC was 11,61 ± 9,57mS/m with a minimum of 4,5mS/m and a maximum of 41,7mS/m (Table 4.5). The number of negative charge sites (measured by cation exchange capacity or CEC) indicates soil nutrient cation retention capacity, with a higher CEC indicating greater nutrient cation storage capacity.

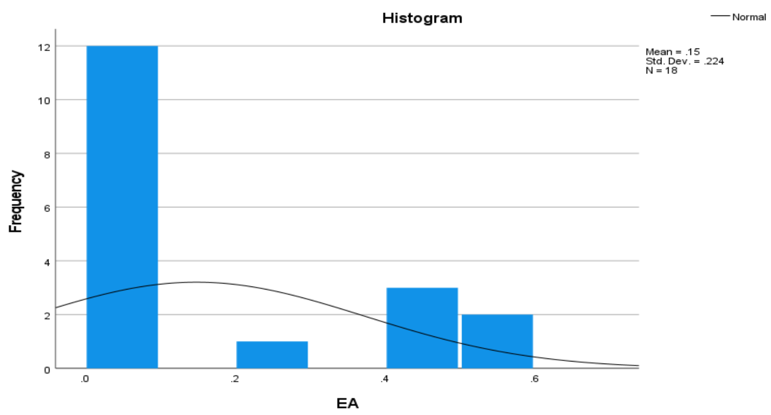

Figure 4.16: Histogram of EA on different land-reform farms illustrating an abnormal distribution

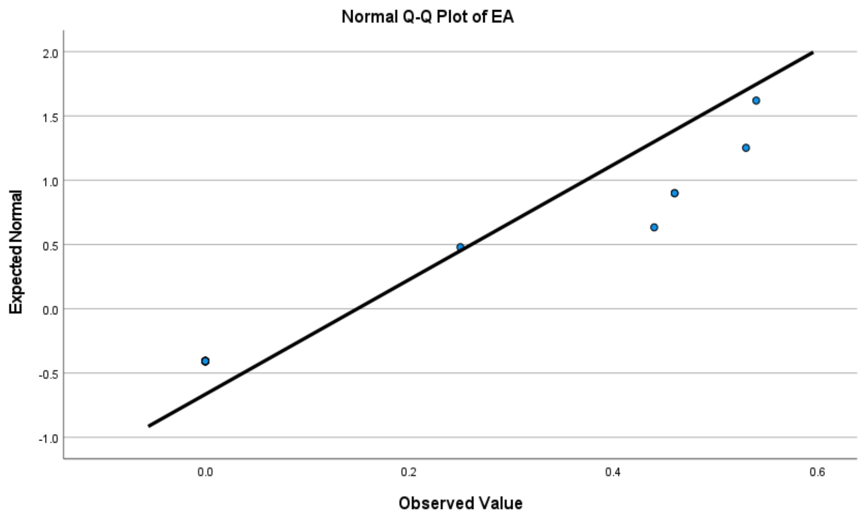

Figure 4.17: Q-Q plot confirming the abnormal distribution of EA

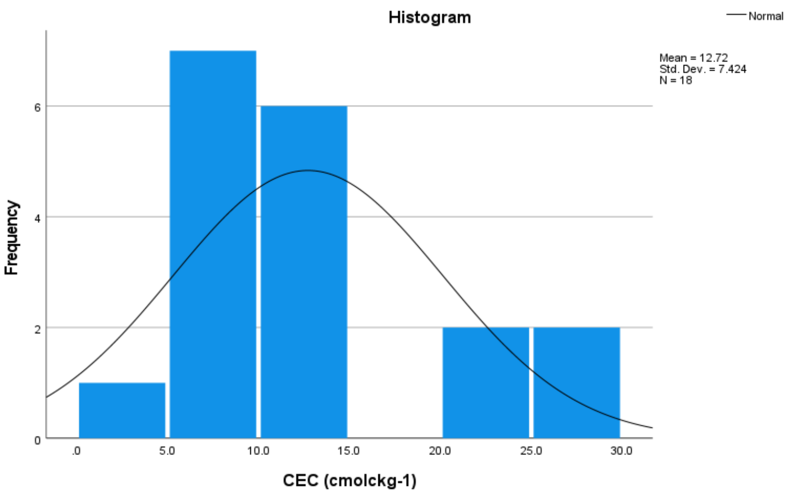

Figure 4.18: Histogram of CEC on different land-reform farms illustrating normal distribution

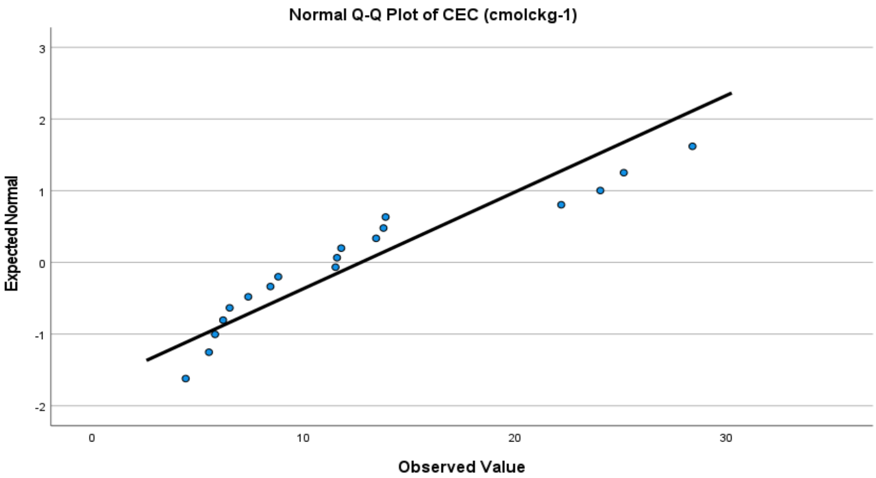

Figure 4.19: Q-Q plot of CEC on different land reform farms confirms relatively normal distribution

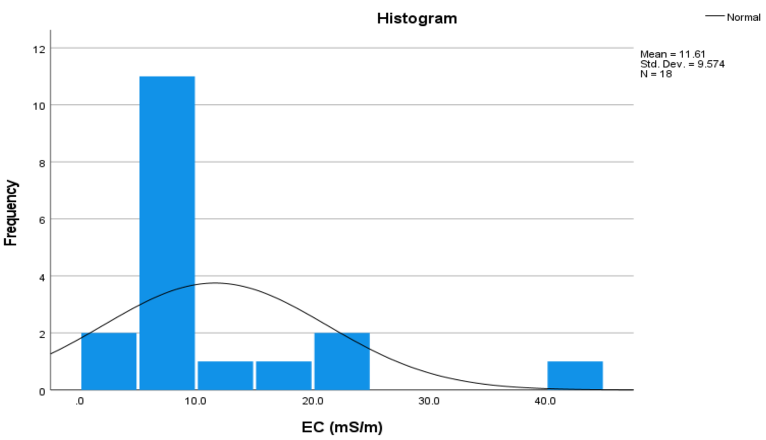

Figure 4.20: Histogram of EC on different land-reform farms illustrating an abnormal distribution

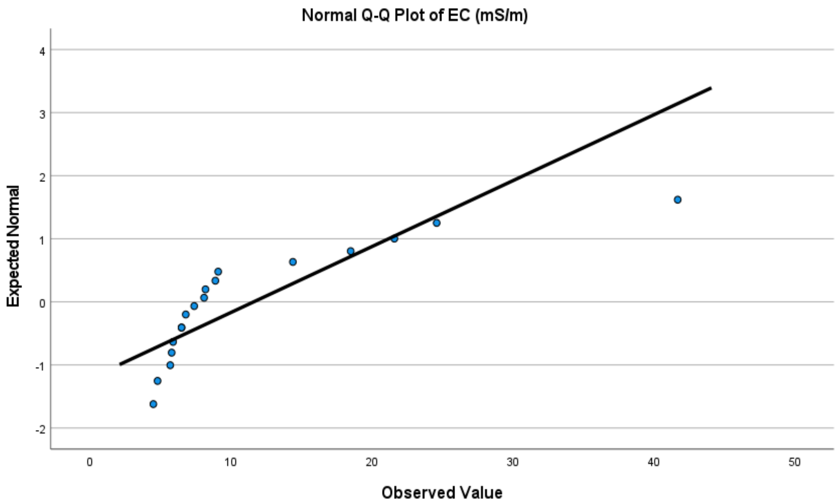

Figure 4.21: Q-Q plot of EC on different land reform farms confirming the abnormal distribution

The CEC amongst sampled farms was relatively normal and followed an average trend, increasing with more clayey soil fraction and decreasing with the decrease of clayey soil fraction. Thus, it is concluded that the CEC distribution amongst farms was normal for natural rangelands with a high mean of 12,72cmolckg-1 comparable to 10.75cmolckg-1 recorded by Kotzé (2015) in the commercial farm in the savanna biome in the North West province of South Africa.

4.4.6 Variations in three soil fractions, sand, clay, and silt distribution, are represented by the mean, std. deviation, maximum and minimum concentration

Table 4.7: Three fractions of soil texture determination

	Density (g.cm-3)	**Sand (%)**	**Clay (%)**	**Silt (%)**
Mean	1,022	73,56	20,22	6,22
95%Confidence Interval for Mean Lower Bound	0,955	69,01	16,43	5,06
Upper Bound	1,089	78,10	24,02	7,39
5% Trimmed Mean	1,020	73,51	20,14	6,25

Mode	1,0[a]	78,00	20,00	8,00
Median	1,025	74,00	20,00	6,50
Variance	0,018	83,673	58,301	5,477
Std. Deviation	0,1348	9,147	7,635	2,340
Minimum	0,8	58	8	2
Maximum	1,3	90	34	10

Density: The mean density was 1,02 ± 0,13g.cm-3 with a minimum of 0.8g.cm-3 and a maximum of 1,3g.cm-3. Sand: The mean amount of sand was 73,56 ± 9,15%, with a minimum of 58% and a maximum of 90%. Clay: The mean amount of clay was 20,22 ± 7,64%, with a minimum of 8% and a maximum of 34%.Silt: The mean amount of silt was 6,22 ± 2,34%, with a minimum of 2% and a maximum of 10% (Table 4.7).

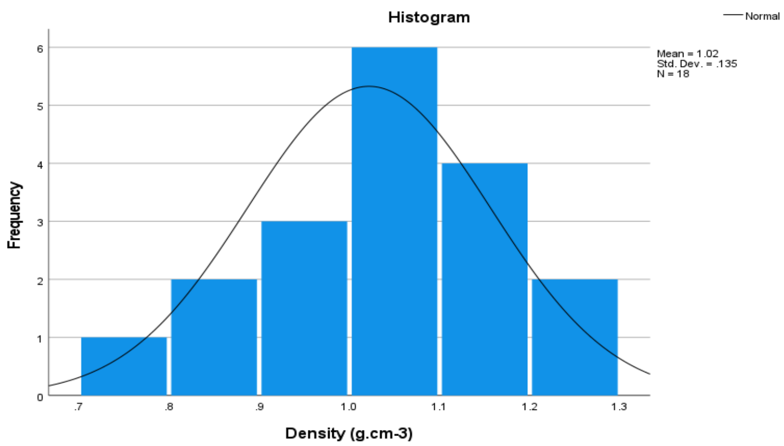

Figure 4.22: Histogram of soil density amongst sampled farms illustrating a normal distribution

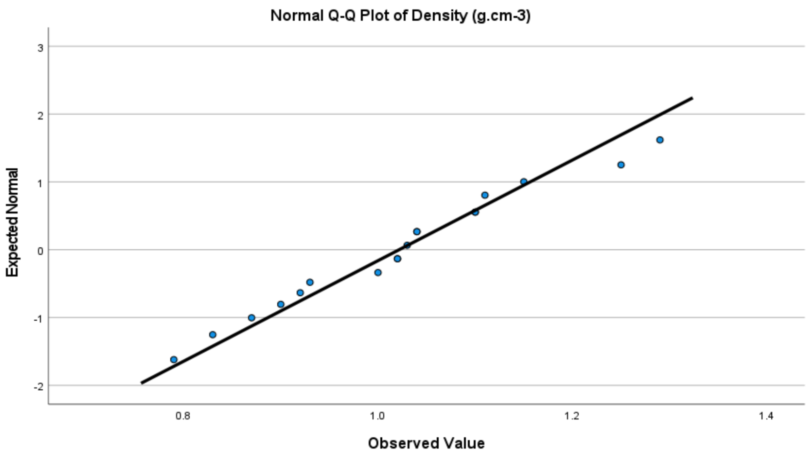

Figure 4.23: Normal Q-Q plot of soil density amongst sampled farms, confirming normal distribution

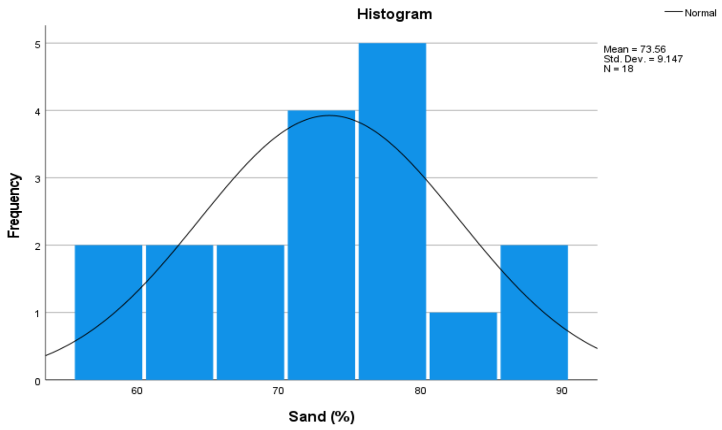

Figure 4.24: Histogram of sandy soil fraction amongst sampled farms

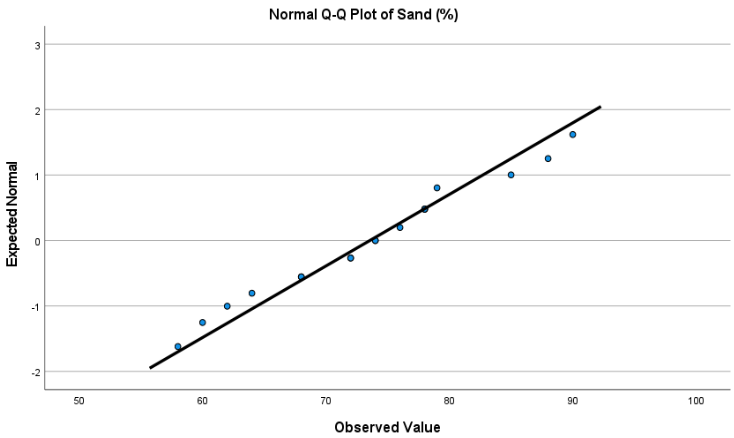

Figure 4.25: Q-Q plot of sandy soil fraction amongst sampled farms, illustrating the normal distribution

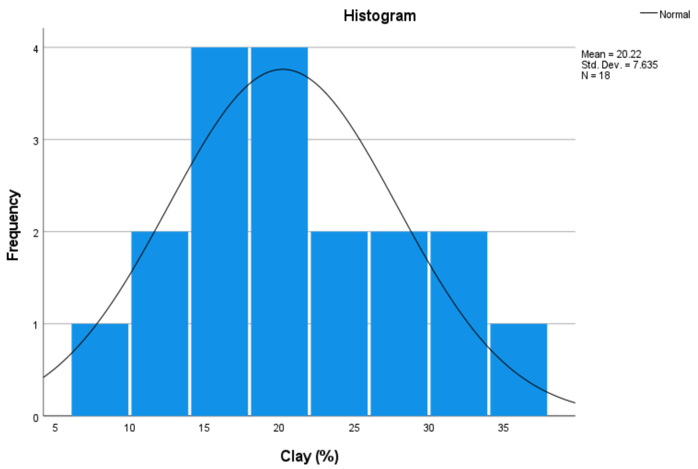

Figure 4.26: Histogram of clayey soil fraction among sampled farms

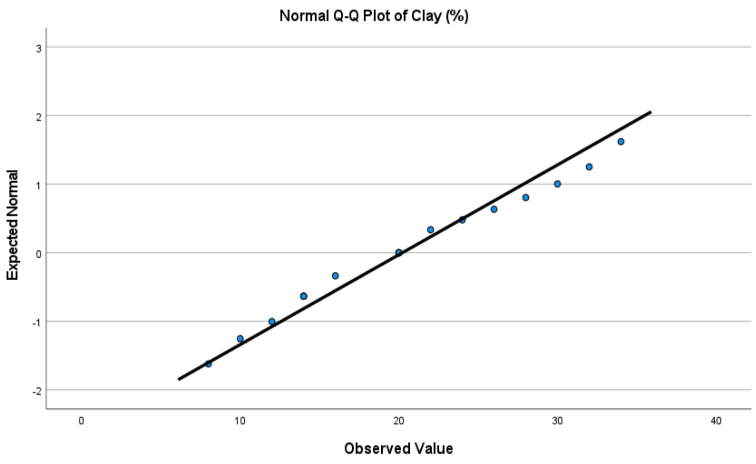

Figure 4.27: Q-Q plot of clayey soil fraction amongst sampled farms, illustrating the normal distribution

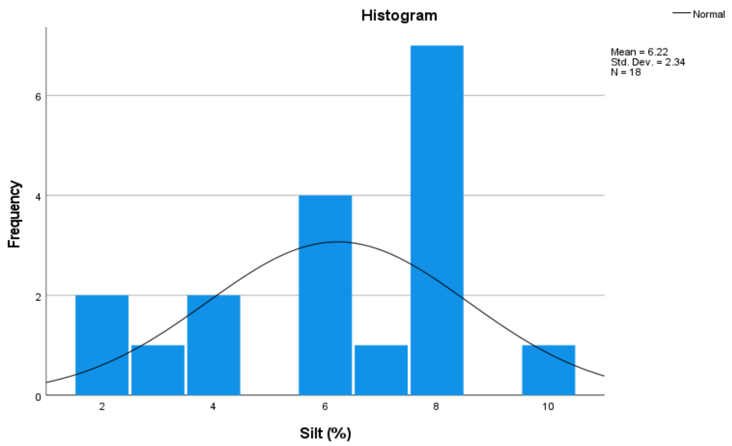

Figure 4.28: 34 Histogram of silt soil fraction amongst sampled farms

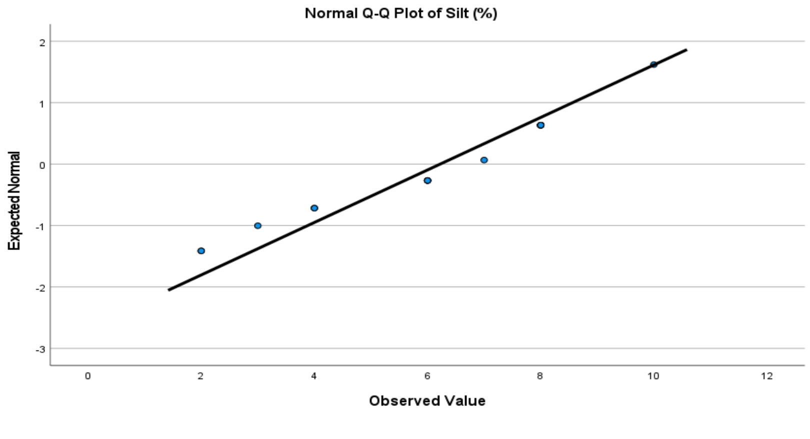

Figure 4.29: Q-Q plot of silt soil fraction amongst sampled farms, illustrating the normal distribution

Std. deviations were considerable, illustrating vast differences and statistical dispersions between soil density and soil forms of different farms. However, there were no significant differences between soil density and soil forms between the camps of each sampled farm. The 34% maximum clay content recorded for this study is comparable to the 35% and more clay content reported by MacVicar et al. (1977) for the study area and Kotzé (2015) for a commercial farm, communal land and the control plot, respectively in Thaba Nchu area east of Bloemfontein.

4.4.7 Comparison between soil chemical properties, soil texture and rangeland condition scores represented by the mean, std. deviation, maximum and minimum

Table 4.8: Correlation between rangeland condition and soil chemical properties

	Descriptive statistics		Correlation with rangeland condition score	
	Mean	**Std. Deviation**	**Pearson Correlation**	**Sig. (2-tailed)**
pH (KCl)	5,36	0,88	0,04	0,88
P (mg/kg)	3,48	3,07	0,19	0,44
K (mg/kg)	418,16	149,46	0,29	0,24
Ca (mg/kg)	1586,22	1166,32	0,18	0,49
Mg (mg/kg)	424,69	231,37	0,36	0,14
Na (mg/ kg)	20,58	21,43	0,35	0,15
S (mg/ kg)	103,60	76,56	-0,09	0,72
EA	0,15	0,22	-0,31	0,20
As (%)	2,47	3,94	-0,42	0,08
CEC (cmolckg-1)	12,72	7,42	0,24	0,34
Density (g.cm-3)	1,02	0,13	0,02	0,94
Sand (%)	73,56	9,15	-0,32	0,19
Clay (%)	20,22	7,64	0,32	0,20
Silt (%)	6,22	2,34	0,24	0,34
EC (mS/m)	11,61	9,57	0,00	0,99
C (%)	2,17	1,07	0,35	0,15

Cu (mg/kg)	0,27	0,14	0,01	0,98
Fe (mg/kg)	2,06	1,34	-0,24	0,34
Mn (mg/kg)	3,47	1,04	-0,01	0,97
Zn (mg/kg)	0,24	0,13	0,02	0,95

There was no statistically significant correlation between rangeland condition and soil chemical properties, as all *p*-values were less than 0,05. However, similar studies in the clayey grassland biome reported a concentration of soil chemical properties, particularly on commercial farms (e.g., exchangeable P, K, Ca, Fe and Zn), which was associated with rotational grazing and good rangeland conditions and decreased soil chemical properties related to continuous grazing and poor rangelands condition (Table 4.8).

4.4.8 Comparison between average rangeland condition scores of farms with a production plan and those without as management input represented by the mean and std. deviation.

Table 4.9: Average rangeland condition scores and production plan

Production plan (Yes/No)	**Studied Farms**	**Rangeland condition scores Mean (%)**	**Std. Deviation (%)**	**Std. Error Mean (%)**
No	6	43.10	18.182	7.424
Yes	3	55.60	19.761	11.409

*Positive correlation between mean % of rangeland condition scores and production plan ($p < 0.05$)

Amongst all livestock managerial input parameters measured for this study, a positive correlation was only found between the average rangeland condition scores and a production plan. Thus, land-reform farmers who indicated they have a production plan had a higher mean rangeland condition score of 55,60 ± 19,761%, compared to participants who did not have a production plan who had a lower average rangeland condition score of 43,10 ± 18,182% (Table 4.9). The study concludes that the difference between average rangeland condition scores and production plan was statistically significant (p<0,05). Thus, Faber (2019) confirms that a properly planned livestock production calendar increases efficiency at the primary production level.

4.4.9 Comparison between rangeland condition scores between camps on a particular farm and between the farms represented by the mean, std. deviation, maximum and minimum

Table 4.10: Comparison of rangeland condition between camps per farm

	Frequency N	Mean	Std. Deviation	Minimum	Maximum
Participant 1	2	61,50%	0,707%	61%	62%
Participant 2	2	37,50%	26,163%	19%	56%
Participant 3	2	51,50%	3,536%	49%	54%
Participant 4	2	77,00%	5,657%	73%	81%
Participant 5	2	50,00%	35,355%	25%	75%
Participant 6	2	47,00%	28,284%	27%	67%
Participant 7	2	51,50%	4,950%	48%	55%
Participant 8	2	21,00%	9,899%	14%	28%
Participant 9	2	55,50%	9,192%	49%	62%
Total	18	50,28%	19,985%	14%	81%

The significant rangeland condition score differences suggesting inconsistencies in rangeland management within farms were recorded for Participants 5 and 6 with the highest standard deviations, followed by Participant 8 with the lowest average rangeland condition score and Participant 2 with the second lowest rangeland condition score amongst the group (Table 4.10).

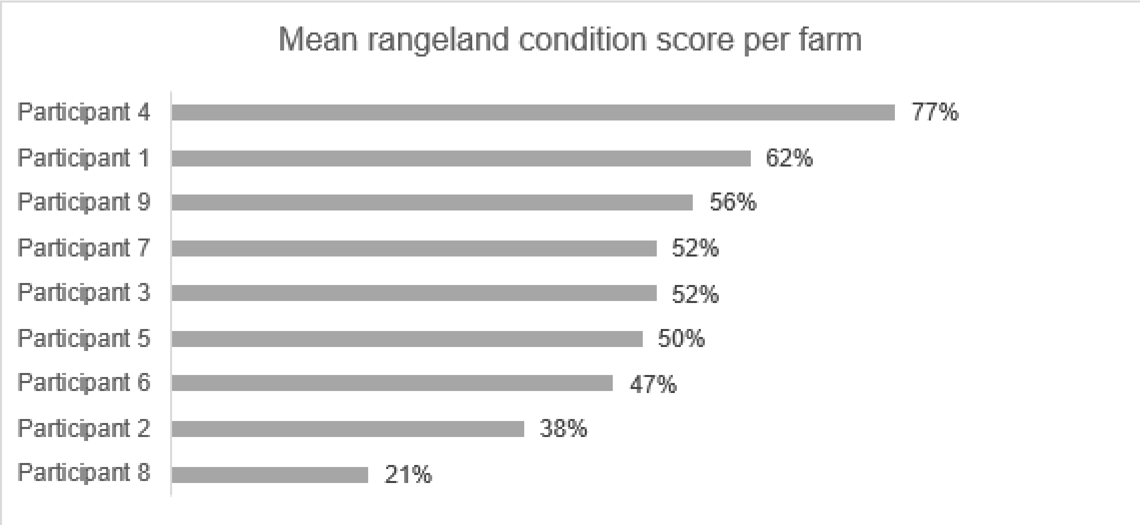

Figure 4.30: Rangeland condition comparison between sampled land-reform farms

The average rangeland condition scores between the farms differed, with the highest average rangeland condition score of 77% reported by Participant 4, second highest rangeland condition score of 62% for Participant 1 and the lowest average rangeland condition score of 21% for Participant 8 suggesting different rangeland management systems amongst the farms, ranging from inappropriate rangeland management systems perpetuating rangeland degradation to good rangeland management systems, essential for rangelands maintenance and sustainability (Figure 4.30).

There were no statistically significant differences in rangeland condition score between farms, Welch's F (8, 3,40) =3,92, p=0,13; however, the differences, even though not significant both between farms and between camps, require careful attention to prevent rangeland degradations and to ensure the sustainability of these rangelands.

4.5 ESSENTIAL PARAMETERS DISCUSSION

4.5.1 Rangeland condition scores and stocking rates

According to Ndandani (2016) and Van der Westhuizen et al. (2020), there is a strong evidence which confirms that good rangelands health, proper stocking rates and good livestock management practices are essential for the profitability and sustainability of extensive livestock farming enterprises. Out of nine total land-reform extensive livestock farms sampled for this study, three farms were 50% understocked, three farms were overstocked, with two of the farms more than 50% overstocked, and three farms were correctly stocked according to the recommended carrying capacity norm of Department of Agriculture and rural development.

However, the highest average rangeland condition score of 77% was reported from one farm among correctly stocked farms, with the minimum average rangeland condition score of 38% among the group. Meanwhile, the lowest reported average rangeland condition score was 21% from a land-reform farm that was more than 50% overstocked amongst the group. Nonetheless, the highest 61.5% rangeland condition score was reported for the farmers who were understocked, which is less than 77% reported on the correctly stocked land reform farm, and the lowest rangeland condition score of 26% reported in the group, which is comparable to 21% rangeland condition score recorded on a land-reform farm that was 50% overstocked illustrating clearly that the importance of the correct animal stocking rates cannot be overemphasised. Thus, Van der Westhuizen et al. (2018) reported that stocking rates are essential for livestock productivity and ecological sustainability.

4.5.2 Soil pH (KCl)

Even though soil pH value is associated with either an increase or decrease of chemical elements such as Ca, Mg, and P, which are important for good soil health when they increase soil structure maintenance and increase microbial action, the acidic pH level of 4.5 which is reported as minimal in this study, was comparable to the pH value of 4.6 reported on a camp with the highest rangeland condition score of 81% and that of the camp with the lowest rangeland condition score of 14%. It is then reported that there was no relationship between soil pH and rangeland condition scores recorded amongst land-reform farmers sampled for this study.

4.5.3 Soil chemical properties

Mofidi et al. (2012) reported that inappropriate stocking rates lead to a decline in soil's physical and chemical properties. As a result, this can cause desertification and rangeland degradation. In this study, rangeland condition scores reported amongst sampled land-reform farms varied significantly, confirming the heterogeneity between the farms regarding management and stocking rates. Nonetheless, no relationship (p>

0,05) was recorded between Ca, Mg, K, Na and S as the essential soil chemical properties measured in this study from the topsoil, despite the positive trend on P and soil pH, related studies undertaken in the grassland and savanna biome respectively strongly associated the increase of these soil chemical properties with good rangeland conditions mostly in commercial farms as opposed to land-reform farms and communal farming. However, this study identified no significant positive relationship between good and bad rangeland conditions and the measured soil chemical properties.

4.5.4 Rangeland management

As a significant resource for extensive livestock farming, the grassland ecosystem has constantly been exposed to different management practices by rangeland managers in the grassland biome. The rangelands management systems on the sampled farms for this study were heterogeneous, ranging from a minimum of four grazing camps per farm to twelve camps per farm utilized on a rotational basis. However, most sampled farms did not have a fixed grazing system to allow proper natural veld utilization with adequate rest periods, evidenced by the recorded lowest rangeland condition scores of 21% and 26%, respectively and by up to 50% over- and understocking on other farms. Thus, low average rangeland condition scores confirm these natural rangelands' inherent sustainability. Furthermore, these discrepancies in rangeland management practices amongst extensive livestock land-reform farmers threaten the positive contribution of natural rangelands towards climate change effects as it increases open patches and pioneer grass species such as *Aristida congesta*, *Aristida bupertita* and *Cynodon dactylon,* which are not beneficial to rangelands sustainability and livestock productivity in the grasslands.

4.5.5 Livestock management and Reproduction performance

A positive relationship was reported for all livestock performance variables and rangeland conditions for this study. Furthermore, there was no positive relationship between livestock management tools utilized by sampled land-reform farmers and their rangeland's condition, with only notable exceptions to the livestock production plan as a management tool. A positive relationship was recorded between the employment of a production plan as a livestock management tool and the rangeland's condition. Land-reform farmers who had livestock management plans had higher rangeland condition scores. The importance of livestock production planning, which, amongst other things, includes a breeding season aligned to natural forage fluctuation cycles, is of paramount importance and beneficial to livestock management and rangelands management since it allows peak livestock fodder requirements period and peak production period of natural rangelands to coincides. The latter is critical in enhancing the inherent rangelands' ability to sustainably support livestock productivity, food security and livelihood development.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In the preceding chapter, conclusions and recommendations are made relating to the five objectives that served as this study's compass. The study aimed to provide holistic guidance for future sustainable livestock production in the semi-arid rangelands of the Bloemfontein magisterial area for extensive land reform livestock farmers. It aimed to compare rangeland condition per land reform farm and between land reform farms, and to establish correlations between rangeland condition, soil chemical properties and managerial inputs on sampled land reform farms. The study also aimed to use land reform livestock farmers' decisions on livestock stocking rates to establish their production efficiency and to establish correlations between rangeland condition and soil carbon.

5.2 CONCLUSION

In this study, rangeland condition assessment, soil analyses and management inputs were investigated on nine extensive livestock land-reform farms in the magisterial area of Bloemfontein. Most other related studies regarding the key investigated parameters compared land-reform farms with commercial and communal farms; some even compared farms located in different biomes. The same studies did not exclude livestock pressure points, such as livestock drinking water and feeding points, in assessing rangeland conditions and collecting soil samples. However, this study purposely excluded these livestock pressure points to avoid their apparent influence on rangeland condition scores soil physical and chemical properties. This study focused only on land-reform farmers to understand the application of science-based knowledge amongst this farmer category in their day-to-day management decisions relating to rangelands management, stocking rates and general prudent livestock management practices. The data in this study indicated that there was no statistically significant relationship between rangeland condition scores, soil chemical and physical soil properties on the sampled land-reform farms, except for positive trends recorded on selected soil chemical properties such as phosphorus, and soil pH, as well as on soil physical properties such as sand, clay and silt proportionality, when compared to rangeland condition scores (see appendix D). The data also did not find significant differences between rangeland scores of camps per land-reform farm. Still, they recorded a significant difference between farms with the average maximum rangeland condition score of 77% and the average minimum rangeland condition score of 21%, respectively. There was also no positive correlation between most managerial inputs and livestock management parameters. Nonetheless, the data confirmed a strong positive correlation between land-reform farmers with production plans and their average rangeland condition scores. According to the methodology used to sample these farmers, the results of this study suggest that the best livestock farmers are not always good rangeland managers since a significant proportion of these sampled farmers had rangeland condition average score of below 50%, and this is also confirmed by the lowest average weaning weight of 183kg, recorded on a farm with the highest average rangeland condition score of 77%, and the highest average weaning weight of 228 kilograms, recorded on a farm with the lowest average rangeland condition score of 21%. Nevertheless, the results of this study also confirm that the application of science-based methodologies on rangeland management and stocking rates decisions are beneficial to ecological sustainability by recording the highest average rangeland condition score of 77% on a land-reform farm that complied with the carrying capacity norm of the area. The differences recorded in stocking rates amongst the sampled land-reform farmers seriously threaten the ecological sustainability and sustainable livestock productivity in these land-reform farms, thus jeopardising their production efficiency. The study also concludes that the differences in rangeland condition and species composition amongst land-reform farms can neither be attributed to the drought nor the wet seasons since there was no data on species composition and rangeland condition assessments before the extreme weather patterns (El Niño and La Niña events). However, these differences in species composition and rangeland condition scores between farms and camps are strongly linked to different management practices on land-reform farms. Finally, the study recorded a positive correlation between rangeland condition scores and soil carbon content by confirming an increase in soil carbon content on good rangeland condition scores of 60% and more. Thus, the hypothetical statement of this study is proven to be null and void on one point by assuming that climatic variations will affect the rangeland condition scores and that there will be a positive correlation between soil chemical and physical properties as well as rangeland condition scores. However, on the other hand, the hypothetical statement is confirmed to be right, by categorically stating that management will directly impact the rangeland condition.

5.3 RECOMMENDATIONS

The reality of climate change and its associated impacts on rangeland ecosystems are worsened by poor management practices, exerting enormous pressure on natural livestock grazing resources by reducing their quantity and quality. In turn, it poses a significant threat to many global communities dependent on the livestock sector for sustainable livelihood development. However, the immediate response by livestock farmers to compensate for poor nutritional forage is by provision of livestock supplementary feeding, mainly through production licks. Nevertheless, livestock supplemental feeding is costly, unsustainable and detrimental to the rangeland ecosystems. Thus, this study recommends strongly rotational grazing systems and proper livestock production planning at the farm level, considering the rangeland condition and variable stocking rates following seasonal natural fodder fluctuation periods, to promote continuous ecological rangelands sustainability and sustainable livestock productivity on land-reform farms. The latter will then contribute towards food security and sustainable livelihood development.

5.4 FUTURE RESEARCH RECOMMENDATIONS

- The study recommends long-term research on rangeland condition assessment and species composition in the grassland biome's central Free State region to have a data pool for future studies and comparison.
- It is recommended that future research studies measure the quantity of forage production and predict future rangelands forage production utilizing the latest rainfall data in this study area.
- Future studies must explore the practicality of implementing variable stocking rates and the participation of extensive land-reform livestock farmers in carbon markets as an incentive.
- Future related research studies must consider different livestock breeds' performance to make a decisive conclusion on weaning weights.

- The study also recommends that future related research studies undertake a more detailed approach by performing rangeland condition assessments for species abundance on all camps per farm instead of only two camps per farm.
- A formal partnership between rangeland scientists, soil scientists and agricultural extension practitioners is recommended to ensure holistic, science-informed pieces of advice for farmers on rangeland management issues.
- Lastly, the study recommends that future studies collect data four months after the breeding season ends to achieve realistic reproduction performance by measuring the conception rate and using that information to predict calving rates or to collect data at the end of the calving period.

5.5 STUDY LIMITATIONS

The following natural anticipated limitations are acknowledged:

- Since the study was conducted in Bloemfontein, findings cannot be generalized across the towns or districts of the Free State province or the country.
- Famers might not always be truthful and honest about their livestock numbers, as they regard their livestock numbers as an indication of their financial wealth and treat this information with absolute confidentiality.
- The snowball procedure utilized in this study's methodology is acknowledged as a limitation, as it relied entirely on the farmers' discretion to sample the best extensive land-reform livestock farmers in the study area.
- The fact that the sampled group was from only farmers who participated in the stocking rate study is also acknowledged as a limitation.
- The fact that there was no budget allocation for this study is equally acknowledged as a limiting factor in terms of sample size and the study duration.

5.6 STUDY CONTRIBUTIONS

The study contributes towards sustainable utilization of rangeland resources amongst Bloemfontein land-reform farmers through proper animal stocking rates and application of science-based information in rangelands management during this unprecedented climate change era and the mitigation of climate change impacts through increased carbon sequestration process on well-managed rangelands. Furthermore, the study advocates for food security and livelihood development through sustainable and efficient extensive livestock farming enterprises.

As primary meat producers, extensive livestock land-reform farmers are pivotal in the South African food value chain. On the other hand, literature unambiguously agrees that the substantial number of livestock within South African borders belongs to emerging farmers, mostly land-reform farmers and predominately historically disadvantaged individuals. Considering twenty-nine years of land-reform existence in South Africa, it became imperative to measure the performance of land-reform farmers through comparison means amongst themselves, as opposed to comparing them with other farmers in different categories, i.e., commercial farmers.

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CONFERENCE CONTRIBUTIONS AND SCIENTIFIC PUBLICATIONS

Back to basics: Mitigating the harmful effects of droughts for efficient livestock productivity in the grasslands of the central Free State.

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ABSTRACT

Extensive livestock production in South Africa depends on rangelands productivity and effective livestock management practices. This study aims to identify various processes to mitigate the adverse effects of droughts on livestock farming in Bloemfontein, South Africa. Stocking rates on land-reform farms during drought (Mokhesengoane et al.*, 2021), rangeland management impacts on the reproduction performance of beef cattle (Van der Westhuizen* et al.*, 2020) and rangeland condition and soil data were investigated. The results showed a significant difference between rangeland condition and soil carbon, demonstrating the essential role of rangeland management in carbon sequestration. In conclusion, knowledge regarding stocking rates and prudent rangeland management practices (condition and carbon sequestration) is paramount for sustainable livestock farming during climate change. Intensive training of farmers in sustainable rangeland management is recommended to mitigate the effect of droughts and to ensure sustainable livestock production with a minimised carbon footprint.*

Keywords: Mitigating droughts effects; livestock productivity; grasslands

1. Introduction

The profitability and sustainability of extensive livestock farming enterprises are determined by various factors, including the health of rangelands and livestock reproductive performance (Van der Westhuizen et al., 2020). A recent report by Avenant (2019) stated that the grassland biome of South Africa covers a total area of 32 534 079 ha (hectares) of which the available livestock grazing area is 21 560 559 ha currently being grazed by 3 934 838 large stock unit (LSU) heads. According to Meissner et al. (1983), large stock unit is an equivalent of an animal with body weight of 450kg, gaining 500g per day in weight on the pasture with a digestible energy (DE) concentration of 55%. In the Free State Province, the total grasslands area is 12 982 516 ha, with an available grazing area of 8 538 734 ha grazed by 1 333 815 LSU heads (Avenant, 2019), indicating an average stocking rate of 6.4 ha/LSU. According to Mokhesengoane et al. (2021), rangeland resource planning and management depends on climatic variations such as rainfall and temperature, influencing the stocking rate adjustments.

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However, over the past four consecutive decades, several research projects have highlighted weather events, such as El Nino induced droughts, to have had detrimental implications on livestock productivity and continue in the future (Thornton et al., 2009).

A study by Van der Westhuizen et al. (2020) emphasised that increased climate variability and climate change significantly threaten essential grassland ecosystems with increased droughts, especially in semi-arid areas with unpredictable rainfall. Additionally, poor rangeland management and overstocking can lead to financial and livelihood losses due to livestock mortalities in extensive livestock farming systems (Mokhesengoane et al., 2021). Natural rangelands management methods based on scientific research promote sustainable beef productivity and can decrease the adverse effects of droughts (Van der Westhuizen et al., 2020).

The sustainability of livestock farming enterprises and grazing resources contribute to global food security as The Food and Agriculture Organization (FAO, 2014) predicts an increase in the world's population growth from 7.2 billion to 9.3 billion by 2050. The degradation of grasslands is a global concern, while ecosystem health also plays a role in hydrological disturbances, water quality, dust storms occurrence and severity, food security, poverty, rural development and the social consequences of uprooted people (Van der Westhuizen et al., 2022). Previous studies have identified a negative relationship between soil organic carbon (SOC) content, soil organic matter (SOM) and low rainfall occurrences (Fynn et al., 2009).

Therefore, sustainable rangeland management practices should be implemented to reduce the carbon footprint. An agricultural extension can be essential to incentivise and support farmers to adopt sustainable livestock production systems. This study aims to present extension personnel with technologies to guide them in this process, concentrating on recent research results for the Bloemfontein area. Data collection included: (1) stocking rates of LSUs on land-reform farms during droughts (Mokhesengoane et al., 2021); (2) rangeland management and reproduction performance of beef cattle (Van der Westhuizen et al., 2020), and (3) a recent assessment of rangelands condition and associated soil health were collected on nine land-reform farms.

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2. MATERIALS AND METHODS

2.1 Study area

The three studies evaluated in the current study were all conducted in the semi-arid grassland biome of the Bloemfontein area (1320 m to 1420 m above sea level), located in the Free State Province of South Africa. According to Van der Westhuizen (2003), the vegetation type can be described as sweet grass-veld often dominated by the perennial *Themeda triandra* (red grass) species when grasslands are in a pristine maintained condition. The average rainfall reported from the last 95 years for this area by ISCW-databank (2018) is ± 556 mm per annum. The most precipitation occurs in the summer months (November to March), resulting in a 62 % increase in vegetation growth (Van der Westhuizen, 2006). The Department of Agriculture (2003) grazing capacity map recommends the grazing capacity norm of 6 ha per LSU for veld in good condition in this area.

2.2 Methods

Purposive sampling was utilised to select three recent research trials supporting ecological sustainability approaches in livestock management in the Bloemfontein area during drought periods. Previous studies reviewed based on their theoretical framework include (1) stocking rates of LSUs on land-reform farms during droughts (Mokhesengoane et al., 2021); (2) rangelands management and reproduction performance of beef cattle (Van der Westhuizen et al., 2020), and (3) a recent assessment of rangelands condition and associated soil health were collected on nine land- reform farms. According to Mokhesengoane et al. (2021), twenty-nine livestock farmers reported a loss of 176.8 LSUs during the 2018 and 2019 mid-summer drought period. In comparison, Van der Westhuizen et al. (2020) described increased livestock production during drought with minimal rangeland management input in the same district. Furthermore, the recent assessment quantified the benefits and limitations of sustainable rangeland management practices during droughts and climate change mitigation by comparing soil carbon content with rangeland conditions.

Soil analyses were performed according to The Non-Affiliated Soil Analysis Work Committee (1990). Rangeland condition scores were determined for every site using the indicator species technique, developed and tested against a degradation gradient technique specifically for central Free State vegetation type (Van Der Westhuizen, 2003).

3. RESULTS AND DISCUSSIONS

Literature studies indicated the influence of stocking rate, rangeland management and condition assessment on sustainable livestock production while mitigating the harmful effects of droughts and climate change.

3.1 Stocking rate

According to Mokhesengoane et al. (2021), the average stocking rate implemented by farmers representing land-reform projects in the Bloemfontein district during the 2018 and 2019 drought was 5.9 ha per LSU. Overstocking occurred on 31 % of the farms, and 38% of farmers reported fodder shortages. Despite the low feed resources, overstocking rates of over 300% (above the recommended 6 ha/LSU) and high mortalities were reported (Table 1). Total livestock mortalities reported for this trial were 176.8 LSUs equal to R 1 760 920.87 at R42.39/kg for an average B2/B3 carcass for November 2018.

Table 1: Mean mortality rate as a percentage of the stocking rate at 6 ha/LSU (± standard deviation); (Mokhesengoane et al.,2021).

Stocking rate	**Mortality %**
More than 130 % overstocked	32.7 ± 50[a]
Rest of farmers	5.7 ± 7.6[b]

[a & b] – Values in columns with different superscripts differ significantly

In the study of Mokhesengoane et al. (2021), respondents were requested to compare the availability of natural fodder with that of their neighbours. Table 2 shows a positive relationship between available fodder and stocking rate and a negative relationship between available fodder and mortality rate (Table 2). The stocking rate of the farms with less fodder available than their neighbours (stocking rate of 378%) contributed to forage shortages and higher mortality rates (22.4%).

Table 2: Fodder availability compared to neighbouring farms with average stocking rate and average mortality rate during the drought of 2018-2019 (Mokhesengoane et al., 2021).

Forage availability in comparison with neighbours	Frequency	Percent (%)	Stocking rate (%)	Mortality rate (%)
Better	12	41.4	88	6.5
Same	6	20.7	147	14.0
Worse	11	37.9	378	22.4
Total	29	100.0		

Furthermore, the influence of stocking rates during drought on beef production and reproduction is also emphasised by Van der Westhuizen et al. (2020). Reduced stocking and calving rates (not reduced lower than 18%) during drought outperformed the 6 ha/LSU for the study area with R 1 534 per cow (Table 3). Future studies could further investigate the practical implementation of the variable stocking rate. Due to the impact of climate variability on sustainable beef production, stocking rates should be determined according to assessments of rangeland potential.

Table 3: Comparison of reproduction performance between fixed and variable stocking rate (%); (Van der Westhuizen et al., 2020).

Years after implementation of rangeland management	Fixed stocking rate	Reduced stocking rate due to drought
Calving rate (%)	58	76
Weaning weight (kg)	188	198
Income per cow mated *	R 4 034	R 5 568

* = Based on a weaner price of R37/kg

3.2 Rangeland management

Van der Westhuizen et al. (2020) recorded a 32% calving rate without implementing rangeland management during the first year of the trial. In contrast, after a year of rangeland management implementation, the calving rate almost doubled to 59%, reaching the maximum of 82% in year four. These calving rates are more profitable than the lower calving rate of 34% reported for commonage farmers, 60% reported for commercial farmers (Scholtz & Bester, 2010) and 32% reported for land-reform farms included from Bloemfontein during drought (Mokhesengoane et al., 2021). Commonage, land reform and small-holder farmers generally report lower calving rates due to their communal livestock farming background, where rangeland management and sustainable beef production practices are not usually implemented (Van der Westhuizen et al., 2020). Additionally, poor livestock performance and degradation of natural resources are more evident in these systems (Van der Westhuizen et al., 2020). Weaning calf weights of 156 kg with no rangeland management inputs and 229 kg during production year four of rangeland management implementation was recorded (Table 4). The implementation of a reduced stocking rate resulted in an increased calving rate, improved environmental health and potential income per cow, further emphasising the importance of a balance between natural fodder availability and livestock numbers (Forbes, 1988).

Table 4: Reproduction performance (calving rate % and weaning weight in kg) and rangeland condition over four production years (Van der Westhuizen et al., 2020).

Years after implementation	**Calving % ± SD**	**Weaning weight (kg) 205 days ± SD**	**Simulated seasonal production**
No rangeland management inputs	$32^{a} \pm 10$	$155.8^{a} \pm 11.1$	Normal
Year 1	$59^{b} \pm 19$	$215.8^{c} \pm 6.7$	Below normal
Year 2	$60^{b} \pm 12$	$214.4^{c} \pm 10.1$	Very high
Year 3	$62^{b} \pm 15$	$190.0^{b} \pm 9.6$	Very low Drought
Year 4	$82^{c} \pm 7$	$228.6^{d} \pm 6.7$	Normal

$^{a, b, c, d}$ – Values (mean ± SD) within a column followed by different superscript letters are significantly different ($p < 0.05$), SD = Standard deviation.

3.3 Rangelands condition

Rangelands condition assessment is crucial to ensure the sustainability and profitability of extensive livestock farming systems. The condition status of grazing resources indicates ecosystem health, production ability and carrying capacity during drought (Van der Westhuizen et al., 2018). The risks associated with droughts escalate if rangeland conditions deteriorate; for example, fodder shortage can increase to 48% for rangelands of average condition (50%) compared to only 5% for rangelands classified as an optimum condition in the Bloemfontein area (Van der Westhuizen, 2006). Where poor rangeland conditions are identified, the probability of forage shortages increases to more than 90%. Results from Trial three indicated significant differences ($p < 0.05$) between rangelands condition (minimum = 14%, maximum = 81%, average = 50%) and topsoil carbon content (Table 5) of land-reforms farms at 20 cm depth (for rangelands in very poor condition, 1% topsoil carbon content was recorded and for rangelands in a good condition, 3.1% topsoil carbon content was recorded). Rangelands in good condition can sequestrate three times more carbon than rangelands in poor conditions, and a positive correlation between rangeland condition and the type of production system executed at farm level was also found ($p < 0.05$).

Table 5: Top soils' carbon content (%) for different rangelands condition classes.

Rangelands condition	**Very poor (≤ 20 %)**	**Poor to Moderate (21 - 60 %)**	**Good (> 60 %)**
Carbon content ± SD (%)	$1.0^a \pm 0.43$	$1.9^a \pm 0.73$	$3.1^b \pm 1.08$

[a, b, c, d] – Values (mean ± SD) within a column followed by different superscript letters are significantly different ($p < 0.05$), SD = Standard deviation.

The grasslands biome covers approximately 50% of the global surface area (Mitchell, 2000), mainly utilised for livestock grazing. Grasslands are essential in carbon sequestration, absorbing atmospheric carbon dioxide during photosynthesis and transporting it through the root systems to be stored in the soil. Carbon (C) then strengthens the soil structure by increasing macro soil pores, substrate and energy to support soil microbial activity, further promoting the storage of organic nitrogen (N), phosphorous (P) and other related soil nutrients. Therefore grassland maintenance through the implementation of management practices and adequate stocking rates increases the potential of the soil to store more C and, as a result, mitigate the effects of climate change (Fynn et al., 2009). Furthermore (Table 6) highlights significant relationship ($p < 0.05$) between higher mean % of rangeland condition scores and production plan implementation, also recorded during Trial three.

Table 6: Mean rangeland condition score and production plan implementation.

Production plan (Yes/No)	**Studied Farms**	**Rangeland condition scores Mean (%)**	**Std. Deviation (%)**	**Std. Error Mean (%)**
No	6	43.10	18.182	7.424
Yes	3	55.60	19.761	11.409

*Positive correlation between mean % of rangeland condition and production plan ($p < 0.05$), n = frequency.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The collective findings of this comparison study illustrate that proper animal stocking rates and prudent rangelands management leads to ecological sustainability, high investment returns, and sustainable extensive livestock farming enterprises. These findings can further be summarised as follows to mitigate the adverse effects of droughts and climate change:

- Overgrazing leads to higher livestock mortalities during droughts.
- Reduced livestock numbers during droughts decrease livestock mortalities.
- Reduced livestock numbers during droughts increase the production and reproduction rate of livestock.
- Production planning for sustainable rangelands utilisation increases livestock production and profitability.
- With the execution of a sustainable grazing system, livestock production can be higher even during drought periods.

- Carbon sequestration for good-condition grasslands is three times higher than that for poor-condition grasslands.

In conclusion, properly managed grasslands and grazing resources, including controlled stocking rates, are effective tools for livestock farmers to mitigate the harmful influence of climate change on the environment. No mortalities were reported during Trail two, with similar environmental parameters to Trial one, reiterating the significance of implementing rangeland management practices and production planning based on scientific research. Trail three results illustrate that SOC and SOM increase as rangelands condition improves, highlighting the importance of grassland health for carbon sequestration and mitigating climate change impacts and a reduced carbon footprint.

4.2 Recommendations

The study recommends a paradigm shift to extension personnel by highlighting the significance of proper rangelands management and animal stocking rates in carbon sequestration to reduce climate change effects. Furthermore, the study recommends that the balanced application of stocking rates, in line with seasonal fodder availability fluctuations, is paramount for sustainable livestock productivity during variable climatic conditions. Knowledge of stocking rates and rangelands management is critical for profitability and environmental sustainability.

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Production levels of selected extensive land-reform livestock farms in the grasslands of central Free State reported during October-November 2021.

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ABSTRACT

Calving rates, weaning weights and stocking rates are the most important indicators of livestock performance and environmental sustainability in the extensive livestock farming systems. The Free State province is the greater part of the grassland biome predominantly suitable for extensive livestock farming enterprises. This study employed non-probability snowball procedure to sample nine out of a total of 29 extensive land-reform livestock farmers, who participated in a 2018/2019 stocking rate study conducted by (Mokhesengoane et al., 2021) and followed quantitative research procedure. The key objective of this study was to determine livestock production levels on sampled farms by measuring calving rates, weaning weights and stocking rates, as well as average rangeland condition scores. A minimum of 14% calving rate and 183kg weaning weight, average of 53% calving rate and 200kg weaning weight and a maximum of 99% calving rate and 228kg weaning weight at roughly 7 to 8 months age were recorded. With 56% of farms reporting overstocking of >100%. Whilst 33% of farms reported understocking of ≤ 50%. Significant relationship ($P < 0.05$) between overstocking and low calving rates was found. The average maximum rangeland condition score of 77% and the average minimum of 21%, was recorded.

Keywords: Production levels; selected land reform farmers; grasslands

1. INTRODUCTION

Livestock productivity in Sub-Sahara Africa accounts for 14% of the world's total livestock production, however from this total livestock production Sub-Sahara Africa supports only 2.8% milk and meat requirements for its population (Coleman, 2022). This is despite the alarming consistent reports of hunger and malnutrition reported across African continent (Hetherington *et al*., 2017). In South Africa the total livestock production supports only 60-80% of the population's meat dietary requirements and the surplus is imported outside the South African borders.

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Nonetheless, according to Zantsi, Cloete and Möhring (2021) the general average land reform livestock productivity in South Africa, is closer to that of commercial farmers when compared to the average crop production, suggesting that land reform livestock farmers can achieve commercial livestock production levels much easier with appropriate support and resources. Thus, this is consistent with the findings of Swanepoel *et al.* (2010) that livestock is the fastest growing sub-sector in the South African agricultural sector.

According to (Daff, 2010) the Free state province's total surface area is 13 million hectares big and 58% of this total surface area is conducive for extensive livestock farming enterprises, while 33% is used for crop farming and the remaining 9% for other land uses. However, Mokhesengoane, Van Der Westhuizen and Van Niekerk (2021) reported low calving rates of 32% during 2018/2019 drought amongst extensive land reform livestock farmers in Bloemfontein, comparable to 48% and 35% calving rates respectively amongst emerging and communal farmers, recorded in a structured survey conducted by Scholtz and Bester (2010) in South Africa.

Over and above, according to Ndandani, (2016) and Van der Westhuizen *et al*, (2020) there is strong evidence confirming that good rangelands health, proper stocking rates and good livestock management practices are essential for profitability and sustainability of extensive livestock farming enterprises.

Thus, low livestock production levels poses a serious threat to sustainable livelihoods development and food-security. The South African Statistics 2022 census report revealed that even though South Africa remains food secured at the national level, this is not the case at households' level, confirming the need for increased food production levels in order to redeem the nation from these disparities.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in the city of Bloemfontein magisterial area, located at the average altitude level of 1 395 m above sea level, in the central Free State.

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Bloemfontein is situated in the grassland biome Rutherford and Westfall (1994), which is the second biggest biome in South Africa covering 29% of the total surface area.

Bloemfontein is predominantly extensive livestock farming area. It is the semi-arid area with big open grasslands dominated by *Themeda triandra* when they are well managed. The average annual rainfall recorded over the years, for the study are is 548 mm and the substantial amount of this rainfall occurs during summer months. It is thus, categorised by Johnson *et al.* (2006) to belong to the Karoo Supergroup in geologic formations.

2.2 Methods

This study followed a non-probability snowball procedure method to sample nine extensive land reform livestock farmers, from a total of 29 extensive land reform livestock farmers who participated in the stocking rate study conducted by Mokhesengoane, Van Der Westhuizen & Van Niekerk (2021) during 2018/2019 drought. Quantitative research method was employed. The famers were asked to recommend a good extensive livestock farmer in their area, from the twenty-nine participants of the stocking rate study, using the perceived group leader theory. The structured questionnaires were completed in an interview with an individual farmer, in their respective farms to gather information on their extensive livestock farming business' production levels. The rangeland degradation gradient method developed by (Van der Westhuizen, 2003), for the semi-arid rangelands of the central Free State province, was used to determine rangelands condition scores, on two camps of each sampled farm.

2.3 Data collection and analysis

The production levels data were collected during October-November 2021 through one-on-one interviews with the participating farmers during farm visits. The numerical data obtained were plotted in an excel sheet. Calving rates were calculated as a number of calves born divided by number of cows exposed to the bull multiplied by hundred. Weaning weights were calculated as the live mass of calves at roughly 205 days. While stocking rates were calculated as a percentage of animals that can be kept in a farm, when rangeland condition is in pristine condition, using 6ha/LSU carrying capacity recommendation of the department of agriculture for the study area.

2.4 South African land reform synopsis

The South African land reform program is on the 29th year of its implementation since 1994. The program similarly to that of other developing countries across the world seeks to redress the anomalies of colonial systems which disposed the native people access to agricultural land (1913 Land Act) thus, leading to many disparities in the socio-economic front. According to Department of Land Affairs (1997), land reform policy in South Africa has three pillars with non-identical aims namely; land tenure to encore residential rights of farm workers and those of former homelands residents, restitution which aspires to restore dignity of families and individual who were forcefully removed from their land during apartheid and finally redistribution which is central to livelihoods development through primary agriculture by distributing large areas of agricultural land to historically disadvantaged individually (Kirsten et al., 2016).

However, land reform farmers in South Africa are not a homogeneous group as their production scales and commodities differ significantly. Nonetheless, despite the differences and lack of political will from government of the day, evident by unscrupulous and indecisive policy direction for land reform beneficiaries' development, these newly distributed large agricultural lands must contribute towards livelihoods development and food security through sustainable contribution to food chain systems.

3. RESULTS AND DISCUSSIONS

Livestock production levels of land-reform farmers are very important for agricultural productivity and sustainable food systems. According to ISRDP (2004) nodal report agricultural production with specific reference to livestock farming, has the ability to eradicate poverty in poor rural communities by enhancing food security and livelihoods development. It is thus, reiterated by Meissner *et al*, (2013) that approximately 70% of agricultural land in South Africa is suitable for livestock production. This study critically analyses the performance of selected Bloemfontein extensive land-reform livestock farms by investigating their stocking rates, calving rates and weaning weights at 205 days.

Table 1: Stocking rates of different farms calculated as percentage of animals that can be kept when rangeland condition is optimal at 6ha/LSU

Stocking Rates	Under stocked (≤ 50%)	Properly stocked (94%)	Over stocked (>100-120%)	Over stocked (>200%)

(Farms) Frequency (n)	3	1	3	2

Proper animal stocking rates are essential for sustainable livestock productivity and rangelands health in the grasslands ecosystems (Mokhesengoane, Van Der Westhuizen & Van Niekerk, 2021). According to Thornton (2010) livestock products account for total estimate of 33% in the global agricultural GDP. Thus, FAO (2009), indicated that livestock sector is key for many poor people in the developing countries due to its enormous contribution towards livelihoods development and as a pathway out of poverty. A total 56% of the participants reported stocking rates >100% and 40% of these farmers reported stocking rates >200%. Whilst 33.3% of participants were ≤ 50% understocked, and 12% was properly stocked at 94% **(**Table 1). These stocking rates are clearly not sustainable, and thus threaten the achievement of sustainable development goal number two of zero hunger, as envisaged in the millennium development goals and outcome seven of the National Development Plan (NDP) Vision 2030 of South Africa aiming to reduce hunger and increase food security.

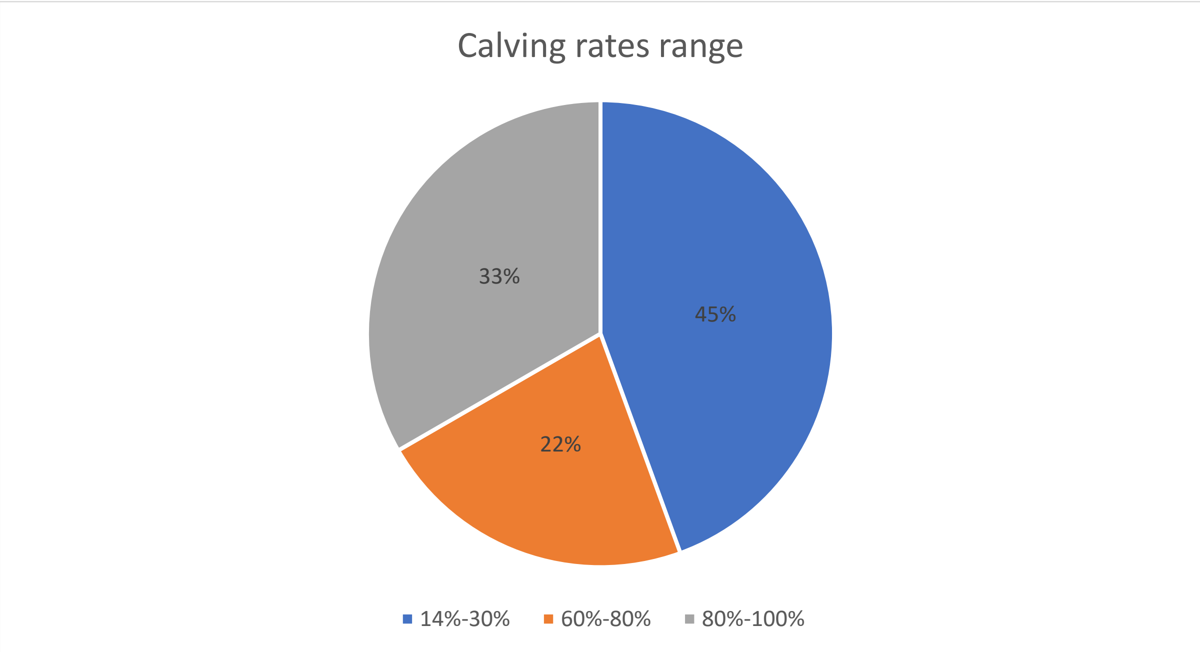

Figure 1: Calving rates range as percentage

Nkadimeng *et al*, (2022) reported the average reproductive performance of smallholder cattle farmers in South African as 50% pregnancy rate less 12% of losses, indicating the average calving rate of 38%. Calving rate is the most important variable when measuring the reproductive performance of a beef herd. On the other hand, Nthakheni (2006) reported 37% calving rate amongst communal livestock farmers in Limpopo province of South Africa. In this study an average of 53% calving rate was recorded amongst participants, with 45% of farmers, reporting calving rates ranging from 14-30%, 33% of farmers reporting calving rates ranging from 80-100% and 22% of farmers reporting calving rates ranging from 60-80% respectively, as captured on (Figure 1) above. Two understocked farms reported the highest calving rates ranging from 80-100%, while one understocked farm reported low calving rate of 28%. However, one of two farms which reported overstocking of >100% reported low calving rate of 15% while the highest overstocked one with stocking rate of >200% reported the lowest calving rate of 14% respectively.

	Total grazing area in (ha)	**Calving rate (%)**	**Weaning weight (kg)**	**Stocking rate (%)**
Minimum	180	14	183	≤50
Average	672	53	200	>100
Maximum	1880	99	228	>200

Table 2: Essential extensive livestock production variables

According to comparison of key extensive livestock production variables on (Table 2) above, there is a positive trend between grazing area, calving rate and weaning weight. However, the stocking rates are not sustainable and thus pose a significant threat to environmental sustainability, sustainable livestock production and subsequently food security. Over and understocking are both detrimental to rangelands ecosystems sustainability and sustainable livestock productivity (Mokhesengoane, Van Der Westhuizen & Van Niekerk, 2021)

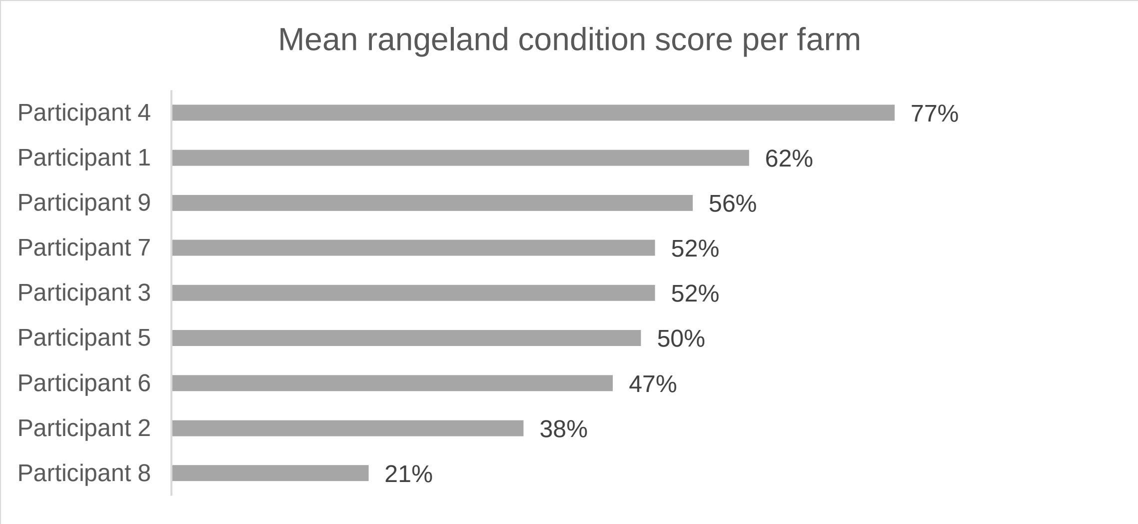

Figure 2: Average rangeland condition score per farm

The average rangeland condition scores between the farms differed significantly, with the highest average rangeland condition score of 77% reported for participant 4, second highest rangeland condition score of 62% for participant 1 and the lowest average rangeland condition score of 21% for participant 8. This suggests different rangeland management systems amongst the farms, ranging from inappropriate rangeland management systems perpetuating rangelands degradation. Three sampled farms had rangeland condition average scores of below 50%. The lowest average weaning weight of 183kg was recorded on a farm with the highest average rangeland condition score, and the highest average weaning weight 228kg was recorded on a farm with the lowest average rangeland condition score.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

These results point out that the average calving rate of selected Bloemfontein extensive livestock land-reform farms is comparable to the calving rate of structured survey conducted by Scholtz and Bester (2010) in South Africa for emerging farmers sector, whilst the minimum calving rates were very low. It is also critical to take cognisance of the fact that, data collection period for this study coincided with the calving season according to central Free State beef cattle management calendar (FSDARD, 2004). This and the cattle breeds' differences between farms are acknowledged as shortfalls. Nonetheless, a significant proportion of sampled farms did not follow the breeding program specified in the central Free State beef cattle management calendar, and this is confirmed by the vast differences in the calving rate reports. On stocking rates, it is concluded that the 12% figure of proper stocking rate recorded is insignificant. The unsustainable stocking rates recorded in this study are inconsistent with sound rangeland management practices. However, significant relationship ($P < 0.05$) between overstocking and low calving rates is confirmed. Thus, Van Der Westhuizen *et al,* (2020) recommends the use of science based rangelands management practices to improve beef cattle productivity and to maintain rangelands ecosystems functioning.

4.2 Recommendations

It is recommended that Bloemfontein extension personnel, must focus more attention on measures to assist extensive land-reform livestock farmers to increase their production levels and sustainable veld management techniques in order to maximise livestock productivity sustainably. As this will contribute towards sustainable livelihoods development and make sustainable contribution into food systems while enhancing food security. Furthermore, this study recommends that similar future research projects must consider different cattle breeds' performance standards when measuring the weaning weight as a parameter.

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STOCKING RATE OF EXTENSIVE LAND-REFORM LIVESTOCK FARMERS DURING 2018/2019 DROUGHT: BLOEMFONTEIN GRASSLAND BIOME CASE STUDY

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ABSTRACT

The study aimed to determine the average stocking rate among land reform beneficiary farmers specialising in livestock production, in order to establish differences between calving percentage, fodder availability and mortality rate of sampled farmers, and to compare forage scarcities of Land Reform farms with their neighbouring farms during the midsummer drought of 2018/2019 in the Bloemfontein area. The average stocking rate was 5.9 ha/LSU in comparison with the Departmental grazing capacity norm of 6 ha/LSU for rangeland in good condition. However, 31% of the sampled farms were found to be severely overstocked and the mortality rate on these farms, in relation to grazing capacity of 6 ha/LSU, was significantly higher ($P < 0.05$) than the mortalities on the other remaining farms. Natural available fodder was found to be heterogeneous, with 37.9% of the respondents observing their available fodder as worse than that of their neighbours. The total mortality of 176.77 LSUs was recorded for the 29 sampled farms. These findings will assist the local extension personnel to prevent future rangeland condition degradation, and to increase land reform farmers' productivity. The study concluded that training is paramount to farmers' development and further recommends more research undertakings.

Keywords: Stocking rate; land reform farmers; drought

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1. INTRODUCTION

Stocking rate must be considered one of the most important determinants of ecological sustainability, sustainable livestock production, and economic returns for extensive livestock farming enterprises (Van der Westhuizen et al., 2001; Van der Westhuizen et al., 2018). Tenacious over-stocking is a major contributor to veld degradation. Nonetheless, to ensure sustainability of extensive livestock businesses and profitability, Forbes (1988) and Van der Westhuizen (2020) indicate that farmers must be in control of equating the animal forage requirements to seasonal forage production cycles and natural periods of forage scarcities. The grazing resources management decisions are heavily dependent on the temporary climatic variations in rainfall and temperature, leading to stocking rate adjustments. Over- and understocking are both detrimental to natural veld; overstocking results in severe defoliation, which cripples the natural veld recovery ability post-defoliation, whereas understocking causes mould on natural veld as a result of underutilization of grazeable material, leading to a decline in both palatability and nutritional value. Thus, it is extremely essential to always strike a balance between available natural veld and livestock numbers.

The results of not equating large stock unit (LSU) numbers to forage availability are detrimental to natural veld. Substantial evidence by Du Preez and Snyman (1993) and by Mokhesengoane (2020) highlights that veld recovery ability post-severe defoliation is almost impossible, to the extent that seed germination and poor plant re-growth ability can result in a shift in the ecosystem state. Overstocking leads to detrimental removal of leaf area and thus retards the ability of plants to regrow. According to Mworia et al. (1997), rangeland recovery ability is heavily dependent on the grazing intensity level. The 1984 White Paper on Agricultural Policy highlighted the tremendous deterioration of natural rangelands in South Africa (Du Toit et al., 1991).

However, according to O’Connor et al. (2010) and SANBI (2014), farmers often manage livestock with the intent to realize production goals only and not to maintain biodiversity. Thus, Dankwerts and Tainton (1996) as well as Van der Westhuizen et al. (2018) reiterate that optimization of long-term forage production quality needs rangeland deterioration prevention. This study aims to determine stocking rate and calving percentage as well as get an indication of available fodder during the mid-summer drought of 2018/2019 on land-reform farms. The results of this study will assist local extension personnel in supporting Bloemfontein’s extensive livestock land-reform farmers, to ensure ethical, sustainable livestock production and to mitigate catastrophic impacts of drought.

2. MATERIALS AND METHODS

2.1 Study area

The research was conducted on 29 land-reform farms in the magisterial district of the city of Bloemfontein in the central Free State, South Africa. Located at an average altitude of 1 395 m above sea level, it is a semi-arid environment with average annual rainfall of 548 mm. The natural vegetation for livestock grazing can be described as sweet grassveld of the grassland biome, with *Themeda triandra* as the most distinctive and well-distributed grass species among other perennial grasses available for extensive livestock production (Acocks, 1988; Van der Westhuizen, 2003). Trees are extremely limited in plain variations of the topography, but dense stands can occur in vlei areas and hill variations. According to the Department of Agriculture and Rural Development (2003), the grazing capacity for veld in a good condition is 6 ha per LSU. Unfortunately, the Departmental grazing capacity cannot be blindly applied, as veld condition varies considerably from farm to farm.

2.2 Methods

Twenty-nine land reform extensive livestock farmers, representing 30.8% of the total land-reform farmers in Bloemfontein, were randomly sampled from farmers who participated in the 2018-2019 mid-summer drought assessment. Commonage, communal and all farmers who acquired their farms through private means were purposely excluded. The analysed data for this study was extracted from the following parts/sections of the 2018-2019 mid-summer drought assessment form: size of the grazing area, including the size of arable lands; livestock inventory part C1, highlighting current livestock on the farm; livestock inventory part C2, highlighting livestock mortalities due to drought, and the section where farmers described their available veld fodder comparing it to that of their neighbours. LSUs were calculated using metabolic body weights (Meissner et al., 1983) for medium-framed beef cattle, mutton sheep and Boer goats, as these were the prevalent livestock types kept on the sampled farms. LSU is the equivalent of an animal with a weight of 450kg which gains 500g per day in weight on the pasture with the average digestible energy (DE) concentration of 55% (Meissner et al., 1983). Three per cent (3%) of the number of matured cows and bulls were calculated as bulls, since the form does not make provision for separating matured bulls from the cows. Among the studied farms, 51.7% had rain-fed arable lands, ranging from the minimum of 1 ha to 250 ha.

These arable lands could not be planted for consecutive years preceding this study and were added to natural grazing areas of specific farms.

To investigate the research topic, a multi-methodological research approach was employed, namely qualitative and quantitative as well as farmers' observations. Stocking rate was calculated as a percentage of the LSUs that can be kept on the farm using a grazing capacity of 6 ha/LSU. Farmers were grouped into five different stocking rate groups. Analysis of variance (ANOVA) was used to compare the mean values and mean differences between stocking rate and mortalities as well as between calving percentage and fodder availability. Market information was also utilized to estimate the value of the financial losses. The rainfall data was collected from Bloemwater weather station and summarised as study area rainfall differences for a period of ten years.

2.3 Rainfall conditions

The South African Weather Services (SAWS) confirmed that summer rainfall areas in South Africa received below average rains for the 2017/2018 and 2018/2019 growing seasons. Furthermore, drought was already declared in parts of the country in 2018. The Bloemfontein local weather station report further confirmed that, for both 2017/2018 and 2018/2019, below average rainfall coupled with extreme high summer temperatures were recorded in the Bloemfontein area. Below average rainfall for September 2018 until the end of January 2019 for the study area, prior data collecting, also contributed to extremely dry conditions. During this period, the area only received 41% of rain in comparison with the long-term average, qualifying the study area as drought restricted.

Rainfall has obvious effects on herbaceous productivity and, as a result, rainfall timing is thus extremely important. Veld growths increased drastically in the Bloemfontein area from November until the end of February and, according to Van Der Westhuizen (2006), the average contribution to rangeland production for these four months is roughly 62%. However, the later process relied on effective rains during August, September and October, which is essential for the ending of the dormant season and contributes immensely to veld quality. Van den Berg (2019) states that, for the period between October and the end of February, the Bloemfontein area experienced below average rainfall for four out of the past five seasons (Figure 1). The aforementioned five-month period is very important for efficient fodder-flow planning. The findings of Fynn and O'Connor (2000) as well as those of Baudoin et al. (2017) and Swemmer et al. (2018), respectively, state that the importance of rainfall on veld compositional change cannot be attributed to a single rainfall season, but also to the preceding seasons.

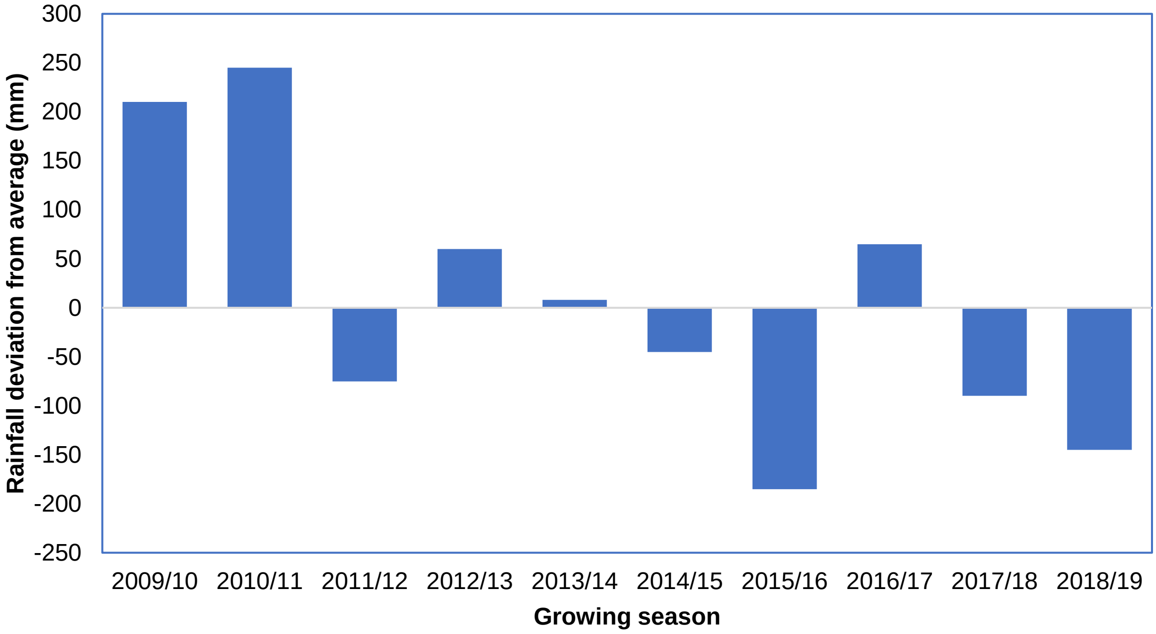

Figure 1: Bloemfontein rainfall differences report for a ten-year period from 1 October to 28 February (Van den Berg, 2019)

3. RESULTS AND DISCUSSIONS

The statistical analyses represent the decisions taken by 29 extensive land-reform livestock farmers sampled for the study, during the 2018/2019 mid-summer drought in the Bloemfontein area. The data are presented in Table 1.

Table 1: Descriptive statistical analyses regarding grazing area, number of large stock units kept, stocking rate, mortalities, and calving rate

	Grazing area, including arable lands (ha)	**Number of LSUs**	**Stocking rate (ha/LSU)**	**Mortalities (LSU)**	**Calving rate (%)**
Mean	514	87.1	5.9	6.1	32
Median	400	54.5	5.7	1.2	31
Std. deviation	446	82.5	6.8	11.2	24
Range	1566	311.3	37.5	55.7	83

Minimum	4	4.6	0.2	0	0
Maximum	1570	315.9	37.7	55.7	83
Total	14902	2526.8		176.8	

The results show that the average number of large stock units were 87.1 allocated to the average grazing area of 514 ha. This means that the average stocking rate of sampled Bloemfontein livestock land-reform farmers was 5.9 ha/LSU during the 2018/2019 drought. According to these findings, the collective land-reform farmers' average stocking rate conceded with the departmental grazing capacity of the study area for veld in a good condition for an average production growing season. These findings correspond with the findings of Foster (2015), where a similar parameter was measured on an extensive commercial beef-farming unit in the Zastron area, south-eastern part of the Free State province in South Africa. However, standard deviations were large, indicating a big variation in stocking rate between the different sampled Bloemfontein land-reform livestock farmers. These findings are inconsistent with good veld management practices, as highlighted by Forbes (1988) that the "farmers must be in control of equating the animal forage requirements to seasonal forage production cycles and natural periods of forage scarcities".

According to Cros et al. (2004) as well as Zuma-Netshyukhwi and Stigter (2016), even though there is consistency on vegetation types at farm level, the farmer has no control over prevailing weather conditions as they are dependent on the climatic conditions. However, the stocking rate is the main parameter that the farmer can control. Stocking rate was divided into different groups, as indicated in Figure 2, while mortality rate was calculated as the percentage of mortalities on every farm in relation with number of LSUs that can be kept on the farm for veld in a good condition with a grazing capacity of 6 ha/LSU.

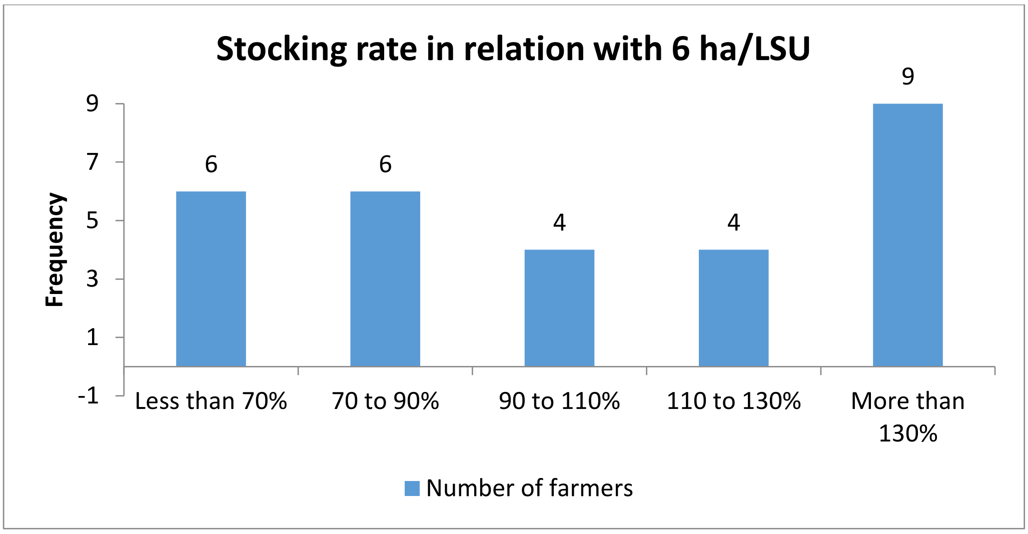

Figure 2: Histogram of stocking rate ranges in relation with veld in a good condition (6 ha/LSU) reported by the farmers

Although the average stocking rate for land-reform livestock farmers in Bloemfontein was observed to concede with the recommended grazing capacity for veld in a good condition, six farmers (21%) reported exceptionally low stocking rates and nine farmers (31%) reported extremely high stocking rates. Four of the nine farmers with extremely high stocking rates reported stocking rates of more than 300% in comparison with veld in a good condition. These findings highlighted that 31% of the sampled Bloemfontein land-reform livestock farmers were totally overstocked, even during the drought/dry spell of 2018-2019. It is clear that these farms are not sustainable.

Table 2: Mean mortality rate as a percentage of the stocking rate at 6 ha/LSU as well as calving rate (± standard deviation)

Stocking rate	**Mortality %**	**Calving %**
More than 130% overstock	32.7 ± 50[a]	32.7 ± 28.7
Rest of the farmers	5.7 ± 7.6[b]	31.9 ± 22.4

[a & b] – Values in column with different superscripts differ significantly.

The mortality rate of the 31% of the sampled Bloemfontein land-reform farmers, who were totally overstocked, was also significantly higher ($P < 0.05$) in comparison with the other farmers, as illustrated in Table 2. On average, the mortality rate for these farmers was 32.7% of the optimal grazing capacity of 6 ha/LSU, while farmers with more moderate stocking rates on average only lost 5.7% of LSUs. Key to note was the fact that no relation between stocking rate and calving rate could be found from data as reported by the farmers.

Average calving rates were, however, exceptionally low and comparable to the results of Van der Westhuizen et al (2020) of 32% obtained with very little or no rangeland management inputs. This trial was executed over a five-year period on the Glen experimental farm of the Free State Department of Agriculture and Rural Development in the Bloemfontein district. The authors highlighted the essential role of sustainable rangeland management in drought and the impact on mitigation, where reproduction of beef cattle was significantly higher during a dry season with sustainable rangeland management in comparison with a normal year, with no rangeland management inputs.

All respondents in this study were requested to make a comparison of their available natural fodder with that of their neighbours, by mere observation, to assess if there was general uniformity on available forage.

Table 3: Respondents' forage scarcity in comparison to that of their neighbours, average stocking rate as well as average mortality rate during drought/dry spell of 2018-2019

Forage in relation with neighbours	**Frequency**	**Percentage (%)**	**Stocking rate (%)**	**Mortality rate (%)**
Better	12	41.4	88	6.5
Same	6	20.7	147	14.0
Worse	11	37.9	378	22.4
Total	29	100.0		

In the study, 41.4% of the respondents, which is the biggest portion of the sampled group, observed that their available fodder was better than that of their neighbours; 20.7% of the respondents observed that their available fodder was similar to that of their neighbours, and 37.9% of the total respondents, which is the second biggest portion of the sampled group, observed that their available fodder was worse than that of their neighbours.

Although not significant, a clear trend was found between available fodder and stocking rate, as well as available fodder and mortality rate, as reported by respondents. The average stocking rate of the farms with less fodder available than their neighbours (378%) contributed to both forage shortages and higher mortality rates (22.4%). These findings clearly point out that there was no uniformity in terms of available fodder between the respondents. However, even though it is essential to note that livestock management systems might differ from one farmer to the next, the 37.9% is not simply a fraction of the respondents and, as a result, a close monitoring and more detailed assessment of production systems and stocking rates for land-reform livestock farmers in Bloemfontein is recommended. Nonetheless, the average calving rate on farms with less fodder available during the drought was significantly higher ($P < 0.05$) at 45% in comparison with the rest of the farms with an average calving rate of 25%. In practice, these findings might suggest that farmers with higher livestock production skills, unfortunately possess lower fodder management skills, which might be a serious threat to sustainable extensive livestock production.

Drought/dry spell drastically reduces the availability and nutritional value of the available fodder for livestock grazing. Nonetheless, literature consistently agrees with the fact that the lack and poor quality of natural fodder in extensive livestock farming systems increase the susceptibility of livestock to diseases, leading to subsequent livestock deaths. A total livestock mortality of 176.8 LSUs for sampled farmers (Table 1) was recorded during the period of this study. This equates to R 1 760 920.87 based on average class B2/B3 beef carcass price for November 2018 of R42.39/kg, which is an enormous financial loss incurred by farmers when converted to monetary value. On average, each farmer from the total sampled group lost 6.1 LSUs, as observed in Table 1. This means that, on average, each farmer incurred R 60 766.65 financial losses. The losses varied from old cows/ewes/does to offspring. However, the older breeding stock accounted for more than 80% of the entire losses. The loss of breeding stock is a major setback in livestock farming, since it can take years to rebuild the breeding stock.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Bloemfontein land-reform farmers' average stocking rate indicated positivity in comparison to the departmental stocking rate norm of 6 ha/LSU, at the time when rainfall data indicated successive years of below average rainfall and when a significant proportion of the sampled farmers observed their natural fodder availability as worse than that of their neighbouring farms. It is thus concluded that the positive relationship is spurious. The stocking rate of 21% of the respondents was exceptionally low, resulting in a loss of income for these farmers, while 31% of the respondents' stocking rates were extremely high, which will contribute to rangeland degradation, unsustainability, and poverty. Mortality rates of livestock was also high for the farmers who were severely overstocked, and they lost on average 32.7% of livestock that can be kept on the farms in optimal conditions, during the 2018/2019 drought. The fact that rangeland condition was not evaluated could further indicate that stocking rate of the vast majority of farmers is too high for sustainability. According to Van der Westhuizen (2003), the grazing capacity for rangelands in moderate condition (50%) is roughly 8 ha/LSU for cattle and 9.5 ha/LSU for sheep for the study area.

In terms of available fodder, 38% of the respondents reported fodder shortages, with available fodder less than on neighbouring farms. On average, the farmers with fodder shortages were severely overstocked during the drought and livestock mortalities for this group of farmers was

22%. As a result, the continued viability of these farming operations is in jeopardy. Calving rates, as reported by farmers, were also exceptionally low, with an average of 32% and a standard deviation of 24%. According to Van der Westhuizen et al. (2020), low calving rates can be classified as the main financial driver in terms of profitability for extensive livestock farming systems.

Due to climate change and global warming, the effect of the correct stocking rates will play a major role in the sustainability of Bloemfontein's extensive land-reform livestock farmers. Imprudent grazing management practices, especially pertaining to veld, already under stress prior to the onset of drought, is one of the most important contributing factors to the devastation caused by the drought (Coleman, 2017). Dry years, particularly when they occur in succession, can reduce perennial plant cover and reduce the number of animals the veld is able to support (Van der Westhuizen et al., 2018). It is recommended that livestock numbers be reduced during extended drought periods. Stocking rates, according to grazing capacity as well as the timely adjustment of stocking rates during droughts is essential to promote sustainable utilisation of natural veld, and subsequently to ensure sustainable productivity on extensive livestock farming systems.

Bembridge (1986) and Mokhesengoane (2020) emphasized the importance of educational programmes both on the formulation of veld management programmes and veld assessment for farmers. Education of farmers on rangeland management, livestock reproduction performance and economics has a major role to play in their decision-making process when managing their rangelands. Farmers, extension personnel and rangeland scientists have a major role to play in this regard, in order to reduce or prevent future rangeland degradations.

4.2 Recommendations

It is recommended that the extension personnel of the Bloemfontein ward office develop systems to closely assess and monitor livestock production systems, and veld management programmes utilized by land reform livestock farmers to narrow 38% of the respondents, who observed their available fodder as worse than that of their neighbours.

It is also recommended that these personnel must arrange intensive training on rangeland degradations and stocking rate alignment with natural forage scarcity periods for their land-reform livestock farmers.

5. ACKNOWLEDGEMENTS

The authors are grateful for the contribution of Mr. Johan van den Berg, a senior Climatologist and Manager Specialized Crop Insurance at Santam Crop Insurance, for his guidance and enormous contribution in this study about long-term rainfall pattern analyses.

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APPENDICES

APPENDIX A: QUESTIONNAIRE

Questionnaire

DATE OF THE SURVEY:

OBJECTIVES OF THE SURVEY

To identify livestock farmers technical and marketing knowledge deficiencies.

To develop extension intervention plan per farm where possible/ per farmer group.

To measure the impact of extension intervention plan on farmer productivity and farmer development.

To report extension profession achievements and challenges to the scientific community.

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For office use only

A. BIOGRAPHIC INFORMATION

A.1 DISTRICT …………………………………….. 1

A.2 MUNICIPALITY …………………………………….. 2

A.3 FARMER NAME ………………………… 3

A.4 FARMER Id No …………………………… 4

A.5 HIGHEST ACADEMIC QUALIFICATION … … ……. 5

A.6 FARM NAME&OWNERSHIP …………………… …

LEASED/OWEN/LRAD/PLAS ………………………………….

A.7 FARM SIZE(ha) …………………… ……

GRAZING VELD (ha) ……………… ARABLE LANDS (ha) ………….

A.8 FARMER CATEGORY /Smallholder/Commercial

(i)NUMBER OF FEMALE FAMILY MEMBERS INVOLVED IN THE BUSINESS AND THEIR RESPECTIVE ROLES
………………………………………………………………
………………………………………………………………
………………………………………………………………
………………………………………………………………

B. FODDER PRODUCTION

(Answer YES or NO to every statement)
……………………
…………

B GRAZING MANAGEMENT PRACTICES

		Yes	No
B.1	Does the farmer follow a grazing system?		

6

B.2 NUMBER OF GRAZING CAMPS(Include residues & Planted Pastures) ……………..

B.3 NUMBER OF HERDS KEPT ON THE FARM …………….. 7

B.4 GIVE SHORT DESCRIPTION OF GRAZING PRACTICES 8

(e.g. Average resting and grazing periods of camps)

…………………………………………………………………………………….

B.5 AVARAGE VELD CONDITION (Mark the appropriate condition with X) 9

Excellent (>80%)

Good (60-80%)

Moderate (40-60%)

Poor (20-40%)

Very Poor (<20%)

B.6 LIST THREE MOST DOMINANT GRASS SPECIES ON THE FARM 10

(List in order of abundance) 1……………………………….

2………………………………… 3…………………………………….

B.7 CULTIVATED PASTURES (ha) :

Pasture1	Pasture2	Pasture3	Pasture4

B.8 RESIDUES CROPS USED FOR LIVESTOCK

Type of crop(ha)	Area(ha)	Average grain production(tons)

B.9 HOW ARE THE CULTIVATED PASTURES AND CROP RESIDUES USED FOR LIVESTOCK PRODUCTION? …………………………………………………………..

B.10 DOES THE FARMER HAVE LICKS SUPPLEMENTATION PROGRAM?

Yes/No ……………………….

(i) DOES HE/SHE PROVIDE SALT BLOCKS?
Yes/No……………………..

(ii) DOES HE/SHE PROVIDE SEASONAL LICKS?
Yes/No…………………..

B.11 DOES THE FARMER ALIGN HIS/HER LIVESTOCK NUMBERS WITH SEASONAL FORAGE PRODUCTION CYCLES AND NATURAL PERIODS OF FORAGE SCARCITIES? Yes/ No………………..

``

B.12 WHAT IS THE DEPARTMENTAL GRAZING CAPAZITY IN THE REGION WHERE THE FARM IS SITUATED (Ha/LSU)...............

B.13 DOES THE FARMER KNOW WHAT IS HIS/HER CURRENT STOCKING RATE (Ha/LSU) IF YES GIVE. …………………………

GENERAL FARMER REMARKS…………………………………………………………..
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

C **LIVESTOCK PRODUCTION**

C.1 INDICATE THE DIFFERENT LIVESTOCK COMMODITIES ON THE FARM
(e.g. Beef, Dairy, Mutton, Wool, Mohair)

(List in order of priority)
1…………………………

2…………………….. 3………………………….

C.2 DOES THE FARMER FOLLOW A BREEDING SEASON FOR HIS/HER DIFFERENT LIVESTOCK TYPES KEPT ON THE FARM? Yes/ No……………….

C.3 IF YES INDICATE MATING SEASON DURATION AND CALENDER MONTHS.
……………………………………………………………………………..

C.4 DOES THE FARMER HAVE A PRODUCTION PLAN/CALENDER OF EVENTS? Yes/No……………

C.5 INDICATE THE RATIO OF BULLS TO COWS ………………………………………….

C.6 INDICATE THE RATIO OF RAMS TO EWES ……………………………………….

C.7 INDICATE THE RATIO OF RAMS TO DOES ……………………………………….

C.8 **BREEDS (I**ndicate if they are either small, medium or large framed breed types**)**

A **BEEF ……………………………………………………………………….**

B **SHEEP …………………………………………………………………….**

C **GOATS …………………………………………………………………….**

LIVESTOCK INVENTORY (Inclusive of livestock age and class)

C.9 BEEF:

Age/Class	Breed 1	Breed 2	Breed 3	Breed4	Total
Bulls					
Cows					
Calves (>7 months)					
Replacement heifers (7-8 months)					
Replacement heifers (7- 18 months)					
Replacement heifers (19-30 months)					
Steers (7-18 Months)					
Steers (older than 19 Months)					

C.10

SHEEP:

Age/Class	Breed 1	Breed 2	Breed 3	Breed4	Total
Rams					
Lactating ewes					
Dry ewes					
Lambs (<4 moths)					
2-tooth replacement ewes and wethers					
6-tooth replacement ewes & wethers					

C.11 GOATS:

Age/Class	Breed 1	Breed 2	Breed 3	Breed4	Total
Bucks					
Lactating does					
Dry does					
Kids (<4 moths)					
2-tooth replacement does and castrates					
6-tooth replacement does& castrates					

C.12 LIST ANY ADDITIONAL ANIMALS KEPT ON THE FARM AND THEIR TOTAL (e.g. Game, Horses and Donkeys)

………………………………………………………………………………………

C.13 INDICATE CURRENT BIRTH RATE OF EACH LIVESTOCK TYPE KEPT

ON THE FARM(Number of offspring's born versus productive female animals)

A **BEEF ………………………**

B **SHEEP ……………………**

C **GOATS ……………………**

C.14 INDICATE CURRENT WEANING RATE OF EACH LIVESTOCK TYPE KEPT ON THE FARM(Number of offspring's survived till weaning)

A **BEEF ………………………**

B **SHEEP ………………………**

C **GOATS ……………………**

C.15 INDICATE CURRENT WEANING WEIGHT AND AGE(Average weight of offspring's at weaning)

,

A **BEEF ………………………**

B **SHEEP ………………………**

C **GOATS ……………………**

C.16 WHAT PERCENTAGE (%) OF THE OFFSPRINGS IS KEPT AS REPLACEMENT STOCK

A **BEEF ………………………**

B **SHEEP ………………………**

C **GOATS ……………………**

C.17 HOW DOES THE FARMER PREVENT IN-BREEDING?

…………………………………………………………………………

C.18 DOES THE FARMER FOLLOW THE PRESCRIBED ANIMAL HEALTH PROGRAM FOR HIS/HER AREA? Yes/No ……………………..

C.19 DOES THE FARMER KEEP ADDITIONAL PRODUCTION RECORDS (e.g. inter-calving or Cow efficiency) IF YES WHAT ARE THEY

………………………………………………………………………………..

C.20 YEARLY MORTALITIES

Age	Cattle	Sheep	Goats
Pre-weaning			
Post-weaning to mature			
Mature			

GENERAL FARMER REMARKS…………………………………………………………..
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

D MARKETING INFORMATION

D1 AVARAGE NUMBER OF LIVESTOCK SOLD ANNUALLY

Age			
	Cattle	Sheep	Goats
Weaners			
Old weaners			
Mature			
Culls			

D2 DOES THE FARMER HAVE ACCESS TO LIVESTOCK MARKETING PRICE INFORMATION (TRENDS) ?(If Yes give price sources/marketing info source)

1 ……………………………..2 ……………………..3 …………………………

D3 WHERE DOES THE FARMER SELL HIS/HER WEANERS/LAMBS/KIDS

…………………………………………………………………………………

D4 HOW FAR ARE THESE MARKETS FROM THE FARM?

……………………………

D5 HOW DOES THE FARMER DECIDE WHAT LIVESTOCK AGE/CLASS, WHEN AND WHERE TO SELL?

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

D6 DOES THE FARMER KEEP FINANCIAL RECORDS? Yes/No

…………..

E TRAINING AND FARMER DEVELOPMENT

E.1 DOES THE FARMER BELONG OR ATTEND (Mark the correct answers with X)

A COMMODITY ORGANIZATIONS

B STUDY GROUP MEETINGS

C TRAINING COURSES

D INFORMATION DAYS

E FIELD DAYS

F ANNUAL AGRICULTURAL SHOWS

E.2 DOES THE FARMER HAVE ACCES TO GOVERNMENT EXTENSION AND ADVISORY SERVICES? Yes/No ………………………….

E.3 DOES THE FARMER HAVE ACCESS TO PRIVATE EXTENSION AND ADVISORY SERVICES (e.g. GWK AND SERNICK)? Yes/No …………………………………..

E.4 WHAT ARE THE FARMER'S ADDITIONAL INFORMATION SOURCES?

(e.g. Formal mentorship, Informal mentorship, Internet)

…………………………………………………………………………………………

E.5 WHAT ARE THE FARMER'S MOST TRUSTED INFORMATION SOURCES?

(List in order of importance)

1 ……………………. 2……………………. 3………………………………..

FARMER GENERAL REMARKS

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

……………………… End of Survey Thank You ...…………………

APPENDIX B: PHOTOS

Pictures of the researcher and Dr. H.C Van der Westhuizen during data collection

APPENDIX C: APPROVED RESEARCH ETHICAL CLEARANCES

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

<u>GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)</u>

30-Aug-2021

Dear Mr Thabiso Mokhesengoane

<u>Application Approved</u>

Research Project Title:
Agro-ecological rangeland condition assessment of extensive land reform pastoral farming sites, in the grasslands of Bloemfontein post two wet seasons preceeded by droughts.

Ethical Clearance number:
UFS-HSD2021/1018/21

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

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APPENDIX D: SOIL ANALYSES RESULTS AND RANGELAND CONDITION SCORES

Camps	pH (KCl)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)	S (mg/kg)	EA	As (%)	Ca/Mg	(Ca+Mg)/K	CEC (cmolckg-	Density (g.cm-3)	Sand (%)	Clay (%)	Silt (%)	EC (mS/m)	C (%)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Rangeland Condition Scores
C1	5.0	3.5	263.1	1155	584.3	80.9	82.40	0.00	0.00	1.21	15.70	11.59	1.00	68	24	8	7.4	4.87	0.39	2.86	4.54	0.26	62%
			-6	-50	-41	-3																	
C2	5.0	12.4	306.3	1582	616.8	9.1	85.82	0.00	0.00	1.57	16.56	13.79	1.02	78	14	8	4.8	2.87	0.57	3.98	4.24	0.69	61%
			-6	-57	-37	0																	
C1	6.1	4.5	333.7	784	173.3	1.5	20.75	0.00	0.00	2.76	6.26	6.20	1.25	88	10	2	6.8	1.83	0.18	0.93	2.65	0.14	19%
			-14	-63	-23	0																	
C2	7.5	3.3	291.0	1901	172.2	29.6	145.60	0.00	0.00	6.73	14.67	11.79	1.29	90	8	2	18.5	0.70	0.09	0.95	2.55	0.15	56%
			-6	-81	-12	-1																	
C1	4.6	3.6	454.3	623	239.3	4.7	25.29	0.25	3.83	1.59	4.37	6.51	1.10	78	16	6	9.1	1.31	0.30	1.78	2.64	0.17	49%
			-18	-48	-30	0																	
C2	4.5	1.1	435.0	476	213.2	9.6	49.28	0.54	9.25	1.36	3.71	5.82	1.10	85	12	3	5.7	1.07	0.22	1.79	1.50	0.12	54%
			-19	-41	-30	-1																	
C1	4.6	5.8	515.7	851	332.5	12.4	49.24	0.46	5.21	1.56	5.29	8.81	1.15	74	22	4	4.5	1.97	0.31	1.77	2.53	0.18	81%
			-15	-48	-31	-1																	
C2	4.9	1.3	642.9	771	352.1	11.9	161.79	0.00	0.00	1.34	4.10	8.44	1.11	68	26	6	6.5	2.25	0.36	1.83	2.58	0.11	73%
			-19	-46	-34	-1																	
C1	6.0	1.2	592.1	3285	507.9	23.0	89.23	0.00	0.00	3.95	13.60	22.20	0.83	62	28	10	21.6	3.85	0.07	0.27	4.80	0.21	75%
			-7	-74	-19	0																	
C2	6.0	1.2	529.6	3644	534.5	20.2	303.78	0.00	0.00	4.16	16.69	24.05	0.79	64	30	6	24.6	2.87	0.07	0.24	4.15	0.20	25%
			-6	-76	-18	0																	
C1	5.1	1.5	491.2	1412	385.4	10.4	70.20	0.00	0.00	2.24	8.14	11.52	0.90	72	20	8	8.1	2.41	0.23	1.47	3.58	0.28	67%
			-11	-61	-27	0																	
C2	4.5	5.0	391.1	757	260.8	7.4	0.88	0.44	5.94	1.77	5.92	7.39	1.04	76	20	4	5.9	1.07	0.36	3.25	2.98	0.30	27%
			-14	-51	-29	0																	
C1	5.0	2.2	344.0	1532	591.1	13.4	236.43	0.00	0.00	1.58	14.22	13.44	1.02	72	20	8	6.5	2.16	0.29	2.01	2.75	0.20	48%
			-7	-57	-36	0																	
C2	5.2	1.2	151.2	1580	665.5	32.9	102.55	0.00	0.00	1.45	34.55	13.89	1.03	74	20	6	8.9	2.25	0.39	2.05	3.79	0.23	55%
			-3	-57	-39	-1																	
C1	4.7	1.6	355.7	520	188.9	3.9	118.20	0.46	8.29	1.68	4.56	5.53	1.04	78	14	8	8.2	2.82	0.37	3.20	4.66	0.41	28%
			-16	-47	-28	0																	
C2	4.6	0.8	284.7	409	136.2	1.3	92.17	0.53	11.94	1.83	4.35	4.43	0.93	79	14	7	5.8	0.76	0.33	3.89	3.99	0.17	14%
			-16	-46	-25	0																	
C1	6.3	8.9	394.7	3445	812.1	61.6	67.57	0.00	0.00	2.59	23.66	25.16	0.92	60	32	8	14.4	2.31	0.06	0.16	5.48	0.23	62%
			-4	-68	-26	-1																	
C2	6.8	3.6	750.6	3825	878.4	36.7	163.56	0.00	0.00	2.66	13.72	28.41	0.87	58	34	8	41.7	1.69	0.34	4.66	3.13	0.20	49%
			-7	-67	-25	-1																	

APPENDIX E: BEEF WEEKLY MARKET

A2/A3
R51.72
per kg

C2/C3
R44.78
per kg

Market feel:

Demand is staying on a higher level which is supporting prices that remain relatively stable on a higher level. However, weaner prices stabilised the past week due to lower demand and feedlots that already bought for December. It is expected that this price can trend sideways over the short term and gain some support in December again. A and C grade prices can remain on a sideways/upward trend as we move towards the end of the year.

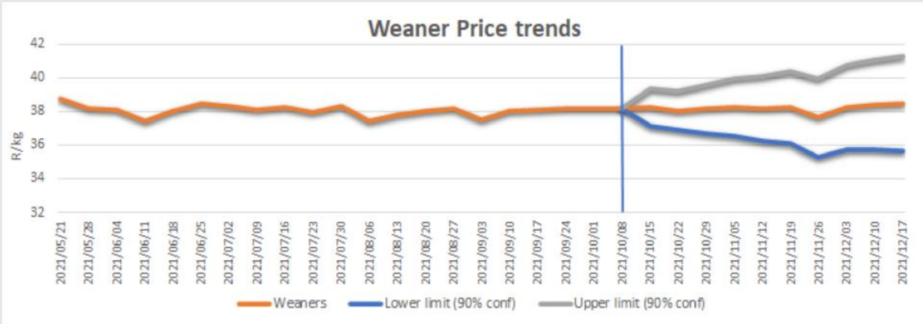
Beef (Excl VAT) - Producer selling prices in c/kg						Forecast
Week ending	09-Oct-20	10-Sep-21	24-Sep-21	01-Oct-21	08-Oct-21	15-Oct-21
Class A2/3	4974	5178	5161	5187	5172	5173
Class AB2/3	4790	5092	5117	5083	5070	5070
Class B2/3	4413	4916	4943	4874	4868	4879
Class C2/3	4177	4441	4442	4513	4478	4496
Weaners (200-240kg) (R/kg)	37.15	38.04	38.18	38.21	38.20	38.24
Feedlot hides (green) (R/kg)	1.33	7.70	7.02	5.67		
Veld hides (green) (R/kg)	0.86	7.17	6.58	5.20		

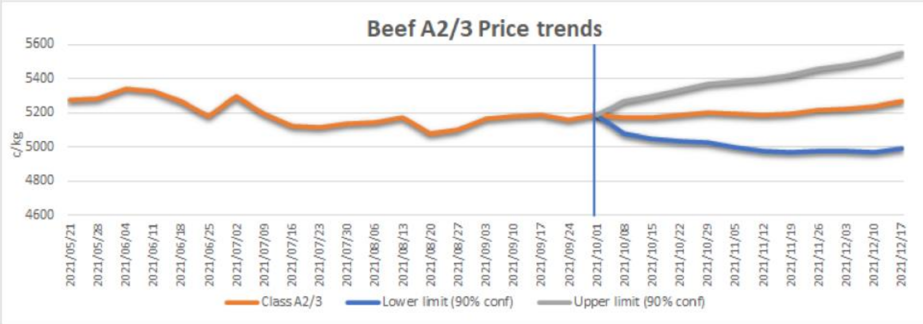
Price movements

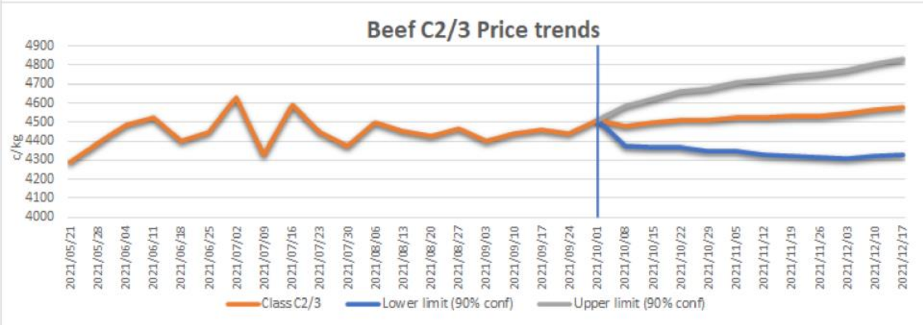
Weaners - The price is 0.03% lower compared to the previous week, 0.42% higher than a month ago and 2.81% higher than last year the same time. Based on historic trends, the price can trend upward over the coming week.

A2/3 - The price is 0.29% lower compared to the previous week, 0.12% lower than a month ago and 3.97% higher than last year the same time. Based on historic trends, the price can trend upward over the coming week.

C2/3 - The price is 0.78% lower compared to the previous week, 0.83% higher than a month ago and 7.21% higher than last year the same time. Based on historic trends, the price can trend upward over the coming week.


Weaner Price trends
R/kg
42
40
38
36
34
32
2021/05/21
2021/05/28
2021/06/04
2021/06/11
2021/06/18
2021/06/25
2021/07/02
2021/07/09
2021/07/16
2021/07/23
2021/07/30
2021/08/06
2021/08/13
2021/08/20
2021/08/27
2021/09/03
2021/09/10
2021/09/17
2021/09/24
2021/10/01
2021/10/08
2021/10/15
2021/10/22
2021/10/29
2021/11/05
2021/11/12
2021/11/19
2021/11/26
2021/12/03
2021/12/10
2021/12/17
Weaners
Lower limit (90% conf)
Upper limit (90% conf)


Beef A2/3 Price trends
c/kg
5600
5400
5200
5000
4800
4600
2021/05/21
2021/05/28
2021/06/04
2021/06/11
2021/06/18
2021/06/25
2021/07/02
2021/07/09
2021/07/16
2021/07/23
2021/07/30
2021/08/06
2021/08/13
2021/08/20
2021/08/27
2021/09/03
2021/09/10
2021/09/17
2021/09/24
2021/10/01
2021/10/08
2021/10/15
2021/10/22
2021/10/29
2021/11/05
2021/11/12
2021/11/19
2021/11/26
2021/12/03
2021/12/10
2021/12/17
Class A2/3
Lower limit (90% conf)
Upper limit (90% conf)


Beef C2/3 Price trends
c/kg
4900
4800
4700
4600
4500
4400
4300
4200
4100
4000
2021/05/21
2021/05/28
2021/06/04
2021/06/11
2021/06/18
2021/06/25
2021/07/02
2021/07/09
2021/07/16
2021/07/23
2021/07/30
2021/08/06
2021/08/13
2021/08/20
2021/08/27
2021/09/03
2021/09/10
2021/09/17
2021/09/24
2021/10/01
2021/10/08
2021/10/15
2021/10/22
2021/10/29
2021/11/05
2021/11/12
2021/11/19
2021/11/26
2021/12/03
2021/12/10
2021/12/17
Class C2/3
Lower limit (90% conf)
Upper limit (90% conf)