Development of guidelines for improvement of reproductive management of smallholder beef cattle in five provinces of South Africa

By

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Dedication

To my sweet angel who could not live to celebrate this achievement, I love you until infinity.

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Abstract

Smallholder beef cattle farming in South Africa is characterized as an important free-range farming system with the potential to alleviate poverty and up-lift the economy of rural communities. In this farming system, reproductive performance has been identified as poor with substantial influence on herd growth and profitability. Understanding reproductive performance in smallholder farms in this study required an integrated research approach that first focused on the current farming practices to provide insight into smallholder beef production and constraints, secondly outlining reproductive norms, and finally defining achievable targets and factors associated with reproductive performance to provide guidelines for improvement. A structured questionnaire was used to capture the current beef cattle constraints and herd reproductive management practices. To evaluate reproductive performance, a multilevel-sampling approach was used to identify study sites, beef cattle herds and breeding cows. A total of 3694 cow records were collected from 40 smallholder herds between 2018 and 2019 over two seasons: in Autumn (March to May) for pregnancy diagnosis and in Spring (September to November) for monitoring of confirmed pregnancies. Data on animal and herd management factors such as body condition score (BCS), cow age class, breed type, lactation status, culling non-productive cows, record keeping, and breeding and calving months were recorded to evaluate associations with performance indicators. Farmers demographics showed that the majority of farmers were males over the age of 60 whose farming objective is mainly for sales from informal markets. The major constraints in smallholder beef cattle farms included lack of farming knowledge, understanding of farm business and information communicated by government agencies. The preferred 25th quartile was used to describe the performance benchmark and the GLIMMIX procedure of SAS was utilized to determine animal and management factors influencing reproductive performance. The SAS frequency procedure was used to show average reproductive performance levels. Measures of reproductive performance highlighted that 50% pregnancy rate, 12% fetal and calf loss, extended calving interval (608) and days open (304) currently defines reproductive performance in smallholder farms. However, achievable benchmarks of 54% pregnancy rate, 1.4% fetal and calf loss, days open and calving interval of 152 and 425 days, respectively were established. Poor management practices such as lack of knowledge on body condition scoring prior breeding, culling of old and non-productive cows, record keeping and low bull to cow ratio ($p < 0.05$) were identified as a standard practice in smallholder farms. Major factors determining reproductive norms included BCS, breed type, breeding and calving months, with breeding month December to March having high likelihood of obtaining pregnant cows and autumn calving season with high fetal and calf loss, extended calving interval and days open. The outcomes of the study were compiled into a set of recommended guidelines for improving reproductive performance in smallholder farms that can be applied by extension and advisory services for improved farm management strategies to enhance reproductive performance in smallholder farms.

Thesis outputs

Publications

The current research published two research articles in peer-reviewed journals.

1. Marble Nkadimeng, Este van Marle-Köster, Nkhanedzeni Baldwin Nengovhela & Makgahlela Mahlako Linah.2022. Understanding beef cattle production practices and associated factors constraining performance: A survey of smallholder farmers in South Africa. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*.123 (1): 131–145. https://doi.org/10.17170/kobra-202204216054.

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Conference proceedings

M Nkadimeng, E van Marle-Koster, ML Mphaphathi, FV Ramukhithi, A Maqhashu, M Tshabalala & ML Makgahlela. Management factors influencing pregnancy in non-commercial beef cattle on natural breeding program in South Africa. 19th International Congress on Animal Reproduction, Bologna (Italy) 28th June 2020.

Marble Nkadimeng, Este van Marle-Köster, Fhulufhelo Vincent Ramukhithi1, Masindi Lotus Mphaphathi1 & Mahlako Linah Makgahlela. Evaluating reproductive performance benchmarks and determining factors influencing reproductive performance in smallholder beef cattle farms. 50th Annual Conference of the IETS, January 9 to 12, 2024, in Denver, Colorado, USA.

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List of Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ARC	Agricultural Research Council
BCFM	Beef cattle farm management recording system
BCS	Body condition score
CA	Contagious abortion
CASP	Comprehensive Agricultural Support Program
CI	Calving interval
CI	Confidence interval
DO	Days open
EC	Eastern Cape
FC	Fetal and calf loss
FSH	Follicle-stimulating hormone
GnRH	Gonadotropin-releasing hormones
HVBP	High Value Beef Partnerships
IVMS	Integrated Village Management System
KYD	Kaonafatso ya Dikgomo
LP	Limpopo province
LRAD	Land Redistribution for Agricultural Development
MP	Mpumalanga
NW	North West
OR	Odds ratio
PR	Pregnancy rate
SA	South Africa
SAS	Statistical Analysis System
SDG	United Nation Sustainable Development Goals
SE	Standard Error
SHS	Smallholder sector
SLAG	Settlement Land Acquisition Grant
TIA	Technology Innovation Agency
WELI	Women's Empowerment in Livestock Index

Chapter 1

Introduction

1.1 Overview

The livestock sector in South Africa (SA) supports the livelihood of approximately 70% of the rural population (Hlatshwayo *et al.*, 2022). Additionally, the beef cattle industry is recognized for its significant role in alleviating rural poverty and improving the living conditions of adults (estimated at 55.5%) and children (88.4%) experiencing multidimensional poverty in rural communities (STAT SA, 2021; Jobirov *et al.*, 2022a). In SA rural areas, smallholder beef farmers are often defined as farmers that farm for their own consumption and only market surplus of their farm produce. These farmers are custodians of cattle production in their communities. They keep cattle for a combination of cultural, social and economic reasons (Queenan *et al*., 2020; Olmo *et al*., 2021; Mbatha, 2021). Smallholder beef cattle farmers are estimated at 3 million with an estimated 5.69 million cattle and provide employment to approximately 9 million people in rural areas (Beef Market Value Chain Profile, 2021). However, with that said, beef production in smallholder farms is challenged by low productivity and profit (Jobirov *et al.*, 2022b). Smallholder beef cattle farms in SA are reported to contribute only 10% at auctions for formal marketing of their livestock (Mbatha, 2021). Therefore, to meet food requirement for the estimated 70% increase in human population by 2050, it is crucial for smallholder farms to improve productivity and increase farm growth (Olmo *et al*., 2021).

Efficiency of livestock production is improved through good breeding practices and therefore, reproduction efficiency is a determinant of production output in all farming systems (Fernandez-Novo *et al*., 2021). Additionally, maximizing herd reproduction is one method of increasing milk and meat production in cattle (Consentini *et al.*, 2021). Therefore, the adoption of herd management plans for monitoring herd reproductive performance indicators such as pregnancy rate, calving interval and days open is of utmost importance (Krpálková *et al.*, 2020; Kaurivi *et al.*, 2020). Moreover, understanding farm management practices and the risk factors that affect performance indicators may give insight into the herd reproduction norms and can be applied for improvements (Tada *et al.*, 2013; Titterington *et al.*, 2017; Hewitt *et al.*, 2018; Kaurivi *et al.*, 2020; Olmo *et al.*, 2021).

Enhancing smallholder farms' reproductive efficiency is a primary objective in SA to reach improvement targets set by the Department of Agriculture, Land Reform and Rural Development. These targets include achieving an increase of 60-80% calving rate from the current recorded 48%, which has remained stagnant for over three decades (DALRAAD *et al*., 2020). Reports have shown that in smallholder farms, monitoring reproductive performance requires understanding the farming system and its heterogeneous, and continued evaluation routine assessments (Olmo *et al.*, 2021; Armengol *et al.*, 2022). It is vital to understand the achievable levels of reproductive performance that smallholder farms can attain given their available resources and environment (McCosker *et al.*, 2022). The strengths and weaknesses of smallholder farms must be known in order to set guidelines for improved reproduction within current constraints.

1.2 Aim of the study

In SA, the concept of free-range or grass-fed beef farming is frequently marketed as an economic opportunity for smallholder farmers since farming in this sector is primarily extensive (Kunene-Ngubane *et al.,* 2018; Malusi *et al.,* 2021). Low input farmers have the opportunity to produce high-quality products for free-range markets and make more profit compared to informal agricultural markets (Kunene-Ngubane *et al.,* 2018; Ume, 2023). Currently, smallholder farmers have an opportunity to supply beef to niche free-range beef market such as Woolworths supermarkets, which targets the growing number of middle to higher income consumers (Mmbengwa *et al.*, 2016). The current research is a component of the larger project titled High Value Beef Partnerships (HBVP) for smallholder and communal beef cattle farmers of SA. The HBVP and its collaborators (Woolworths and Pick 'n Pay) offer the smallholder beef cattle farming an opportunity to access the free-range market for cattle that are raised and finished on natural pastures with slaughter weight of 200-360 kg by 3 years of age. To successfully attain the supply of year-round beef and be able to fulfill the free-range market, smallholder farmers must successfully overcome significant farming constraints such as the reported poor reproductive performance. Therefore, the current research answers to ''*what breeding systems need to be developed and implemented to cost-effectively improve reproduction performance in the smallholder beef cattle sector*''. Improving reproductive performance requires farmers to maintain a high proportion of breeding females in their herds with an annual calving rate of ≥70% (Jobirov *et al.*, 2022a).

Beef cattle reproduction in the smallholder farming sector in SA however, has been reported to be unacceptably low (Nowers *et al*., 2013; Mugwabana *et al*., 2018). At a national level, the sector reports herd reproduction with calving rates below 50%, high pregnancy losses (10%), extended calving intervals, high pre-weaning (≤ 50%) and post-weaning mortality rate (15%) (Mokantla *et al*., 2004; Nowers *et al.*, 2013; Nengovhela *et al*., 2021). The reproductive performance of beef cattle in SA has been decreasing since the 1960s, as indicated by perinatal survival and calving rates as low as 25% and 40%, respectively in commercial farms (Boyens, 1964; Maule, 1973). However, it is worth highlighting that there has been a significant improvement in beef cattle reproductive performance within the commercial sector due to enhanced management practices. Calving rates have risen from a reported 40% in the 1960s to a current minimum of 65% and a reduction in pre-weaning mortality now ranging between 4% and 2% (Grobler *et al.*, 2014; Van der Westhuizen *et al*., 2020; Nengovhela *et al*., 2021). However, these figures fall below the recommended national guidelines set by for calving rate (85%), pre-weaning mortality (2%), and post-weaning mortality (2%) in beef cattle (DALRAAD, 2020).

The ripple effect of poor herd reproduction in smallholder farmers is limiting profit and slow sectorial growth of the farming system. This delays the Department of Agriculture Land Reform and Rural Development's (DALRRD) strategic goal for sustainable production in smallholder beef cattle farming. To date, there are no routine reproductive records collected of important performance indicators such as pregnancy rate, losses, and inter-calving period in smallholder farms (Tada *et al*., 2013). Furthermore, there is limited data focusing on reproductive management of naturally mated cattle in smallholder farms. A better understanding of farmers' management practices and identification of the factors that impact cow reproductive performance may improve breeding systems and enable smallholder farmers to effectively deliver high-value, free-range beef. The current study aims to deliver recommended guidelines on how best to manage and improve herd reproduction. The study will evaluate reproductive performance and factors associated with improved performance to identify management interventions and establish guidelines for improvement of smallholder farms. To achieve this aim, the following objectives were formulated:

1. To assess the current beef cattle farming practices and evaluating constraining factors in smallholder beef cattle farms through a survey.
2. To assess achievable levels of reproductive performance for establishing benchmarks of smallholder beef cattle farms and identify factors underlying reproductive performance.

The foundational understanding of smallholder beef cattle farming and its challenges in alignment with the findings from Objective 1, as well as the achievable reproductive performance and the identification of factors influencing reproductive outcomes in line with findings from objective 2, will provide critical and evidence-based recommendations for reproductive performance. These recommendations will be used in developing user-friendly guidelines of targeted interventions aimed at improving reproductive performance within smallholder beef cattle farms.

1.3 Thesis outline

This thesis is arranged into five chapters, an introduction of the purpose and significance of the research is provided in Chapter one. Chapter two presents a review and discussion of challenges affecting beef cattle reproductive performance and outlining mitigation strategies for improvement of beef cattle raised on extensive systems in smallholder farms. A structured questionnaire was designed to address interacting factors to better understand the current beef cattle systems of smallholder farms in Chapter 3. The questionnaire collected data on farm and farmer demographics, constraints of production, marketing, ecological and reproduction management. This Chapter was published by the *Journal of Agriculture and Rural Development in the Tropics and Subtropics*. In Chapter four, reproductive norms, benchmarks and factors affecting herd reproductive performance were established from key performance indicators: pregnancy rate, fetal and calf loss, days open and calving interval. The results of this chapter were published in the Journal *Animals*. Chapter five present a general discussion and conclusion for research findings, as well as recommendations for future studies.

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Chapter 2

Literature review

2.1 Introduction

Livestock production has developed into a highly specialized industry with beef cattle production being the second largest contributor towards the South African Gross Domestic Product (Ngarava *et al.*, 2019; BFAP-Baseline-2021). South Africa (SA) has been characterized by a dual agricultural system with highly developed commercial and less developed smallholder sectors (Beef Market Value Chain Profile, 2021). In the developed commercial sector, farmers often focus on genetic selection and record keeping to improve production and reproductive performance (Van der Westhuizen *et al*., 2020). However, 90% of farmers within the smallholder sector have been noted with limited farming skills, support services and low reproductive performance (Oduniyi *et al*., 2020a).

Improved reproductive performance of beef cattle in smallholder farming systems can be achieved through an in-depth understanding of the challenges in these farming systems. This knowledge may provide basis for propose cost-effective on-farm strategies suitable for farmers in their adaptive environment (Terlau *et al*., 2018; Katikati & Fourie, 2019a; Oduniyi *et al*., 2020b). The review chapter discusses the challenges affecting smallholder beef cattle reproductive performance and outlines proposed cost effective mitigation strategies for the improvement of beef cattle in extensive systems.

2.2 Overview of the developing smallholder systems of South Africa

Smallholder farming was adopted from racial land laws such as the Native land act of 1913 and 1936 (https://www.sahistory.org.za/article/natives-land-act-1913). These laws denied an opportunity for black African farmers to compete with white settlers during the mid-19th century as they were characterized as being small to support independent production, hence the name smallholders or also referred to as family farms (Binswanger & Deininger, 1993; Pienaar *et al.*, 2019). As a form of oppression, the SA constitutional land supporting apartheid in the 1880s allocated smallholder farmers small portion of land of 0.76 million out of 6 million hectares and 0.84 million out of five million hectares in the former Transvaal and Natal provinces, respectively, which only amounted to 7.9% of the country's' area (Binswanger & Deininger, 1993). These unequal land laws supporting the commercial white sector resulted in a dualistic agriculture between the commercial and smallholder sector in SA (Queenan *et al.*, 2020).

In the 1990s, the SA government reviewed the land laws and introduced policies such as the Settlement Land Acquisition Grant (SLAG) scheme and the Land Redistribution for Agricultural Development (LRAD) scheme in agriculture with the aim of introducing equal distribution of farming land in the country (Mapiye *et al.*, 2018). Beneficiaries of the programs were granted funds to assist communal farmers to enter the agricultural enterprises with the aim of promoting sustainable farming (Lahiff & Li, 2012; Mapiye *et al.*, 2018). Following this, more programs such as the Comprehensive

Agricultural Support Programme (CASP), Letsema and the Land Reform were established to support smallholder farmers in developing democratic agriculture through extension services, short-term financing, production inputs and infrastructural grants (van Averbeke & Mohamed, 2006). To date, the smallholder sector is divided into distinct sub-sectors based on farmers' production scale (Table 2.1).

Table 2.1: Smallholder farmers division in South Africa (Queenan *et al.,* 2020; DALRRD, 2020).

Category	**Definition**
Subsistence farmers or household producers	Farmers in the former homelands farming primarily for household consumption.
Smallholders	Farmers that primarily farm for their household consumption, However, have higher productivity than subsistence with annual turnover ≥ R50 000 from access production.
Small-scale farmers	Farmers referred to as both subsistence and smallholders. Their farming management practices are still referred to as communal.
Commercial smallholders or market-orientated smallholders	Farmers producing primarily for financial gain and small access of their production is for home consumption.
Small-scale commercial (emerging) farmers	Transitioning farmers from commercial smallholders to medium and large-scale commercial farming.

The beef cattle industry has the potential for providing steady income within the agricultural sector. It is a growing industry with increase in gross value to over 12% from the R33 billion reported in 2016/17 (Beef Market Value Chain Profile, 2021; BFAP-Baseline-2021). According to the Bureau for Food and Agricultural Policy, the smallholder sector holds 40% of the country's cattle herd, while the remaining 60% is owned by the commercial sector (BFAP-Baseline-2021). Smallholder farmers in the beef industry are making an effort, however the transition to commercialization has been difficult due to herd management challenges such as higher mortality and poor reproductive performance. Only 2% of these farmers produce sufficient beef to feed the country as opposed to 90% in the commercial sector (Greyling *et al.*, 2015). The primary difference in farming between smallholder and commercial sectors lies in management, infrastructure, recording and their limited knowledge of basic animal husbandry.

2.3 Beef cattle management practices in smallholder farms

Smallholder beef production systems are vulnerable systems constrained by multiple factors (Nyamushamba *et al.*, 2017). Beef production in the smallholder sector is susceptible to constraints such as disease infestation, poor breeding management practices and poor feeding regimes (Tada *et al.*, 2013; Ojango *et al.*, 2017). Management practices carried out in commercial sector such as vaccinations, dipping of cattle and deworming are mostly performed through government service programs for a given period in the smallholder and household farms in SA (Nowers *et al.*, 2013).

Infrastructure to perform routine on-farm activities such as handling facilities with neck clamp are limited, poor or nonexistent for majority of smallholder farms (Mngomezulu-Dube *et al.*, 2018).

Infrastructure for proper reproduction management activities such as estrus synchronization, artificial insemination, and calving management are inadequate (Mutenje *et al*., 2020). Multiple studies have highlighted that uncontrolled breeding seasons are the most adopted practice in smallholder farms and only 5% considered seasonal breeding (Molefi *et al*., 2016; Mthi *et al*., 2020). Inbreeding is a common challenge in low input management systems due to uncontrolled mating and the absence of pedigree recording (Burrow, 2019; Mutenje *et al.*, 2020). Inbreeding depression manifests in lower growth rates, increase mortality, decreased weaning weights, meat quality, reduced pregnancy rate in heifers and reduced scrotum circumference in yearling bulls (Murungweni *et al.*, 2017; Burrow, 2019).

Smallholder farmers do not normally implement selection programs on high-quality breeding animals to improve herd genetics and their farm operations are mainly characterized by cattle with uncertain genetic backgrounds (Mapiye *et al.*, 2019). According to Khapayi & Celliers (2016) and Mapiye et al. (2018), 60% of farmers in the smallholder system are challenged by the lack of sufficient camps for keeping breeding stock apart in combination with lack of sound breeding management. About 60 to 80% of farmers rely on their neighbors' breeding bulls for mating (Nqeno *et al.,* 2011; Molefi *et al*., 2016). This increases the possibility of reproductive diseases such as Brucellosis and Campylobacter fetus spreading between herds. Their limited access to veterinary care and vaccines to prevent reproductive diseases lead to increased rates of these reproductive diseases, which significantly reduce fertility rates (Monkwe *et al*., 2023). Often animals in smallholder farms are used as draught animals and still expected to reproduce (Tada *et al.*, 2013). In addition, smallholder farmers keep a large number of cattle that are difficult for them to maintain, and without clear breeding objectives.

Investing in supplementary feeding may be economically challenging in smallholder farms (Van der Westhuizen *et al*., 2020). Moreover, the knowledge and strategies on securing cost-effective fodder bank as well as supplementary feeding during winter and in periods of drought is limited in smallholder farms leading to animals with low body condition score (BCS) (Mngomezulu-Dube *et al.*, 2018). This is an aspect of paramount importance since their cattle depend on grazing lands with seasonal forage availability (Katikati & Fourie, 2019a; Burrow, 2019). Moreover, achieving an appropriate BCS and weight gain is crucial for heifers to ensure they reach puberty at the right age, typically between 12-15 months in beef cattle. Delayed puberty can result in a longer time to first calving and decreased lifetime productivity. These are some of the integrated constraints that need to be addressed for the overall improvement of smallholder beef cattle production presented in Figure 2.1: a schematic representation of constraining production success in smallholder beef cattle farming.

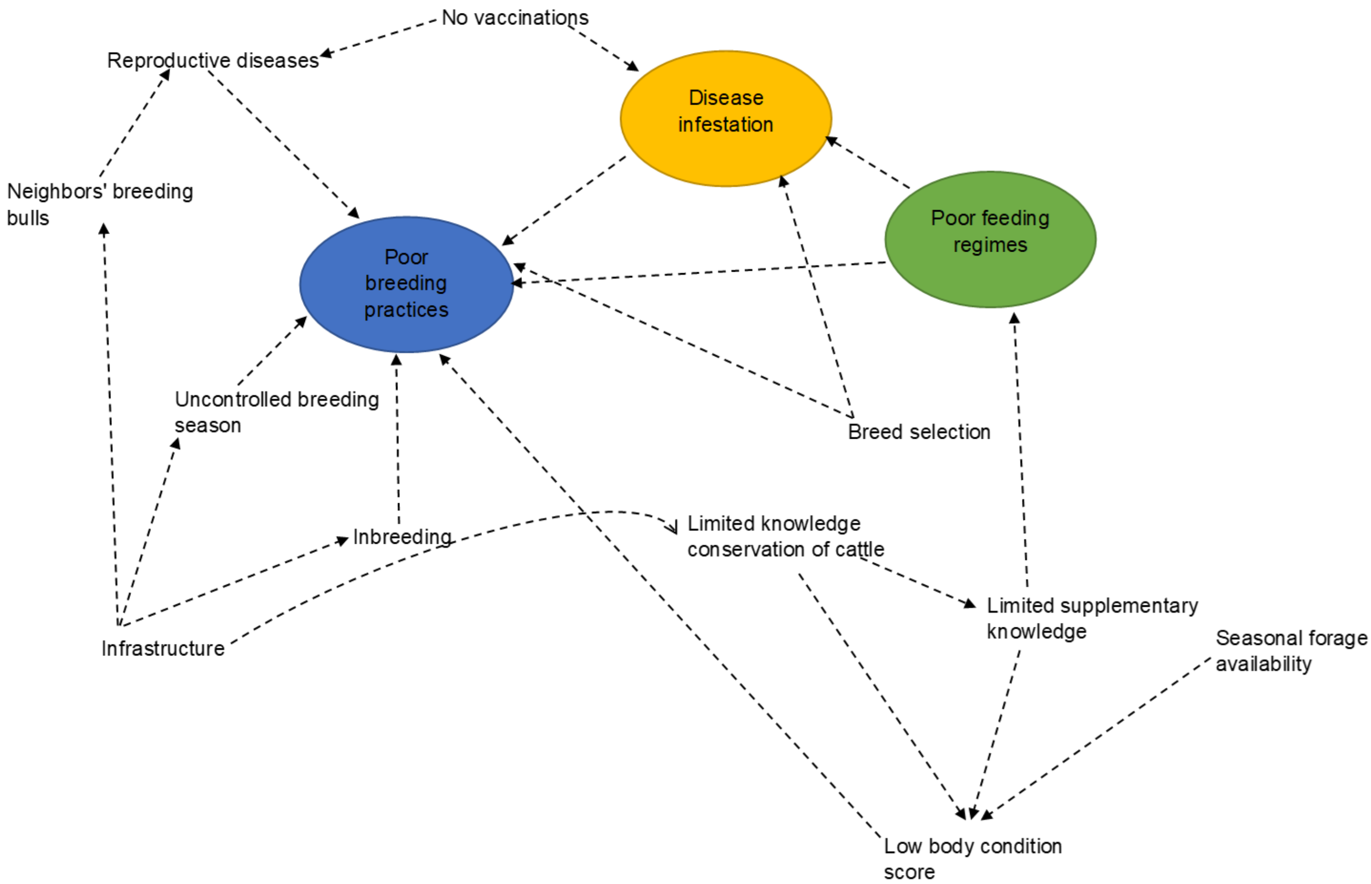

Figure 2.1: Diagrammatic representation of on constraining factors in beef cattle smallholder production

2.4. The reproductive performance of beef cattle in smallholder farms

An ideal cow for breeding should have a history of regular estrous cycles, the ability to conceive and carry pregnancies to term, and relatively short calving interval (McCosker *et al*., 2022). Improved profitability of a farm depends on profiling farm reproductive performance through regular measure of key performance indicators (Armengol *et al*., 2022). Performance indicators such as calving percentage, pregnancy rate, days open, calving interval, and fetal or calf mortality are some of the measurements commonly used to monitor herd reproductive performance (Carthy *et al.*, 2016). Calving percentage is used as a key determinant for reproductive performance and the average for SA is estimated to be lower than 50% (Malusi *et al.*, 2021). Low calving rates in smallholder farms is not only a challenge in SA, however, it is also recorded in other countries in African such as Zimbabwe, Zambia and Botswana (Table 2.2). In most smallholder farms indicators such as pregnancy diagnosis, fetal or calf loss, and days open are not regularly applied in monitoring reproductive performance (Tada *et al.*, 2013). This may be due to a lack of skills and knowledge in recording and application of these indicators. A survey in the Eastern Cape Province highlighted that only 12 to 5% of smallholder farms perform pregnancy testing (Katikati & Fourie, 2019a). To date at a national level, pregnancy rate in smallholder farms is recorded at 50% (Nengovhela *et al*., 2021). This is lower than the reported average pregnancy rate in Namibia and the achievable levels determined in Australia for pregnancy rate in tropical countries (Table 2.2) (Samkange *et al.*, 2019; McCosker *et al.*, 2022). Therefore, steps to improve breeding management practices to achieve higher pregnancy rates are essential for SA smallholder farmers.

In an extensive production system, the most vulnerable time for calf survival is the period from birth to 28 days of life (Burns *et al.*, 2010). Abortions and calf mortality up to 28 days are both considered as traits of importance as they determine herd reproductive production loss and profitability (Segura-Correa *et al.*, 2018). The high annual fetal and calf pre-weaning mortality in SA and Ethiopia as compared to Mexico and Brazil shows major concerns in decisions regarding farm management of smallholder farmers (Table 2.2). Malnutrition, respiratory disorders and lack of vaccination diseases were reported as the major course of abortion and pre-weaning mortality primarily in first parity heifers and aged cows (Tessema *et al.*, 2022). Calving intervals that are two years longer than the recommended range of 398 to 477 days for tropical conditions as suggested by Webb et al. (2018) has become a norm in SA and Somalia beef cattle smallholder farming. This pattern shows challenges in re-conception, as noted by Nqeno et al. (2011).

Table 2.2: Summary of reproductive performance indicator traits measured in different countries.

Fertility traits	Level of performance	Country	Reference
Pregnancy rate (%)	50	Brazil	Lemes *et al.*, 2017
	72	Chile	Müller *et al.*, 2020
	71	Namibia	Samkange *et al.*, 2019
Calving interval (days) (n)	425	Indonesia	Nugroho *et al.*, 2020
	457	Malawi	Bhatti *et al.*, 2020
	582	Somalia	Hassan *et al.*, 2020
	456	Vietnam	Van Dung *et al.*, 2019
Calving rate (%)	30-40	Zambia	Food Security Cluster, 2022
	39	Zimbabwe	Gusha *et al.*, 2013
	38.9	Botswana	Kgosikoma, 2012
	40	Nigeria	Mai *et al.*, 2015
	65	Brazil	Lampert *et al.*, 2019
Foetal and calf loss (%)	2.5	New Zealand	Kaurivi *et al.*, 2020
	0.98	Mexico	Segura-Correa *et al.*, 2018
	8.16	Brazil	Parvez *et al.*, 2020
	26.7	Ethiopia	Tessema *et al.*, 2022
	10	South Africa	Mokantla *et al.*, 2004

The low pregnancy rate, foetal loss, calving interval, and calving rate in SA smallholder farms significantly influence the productivity and profitability and therefore, essential for farmers to identify and address the underlying factors contributing towards these measures.

2.5 Non-genetic factors influencing reproductive performance and possible mitigating strategies

Several non-genetic factors influence reproductive performance may have more severe outcomes for smallholder farmers due to the constraints discussed in the previous section (Mthi *et al.,* 2020). These are factors ranging from climatic factors to nutritional and disease status and herd management. The factors and mitigating strategies for smallholder farms are here briefly reviewed.

2.5.1 The environment

Extensive farming systems in sub-tropical countries are particularly vulnerable to harsh environmental conditions including drought, low rainfall and high temperatures. It is also known that the sensitivity or vulnerability of these conditions may vary among different counties (Kotir, 2011; Elum *et al.*, 2017; Kom *et al.*, 2022). Smallholder farmers are less resilient to the variations in temperature and erratic rainfall patterns. In addition to climatic variation in sub-tropical regions, climate change now exacerbates these effects and studies have indicated that most regions in SA are affected by extreme temperatures and droughts to a more or lesser extent (Rust & Rust, 2012; Zwane, 2019).

Extreme heat and drought in the KZN region during the 2014/2015 summer season resulted in significant cattle mortality among smallholder farms with a death toll of 40 000 (Mthembu & Zwane, 2017). In the northern and western regions of the Western Cape, rainfall in 2016 was less than 50% of the normal average. Due to droughts in these regions, an estimated 30 000 cattle have been sold (Zwane, 2019). A report by Scholtz et al*.* (2018) highlighted a decline in the pre-weaning performance of beef calves in the Northern Cape as a result of extreme heat during the summer of 2015 to 2016. Furthermore, drought in Limpopo province has contributed to the deaths of 719 cattle during the spring and summer months (October-February) of 2012 and 2013 (Maluleke & Mokwena, 2017).

It is reported that the optimal temperature range for beef cattle production is typically observed between 15 and 25°C, with 20°C representing the thermoneutral zone (Cooke *et al*., 2020; Zazueta-Gutiérrez *et al*., 2021). A decline in animal production is noticeable when the air temperature exceed 27°C and heat stress may be triggered (Khan *et al*., 2023). High environmental temperatures have been a determining factor hampering animal production and reproduction worldwide (Ali *et al.*, 2020). One of the primary challenges during high temperatures is infertility or subfertility in genetically superior breeding stock (Roth, 2020). During high temperatures, a range of challenges that negatively impact reproductive performance such as reduced libido, increased embryonic mortality, and decreased expression of estrus are observed in breeding cows (Hufana-Duran & Duran, 2020). Heat stress decreases feed intake by affecting the appetite center of the hypothalamus. Feed intake declines by 40% at a rectal temperature above 39°C (Kim *et al.*, 2022). As a result, animals experience a stage of negative energy balance, thus body weight and BCS go down and consequently decrease reproduction rates (Nazhat *et al.*, 2021). Temperature plays a pivotal role in the intricate regulation of reproductive hormones in cattle including Gonadotropin-Releasing Hormone (GnRH), Luteinizing Hormone (LH), Follicle-Stimulating Hormone (FSH), Progesterone and Oxytocin. These hormones shows a profound effects on the various stages of reproduction (Khan *et al*., 2023). The GnRH, secreted from the hypothalamus initiates the reproductive cascade by stimulating the pituitary gland to release LH and FSH. During puberty, these hormones coordinate the emergence of secondary sexual traits and the onset of reproductive maturity in both males and females (Bova *et al*., 2014). In the estrous cycle, optimal temperature conditions are essential for the synchronized release of GnRH, triggering the surge of LH and FSH (Evans *et al*., 2021). The LH is crucial for ovulation while FSH continues to support the growth of new follicles (Boni, 2019). After ovulation, Progesterone produced by the corpus luteum maintains the uterine environment thereby facilitating pregnancy establishment. In late pregnancy, Oxytocin stimulate uterine contractions for parturition and promoting milk ejection during lactation (Mota-Rojas *et al*., 2023). The interplay between temperature and reproductive hormones underscores the critical role of environmental conditions in the successful orchestration of cattle reproduction across different stages, from puberty to ovulation and pregnancy (Molefe & Mwanza, 2019). Therefore, the changes in temperatures affects the down or up regulation of reproductive hormones for performance as highlighted in Table 2.3. For an example an increase in temperatures increase the level of oxytocin to contract the uterus and lead to premature birth during pregnancy. Table 2.3 shows the effects of temperature on reproductive performance in beef cattle at different stages of reproduction.

Table 2.3: The effects of temperature on reproductive performance in beef cattle at different stages of reproduction (Khan *et al*., 2023)

		Optimal temperature for reproduction	**High temperature for reproduction**
		15-25 °C	**>35** °C
Reproductive stages	**Hormone responsible**		
Puberty	GnRH, FSH, LH	↑	↓
Oestrus	GnRH, FSH, LH	↑	↓
Ovulation	LH	↑	↓
Pregnancy	Progesterone	↑	↓
	Oxytocin	↓	↑

It is to note that the temperature ranges provided in the table may vary depending on the specific region in SA. The provinces located in the northern regions of South Africa, including Free State, Limpopo, North West, and Gauteng typically record average maximum summer temperatures of around 28°C, whereas the Eastern Cape and Western Cape provinces maintains an average maximum summer temperature of approximately 24°C. Tropical regions are experiencing warmer conditions, leading to more frequent and prolonged heatwaves that increase heat stress in cattle (Thornton *et al*., 2021). The adverse effects of heat stress in SA were particularly pronounced in some regions in the Northern Cape (Augrabies) and Western Cape (Redelings, Vredendal) provinces. These areas experienced exceptionally high summer temperatures, ranging from 42 to 48°C during the summer of 2015/2016 (Hove, 2017). Hence the earlier argument on beef cattle production being affected in this provinces during the 2015/2016 years.

The most cost-effective methods of minimizing heat load from animals in a hot environment include provision of shade (Edwards-Callaway *et al*., 2020). Cattle that are shaded have been observed to exhibit lower respiration rates, panting scores and body temperatures. Moreover, shading can reduce solar radiation by 30% (Zazueta-Gutiérrez *et al*., 2021). A report by Lee et al. (2020) highlighted that Brahman cattle kept in shade exhibited a panting score as low as 0.13%, whereas unshaded Angus cattle showed a rise in their panting score by 0.71%. Smallholder farmers can make use of trees as cost effective measures for provision of shades. Moreover, trees do not only provide shade to the animals however, it also provides cooling through the evaporation of moisture from their leaves (Krishnan *et al*., 2017).

Implementing a drought management plan, such as early weaning or culling unproductive cows, to reduce the demand for feed and water is important. Early weaning can improve reproductive performance in beef cows by reducing the stress on the cow during periods of drought or feed scarcity. This stress reduction can lead to improved body condition and a shorter postpartum interval, which can result in earlier rebreeding and an improved conception rate. Additionally, early weaning allows cows to allocate more resources to their own maintenance and reproductive functions, rather than lactation (Orihuela & Galina, 2019).

2.5.2 The feeding regime and Nutrition

Nutrition has a major impact on the reproductive development of breeding stock. It is regarded as the principal factor as it can reduce an animal's performance below its genetic merit (Ibtisham *et al.*, 2018). The nutritional status of beef cows is significant influenced by its body condition which reflects the metabolizable energy stored in fat and muscle (Nazhat *et al.*, 2021). Nutrition in beef cattle is similarly linked to hormonal factors such as temperature. It is reported that an energy balance can be maintained and reproductive performance can be supported at a herd-level with BCS of 2.5 to 3 (Fernandez-Novo *et al*., 2020). Moreover, cows with excessively high (≥4.0 points) or excessively low (<2.0 points) BCS on a scale of 1 to 5 reduce fertility rates for beef cattle. Low BCS has been reported to affect estrus through delaying maturation and the release of mature oocytes. This is due to a delayed release of FSH, infrequent pulses of LH, inadequate follicular responses to gonadotropins and decreased follicle functional competence (Bezdíček *et al.*, 2020; Fernandez-Novo *et al.*, 2021). Moreover, low BCS of a cow results in low pregnancy rate, high fetal loss and longer calving interval (Nazhat *et al.*, 2021). The study by Burke et al. (2010) highlighted that the BCS of two in breeding cows, using a 1 to 5 scoring scale during mating periods reduced pregnancy by 8%. Moreover, 30% of pregnancy losses are observed in cows with lower BCS (Lee & Kim, 2007). However, breeding cows with moderate BCS present improved reproduction rate as reported by Nengovhela et al. (2021) who highlighted high pregnancy rate (73%) on cows with BCS≥3 versus BCS≤2 (Table 2.4).
Table 2.4 present the influence of BCS in different reproductive performance traits.

Table 2.4: Impact of Body Condition Score (BCS) on reproductive performance traits in smallholder farms (adopted from Vickers, 2019; Atieha & Abdelsalam, 2021; Nengovhela *et al*., 2021)

BCS	Age at first calving (months)	Pregnancy rate (%)	Days open (days)	Calving interval (days)
≤2.0	28	14	149	433
2.5-3	26	66	92	382
3.5-4	25	73	135	364

Similar to how poor nutrition affects females, it also has an impact on the bloodstream release of gonadotropin-releasing hormones (GnRH) in bulls. In males, the disruption of the GnRH release reduce the release FSH and LH, which stimulates the development of the testicular mass and the growth of the seminiferous tissue, which has an impact on the productivity of spermatogenesis (Harrison *et al*., 2022). Poor nutrition significantly delays the age at puberty in males by reducing the number of spermatozoa per ejaculate. In cases of inadequate nutrition, bulls may not reach puberty until 18 to 24 months of age (Singh *et al*., 2018).

Community grazing pastures are the primary source of nutrition for smallholder cattle however, grazing land available to smallholder is challenged by low quality pasture and imbalance nutrients content on natural pastures in low input countries (Ayele *et al*., 2021). The combination of the lignin and fast maturation of grasses provides low digestibility of these grasses and this serve as the main limiting factors to animal production primary in the sour veld regions (Ndazigaruye *et al*., 2018; Fust & schlecht, 2018). Sourveld is one of the rangeland in SA is found in high moisture areas (Mpumalanga, Kwazulu-Natal, and some parts of the Limpopo) with rainfall of up to 650 mm. During dry periods, animals in sourveld rangeland experience a reduction in forage quality necessary to support growth, which result in a general decline in their body weights. According to Nqeno (2008), a decrease in body weight from 400 to 300 kg during the months of March to October was noticeable in the sourveld regions in the Eastern Cape Province. The sweet veld (the second type of rangeland in SA), on the other hand is palatable and can support animal production year-round, however with low quantities, overgrazing is common in the sweetveld regions (Northern Cape, Free state, North west and some parts in Limpopo province) (Dannhauser, 2021). The absence of a management system, coupled with overstocking and expanding human settlements has led to the degradation of communal grazing (Palmer& Bennett, 2015). Despite occupying just 17% of the overall farming area, communal grazing systems support a substantial 52% of the cattle population (Franke & Kotzé, 2022). All these implications of grazing land contribute to a very low off-take (± 3%) and poor economic returns from smallholder farms (Scholtz & Bester, 2010).

Reproductive performance is driven by the quality and quantity of grazing pastures as cattle are raised in community rangelands in smallholder (Mapiye *et al.*, 2019). As a result, the concept of community-based natural resource management in managing natural pastures is important (Mapiye *et al*., 2019). This entails cooperative pasture management between villages and pooling of herds to share resources and increase output (Fernández-Giménez *et al*., 2015). With this approach, strategies for managing grazing pasture such as rotational grazing for sustainable community pasture management may be applied, where one village's grazing pasture is grazed while the others are rested (Teague, 2018). Since either the chief or a village tribe owns land in the villages, farmers can group themselves and negotiate to manage a piece of land for grazing at a fee paid to either the chief or a village tribe. Farmers can then apply the stocking rate principle by Van der Westhuizen et al. (2020) which suggest a stocking rate of 6ha/LSU grazing for a period of one to three months for each grazing unit and a resting period of at least eight months for rotational grazing. The adoption of this strategy has resulted in a significant improvement in calving rate, which has increased from 32% to 82%. Similarly, there has been a remarkable increase in weaning weight of 155.8kg to 215.8kg in commercial farmers in the Free State province of SA.

Supplementation is important for breeding animals to meet their nutritional demands as the cow nutrition level gradually rises throughout gestation and pre-calving periods (Erickson *et al*., 2020). Feeding cattle with crop residues during dry periods has been found to be cost-effective supplementation strategy in smallholder farms (Burrow, 2019). Cultivated fodder crops residues have been successfully implemented to supplement feed in the dry season for majority of smallholder farms in extensive production systems (Nyaata *et al.*, 2000; Lamidi & Ologbose, 2014). Although it is well known that crop residues have low-quality crude fiber percentages (18%) and low-quality total digestible nutrient percentages (less than 60%), the challenge with smallholder farms is not only low feed quality however, limited amount of feed of any kind. It is then advisable for farmers to select dry roughages leguminous crops such as barseem, lucern, shaftal soybean, cluster beans, and cowpea, and also consider non-leguminous cereal forages including maize, sorghum, millet, and oats for better crude protein levels (Iqbal *et al.*, 2015). The report by Ayantunde et al*.* (2007) highlighted on optimizations of crop residue for digestibility and low crude protein contentment to enhance its significance as supply of feed. In their report, a basic way to improve crop residues including rapid removal from the field after grain harvest to restore leaf damage losses through senescence. Moreover, the addition of nitrogen (N) through the use of urea or a protein and energy source, such as molasses in straws and stovers maximizes rumen digestion and supplies the balance of protein and energy needed for optimum productivity (Panday, 2011). That is a 5% addition of urea in rice straw, maize stover, millet stover and sorghum stover assist in their palatability and digestibility.

However, adoption of mix farming to achieve the latter in smallholder beef cattle farms may become a challenge on some farmers as a result of land scarcity. Therefore, integrating farming for both animals and crops farmers has been shown to be successful in areas where land has become a scarce resource. This is also advantageous in a sense that cattle provide manure for which can be a substitute for fertilizer on agricultural land, while crop residues provide feed to livestock. It is important that both livestock and crop farmers work together for the success of agricultural sustainability in smallholder production systems (Mugumaarhahama *et al.*, 2021).

Awareness needs to be made among farmers and policy makers about the importance of indigenous trees such as Morus alba, Terminalia arjuna and Moringa oleifera for livestock feed (Iqbal *et al.*, 2015). These are readily available in the villages and are well-known for their numerous uses such as shelter, wood and medicine. Scientists have investigated that the leaves of Moringa stenopetala contain high crude protein contents (9% of DM), 280 mg kg-1 of vitamin C and 160 mg kg-1 of â-carotene contents with iron and calcium contents of 30.8 and 7928 mg kg-1, respectively (Iqbal *et al.*, 2015). Above all, the knowledge of aligning animal reproductive activities with the availability of forage is important in tropical and subtropical countries such as SA (Burrow, 2019). In these instances, it will be matching the forage production curve with pregnant and lactating cows to maintain body condition.

2.5.3 The health and welfare of animals

Cattle raised in tropical and subtropical environments are exposed to a range of diseases that may affect reproduction directly or indirectly (Burrow, 2019). In the sub-tropical regions, tick-borne diseases and internal parasites may affect body weight and subsequent fertility (Kumar *et al.*, 2013). Reproductive diseases in cows is most evident with increased abortions, stillbirths or death of calves, retained placentas, prolonged postpartum interval to conception, increased days open and decreased milk production (Hossein-Zadeh, 2013).

Reproductive diseases such as Brucellosis, Campylobacter, and Leptospirosis have been recorded since the early 40s. The first recorded case of Brucella abortus infection in SA dates back to 1913 in the Limpopo province formally known as Transvaal province (Van Drimmelen, 1949). Consequent to the first outbreak, Brucellosis infections to date has escalated to the central regions of the country (Govindasamy *et al.*, 2021). The disease has a significant impact on the reproductive performance of cattle which lead to infertility, abortion and decreased milk production. These health challenges can lead to economic losses for smallholder farmers who heavily rely on their livestock for income and food security (Kolo *et al.*, 2020). Smallholder beef cattle farms in particular are vulnerable to the outbreak of this disease, as they may lack the resources and knowledge to implement effective control measures. In many instances, smallholder farmers have limited resources to invest in disease control and eradication measures which makes them particularly susceptible to the negative effects of brucellosis (Olaogun *et al*., 2023). In Rwanda more than 65.8% of smallholder cattle that tested positive for brucellosis recorded a calving interval exceeding 12 months (Ndazigaruye *et al*., 2018). Smallholder cattle farms in the North West province of SA highlighted 34% of abortion cases associated with Brucellosis abortus (Molefe & Mwanza, 2019). The implication of the infection at herd level affects a wider community as communal grazing accounts for approximately 91.5% of shared grazing practices (Molefe *et al*., 2017). Lacking sufficient understanding of reporting, majority of the farmer's first instinct when there is an abortion is to sell the cow to the next farmer. Moreover, aborted foetuses are being fed to dogs in most cases (Cloete *et al*., 2019). This results in a circular chain of infection. Moreover, limited access to veterinary services hampers effective disease surveillance, diagnosis, and control measures for brucellosis in smallholder farms (Özlü *et al*., 2019).

The impact of Leptospirosis and Campylobacter on the reproductive performance of beef cattle in smallholder farms is a topic of concern as they are known to cause 50% of all reproduction losses in the beef cattle industry (Kolo *et al.*, 2020). Leptospirosis in cattle has mostly been reported in Mpumalanga, KwaZulu Natal and the coastal area of the Eastern Cape provinces of SA due to high rainfalls with a prevalence of up to 19.4% (Hobson, 2018). The scale of infection in cows may vary between 30 to 70%, however, 95% of the infections were recorded in heifers (Bondurant, 2005). Based on a study reported by (Schmidt *et al.*, 2010) Campylobacter in SA has been recorded on communal cattle at a prevalence of 29%. Moreover, infection rates of multifactorial disease in lactating cows such as mastitis range from 10 and 54% in beef cows (Dueñas *et al.*, 2001). Breeding bulls are known to be the carriers of most detrimental pathogens in these reproductive diseases (Table 2.5) (Underwood *et* *al.*, 2015; Moore *et al.*, 2021). The effect of these pathogens is visible in different physiological stages in breeding cows.

Table 2.5: Reproductive diseases in different physiological stages.

Cow physiological stage	Reproductive disease	Carrier	Symptoms	Reference
Estrus	Endometritis	Infected breeding bulls	Enlarged uterus, odor red-brown watery discharge	Dahiya *et al.*, 2018
Pregnancy	Bovine brucellosis	Infected breeding bulls	Abortions, still-born, weak calves, retained placentas, infertile bulls.	Tulu, 2022
	Leptospirosis	Pigs, Nyala, Reedbuck, and wildebeest	Early and late embryo loss	Orr *et al.*, 2022
	Campylobacter fetus	Infected breeding bulls	Abortions, repeated signs of estrus	Hoque *et al.*, 2022
	Trichomoniasis	Infected breeding bulls	Embryo death	Ondrak, 2016
Lactation	Mastitis	Staphylococcus	Large teats, pendulous udder suspension	Monistero *et al.*, 2018

It has been reported that disease prevention among smallholder farmers in SA and most developing countries remains a challenge (Myeni *et al.*, 2019). Some challenges include farmers concealing information of their animal health status or possible exposure to disease infection to avoid losses in sales. However, this challenge accelerates the spread of diseases in the community. Additionally, farmers are choosing vaccination treatment based on their personal experience or word of mouth (Katikati & Fourie, 2019). Moreover, limited contact with local veterinarians is reported as the biggest issue in managing animal health in smallholder farms and this can result in inadequate disease control (Hernández-Jover *et al.*, 2019).

The rationale of indigenous knowledge system in managing herd health may have a positive impact on disease control and should be encouraged in livestock development programs of smallholder farms (Mkwanazi *et al.*, 2021). Knowledge and strengthening of ethno veterinary medicine should be evaluated as this information is enriched from the elderly and herbalists in local farming communities (Mapiye *et al.*, 2019). Therefore, more scientific understanding and a practical approach of traditional knowledge for disease control in underdeveloped nations need to be studied (Ndlela *et al.*, 2022). In India, herbal remedies have been successfully endorsed by the government and veterinary services to reduce the use of antibiotics by 49%. It has been successfully used for diseases such as foot and mouth, mastitis and diarrhea in dairy cows. A recent study on goat production by Mkwanazi et al. (2021) in SA revealed a total of 21 ethno-veterinary plants known for controlling ticks. Ethno-veterinary herbs have also been found to be effective in treating a variety of illnesses, such as cow reproduction disorders in SA (Chakale *et al.*, 2021). The plant species Dicerocaryum senecioides also locally known as

Tshetlho ya mamitlwa a mabedi and Dichrostachys cinerea referred to *Moselesele* are known to treat retained placenta and dystocia (Chakale *et al.*, 2021).

Increased awareness and support by the government for the endorsement of these medicinal plants may be a cost effective strategy in assisting smallholder farmers addressing health issues. It is also necessary for smallholder farmers to be familiar with vaccination programs and basic knowledge of how to handle sick animals, such as separating them from watering and grazing areas to prevent reinfection. Educating farmers on the natural cycle of internal and external parasites and understanding their natural cycle may minimize veterinary costs (Kumar *et al.*, 2013).

2.5.4 Animal and herd management

Animal factors including age, parity and lactation have been shown to have an impact on reproductive performance (Inchaisri *et al.*, 2010; Kim & Jeong, 2019; Probo *et al.*, 2022). Parity has shown to have an influence in calving interval with longer calving intervals reported in parity one and two (Webb *et al.*, 2018). In a study by Segura-Correa et al*.* (2018), first parity cows had 15% greater calf loss as compared to multiparous cows. Moreover, in Australia, McCosker et al*.* (2022) reported an increased odds of extended days open in first and second lactating females compared to matured cows. The significant effect of parity on primiparous cows is as a result of nutritional demands associated with lactation while still maturing (Temesgen *et al.*, 2022). Therefore, smallholder farmers must make critical management decision on providing extra care and attention on cows when they calve the first time. Fertility in cattle is reported as high between age 4 and 9 years, and decline after 10 years of age (Marrella *et al*., 2021). This is due to hormonal imbalance that may advance in aged cows. In aged cows, the quality of oocytes decreases as a result of decreased secretion of gonadotrophin released from the pituitary gland (Khan *et al.*, 2015). Therefore, it is essential for smallholder farmers to monitor the age of their breeding cows and cows that are no longer reproductively efficient.

Lactation during breeding seasons is also a factor that results in long parturition intervals and loss of body condition on beef cattle in the tropics. The impact of extended lactation in smallholder farms in most developing countries is associated with extended postpartum anestrus, lower conception rates and longer calving intervals (Swai *et al.*, 2005; Manzi *et al.*, 2019; Katikati & Fourie, 2019b). The low reproductive performance in extended lactating cows is due to the release of prolactin hormone through chronic sensory stimulation in the teats. Prolactin inhibits the secretion of essential hormones for ovulation and estrus, such as GnRH and LH (Orihuela & Galina, 2019;Fernandez-Novo *et al.*, 2021). Moreover, lactation reduce weaning weights due to less milk during periods of poor nutrition (Erickson & Kalscheur, 2020).

Mating management in smallholder farms has been constraint by uncontrolled breeding and limited access to bulls of superior genetics (Mapiye *et al.*, 2018). The limited availability of elite bulls poses a significant challenge for smallholder production systems in low-input countries (Mapiye *et al.,* 2019). This challenge directly contributes to a 25% reduction in performance, resulting in decreased conception rates, lower calving rates, and extended calving intervals in communal farms (Maime, 2015; Chawala, 2020). The limited availability of superior genetics poses a challenge in maintaining genetic diversity within smallholder herds and increases undesirable traits such as lower growth rates, reduced milk production, and inferior meat quality (Mwai *et al*., 2015; Nyamushamba *et al*., 2017). Overall, limited knowledge of best practices for controlled breeding among smallholder farms contribute to a decline in the overall reproductive performance of their herds (Khapayi & Celliers, 2016; Mutenje *et al*., 2020; Wathes, 2022).

To maintain a sustainable beef cattle farm, farmers are advised to track reproductive lifespan of breeding cows. That is, monitoring the health and nutrition of older cows that are still capable of reproducing or provide energy-rich supplements and wean calves earlier for better growth and recovery in primiparous cows (McCosker *et al*., 2022). This will inform farm decisions such as culling cows that are no longer performing well reproductively after several unsuccessful mating attempts (Bonneville-Hébert *et al.*, 2011; Rilanto *et al.*, 2020). Moreover, culling improves reproductive performance of the herd as it allows for more resources to be allocated to the remaining cows that are more fertile (Rilanto *et al.*, 2020). In smallholder herds, farmers may choose to practice extended lactation as part of management strategy of their feed resources or due to unavailable feed for the calfs (Orihuela & Galina, 2019). It is therefore recommended that during this period proper management practices, such as monitoring the body condition of the cow to ensure it does not fall below 3 should be implemented (Nazhat *et al*., 2021).

In low-input systems with limited resources found in smallholder farms, adapted indigenous breeds offers valuable genetic resource (Mapiye *et al*., 2019). These breeds often possess superior traits that make them survive and produce in low input systems (Nyamushamba *et al.*, 2017). Breeds such as Afrikaner, Bonsmara, Drakensberg, and Nguni have been classified as landrace breeds under the South African Animal Improvement Act (Act 62 of 1998) due to their ability to cope with harsh local environments (Jordaan *et al*., 2021). They exhibit traits low maintenance and adaptation that make them resilient to common challenges faced by smallholder farmers, including diseases, heat stress, and limited feed resources (Table 2.6) (Widyas *et al.*, 2022). Their small frame sizes, exemplified by the Nguni breed, allow them to thrive on minimal nutrient resources found in the grazing veld, including steep hills and thick bushes (Rege & Tawah, 1999; Ramsay *et al*., 2000; Gray, 2023). Similarly, the rumen capacity of the Afrikaner breed enables them to make the most of low-nutrient pastures (https://www.thecattlesite.com/breeds/beef/25/africander). Meanwhile, the Drakensberg breed stands out for its ability to survive on low-quality foraging within rough terrains (Bisschoff & Lotriet, 2013). The adaptation attributes of indigenous breed including the smooth coats of Bonsmara, Afrikaner and Drakensberg and skin colour patterns of the Nguni aid as a protection against sunburn, repel ticks, providing immunity against parasites and pests (Bisschoff & Lotriet, 2013; Cosgrove, 2023; Gray, 2023). The deep-set eyes in the Afrikaner and heavy brows in Drakensberg shield them against insects, flies, and solar radiation (https://www.thecattlesite.com/breeds/beef/25/africander; Bisschoff & Lotriet, 2013). Glossy coats and thick skin in these breeds facilitate heat regulation through evaporation and radiation while offering resistance to external parasites. Moreover, the air sinuses in the skull in the Afrikaner and, large heads and nostrils in Bonsmara aid respiration and guarding against brain overheating and nerve illnesses (Cosgrove, 2023).

Table 2.6: A summary of Characteristics of South African Indigenous Breeds

Breed (Frame size)	Characteristics			References
	Low maintenance	**Adaptation**	**Mothering ability**	
Nguni (Small)	Small frame size Graze well on steep hills	Skin color patterns Smooth coat	Slim bodies around the neck area and sloping rump. Low calf mortality.	Rege & Tawah, 1999; Ramsay *et al*., 2000; Gray, 2023
Afrikaner (Small)	Good rumen capacity. Their hard hooves. Capacity to travel long distance for food and water	Deep set eyes The short glossy coat and the thick skin Air sinuses in the skull and eyebrows.	Low calf mortality	https://www.thecattlesite.com/breeds/beef/25/africander
Drakensberg (Medium)	Survives on low-quality foraging in rough terrain Good FCR (6.96) and being good foragers.	Shiny coat. Short and strong legs and heavy brows.	Rapid growth rate of calves	Bisschoff & Lotriet, 2013; https://petkeen.com/drakensberger-cattle-breed/
Bonsmara (Medium)	Sound feet and legs to travel for feed	Smooth coat with wide head and convex. The large head and nostrils.	Good milking ability	Cosgrove, 2023

Additionally, indigenous breeds exhibit high fertility rates and good to optimize reproductive success under native conditions (Table 2.7) (Gaughan *et al.*, 2018). With these unique traits, smallholder farmers can gradually improve the genetic potential and productivity of their herds while retaining the valuable adaptations of the breed.

Table 2.7: Summary of fertility trait of indigenous breeds reported between 2006-2023

Breeds	**AFC (months)**	**Calving interval (days)**	**Cow weight (kg)**	**Weaning weight (205 days)**	**References**
Nguni	30-34	400-427	225-450	135-146	Maciel *et al*., 2016; Zindove & Chimonyo, 2015
Afrikaner	36-37	445-487	525 - 600	173-191	Beffa *et al*., 2009;Samkange *et al.,* 2019;
Bonsmara	30-34.8	412-436	424-503	215-230	Corbet *et al*., 2006; Webb *et al*., 2018 Slayi *et al*., 2023;
Drakensberg	32-34	403-430	479-466	213-232	Bisschoff & Lotriet, 2013; Mkhize *et al*., 2018
		Male traits (average)			
	Bull weight (kg)	**Scrotum circumference (cm)**	**Sperm Motility (%)**	**Morphology Live normal (%)**	
Nguni	482	35	88	93	Mphaphathi, 2017, van der Horst *et al*., 2022
Afrikaner	955	37	82	-	van der Horst *et al*., 2022; Mphaphathi *et al*., 2017
Bonsmara	698	42	87	91	Mphaphathi, 2017, van der Horst *et al*., 2022
Drakensberg	960	33	83	-	Bisschoff & Lotriet, 2013; Mukuahima;2013 Celliers, 2020

Alternatively, more structured crossbreeding production systems that aim to produce animals with up to 50% genetic composition of indigenous breeds are recommended (Esfandyari *et al*., 2015). The report by Philipsson et al. (2011) & Ouédraogo et al. (2021) recommended an open nucleus breeding scheme for conservation and improvement of local breeds maintaining 50% of the indigenous breed's genetic make-up program adopted in Kenya. The program firstly screens the best purebred indigenous females within the village, which will form the nucleus herd for continuous selection of females for crossbreeding. Secondly, the program identifies and selects exotic males to breed the selected indigenous female to produce F1 in the village. The F1 males are then distributed in the village to upgrade local population. This system, however, can be effective at a community-based breeding program where farmers in the community can divide their farms into camps and decide which camps may serve as a nucleus herd and how new animals are distributed to the villages. Therefore, it is important that mating decisions of the farmers need to align with adaptation of breeds to their local environment.

Successful mating management requires a combination of good breeding practices, careful planning, and effective management of resources. Smallholder farmers need to have clear breeding objectives that guide their mating plans. These objectives may be influenced by factors such as market demand, available resources, and the desired traits in the offspring (Zantsi & Bester, 2019). Regardless of the farm objective, a defined breeding season is used as a cost-effective strategic tool for sustainable reproductive management in livestock. It assists farmers in managing calving by matching with pasture availability primarily in tropical countries where availability of fodder is erratic (Pessoa *et al.*, 2018). Breeding season should be managed in order to avoid late or early calving season (6-8 weeks) before adequate summer pasture (Bergh, 2004). The report by Bergh (2004) has provided a guide for breeding season calendar for different bioregions in SA (Table 2.8).

Table 2.8: Breeding seasons in different South African Bioregion.

Region	Breeding period	Calving period
Eastern Highveld	Nov - Jan	Aug - Oct
Western Highveld	Dec - Feb	Sept - Nov
High rainfall Bushveld	Jan - Feb	Oct - Dec
Low rainfall Bushveld	Feb - Apr	Nov - Jan

Note: *Jan=January, Feb =February, Apr =April, Aug=August, Sep=September, Oct=October, Nov=November; Dec= December.*

Breeding calendars are successful if reliable recording system is in place. Through performance records, farmers will be able to identify success and limitations in their farms.

Animal recording in smallholder farms of SA has been achieved through Kaonafatso ya dikgomo (KyD) in 2007. The scheme was designed to be assessable to smallholder farmers in all SA provinces and has by far serviced over 8 000 farmers. It makes possible for farmers to manage animal production through routine animal recording. Therefore, implementation of keeping reproductive performance records on performance indicators such as pregnancy success or failures, calving interval and days open through the KyD scheme may assist in identifying production efficiency and determining futures of herds reproductive performance in smallholders (http://www.arc.agric.za/arc-api/Pages/KyD.aspx).

Overall, improved access in extension services for on-site support and collaborative efforts between smallholder farmers, extension services, and other stakeholders can help improve reproductive performance in beef cattle smallholder farms through identifying and addressing any issues that may affect reproductive success. Such efforts can include community-based programs, public-private partnerships, research collaborations with farmers to access information, training, and resources that can help improve reproductive performance.

2.7 Conclusion

Reproductive performance has been well documented as the determining factor on the efficiency of animal production and is closely related to the herd's profit. Most of its inefficiencies come from vulnerability and management of external factors such as climate, nutrition, and health. These factors can suppress fertility by up to 50%, ultimately impairing the profitability of cow/calf operations in smallholder farms. Additionally, practical animal husbandry practices such as mating management, culling nonproductive cows, breed selection and record-keeping remains a challenge in smallholder farms. However, implementation of cost-effective strategies, such as selecting adaptive cattle breeds, establishing a defined breeding season, implementing a recording system to detect infertile animals, providing strategic supplementary feeding, and utilizing ethno-veterinary medicines for herd health management are vital for improving reproduction performance in smallholder farms.

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Chapter 3

Understanding beef cattle production practices and associated factors constraining performance: A survey of smallholder farmers in South Africa

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Article

Understanding beef cattle production practices and associated factors constraining performance: A survey of smallholder farmers in South Africa

Abstract

Farm practices of beef cattle smallholders in South Africa are characterized by poor management practices with limited advisory services. This study aimed to assess current beef cattle farming practices and limiting factors for improved beef production in South African smallholder farmers. A questionnaire was administered to 460 individual smallholder farmers purposively selected from seven provinces of South Africa (SA). The questionnaire captured information on demographics and farm profiles, constraints on production, marketing, ecological and reproduction management. Frequency procedure and logistic regression were used for data analysis. The majority of farmers were males (77%), fully committed to cattle farming (92%) and participated in informal markets (61%). Farmers constraints included extreme weather events, disease outbreaks, lack of access to information on farm management, supply of cattle nutrition and fair market pricing. The majority (93%) of farmers had no knowledge on body condition scoring (BCS) prior breeding and recorded inter-calving periods of two years (77%). Only 17% of farmers kept calving records and 80% do not practices culling of old cows. The regression model revealed that lack of information and understanding of farm business, and information communicated by government were among the dominating factors associated with the constraints. The study confirmed the need to enhance the approach of farm information dissemination and skills transfer to mitigate farming challenges and improve productivity. Policy makers may ensure adoption of farm information chains through more implementations of open platforms such as farmer's schools and farmers days.

Key words: Beef farming, Farm constraints, Farm management, Questionnaire

3.1 Introduction

Over many centuries, livestock has been central to the economic and social livelihoods of communities in developing countries (Hatab *et al*., 2019). In South Africa (SA) and Africa at large, livestock is kept by 90% of rural communities (Nyamushamba *et al*., 2017; Njisane *et al*., 2019). South Africa has a diverse climate with up to 80% of land only suitable for grazing by cattle, sheep and goats (DAFF, 2019). Cattle are the major livestock species farmed compared to small ruminants with 80% comprising of beef and 20% for dairy production (Oduniyi *et al*., 2020).

Over many decades the SA agricultural sector has been characterised by its dualistic systems with highly commercialised sector with an annual turnover between R10 – R50 million and a smallholder sector (SHS) that primarily farm for household consumption and profit of excess production (Greyling, 2015; DALRRD, 2020). The commercialised sector accounts for 90% of the national food supply while in the smallholder sector, production is divided amongst household diet supplementation (77%), main food source (8%), additional income (6%) and main income (2%) (Greyling *et al*., 2015; Queenan *et al*., 2020). In SA context, smallholder farming is divided into three groups: The household farmers (vulnerable and subsistence) that farm in former homelands and they constitute the majority (92%) in this sector. The subsistence farmers within the household group participate in marketing a portion of their access production and generates less than R 50 000 in sales annually. The second group is referred to as smallholder farmers whose farming is for household production, however have higher annual turnover between R50 001 to R1 million. The last group, which is the minority, are market-oriented farmers whose production is mainly for income through farm produce and household consumption (DALRRD, 2020**;** Queenan *et al*., 2020).

The SHS is generally characterized by limited farm knowledge, advisory services, recording systems, marketing access and poor breeding management (Baker *et al*., 2015; Dinku, 2019; Myeni *et al*., 2019). Despite these limitations, smallholders are identified to have potential to alleviate poverty in rural communities in line with United Nation Sustainable Development Goals (SDGs) SDG 1 (Terlau *et al*., 2019). As a result, SA government has in the past 18 years implemented programs aimed at providing support on advisory services, marketing, business development and improving herd reproduction performance in the SHS (TIA, 2013; NRMDP, 2017; DALRRD, 2020). These interventions have however yielded a negligible impact (Cheteni & Mokhele, 2019). To date, approximately 37% of farmers are aware of different marketing avenues, less than 70% receive extension services and 77% of beef farmers express constraints in poor breeding management (Molefi *et al*., 2017**;** Mapiye *et al*., 2018). These figures are not different from the reported 76% limited market information and 56% local extension officers visits from the past decade (Musemwa *et al*., 2008; Baloyi, 2010;).

This study assumes that for improved understanding of beef cattle production in smallholder herds, integrated factors on farm demographics and constraints related to production, marketing, ecological and reproduction management should be evaluated. Insights on these constraints may assist in designing support targeted to the diversity and complexity of different farmers groups recognizing gender, age, employment and access to agricultural land. These factors may expand the narrative of cattle feed availability, nutrition and health in smallholder systems. Proper nutrition and health can increase reproduction efficiency by up to 25% (McGowan *et al.*, 2014), ultimately, improved reproduction management means improving farm outputs and attraction of marketing channels that lead to maximization of farm profits. The current study was based on a quantitative survey to assess beef cattle farming practices and identify the primary constraints influencing smallholder beef cattle farmers in SA.

3.2 Materials and methods

3.2.1 Data origin

Ethical clearance for the use of external data to conduct the study was granted by the Animal Ethics Committee (AEC) of the University of Pretoria (NAS339/2020). Data for the study was obtained from the behaviour change survey within the High Beef Value Partnerships (HBVP) project funded by the Australian Centre for International Agricultural Research (ACIAR).

A structured questionnaire with 114 questions was developed to investigate cattle production profiles and constraints. The study followed a cross-sectional research design approach. The questionnaire provided close-ended questions and a five-point likert scale ranging from very low to very high was used to capture the responses level of each constrain (Mapiye *et al*., 2018). The questionnaire was structured in English and administered in respective languages of the farmers. The targeted farmers for the current research were smallholder farmers.

Data collected consisted primarily of (i) demographic profiles (gender, age, education level, off farm income), (ii) farm profile (reason for farming and farming engagement, herd size composition, and farmers objectives on their cattle farming operations), (iii) reproduction management which captured information on breeding systems, bull management (source of breeding bulls, bull to cow ratio), cow management (body condition score awareness, calving interval, calving records, handling of non-productive and old cows) and heifer management (age of breeding heifers, selecting criteria of heifers for breeding). Lastly (iv) constraints limiting farmers performances. Data on farming constraints included farmer's responses on provided ecological, production and marketing constraints (Table 3.1).

Table 3.1: Summary of categories of constraints faced by farmers considered in the study.

Category	Parameters
Production constraints	Disease outbreak
	Cattle nutrition
	Stock theft
	Annual cattle income
	Access and interpretation of farm information
Marketing constraints	Complying with market regulations
	Access to reliable markets
	Fair cattle pricing
Ecological constraints	Extreme weather events
	Weed encroachment
	Competing agricultural land use

3.2.2 Sampling strategy

The current study analysed a subset sample of 460 cattle farmers purposively selected based on cattle farming and ownership from 789 respondents of the behaviour change survey that included poultry farmers. Seven provinces (Limpopo, Mpumalanga, Free State, Gauteng, Eastern Cape, North West and Northern Cape) were randomly selected to participate in the main survey based on the HBVC project provinces. The number of participants extracted for the current study differed per province as provided in Figure 3.1. Purposive sampling was used to administer the reproduction management questionnaire. This was based on available herds where monitoring and collection of herd reproduction performance such as pregnancy diagnosis on breeding cows was achievable. As a result, five provinces Limpopo, Mpumalanga, Free State, North West and Eastern Cape participated in the reproduction management questionnaire. A total of 21 reproduction management questions were administered to 30 exclusively available farmers across the five provinces. The questionnaire followed the same methodology as in 3.1.

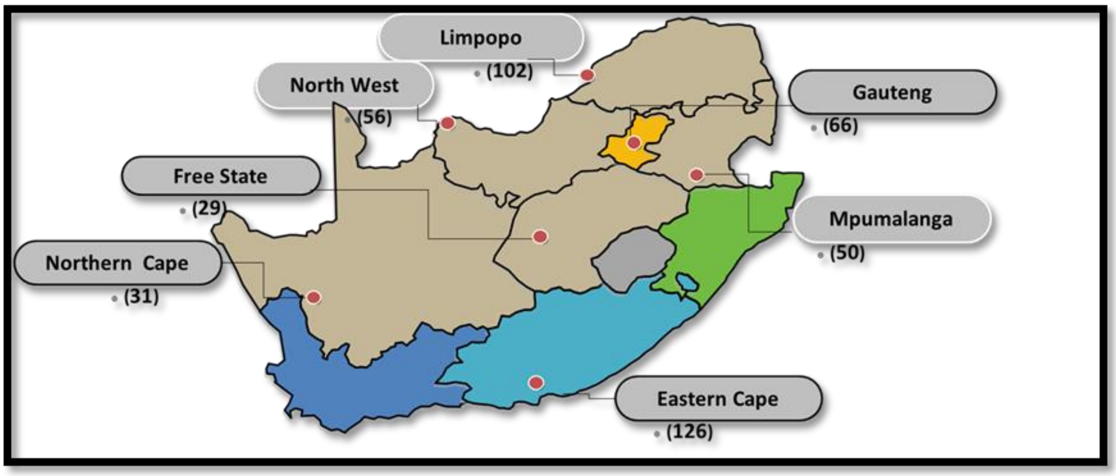

Figure 3.1 *Map of South Africa indicating seven provinces and numbers of cattle farmers studied in each province*.

Description of explanatory variables used in the study and hypothesized effect are highlighted in Table 3.2. All the variables have been selected at the alpha level of ≤ 0.05, however selection differed amongst each predictor variable.

Table 3.2: A description of variables included in the study.

			Dependent variable: Constrain		
			Production	**Marketing**	**Ecology**
	Variables	Description			
X1	Availability of skilled farm labourers	1=yes, 2= no	±	-	±
X2	Lack of access information on managing farm business	Farmer's concern on information on managing (1= very low ; 5 very high)	±	+	+
X3	Difficulty accessing services	Farmer's concern on access to services (1= very low; 5 very high)	±	+	-
X4	Years farming with cattle	Period farming in years	±	-	-
X5	Disease outbreak concern	Farmer's concern about disease outbreaks in the area (1=very low; 5 very high)	+	+	±
X6	Herd size	1= small(1-50), 2=medium (50-100),	+	-	±

			Dependent variable: Constrain		
	Variables	Description	Production	Marketing	Ecology
		3= large (100-200), 4= extra-large (over 200)			
X7	Education level	1= primary, 2= high school, 3=Tertiary,4= no school	-	-	±
X8	Cattle nutrition	Farmer's concern on cattle nutrition (access to grazing and supplementary feeding) (1= not concern; 5 very)	+	+	±
X9	Lack of understanding information communicated by gov	Farmer's concern on understanding farm information by government agencies (1= very low; 5 very high)	±	-	+
X10	Cattle sold in 12 months	Numbers cattle sold	-	+	-
X11	Lack of trust of value chain trust	Farmer's concern on value chain trust (1= very low; 5 very high)	-	+	-
X12	Lack of fair pricing for cattle	Farmer's concern on cattle pricing (1= very low; 5 very high)	-	+	-
X13	Cattle theft	Farmer's concern on cattle theft in the area (1= very low; 5 very high)	-	+	-
X14	Climate change concerns	Farmer's concern on access to reliable markets (1= very low; 5 very high)	+	-	±
X15	Credit loan repaying	1=yes; 2= no	-	-	±
X16	Province	Limpopo, Mpumalanga, North West, Free state,	+	-	±

		Dependent variable: Constrain		
		Production	**Marketing**	**Ecology**
Variables	Description			
	Northern Cape, Eastern Cape			

Note: All variables were selected at a significant level of P≤ 0.05 into the model.

3.2.3 Statistical analysis

The majority of the questions were categorical and were analysed by frequency tables and graphs, as well as ordinal logistic regression using Statistical Analysis System (SAS, 2012). Descriptive statistics included frequencies and percentages on household demographics, farm profiles and reproduction management data. Stepwise ordinal logistic regression procedure with a cumulative logit was used in the model building processes to determine factors associated with production, marketing and ecological constraints in smallholder herds. Literature has established that farmers in the smallholder sector face multiple challenges on production, marketing and ecology. However, the logistics model applied in the study primarily captured disease and nutrition factors on production constraints and compliance of market regulations factors on marketing constraints. The ecological constraints predominately captured factors on competing of agricultural land use and weed encroachment on grazing lands.

The cumulative logit procedure simultaneously estimates multiple equations for the comparison of the cumulative odds of high versus low response level. For this study, each farmers concern on a given constrain had 5 outcomes as follows:

$$J_{=5}\begin{cases} very\ low \\ low \\ moderate \\ high \\ very\ high\ concern \end{cases}$$

where level of concern as very low = 1, low = 2, moderate = 3, high concern = 4 and very high = 5. Therefore the logits regression model used for analysis was define as:

$$[Logit\ (y \leq j)] = log\left[\frac{P(Y \geq j)}{1 - P(Y < j)}\right] = \alpha_j + \beta_{x,} \quad (j = 1,2,3, \ldots j - 1)$$

Where P($Y \geq j$) is the odds of the event of the farmers response to the category *j* of a given predictor variable (constraint); α_j is the intercept parameter and β is the vector of regression coefficients corresponding to x covariates. The model specifies that the intercept parameter differs across all *j* categories however, the x covariates remain constant. The logits for the model intercepts for *j* categories are defined in Table 3.3:

Table 3.3: Logit models for intercept parameters.

Farmer response level	Intercept models
Very low	$\left[Logit\ (P \leq 1) = \log\left(\frac{\pi_1}{\pi_2 + \pi_3 + \pi_4 + \pi_5}\right)\right] = (P = 1)$
Very low versus low	$\left[Logit\ (P \leq 2) = \log\left(\frac{(\pi_1 + \pi_2)}{\pi_3 + \pi_4 + \pi_5}\right)\right] = (P \leq 1) + (P \leq 2)$
Very low, low, moderate versus high	$\left[Logit\ (y \leq 3) = \log\left(\frac{(\pi_1 + \pi_2 + \pi_3)}{\pi_4 + \pi_5}\right)\right] = (P \leq 2) + (P \leq 3)$
Very low, low, moderate versus high versus very high	$\left[Logit\ (y \leq 4) = \log\left(\frac{(\pi_1 + \pi_2 + \pi_3 + \pi_4)}{\pi_5}\right)\right] = (P \leq 3) + (P \leq 4) = Very\ high(1 - P \leq 4)$

Note: The model described cumulative odds with four response level for each dependent variable. The odds of the highest level is used to compare famers response with the lower level

The explanatory variables that specify the effect of the dependent variable for the response of farmers to a specific constraint where as follows:

Disease outbreak = $a_i + \beta_1 X_2 + \beta_2 X_8 + \beta_3 X_9 + \beta_4 X_{14} + \beta_5 X_6$

Cattle nutrition = $a_i + \beta_1 X_1 + \beta_2 X_3 + \beta_3 X_4 + \beta_4 X_5 + \beta_5 X_{16} + \beta_6 X_6$

Complying with market regulations = $a_i + \beta_1 X_2 + \beta_2 X_{10} + \beta_3 X_{11} + \beta_4 X_8 + \beta_5 X_3 + \beta_6 X_5 + \beta_7 X_{13} + \beta_8 X_{12}$

Computing of agricultural land use = $a_i + \beta_1 X_2 + \beta_2 X_{16} + \beta_3 X_{15} + \beta_4 X_9 + \beta_5 X_7$

Encroachment of weeds on grazing land)= $a_i + \beta_1 X_8 + \beta_2 X_2 + \beta_3 X_1 + \beta_4 X_{14} + \beta_5 X_6 + \beta_7 X_9 + \beta_8 X_{16}$

The chi-square test was used to assess collinearity between the covariates with the Cramer V statistics at 0.07. All variables that reflected collinearity were eliminated from the model. Results are presented in the form of odds ratio (OR) and corresponding 95% confidence interval (CI).

3.4 Results

3.4.1 Demographic characteristics of cattle farmers

Table 3.4 shows the demographic profiles of the interviewed farmers. The majority of farmers were males (77%) above the age of 60 (42%). Most of the farmers had high school education (53%) and generates their off farm income through pension funds and business operations (29%). It was also found that majority in the households practice livestock farming (76%) compared to mixed farming (24%).

Table 3.4: Demographic characteristics of interviewed farmers.

Variables	Modalities	Percentage (%)
Age	Below 35	12
	46-55	20
	35-45	14
	55-60	12
	Above 60	42
Education	No formal education	6
	Primary	20
	high school	53
	Tertiary	21
Gender	Female	23
	Male	77
Type of farming	Livestock	76
	Mixed	24
Type of grazing livestock	Cattle	67
	Cattle, sheep and goats	31
	Cattle sheep, goats donkeys and horses	2
Off farm income	Employment	16
	Pension	29
	Social grant	26
	Business operations	29

Frequency percentage (%) of the surveyed farmers.

3.4.2 Production management of farm profiles

3.4.2.1 Main reasons for cattle farming and farm engagement

The primary reason for cattle farming to majority of the farmers was for sales purposes (78%) and farming engagement was regarded as a full-time practice to majority (92%) of the respondents (Figure 3 2).

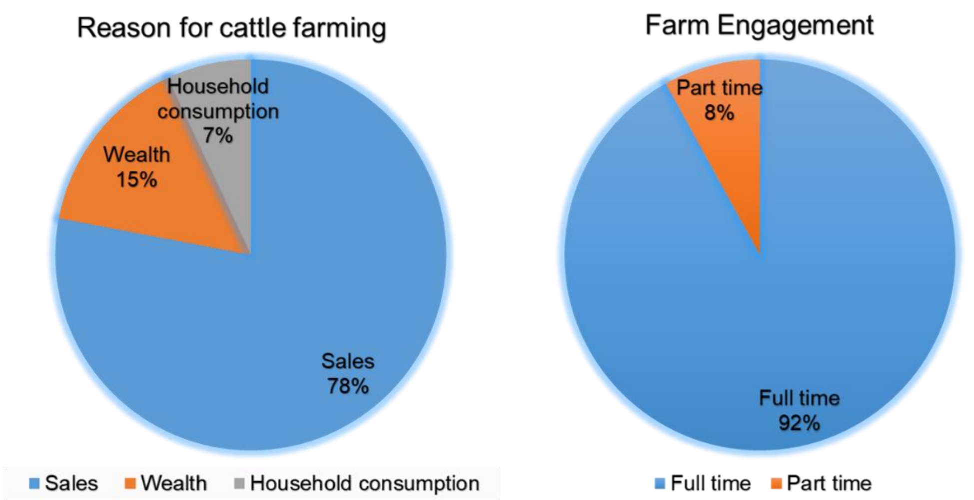

Figure 3.2 *Percentage responses of the main reasons for cattle farming and farming engagement of surveyed farmers.*

3.4.2.2 Farmers intentions and future prospects to cattle farming.

There were variations in farmers perceptions and future prospects of farm operations. Within the group, majority of the farmers anticipated that their farming business will benefit the local economy (37%), become reliable source of income (36%), benefit the community (36%) and provide food for the family (36%). Meanwhile, 38% and 31% of the farmers intentions were for cultural needs and gaining respect from the community (Fig. 3.3).

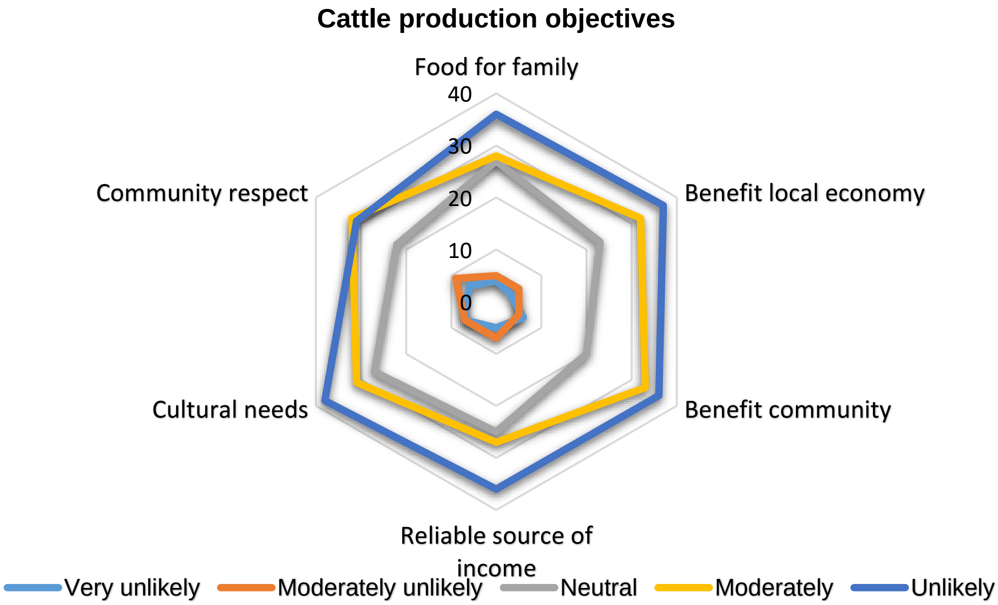

Figure 3.3 *Percentage responses of surveyed farmers objectives to beef cattle production*.

3.4.2.3 Farmers herd size, market outlets and proportion of sales of cattle farming.

The majority of farmers sell cattle at informal markets (61%) compared to auctions (34%) feedlots (4%) and abattoirs (1%). The results further showed that most farmers own small herds (49%) with annual cattle sales (60%) within the R 1-50 000 scale (Table 3.5).

Table 3.5: Herd size, market outlets and proportion of sales in cattle farming.

Parameter	Frequency	Percentages (%)
Herd size		
Small herds	223	49
Medium herds	124	27
Large herds	60	13
Extra large	53	11
Market outlet		
Informal market	279	61
Auction	157	34
Feedlot	17	4
Abattoir	7	1
Cattle annual income		
Zero	96	20
R1-50 000	277	60
R 51 000-R100 000	61	13
Over R100 000	21	7

Frequency percentage (%) of the surveyed farmers.

3.4.2 Reproduction management

On reproduction management, the present study observed that 63% of the farmers do not practice breeding seasons and up to 53% obtain breeding bulls from commercial stock auctions. Majority of the farmers (87%) do not perform heifer selection either by age or parent breeding history and 60% reported their replacement heifers not to be pregnant at first service after breeding season. The results also indicated that majority of the farmers (53 and 80%) do not cull non-productive and old cows, respectively. Furthermore, 83% of the farmers do not keep calving records and 93% have no knowledge on evaluations of body condition score prior breeding. Most farmers (77%) reported intercalving of two years, and 27% of the farmers experience abortions in their herds (Fig. 3.4).

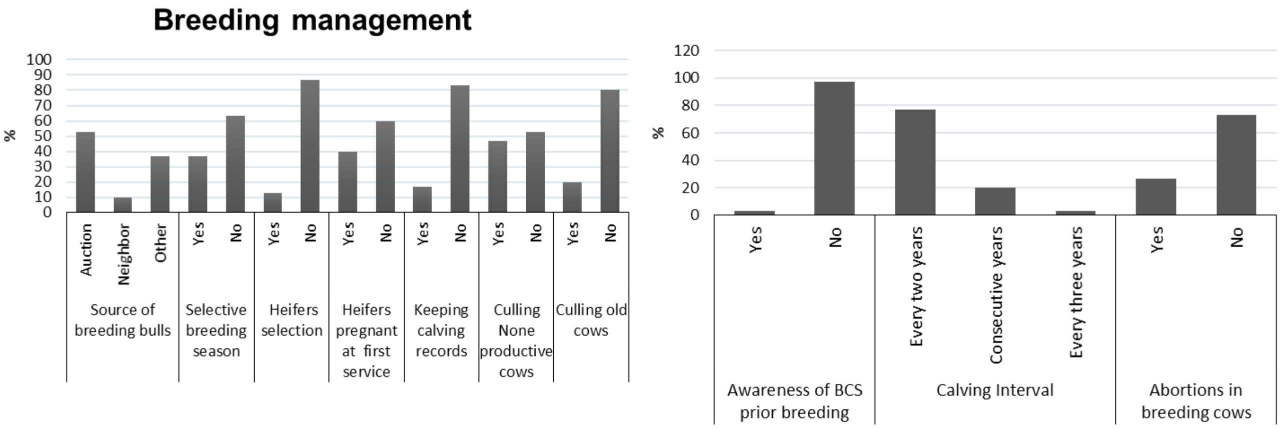

Figure 3.4 *Percentage responses of breeding management practices of surveyed farmers*.

3.4.3 Constraints faced by farmers

3.4.3.1 Production constraints

Fig. 3.5 represents production constraints faced by farmers. Famers were very highly affected by variety of constraints including cattle nutrition (35%), difficulty in assessing services (36%), lack of access of information on farm management (34%), disease outbreaks (31%) and lack of understanding of information communicated by government (40%).

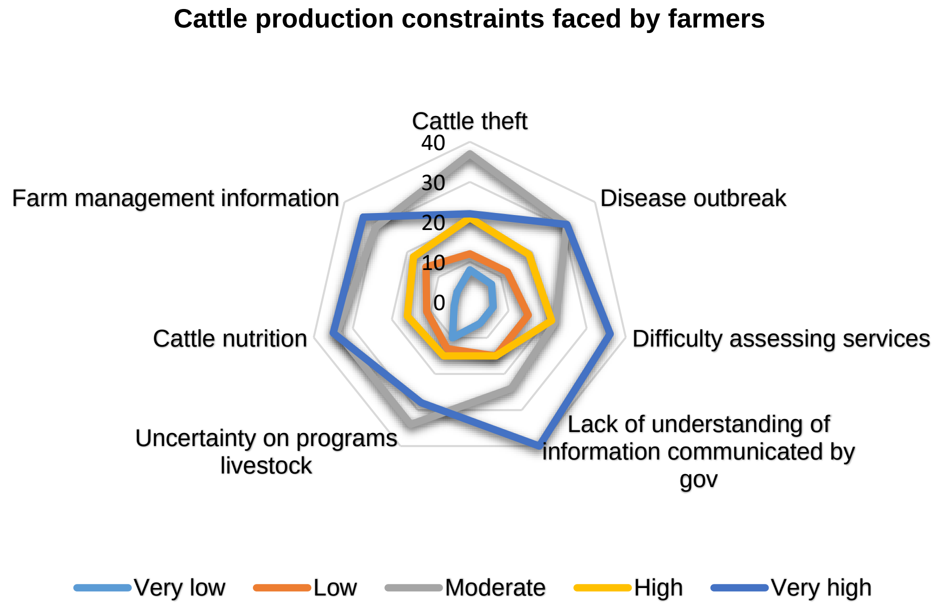

Figure 3.5 *Percentage responses of major cattle production constraints faced by surveyed farmers.*

Table 3.6 presents the logistic regression model analysis for concerns of disease outbreaks. The model predicted variables: lack of access of information on managing farm business, cattle nutrition and province to be highly significant factors associated with disease outbreak concerns p <.0001. There was an increase in the odds [OR=1.588] of disease outbreaks concern for farmers on every increase in lack of access of information on managing the farm. The model predicted greater increase in the odds [OR=1.749, 1.172, 1.070 and 1.312] of disease outbreak concern for farmers in Gauteng, Limpopo, Mpumalanga and North West compared to Eastern Cape and Free State province respectively [OR=0.274 and 0.349]. Extra-large herd size, climate change concerns and lack of understanding information communicated by government agencies were also variables predicted to have greater odds [OR=1.745, 1.281 and 1.209] of concerns on disease outbreaks.

Table 3.6: Summary of association between risk factors and the odds of production constraints (disease outbreak) in smallholder beef cattle herds.

Variable	SE	OR	95% CI of OR		P value
			Lower	Upper	
Lack of access of information on managing farm business	0.1043	1.588	1.295	1.949	***<.0001***
Cattle nutrition	0.1004	1.596	1.310	1.943	***<.0001***
Province					<.0001
Eastern Cape vs Northern Cape	0.2041	0.274	0.127	0.588	<.0001
Free state vs Northern Cape	0.3697	0.349	0.122	0.995	0.0189
Gauteng vs Northern Cape	0.2415	1.749	0.762	4.014	0.0021
Limpopo vs Northern Cape	0.1958	1.172	0.551	2.494	0.0794
Mpumalanga vs Northern Cape	0.2630	1.070	0.456	2.513	0.3381
North West vs Northern Cape	0.2741	1.312	0.537	3.210	0.0960
Lack of understanding information communicated by gov	0.0872	1.209	1.019	1.434	**0.0002**
Climate change concerns	0.0842	1.281	1.086	1.511	**0.0023**
Herd size					**0.0456**
Extra-large herds vs Small herds	0.2263	1.745	0.947	3.215	0.0263
Large herds vs Small herds	0.2157	0.626	0.348	1.127	0.0154
Medium herds vs Small herds	0.1649	1.135	0.731	1.765	0.6571

Note: Bold values are generalised Wald-test P values. Statistical significant at level (p <0.01; p < 0.05).SE= Standard Error, OR= odds ratio, CI = confidence interval.

The results of the analysis of cattle nutrition concerns demonstrated that farmers with concerns on the availability of skilled farm labourers, lack of information on managing farm business and difficulty accessing services [OR=2.810, 1.707 and 1.282] had increase odds of concerns on cattle nutrition. There was an increase in the odds of concerns of cattle nutrition for every increase in disease outbreaks and farmers with larger herds [OR=1.283 and 2.918]. The model further predicted farmers in the Eastern Cape and Limpopo province [OR=3.789 and 2.081] to have an increase in cattle nutrition concerns compared to other provinces (Table 3.7).

Table 3.7: Summary of association between risk factors and the odds of production constraints (cattle nutrition) in smallholder herds.

Variable	SE	OR	95% CI of OR		*P value*
			Lower	Upper	
Availability of Skilled farm labourers	0.1144	2.810	2.246	3.516	**<.0001**
Lack of information on managing farm business	0.1104	1.707	1.375	2.119	**<.0001**
Difficulty accessing services	0.0828	1.282	1.090	1.508	***0.0003***
Years farming with cattle	0.0851	0.725	0.613	0.856	***0.0028***
Disease outbreak concern	0.0808	1.283	1.095	1.503	***0.0465***
Province					***0.0363***
Eastern Cape vs Northern Cape	0.2113	3.789	1.693	8.479	<.0001
Free state vs Northern Cape	0.3740	0.857	0.297	2.472	0.1310
Gauteng vs Northern Cape	0.2518	1.352	0.568	3.217	0.6673
Limpopo vs Northern Cape	0.2095	2.081	0.945	4.583	0.1234
Mpumalanga vs Northern Cape	0.2743	1.651	0.679	4.012	0.7394
North West vs Northern Cape	0.2989	1.170	0.453	3.022	0.3972
Herd size					***0.0106***
Extra-large herds vs Small herds	0.2507	1.371	0.672	2.796	0.4980
Large herds vs Small herds	0.2264	2.918	1.533	5.553	0.0097
Medium herds vs Small herds	0.1743	1.742	1.103	2.752	0.6891

Note: Bold values are generalised Wald-test P values. Statistical significant at level (p <0.01; p < 0.05).SE= Standard Error, OR= odds ratio, CI = confidence interval.

3.4.3.2 Marketing constraints faced by smallholder farmers

Figure 3.6 shows results of marketing constraints faced by farmers in the study. Majority of the respondents were moderately concerned about reliable markets (34%), value chain trust (40%). High concern on fair cattle pricing (31%) and complying with market requirements (41%) on the majority of the farmers were also observed.

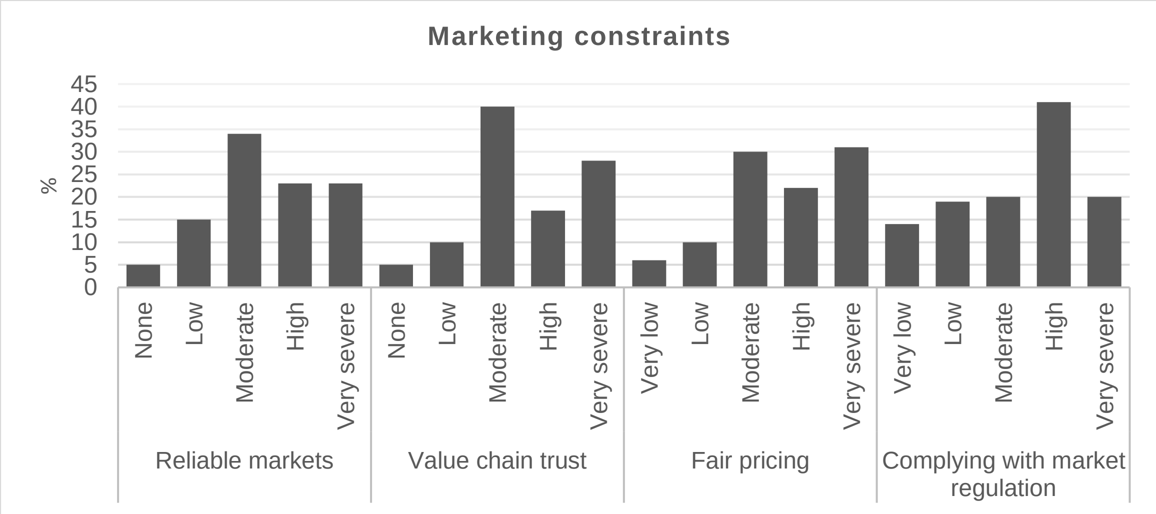

Figure 3.6 *Percentage responses of marketing constraints faced by surveyed farmers*.

Table 3.8 presents factors associated with concerns on compliance of market regulations by farmers. The model revealed that farmers with lack of information on managing farm business, difficulty accessing government services, cattle theft and value chain trust are predicted to have an increase in odds [OR=1.462, 1.207, 1.341 and 2.967] of concerns on complying with market regulations. Moreover, farmers who had concern on cattle nutrition and disease outbreaks are expected to have an increase [OR=1.156 and 1.150] odds for concern of complying with market regulations. The model further cattle sold in 12 months (P<.0001) as a factor associated with concerns on compliance of markets regulations.

Table 3.8: Summary of association between risk factors and the odds of marketing limitations (complying with market regulations) in smallholder beef cattle herds.

Variables	SE	OR	95% CI of OR		P value
			Lower	Upper	
Lack of information on managing farm business	0.0850	1.462	1.237	1.726	***<.0001***
Cattle sold in 12 months	0.0954	1.520	1.261	1.833	***<.0001***
Value chain trust					***0.0002***
None vs severe concerns	0.3113	2.756	1.126	6.749	0.0966
Low vs severe concerns	0.2553	0.740	0.342	1.602	0.0018
Moderate vs severe concerns	0.1672	1.978	1.120	3.494	0.2670
High vs severe concerns	0.2117	2.967	1.594	5.520	0.0052
Cattle nutrition	0.1001	1.156	0.950	1.406	***0.0011***
Difficulty accessing services	0.0804	1.207	1.031	1.413	***0.0055***
Disease outbreak concerns	0.0738	1.150	0.995	1.328	***0.0292***
Cattle theft	0.1678	1.341	0.965	1.863	***0.0529***
Lack of fair pricing	0.2244	1.030	0.499	2.128	**0.0375**

Note: Bold values are generalised Wald-test P values. Statistical significant at level (p <0.01; p < 0.05).SE= Standard Error, OR= odds ratio, CI = confidence interval.

3.4.3.4 Ecological constraints

Figure 3.7 highlights the ecological constraints smallholder farmers encountered in the present study. The results shows that majority of the farmers had (38%) severe concerns on extreme weather events. Respondents were further affected by the encroachment of weeds in grazing areas (37%) and competing of agricultural land use (36%).

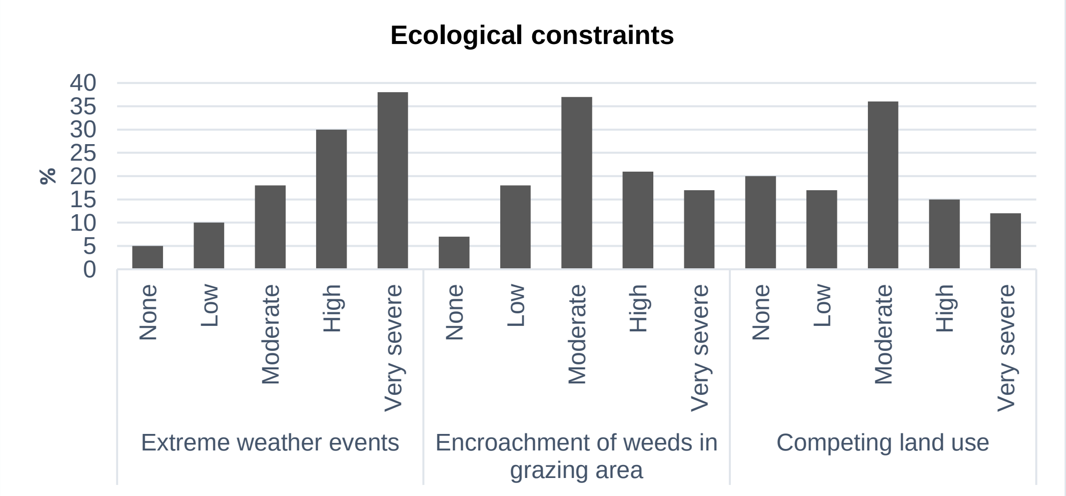

Figure 3.7 *Percentage responses of ecological constraints faced by surveyed farmers*.

The regression model showed an increase in the odds [OR=2.070, 1.933, 1.550, 1.698 and 1.126] of concern of competing of land use in the Gauteng, Limpopo, Free State, Mpumalanga and North West, respectively. Farmers who had concerns on accessing of information on managing farm business, lack of understanding of information communicated by government agencies and disease outbreaks were predicted to have greater increase [OR=3.169, 1.191 and 1.464] in concerns of competing agricultural land use. The model further predicted education level to have an increase in odds [OR=1.168] of concern of competing of land use (Table 3.9).

Table 3.9: Summary of association between risk factors and the odds of ecological constraints (competing of agricultural land use) in smallholder herds.

Variables	SE	OR	95% CI of OR		P value
			Lower	Upper	
Lack of information on managing farm business		3.169	2.543	3.951	***<.0001***
Province					***<.0001***
Eastern Cape vs Northern Cape	0.2139	0.520	0.224	1.210	<.0001
Free state vs Northern Cape	0.3755	1.550	0.533	4.513	0.6345
Limpopo vs Northern Cape	0.2555	1.933	0.772	4.839	0.1181
Gauteng vs Northern Cape	0.2046	2.070	0.914	4.689	0.0223

Mpumalanga vs Northern Cape	0.2770	1.698	0.670	4.307	0.3304
North West vs Northern Cape	0.3030	1.126	0.414	3.059	0.6403
Disease outbreak	0.0808	1.464	1.250	1.715	***<.0001***
Credit loan re-paying	0.3169	0.237	0.127	0.441	***0.0005***
Lack of understanding information Communicated by gov	0.0889	1.191	1.001	1.418	**0.0049**
Education level	0.0861	1.168	0.986	1.382	**0.0108**

Note: Bold values are generalised Wald-test P values. Statistical significant at level (p <0.01; p < 0.05).SE= Standard Error, OR= odds ratio, CI = confidence interval.

Table 3.10 presents factors associated with concerns of weed encroachment in grazing lands. The model predicted cattle nutrition (P<.0001), lack of access of information on managing farm business (P<.0001), availability of skilled farm labourers (P=0.0002) and province (P=0.0007) as factors associated with weed encroachment. Extra-large herds and climate change concerns had increase odds [OR=1.758 and 1.166] in concern of weed encroachement in grazing land compared to small herds. Farmers with increased concerns of lack of understanding of information communicated by government agencies had greater odds [OR=2.222] in the increase of weed encroachment on grazing land.

Table 3.10: Summary of association between risk factors and the odds of ecological constraints (encroachment of weeds on grazing lands) in smallholder herds.

Variable	SE	OR	95% Limits of OR		*P value*
			Lower	Upper	
Cattle nutrition	0.7985	2.222	1.810	2.729	**<.0001**
Lack of access of information on managing farm business	0.5242	1.689	1.369	2.084	**<.0001**
Availability of skilled farm labourers	0.4368	1.548	1.251	1.916	**0.0002**
Climate change	0.1538	1.166	0.993	1.369	**0.0388**
Herd size					**0.0072**
Extra large herds vs Small herds	0.5275	1.758	0.939	3.291	0.0218
Large herds vs Small herds	-0.4817	0.641	0.358	1.147	0.0235
Medium herds vs Small herds	-0.00893	1.028	0.664	1.592	0.9564
Lack of understanding information communicated by gov	0.1069	2.222	1.810	2.729	**0.0278**
Province	0.8066	2.534	1.100	5.837	**0.0007**

Note: Bold values are generalised Wald-test P values. Statistical significant at level (p <0.01; p < 0.05).SE= Standard Error, OR= odds ratio, CI = confidence interval.

3.5 Discussion

This paper described smallholder beef cattle farming practices and challenges in seven provinces of SA. The reported higher percentage of male compared to female farmers correspond with multiple studies conducted on smallholders in SA and neighbouring countries (Otieno, 2013; Chingala *et al*., 2017; Cheteni & Mokhele, 2019). Gender inequality in the agricultural sector has been a prominent subject in rural farming in which customs and traditions such as *"restrictions of women to enter cattle kraal*" are used as a tool to discriminate against women (Gumede *et al*., 2018). The report by Wisborg (2014) highlighted that women face discrimination regardless of gender equality being enforced. Despite the dominance of males in agriculture, tools such as the Women's Empowerment in Livestock Index (WELI) developed for communities in East Africa are available to monitor the enforcement of equal opportunities to women and girls in the livestock sector according to the SDG five (Alkire *et al*., 2013; Galiè *et al*., 2019). This tool may be an effective way of addressing gender inequality in SA agriculture.

In livestock production, old age has been associated with smallholder farming (Mapiye et al. 2018; Myeni *et al*. 2019) and similarities have been reported on the current study with majority of farmers above the age of 60. Studies by Otieno (2013) and Bahta & Baker (2015) argue that older farmers have been found to be enthusiastic towards farming, this may be the reason for their dominance in beef cattle smallholder farming. However, more emphasis on developmental projects to encourage participation of youth and middle age group to farming are needed as this may be vital to the direction of the future of SHS. The reported high percentage of farmers solely committed to farming may imply that smallholder farmers are dependant on agriculture to sustain household needs (Jari & Fraser, 2009). The above further emphasize that agriculture is the centre of poverty alleviation in smallholder sector as it has been recognised by major government entities (DAFF, 2019; DALRRD, 2020). Farmers demographics further indicated that majority practices livestock compared to mixed farming. This may suggest the need for sufficient knowledge on crop production and its benefit on feed provision for cattle especially in smallholders where livestock feeding is a scarce resource.

Low literacy has been considered to be dominating in smallholder farmers and the present study was no different (Marandure *et al*., 2017). The report by Myeni *et al*. (2019) stated that education is known as a barrier between farmers adoption to new technology and transformation for improved farm outputs. Moreover, Ferreira (2018) found that education is associated with a 1.0% and 3.0% increase in agricultural productivity in Malawi. The above, therefore, may anticipate a potential link between the level of education attained and the minimal (7%) annual return of over R100 000 reported by the respondents.

Within the group, majority of the farmers anticipated that their farming business will benefit the local economy. These findings highlight clear intentions of smallholder farmers to the livestock industry. However, as much as majority of farmers highlighted sales as main reason for keeping cattle, it is concerning to note that 38% of farmers were still in cattle farming for cultural reasons. Culture has over time become a persistent factor as a barrier between subsistence and commercial value chain (Sikhweni & Hassan, 2013; Mapiye *et al*., 2020). Kahan (2012) suggested that the enforcement of entrepreneur behaviour to farmers may be one of the initiatives to break through the barrier between culture and profitization. In essence, farmers are thus far running a business with all the cattle maintenance such as purchasing of feed, medication and hiring of a herdman. Therefore, more entrepreneurship support from provincial departments is needed to guide farmers to profit without defining cultural views, however, reconciling farmers values.

Farm engagement, objectives and choice of market are linked to farm revenue and define farmer's produce (Zantsi & Bester, 2019). Majority of the farmers sell cattle at informal markets and fall within the R1-50 000 annual scale of earnings. These results are similar to Khapayi & Celliers (2016) who reported that 84% of farmers make use of informal markets as the main market for livestock. The sentiment, however, differs with small stock and cattle smallholders from other neighbouring countries. Cheteni & Mokhele (2019) highlighted 65% of sheep farmers to have adopted formal markets compared to farm gates markets. Moreover, empirical studies in countries such as Swaziland and Kenya demonstrated that majority of smallholder cattle farmers have now adopted formal markets outlets such as auctions, abattoir and butcheries (Otieno, 2013; Dlamini & Huang 2020). Access to formal markets in these countries might have been as a results of availability of information regarding farm business. For example, in the study reported by Dinku (2019) in Ethiopia, majority of farmers have access to extension services and are visited by local extension officers and advisors at least twice a week. However, majority of SA farmers relies on inexperienced personnel such as family members or neighbours for market information and thus most farmers are therefore unable to participate in markets due to failure to meet market regulations (Khapayi & Celliers, 2016; Ndoro *et al*., 2015). It was also noted that 20% of the farmers fell within a category that generated zero income per annum. This indicates a matter of concern that requires an in-depth investigation to current systems in the smallholder. In Vietnam, participation of cattle smallholder in the value chain includes fattening of cattle in pens using farm-grown fodders (Stür *et al*., 2013). Consequently, more adoption of initiations such as stall-fed systems by SA cattle smallholders may increase participation of beef supply in the domestic market.

There were numerous production constraints identified from the surveyed households. Respondents were constraint by the accessibility of farm information, lack of access of information on farm management, disease outbreaks and cattle nutrition. Support services remains a barrier for smallholder livestock farmers and may impact poverty alleviation in rural area. However, accessibility of farm information that is clear and understandable to farmers may serve as a stepping stone for the improvement of rural development and farm growth (Baker *et al*., 2015).

The present study highlighted that farmers with lack of access to information on managing the farm and lack of understanding of information communicated are less likely to respond to disease outbreaks. These findings are in line with Khapayi & Celleirs (2016), who reported that majority of smallholders have limited knowledge on the identification of livestock diseases with 94% of farmers illiterate on animal hygiene and clear protocols on how to respond to outbreaks and vaccination programs. Unlike SA, farmers in Swaziland are practicing health screening of purchased cattle and selecting replacements from their herds (Dlamini & Huang, 2020). Such practices may be of importance to the improvement of cattle production in SA as disease in livestock remains an obstacle for smallholder farmers to trade their produce (Namayasha *et al*., 2017).

The report by Fidzani (1993) and Cheteni & Mokhele (2019) indicated that large herds provide higher marketable surplus compared to smaller herds, however in concurrence with sound knowledge of good management of the farm. This might be the reason reported disease outbreak concerns for farmers in larger herds in this study as a result of limited and accessible knowledge of farm operations including identification of sick animals. Despite the limitation of farm health information in smallholder, the Ciskei and Transkei formally known as the Eastern Cape was the first province to have benefited from SA state veterinary services in the 1970s followed by post apartheid smallholder farmers in 1994 in the Eastern Cape (Jenjezwa & Seethal, 2014). Therefore, this may be the reason the model predicted Gauteng, Limpopo, and North West to have greater odds of disease outbreaks concerns as compared to Eastern Cape Province.

Similar to disease outbreaks, the model predicted lack of information on managing farm business and difficulty accessing government services as major factors associated with cattle nutrition concerns and weed encroachment in grazing land. Therefore, knowledge of programs on rotational grazing, veld rest and stocking rate needs to be implemented in smallholder herds. Moreover, the adoption of crop residues as supplementation needs to be promoted and this emphasis on the argument made earlier that cattle smallholder farmers should implement mixed farming.

The model in this study predicted cattle theft to have an impact on markets participation. Stock theft has been an ongoing issue for decades in SA, the cost has amounted to close to R118 million (Ndoro *et al*., 2015). Smallholder farmers can however, do better by adopting animal identification for livestock since Coetzee *et al*. (2005) highlighted that animal identification remains a rare practice in smallholder herds since farmers view it as an expensive task.

Majority of smallholder farmers cattle fails at market point often due to farm nutrition as most animals appear lean and unhealthy (Ndoro *et al*., 2015), hence the model predicted adequate supply of nutrition to have increased odds of concern in complying with market regulations. However, extension officers have skills and appraisal to identify market issues and transparency to benefit farmers (Devendra *et al*., 2000). Therefore, there is a need to strengthen the relationship between these two parties to permeate information gap on value chain trust and market pricing.

Ecological constrain of extreme weather events has drastically affected both commercial and smallholder sector (Mare *et al*., 2018). Agricultural production declined by 8.4% due to the 2015 drought (Agri SA, 2016). The impact have been advanced on smallholders as a result of vulnerability in the sector, hence majority of the farmers responded very severe consent on extreme weather events in the study. Similar to extreme weather events competing of agricultural land has been a trend in the agricultural sector worldwide (Kanianska, 2016). The model predicted an association on lack of information on managing farm business and understanding information communicated with concern of competing of agricultural land use. This calls for information transparency of land policies from entities protecting agricultural land to landholders (Ladu *et al*., 2019).

Urbanization has grown in the past year due to increasing population and many cities are being built on fertile agricultural land. In Europe, approximately 64% of agricultural land has been taken over by urbanization (Primdahl *et al*., 2013). A simulation study in Belgium has shown 50% in reduction of farmers as a result of urbanization (Beckers *et al*. 2020). Migration in SA has been the main reason for urbanization. Urbanization occurs in most SA provinces, however is more prevalent in Gauteng province

(Annobea, 2018). Henceforth, the model predicted Gauteng to have higher odds of concern for competing of agricultural land as compared to other provinces.

There is an improvement in the source of breeding bulls reported in this study as majority of the farmers reported buying from auctioneers as source of breeding bulls compared to neighbours bulls (Molefi *et al*., 2017). However, cow management remains a challenge as majority of farmers do not practice culling of non-productive cows and old cows. This provides zero contribution to the production growth and may have a greater deal to the farmers pocket. Bahta & Baker (2015) once said "*In agribusiness, a competitive farm is one that has the ability to produce and sell quality products in a given market at a profit over the life of the farm*". The reported statement needs to be one of the imperative knowledge to be transferred to SA smallholder farmers. Tait *et al*. (2017) emphasize that BCS in cows during and post-breeding season influence pregnancy rates and calving interval as it may encourage the incidence of anestrus and anovulatory cycles. This is an unpleasant reality in smallholder herds as majority of the herds are not aware of BCS and it may have had an influence on the extended inter-calving periods reported in the study. Moreover, The non-adoption of a planned breeding season by majority of the farmers is a contributing factor to the slow economic growth within smallholders as breeding season should be align with available grazing for the achievement of more healthier and heavier calves (McGowan *et al.*, 2014). Furthermore, an investment on selection of herd replacement should be top priority as it affects the long-term sustainability and productivity of the cowherd, therefore the decision of majority of the farmers not selecting replacements may affect farm growth. The above mentioned imply that lack of reproduction knowledge remains a need for improved farm management practices.

Improvement in beef cattle smallholders may depend on developmental strategic plans to be implemented for programs targeted to disseminate farm knowledge and management skills. Promotion of open platforms for more deliberations of scientific outputs such as national farmer's days are needed as they strengthen information chain from scientist to extension officers and farmers. Farm business schools is another platform to provide a positive way to access farm information with extension officers as facilitators to exchange efficient advisory services. The school may open up ventures for a do one teach one for farmers to share farm experiences. Furthermore, a key step to improved production may involve interventions such as contract farming as a way of enhancing the economic growth in smallholder farmers according to National developmental plan vision 2030 and SDG 8.

3.6 Conclusion

The study assessed smallholder beef cattle farming practices and the primary constraints limiting the system. The results outlined that there is a need to amplify the mode of communication to farmers given majority of the farmers are constrained by lack of access and understanding of farming knowledge that is necessary to combat challenges on nutrition, disease outbreaks, marketing and reproduction management.

3.7 Declaration of interest

The authors declare that they have no competing interests.

3.8 Funding

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Chapter 4

Assessing Reproductive Performance to Establish Benchmarks for Small-Holder Beef Cattle Herds in South Africa

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Article

Assessing Reproductive Performance to Establish Benchmarks for Small-Holder Beef Cattle Herds in South Africa

Summary: In South African beef cattle smallholder farms, there has been no recommended target benchmark that provide a baseline for improving the reported low herd reproductive performances. A multi-stage sampling approach was performed to examine reproductive performance as defined by pregnancy rate, fetal and calf losses, calving interval and days open to benchmark smallholder herd reproduction. It was found that smallholder farms recorded on average, 50% pregnancy rate and 12% fetal and calf losses, with days open and calving interval achieved at 334 and 608 days, respectively. Targeted benchmarks for performance derived from this study were 54%, 1.4%, 152 and 425 days, respectively for pregnancy rate, fetal and calf losses, days open and calving interval for smallholder farms in South Africa. The study showed that herd management practices including non-culling of old and non-productive cows, no knowledge of body condition score prior to breeding, no record keeping, continuous breeding season and low bull to cow ratio are associated with recorded reproductive performance norms in smallholder farms. The study found that smallholders have the potential to improve their performance levels if management knowledge is provided through advisory and extension services.

Abstract: Smallholder beef cattle farms in South Africa have had low reproductive performance, which has been associated with management practices. Considering current farm management practices, a multi-stage selection study was conducted to assess reproductive performance as defined by pregnancy rate, fetal and calf losses, calving interval and days open to benchmark reproductive performance. Data were collected twice, in autumn (March–May) for pregnancy diagnosis and in spring (September–November) for monitoring of confirmed pregnancies. Overall, 3694 cow records from 40 smallholder herds were collected during 2018 and 2019 breeding seasons from five provinces. The preferred 25th quartile described target performance and GLIMMIX procedure determined associations between management practices and performance. Smallholder farms on average recorded 50% pregnancy rate and 12% fetal and calf losses with 304 and 608 days open and calving interval, respectively. The derived target benchmarks for pregnancy rate, fetal and calf losses, days open and calving intervals in smallholder farms were 54%, 1.4%, 152 and 425 days, respectively. Reproductive performance was associated with no knowledge of body condition scoring before breeding, culling of old and non-productive cows, record keeping and low bull to cow ratio ($P < 0.05$). The performance benchmarks implied that industry averages may be improved if sustainable management services are provided through extension and advisory services.

Keywords: cow fertility; management factors; performance benchmarks; pregnancy rate

4.1 Introduction

The potential of smallholder farmers on eradicating poverty and improving food security in rural communities of most African countries including South Africa (SA) has been well-recognized [1,2]. The smallholder sector is a driving force of farming in developing countries. In sub-Saharan Africa and Asia, 80% of the food supply is produced by smallholder farmers [3]. Worldwide, the sector supplies 60% of meat and 75% of dairy produce [4,5]. Thus, the improvement of this sector towards a sustainable farming system can respond to multiple Sustainable Developmental Goals [6].

In livestock production, a sustainable farming system is characterized by improved herd productivity and profitability. Reproductive performance is one of the factors influencing farm productivity because successful pregnancy and parturition rates are drivers of farm profit [7,8]. In South African smallholder farms, reproductive performance of beef cattle under extensive systems has been reported as low for over a decade with average calving rates of ≤48% [9–13]. This figure is lower than the established industry standard of 65% calving rate in commercial herds and the department of agricultures' recommended national average of 85% for beef cattle in SA [14,15]. To date, beef cattle farming in SA smallholder farms reports no measures of herd selection for reproductive performance indicators. Moreover, lack of understanding of basic herd management principles and uncontrolled breeding systems are a norm to majority of the farms [7,16–18].

Calving rate has been utilized as the single and most prominent indicator to define reproductive performances in SA smallholder herds [12,13,19,20]. However, as an effective measure of production, calving rate may have limitations in detecting underlying reproduction components. For example, assessing early warnings of reproductive diseases such as trichomoniasis and brucellosis, as well as reproduction challenges such as infertility in males and females [21]. A reflection of good herd reproduction is an indication of successful cow conception to produce viable offspring within an acceptable timeframe [22]. Therefore, there is a need to define a set of indicators, which to an extent may provide a comprehensive summary assessment defining herd reproductive performances from conception to calving. This is to provide a greater understanding of herd reproductive performance and reveal areas that require attention [23,24]. Assessment of indicators such as pregnancy rate, days open, calving interval and pregnancy losses collectively can provide detailed performance levels of fertility in the herds [18,25]. Selection to improve these performance indicators in smallholder farmers has been predicted to promote participation in designing efficient on-farm community-based breeding systems [26]. However, knowledge of herd management practices is required in understanding performance benchmarks for these indicators in smallholder farms [27].

Previous research reporting on reproductive performance in SA smallholder farms relied on farmer questionnaires and surveys. These studies are dependent on farmers' memories of their herd performances as recording has not been adequately prioritized in smallholders [11,16,28,29]. Added to these, assessments of reproductive performance are focused on single areas and this is prohibiting a holistic view of performance at national, herd and animal level [29]. The current research acknowledges these gaps and attempts to study current breeding practices by evaluating multiple performance indicators from on-farm animal records at an extended geographic area to broaden information within the SA smallholder farms. The research aims at assessing reproductive performance as defined by pregnancy rate (PR), fetal and calf losses (FC), calving interval (CI) and days open (DO) on beef cattle farms to set benchmarks for herd reproductive performance. Furthermore, the study aims to assess whether management practices have an impact on levels of performance. Setting benchmarks for these performance indicators will provide guidelines for the establishment of developmental goals and extension advisory services toward an improved and efficient on-farm breeding system in smallholder farms.

4.2 Materials and Methods

4.2.1 Ethics Study Areas

The Ethics Committee (AEC) of the University of Pretoria (NAS339/2020) granted ethical approval for the use of external data. The current study is a sub-project of the High Value Beef Partnerships (HVBP) project funded by the Australian Centre for International Agricultural Research (ACIAR). The HVBP project (LS-2016-276) is a multi-provincial project that provides opportunities for SA smallholder farmers to participate in the free-range beef cattle market targeting middle-higher income consumers. One of the prerequisites for the success of the HVBP project is the improvement of on-farm breeding systems in SA smallholder farms. Data of the current study provides baseline herd reproductive performance levels required for setting improvement goals as a starting point in building a cost-effective on-farm breeding system. Reproduction records for the current study were collected from five of the nine SA provinces (Eastern Cape, Free State, Limpopo, Mpumalanga and North West province). The provinces represented the central and eastern regions of the country.

The majority of participating herds in the central regions (Free State, Limpopo, Mpumalanga and North West province) are found in two intermixed agriculturally productive rangeland biomes, the Savanna and the Grassland [30]. The region occupies 487,535 Km^2 of land with average temperatures between 28 °C in summer and 23 °C in winter. The annual rainfall range between 632 to 1600 mm [20,31–35]. Herds in the eastern region (Eastern Cape province) were sampled from the Albany thicket, Nama-Karoo, Stromberg plateau grassland, Grassland and Savanna biome. Grassland and Savanna biome contributed to majority of the sampled herds in this region. The eastern region covers 129,825 Km^2 of land with 24 °C maximum temperature in summer and 19 °C minimum temperature in winter. The province receives annual rainfall between 400 to 600 mm [36]. A map of SA showing the provinces where data were collected is presented in Figure 3.1.

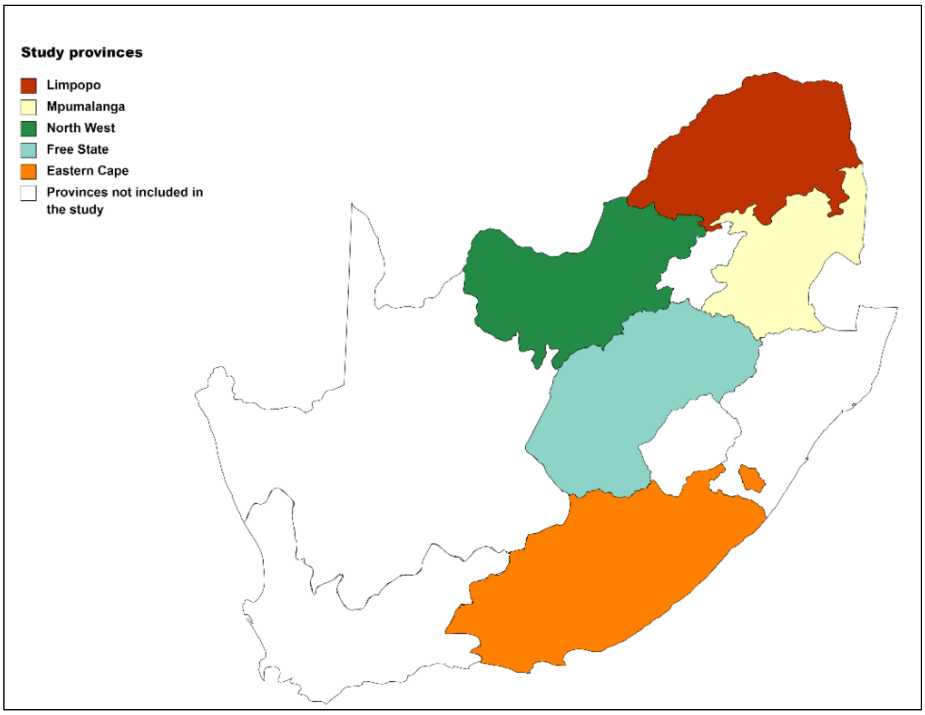

Figure 4.1. *A map of SA showing the provinces where data were collected*.

4.2.2 Sampling Procedure and Data Collection

A multi-stage sampling method was implemented for the selection of provinces, herds and breeding cows within the herds. The study provinces were selected at a national level from provinces contracted within the HVBP project. Participating beef cattle herds within study provinces were purposefully selected based on the availability of handling facilities where reproductive measures such as pregnancy diagnosis were possible, while breeding cows were selected with the requirement that they had previously given birth to a calf. Cow indicators for reproductive performance (i.e., PR, FC, DO and CI) were collected in 2018 and 2019. The PR was obtained through pregnancy diagnosis using a portable ultrasound scanner [monitor (Ibex pro, EI medical imaging, USA; transducer (5 MHz/12 cm depth)]. It was defined as the percentage of cows found pregnant from all the cows checked for pregnancy in participating herds during pregnancy diagnosis. Pregnancy diagnosis was performed after every five months for each cow for the duration of the project and gestation length for each pregnant cow was measured in months. Cows were defined as having experienced FC when they were diagnosed as pregnant to the first pregnancy diagnosis but open and not lactating at the final pregnancy diagnosis. The FC for this study was defined as the percentage of both abortion and calf mortality in a herd. That is the period from prior birth to up to the first 28 days of life. Calf mortality in the current study was recorded from birth to 21 days of life. However, peri-natal mortalities may occur from birth to up to 28 days of life, these are therefore the most vulnerable time for the calf survival in an extensive production system [37,38]. Gestation length and age of the last calf for each participant cow was used to estimate DO and CI. Indicator DO was defined as the number of days between calving and conception and CI was defined as the number of days between two consecutive calving events. The estimate for CI was calculated by adding the gestation length (remaining months to calving) with the age of the last calf in months and DO was estimated from subtracting gestation length to the age of the last calf. That is the differences between the gestation intervals from the birth month of the age of the last calf to the current gestation during pregnancy diagnosis. As a result of challenges on accurate recording of performance data by farmers, the indicators FC, DO and CI were estimates and modified into categories (Table 4.1). The variables CI and DO were divided into four groups (acceptable, concern, extended, and overly extended) to better understand the heterogeneity within smallholder farms and establish the range in which the majority of farms fell within. Additional data collected on each cow included: breed, age and parity. Breeds were recorded as ‘‘type’’ according to the strongest resemblance of a specific breed type (Table S2). Cows were raised on natural pasture with no supplementation. The above measurements were collected from 40 herds, distributed as follows: 16 herds in 2018 ((Limpopo (4), Mpumalanga (9) and North West (3)) and 24 herds in 2019 ((Eastern Cape (12), Free State (2), Limpopo (2), Mpumalanga (6) and North West (2)). Herds were visited twice a year, in autumn (March-May) for pregnancy diagnosis and again in spring (September–November) to monitor confirmed pregnancies, record pregnancy losses and identify new pregnancies. In addition, the second on-farm visit in the second year (2019) included questionnaire-guided interviews with each farmer to collect information on herd management. Farmer demographics and farm information (e.g., gender, education, off-farm income, farm engagement (part-time or full time), type of farming, herd size), as well as reproduction management data (e.g., knowledge of body condition score (BCS) prior to breeding, culling old and non-productive cows, type of breeding season, records keeping and bull to cow ratio) were recorded (Table 4.2). Breeding seasons ranged from continuous to a defined breeding season according to the farmers’ herd management preferences. The following breeding seasons were identified and recorded: January–March, March–June, August–October, September–December, November–February and December–March depending on the farmers’ choice.

Table 4.1: Categories of reproductive performance indicators.

Indicators	Categories	Duration (Days)
PR	Pregnant Not pregnant	-
FC	Aborted Calf mortality	- 1–7 8–14 15–21
DO	Accepted Concern Extended Overly extended	121 ≥182 ≥243 >304
CI	Accepted Concern Extended Overly extended	365 ≥425 ≥456 >608

4.2.3 Data Preparation and Editing

The validity and quality control of data in this study were guided by the overall HVBP project specifications including (1) the ability of farmers to finish their cattle on natural pastures for three years to meet free-range market specifications, and (2) herd health in line with the department of agriculture and the Animal Diseases Act 35 of 1984. The Act state that herds that test positive for venereal diseases such as contagious abortion (CA+), Trichomoniasis and Campylobacter must be referred to the state veterinarian for further evaluation. Given this, herds with venereal diseases were excluded from the study post first collection until they were cleared by the state, which greatly affected the number of repeated measurements. The final specification was the market price of the animal at 420 kg live weight at 3 years of age presented to the farmers. Some farmers were in agreement with the market price and others were not. This resulted in withdrawals of some farmers from the project.

The above specifications influenced the amount of data collected for this study as herds withdrew voluntarily or owing to herd health challenges, making them unavailable for data collection follow-ups, as shown in Figure 2 below. As a result of the above explained challenges, 5 of 16 herds collected in 2018 were repeated in 2019. Data were pooled across five provinces to report reproductive performance across a broader geographic spectrum in order to represent national reproductive performance in smallholder farms. Furthermore, the study provides an insight into reproductive performance at a provincial level with selective provinces representing the central and the eastern regions. Provincial representation was based on provinces with six or more herds where data were successfully collected twice a year (Eastern Cape and Mpumalanga provinces). At a national level, PR proceeded with all 3694 records collected from 40 herds. Indicator DO, CI and FC were assessed on 1401 records from 24 repeated herds (Autumn and Spring collection). The provincial level continued with 1003 records from Mpumalanga (central region) and Eastern Cape (eastern region) provinces. The flow of data is represented in Figure 3.2.

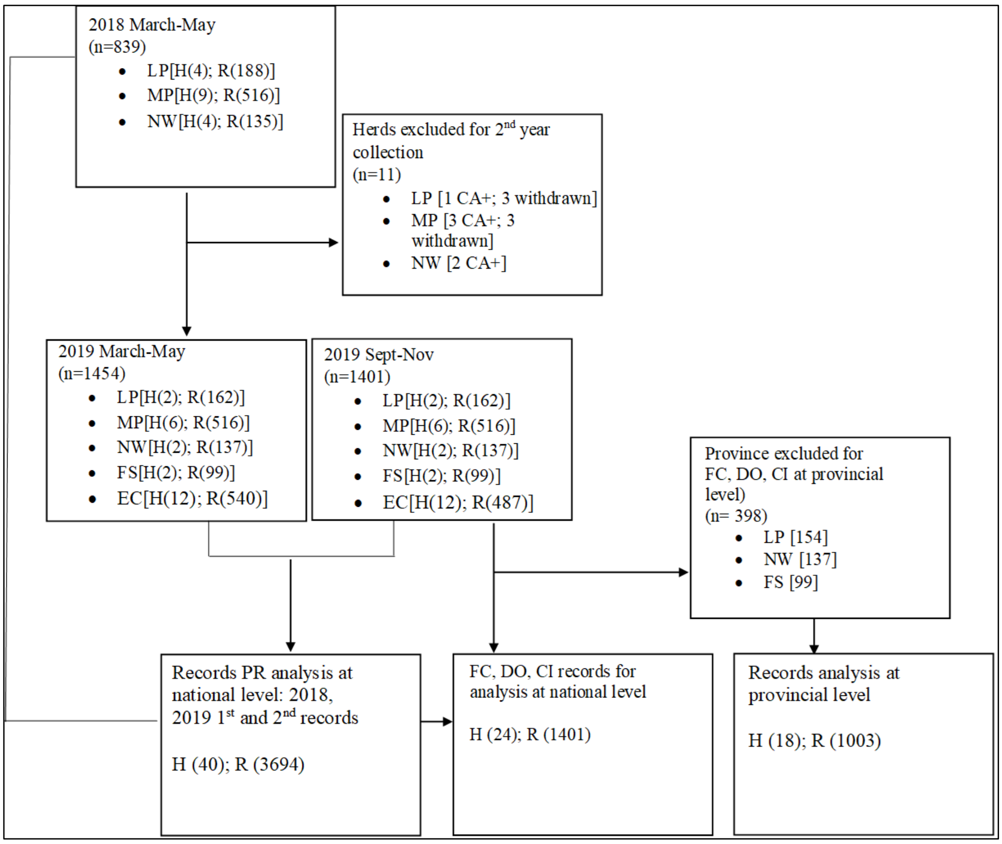

Figure 4.2. Demonstrate the flow of the data collected for the study in 2018 and 2019. Note: n = the number of records (R) from participating herds (H) in five provinces (EC = Eastern Cape; FS = Free State; LP = Limpopo; MP (Mpumalanga) and NW = North West) prior analysis of PR, FC, CI and DO.

4.2.4 Statistical Analysis

Data were analyzed using Statistical Analysis System (SAS) 9.4. Frequency tables were used for summary statistics to show average performance levels. Chi-square test was performed to test for equal proportions.

A multilevel logistic regression model with random effects was applied using GLIMMIX procedure to assess measures of association between management factors and performance indicators (PR, FC, CI and DO). The model included provinces as random effects and management factors were fitted as fixed effects. Farms were considered as the experimental unit. An empty unconditional model without any predictorsserved as the starting point for the modeling procedure. This model provided a general estimation of the reproductive performance (PR, FC, CI, and DO) for farms at a typical province and information regarding the performance variation between provinces. Afterward, the model-building process continued to include herd management variables as fixed effects while controlling for provinces to estimate factors associated with performance measures at a national level. The regression model computed a cumulative ordinal regression procedure for the indicators CI and DO and a binary logistic regression procedure for the indicators PR and FC to estimate management factors associated with performance indicators. The binary model was described as follows:

$$In\left(\frac{P(Y_{ij=1})}{(Y_{ij=0})}\right) = a_i \ + \beta_{xij} + u_{ij}$$

Yij is the binary indicator of the *ith* farm in the *jth* province, with *Yij* = 1 representing the probability of success (pregnancy/loss) and *Yij* = 0 otherwise. Additionally, a_i is the intercept and β is the regression coefficient of the *xij* covariates. Furthermore, u_{ij} is the random effect representing the effect of the *jth* province.

The cumulative logit procedure simultaneously estimates multiple equations for the comparison of the cumulative odds of high versus low CI and DO categories. For this study, the predictor variable CI and DO have four categories as follows:

$$j = \begin{cases} Accepted \\ Concern \\ Extended \\ Overly\ extended \end{cases}$$

where the overly extended category represents high outcome category and accepted category represent low outcome category.

Therefore, the logits regression model used for CI and DO was defined as:

$$\left(\frac{P(Y \geq j)}{1-P(<j)}\right) = a_{j+\beta_x+u_{j,}} \ (j = (1,2 \ldots \ldots j-1))$$

where *p* (*Y* ≥ j) is the odds of the event of the category *j* of a given predictor variable (CI and DO); *αj* is the intercept parameter and *β* is the vector of regression coefficients corresponding to *x* covariates and u_{ij} is the random effect representing the effect of the *jth* province. The model specifies that the intercept parameter differs across all *j* categories; however, the *x* covariates remain constant. The odds of the highest *j* level category (overly extended) was used to compare with the lower level category (accepted). Variables included in the models are presented in Table 4.2.

Table 4.2: Variables included in the regression model.

Variable	Description
Gender	1 = male, 2 = female
Farm engagement	1 = part-time, 2 = full time
Education	1 = primary, 2 = high school, 3 = tertiary, 4 = no school
Off-farm income	l = Employment, 2 = Social grant, 3 = pension and business
Herd size (no = cattle)	1 = small (1–50), 2 = medium (50–100), 3 = large (100–200), 4 = extra-large (over 200)
Type of farming	1 = mixed = livestock and crops, 2 = livestock = cattle, goats, sheep
Bull to cow ratio	1 = ideal = (1:30), 2 = under = (1:15) and 3 = over = (1:70)
Culling old and non-productive cow	1 = yes, 2 = no
Body condition scoring prior breeding	1 = yes, 2 = no
Keeping calving records	1 = yes, 2 = no

4.2.5 Determining Targeted Achievable Levels of Performance

To benchmark useful targets for beef cattle performance indicators in smallholder farms, the 25th, 50th (median), and 75th percentiles were chosen as summary statistics for all performance indicators. The preferred 25% of the herd for each performance indicator was used to determine the target levels for that indicator. This was a value higher for the first quartile (25%) or third quartile (75%). For this study, the 25th (lower) percentile was the target achievable level of indicators FC, DO and CI, while the 75th percentile (higher) value was the target achievable level for PR [39].

4.3 Results

The summary of reproductive performance records in smallholder herds at national level is presented in Table 4.3. Overall, majority of smallholder herds recorded 50% PR with 12% FC (abortion and calf mortality) and high CI (62%) and DO (39%) in the overly extended category (>608 and >304 days) (Figure 4.3).

Table 4.3: Summary of reproductive performance of smallholder beef cows at national level.

Parameter	Herd	% of Parameter Measured
PR	40	50
CI	24	62
DO	24	39
FC	24	12

Note: % of parameter measured is the frequency % of the performance indicators (PR, CI, DO and FC).

Table 4.4 present a summary of reproductive performance records in smallholder herds at provincial level. Overall, PR yielded 61% with FC of 10% and majority of the herds recorded overly extended CI (55%) and DO (46%) days (Figure 4.3).

Table 4.4: Summary of reproductive performance of smallholder beef cows at provincial level.

Reproduction Parameters	Herds	% of Parameter Measured
PR	20	61
CI	20	50
DO	20	39
FC	20	10

Note: % of parameter measured is the frequency % of the indicators (PR, CI, DO and FC).

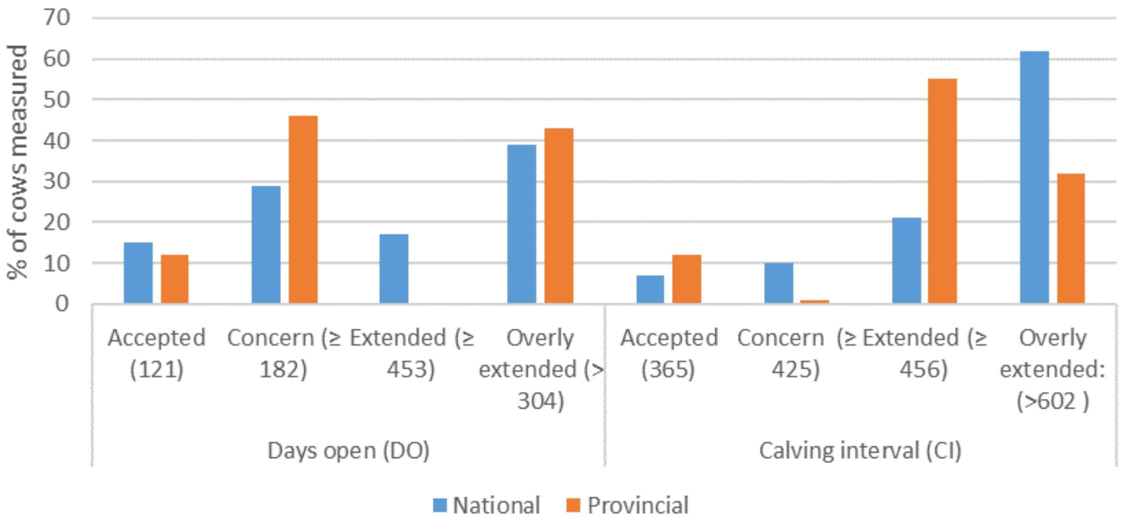

Figure 4.3. Measures of DO and CI levels in beef cattle farms at national and provincial level. DO and CI are recorded in days. The blue bar = DO and CI at national level and the orange bar = provincial level.

Summary of incidence of FC at provincial and national level is presented in Table 5. The chi-square test of equal proportions showed that, the incidence of FC was higher in cows that calved and lost the calf compared to aborted cows (P < 0.01). The majority of calves died during the 1–7 days period (national (5%) and (4%) provincial level) compared to during 8–14 days (national (3%); provincial (3%) and 15–21 days (national (1%); provincial (1%) (Table 4.5).

Table 4.5: Occurrence of fetal and calf losses in beef cattle smallholder herds.

	No. Cows Pregnant	**No. Cows Calved (%)**	**No. Cows with FC (%)**	**Period of FC (%)**				***p*-Value**
		Calving records		Aborted	1–7 Days	8–14 Days	15–21 Days	
National	918	805 (88)	113 (12)	35 (4)	45 (5)	23 (3)	10 (1)	<0.0001 **
Provincial	691	620 (90)	71 (10)	15 (3)	30 (4)	17 (3)	9 (1)	<0.0001 **

Note: Statistically significant at level (** $p < 0.01$; * $p < 0.05$).

Figure 4.4 presents the interaction between breeding season and performance indicators (PR and FC) in smallholder farmers. Majority of incidences of FC and non-pregnant cows in the herds occurred during continuous breeding season as opposed to defined breeding season.

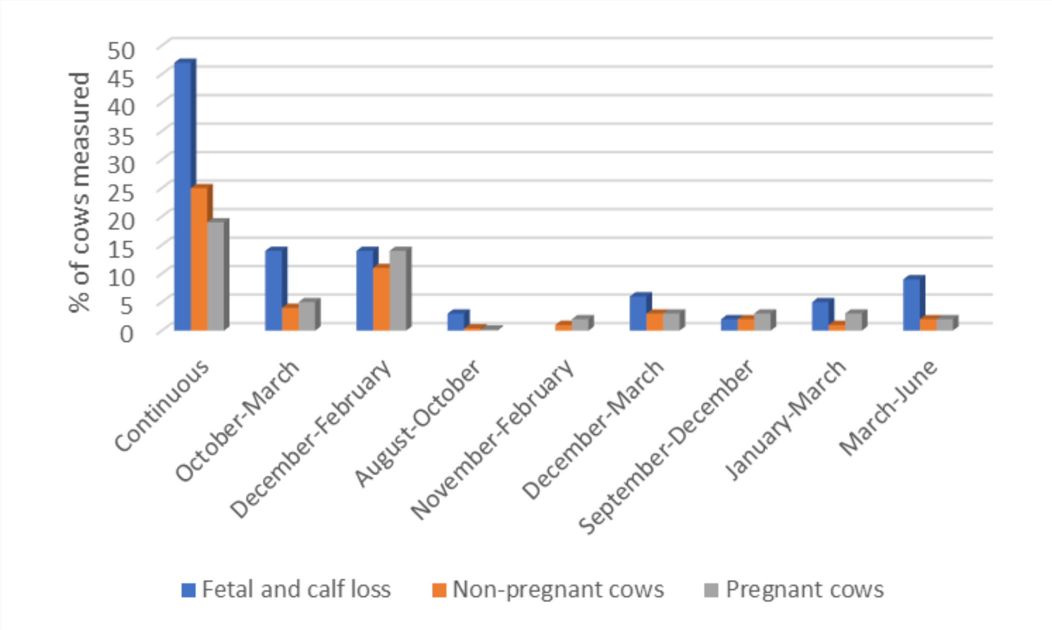

Figure 4.4 Occurrence of FC, non-pregnant and pregnant cows by breeding season.

Table 4.6 represent the unconditional logistic regression model to test for the likelihood and variation of performance indicators between provinces at provincial level. The model revealed that at the provincial level, the probabilities of PR and FC are 0.62 and 0.09, respectively. Moreover, the cumulative likelihood of being in the overly extended CI and DO versus the accepted level were 0.69 and 0.89, respectively. The model shows no significant difference among provinces ($p > 0.05$), indicating that the likelihood of the performance indicators is constant across Eastern Cape and Mpumalanga province. Similar to the provincial level, there were no significant differences between the provinces (Eastern Cape, Free State, Limpopo, Mpumalanga and North West) on performance indicators at the national level ($p > 0.05$). The model revealed that the probabilities of PR and FC are 0.48 and 0.13, respectively. Moreover, the cumulative likelihood of being in the overly extended CI and DO versus the accepted level were 0.92 and 0.83, respectively, as shown in Table S1.

Table 4.6: Summary of the likelihood and variation of reproductive performance of smallholder beef cattle herds at provincial level (Mpumalanga and Eastern Cape).

			95% CI				
Indicator	**Estimate**	**Standard Error**	**Lower**	**Upper**	***p*-Value**	**PP**	**Variation**
PD					0.1856	0.62	0.02
Mpumalanga	0.2539	0.202	−0.1439	0.6518	0.2107		
Eastern Cape	−0.2555	0.2028	−0.6535	0.1425	0.2080		
FC					0.1869	0.09	0.13
Mpumalanga	0.6156	0.4821	−0.3310	1.5621	0.2021		
Eastern Cape	−0.5853	0.4806	−1.5289	0.3582	0.2236		
DO					0.2614	0.89	0.04
Mpumalanga	0.09073	0.1067	−0.1187	0.3002	0.3955		
Eastern Cape	−0.09099	0.1069	−0.3007	0.1187	0.3948		
CI					0.3324	0.69	0.02
Mpumalanga	0.2600	0.2036	−0.1395	0.6594	0.5931		
Eastern Cape	−0.2602	0.2036	−0.6596	0.1393	0.5930		

Note: Statistically significant at level ($p < 0.05$). SE = Standard Error, PP = predicted probabilities, CI = confidence interval.

The target level of performance for PR was (54%) at the 75th percentile and FC recorded (1.4%) at the 25th percentile. At the 25th percentile, DO and CI target levels yielded 152 and 425 days, respectively (Table 4.7).

Table 4.7: Target level of reproductive performance in smallholder herds at 25th to 75th percentiles.

Parameter	No. Records	No. Herds	25th Percentile (Lower Quartiles)	50th Percentile (Median)	75th Percentile (Upper Quartiles)	Target Level
PR	3694	40	40	44	54	54
FC	918	24	1.4	1.9	2.4	1.4
DO	1344	24	152	212	516	152
CI	1344	24	425	516	608	425

Note: Target level is the level of performance based on either 25th or 75th quartile.

Table 4.8 represents tests of association between herd indicators and household characteristics. There was no association ($p > 0.05$) between gender, farm engagement and off-farm income with PR within herds. Performance indicator DO was significantly different between different off-farm income ($p < 0.05$). An association was observed between CI and education level, off-farm income, herd size ($p < 0.01$), and gender ($p < 0.05$). Furthermore, FC was not different between different gender however, different ($p < 0.01$) between off-farm income and herd size.

Table 4.8: Summary of association between herd dynamics and the odds of performance in smallholder beef cattle.

Parameters	Gender	Education	Off-Farm Income	Herd Size	Farm Engagement	Type of Farming
PR	NS (0.7289)	<0.0001 **	NS (0.0581)	0.0092 **	NS (0.3886)	<0.0001 **
OR	0.964	3.044	1.061	1.115	1.116	1.838
FC	NS (0.0696)	NS (0.7491)	<0.0001 **	0.0003 **	NS (0.2469)	NS (0.1173)
OR	3.112	0.857	4.560	0.347	1.831	0.420
DO	NS (0.1595)	NS (0.1604)	0.0302	NS (0.1301)	NS (0.9747)	NS (0.5246)
OR	1.504	1.531	2.580	1.170	0.991	1.170
CI	0.0025	<0.0001 **	<0.0001 **	<.0001 **	NS (0.3317)	0.0216 *
OR	2.937	4.078	0.717	0.333	1.418	1.931

Note: OR= odds ratio, Significant at (** $p < 0.01$), (* $p < 0.05$) and NS= not significant at $p > 0.05$.

The logistic regression model analysis for the relationship between management factors and performance indicators is shown in Table 4.9. There was an association between PR and culling old cows ($p < 0.0022$), and BCS prior breeding ($p < 0.033$). There was an increase in the odds (OR = 3.078) of FC for farmers who do not practice BCS prior to breeding. Farms that do not cull old cows and do not practice BCS prior breeding with a low bull to cow ratio had an increase in the odds (OR = 2.263; 1.306 and 2.332) of overly extended CI. Similarly, ex-tended DO was observed on farms that do not practice culling non-productive cows [OR = 1.880] and where calving records are not kept (OR = 2.274).

Table 4.9: Summary of association between management factors and the odds of performance in smallholder beef cattle.

Management Variables	Indicators	95% CL				
		OR	SE	Lower	Upper	*p*-Value
	PD					
Culling old cows						0.002
YES vs. No		0.667	0.1323	0.515	0.865	
NO		Ref				
BCS prior breeding						0.033
YES vs. No		1.362	0.1452	1.025	1.811	
NO		Ref				
	FC					
BCS prior breeding						0.039
NO vs. YES		3.078	0.5442	0.05621	2.1922	
YES		Ref				
	CI					
Culling old cows						0.002
No vs. YES		2.263		1.341	3.819	
YES		Ref				
BSc prior breeding						<0.001
NO vs. YES		1.306	0.2421	0.191	0.493	
YES		Ref				
Bull to cow ratio						<0.001
Bull to cow ratio 3 vs. 2		2.332	0.1736	0.9500	1.6313	
Bull to cow ratio 1 vs. 2		0.275	0.7089	0.7093	1.6605	
	DO					
Culling non-productive cows						0.002
NO vs. YES		1.880		−0.1818	0.6191	
YES		Ref				
Calving records						0.005
NO vs. YES		2.274	0.2363	0.277	0.699	
Yes		Ref				

Note: Statistically significant at level ($p < 0.01$; $p < 0.05$). SE = Standard Error, OR = odds ratio, CI = confidence interval.

4.4 Discussion

The objective of this study was to assess reproductive performance as defined by PR, FC, CI and DO in SA smallholder farms to benchmark reproductive performance. The study presented reproductive performance norms and benchmarks for reproductive performance of beef cattle managed on natural pastures at an extensive system in smallholder farms of SA. The study also provided insight on associations of farmers' management practices within the recorded performance indicators. Smallholder farmers need these benchmarks to identify current management weaknesses on herd reproductive performance and to provide a structured approach in addressing areas requiring improvement. In the current research, herd management influenced benchmarks of performance indicators. Reproductive performance in the study was categorized by low PR, high FC, extended DO and CI.

The overall annual PR reported at both national and provincial level was comparable with those reported in Bangladesh, Brazil and SA [21,40,41]. This level of performance is lower than the >75% recommended achievable performance of PR for beef cattle at extensive systems in tropical regions such as Australia [39,42,43]. The causes of variation in performance may be explained by consequences of chosen management practices such as uncontrolled breeding season by majority of the smallholder farmers in this study. It is to note that continuous breeding season in the current study reported more non-pregnant than pregnant cows and high percentage of FC. This highlights management flaws and may reflect on the reported limited advisory and extension services on farm management to smallholder farmers [44].

The current study reported FC losses that are consistent with the reports from past decade (12.83%) in smallholder beef cattle farms of SA [21]. This amplifies no improvement within the past decade and a half. South Africa is reporting annually higher losses than countries such as Brazil 4.1% and Portugal 5.7% [45,46]. Records in these countries may be influenced by openness to adoption of developmental programs such as the Welfare Assessment Protocol applied in New Zealand and Namibia. Application of this protocol assists in combating reproduction failures and the aforementioned countries are currently achieving <2.5% losses [27,47]. Similar to the current study, Australia reported majority of the losses to have occurred in the first week of calving in an extensive production system [38]. This area signifies the need for improvement to reduce calf mortality and improve weaning rates according to the recommended 2% pre-weaning mortality rate for beef cattle by the department of agriculture in SA [15].

Calving interval of 365 days for extensive beef cattle breeds in Southern Africa has been reported as impractical due to environmental stressors, therefore, a more reasonable range in this region may fall within 398 to 477 days [48]. This is in agreement with the targeted level derived for smallholder farms in this study. However, 75% of the herds in the current study obtained extended CI and DO (608 and 334 days), respectively, as achievable levels. This indicates that re-conception is potentially one of the major areas that require significant management interventions. The extended CI and DO highlight that farmers are either not aware of the cost to infertility or may not have the necessary skills and knowledge to manage it. Shortening these periods through better management can be beneficial on production and subsequently increase herd profit [39]. The study further revealed that farmers' decisions of not culling old and non-productive cows, and not recording animal performances in herds needs to be revised as it consequently puts smallholder farmers at the 75th percentile for extended DO and CI periods. Amongst current management practices in smallholder farms, lack of knowledge of BCS prior to breeding by farmers in the current study was associated with increased FC and extended CI levels. The report of [49], indicated that for each BCS lost, postpartum anestrus is extended by 43 days and cows were further subjected to pregnancy losses [50]. Moreover, the study of [50] indicated that cows under 2–3 BCS of a five point scale was associated with the highest (14.91%) pregnancy losses in dairy cattle. That is, postpartum nutritional deficiency in cattle may impede uterine involution and expose cows to metabolic and infectious diseases which may result in pregnancy failure [51]. Therefore, a shift in management and receptivity to development interventions should be prioritized. A report on Indonesian beef cattle by [52], suggested that cost-effective interventions such as a defined breeding calendar, suckling restriction period, and pre and post-calving nutrition should be implemented for fertility improvement. A breeding calendar that is in concurrence with the rainy season is of most importance and can assist balance peak nutritional demands with the provision of enough grazing pasture preferably at late pregnancy and early lactation to promote re-conception [53,54]. Moreover, training of BCS and the importance of supplementation to maintain BCS primarily at the beginning of the breeding season to support pregnancy requirements and post-calving for support of estrus is encouraged [55]. These interventions may not only assist beef cattle smallholders in SA but other tropical countries such as Somalia, Vietnam, and Indonesia reporting similar results [56–58].

Record keeping is critical for analyzing areas of concern affecting farm growth. The present study has found that overly extended DO results from no record keeping. This expands the need for more awareness efforts emphasizing the importance of excellent record keeping towards the establishment of farm improvement [59]. Recording systems are gradually introduced in developing countries from paper to digital applications. The beef cattle farm management recording system (BCFM) in Thailand and the SA Long-term EU-Africa research and innovation Partnership on food and nutrition security and sustainable Agriculture (LEAP Agri) project is to gain popularity in smallholder farmers as a tool for record keeping [60,61]. These tools are to encourage farmers in collecting data and keeping up to date with farm productions in their pockets. Moreover, participation of farmers in programs such as the Agricultural Research Council (ARC) Kaonafatso ya Dikgomo (KyD) (Animal Recording and improvement Scheme) program in SA will not only provide recording knowledge but also assist farmers to practice good animal husbandry [62]. A proper recording will alert the farmers to reproduction failures such as non-productive cows which contribute to the overcrowding of reportedly strained rangeland of SA smallholder farms [62]. The results of the current study highlighted no association between gender and majority of reproductive performance as compared to those reported by [63]. This highlights that determination and drives to achieve performance are not gender dependent and that women are just as capable as men unlike in previous report by [9] where men outperformed women by over 50% in farm production. The current study further showed that larger herd sizes are associated with increased PR; however, were associated with higher FC and longer CI. The increase in FC and extended CI may indicate the lack of knowledge on herd management on production outputs and that large farms can have high marketable outputs however when the farm is managed well and with appropriate expertise [64].

Initiatives such as the Integrated Village Management System (IVMS) in Indonesia and the community-based breeding programs have improved reproductive management in village farms [65]. These programs promote good husbandry practices such as supplementary feeding of cows during late pregnancy and early lactation, and weaning calves at 6–8 months old for maintenance of BCS to promote re-conception. Through the IVMS program, calving rate in Indonesia has increased by 70% and 13.43 months of calving interval is observed [53]. Additionally, in Bali through supplementation feeding of breeding cows, smallholder farmers improved re-conception to up to 20% [66]. It is the adoption of such initiatives in SA that can assist in improvements of beef cattle reproduction. Lastly, recognition programs for excellent herd performance of smallholder farmers can implement a change in attitude on management behavior thereby creating a sense of belonging and reflecting the importance of smallholder farmers' contribution to the beef cattle industry.

In SA smallholder farms, strategies for improving herd reproductive performance in an extensive farming system may include: understanding the significance of breeding season and modifying breeding season to match the quality of summer grazing. Additionally, supplementary feeding especially for high demanding animals such as pregnant and nursing cows is encouraged. This is for the maintenance of BCS and reducing the re-conception norm of two years and more in SA. For farm decision-making, farmers should invest in keeping thorough breeding records, as it is crucial in identifying challenges such as old and non-production cows, moreover through recording herd improvements can be identified. Extension and advisory officers may convey the outcome of this study and provide improved herd strategic management through open platforms such as farmers' days, workshops and farmers study groups. These platforms may also encourage interactions with farmers and strengthen information chain between extension officers and farmers.

4.5 Conclusions

The study found that SA smallholder farmers at national and provincial level achieved performance levels for PR within the 50–60%, FC in the 10–12% and extended calving and days open within 608 and 334 days, respectively. The present study was also able to highlight key areas that require attention, firstly the period between calving to re-conception since majority of the herds achieved extended CI and DO. Secondly, the period between 1–7 days post calving due to more calf losses recorded in the first week of calving and finally the practice of continuous breeding season necessitates attention because of an increased number of non-pregnant cows obtained by continuous breeding season. Furthermore, the targeted performance benchmarks in the study highlighted that optimal reproduction in smallholder herds can be possible however with sound management structure in place. That is a management system that takes account of non-productive cows, defined breeding season, record keeping and awareness of herd nutrition status primarily prior to breeding. The defined areas of concern in the study provide an opportunity for the industry' s extension and advisory services to know where to start in making management interventions towards improving reproductive performance benchmarks. It is recommended that further studies should take into account animal risk factors and environmental factors to refine the herd reproductive performance benchmarks and provide more insight into the reproductive performance of beef cattle in smallholder herds.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: Summary of the likelihood and variation of reproductive performance in smallholder beef cattle herds between provinces (Eastern Cape, Free State, Limpopo, Mpumalanga and North West). Table S2: cow characteristics (breed, age, parity).

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Supplementary material

Table S1. Summary of the likelihood and variation of reproductive performance in smallholder beef cattle herds between provinces (Eastern Cape, Free State, Limpopo, Mpumalanga and North West).

Indicator	Estimate	Standard error	95% CI of OR Lower	Upper	P value	PP	Variation
PD					**0.0717**	**0.48**	**0.03**
Mpumalanga	0.5066	0.1538	0.2050	0.8081			
Eastern Cape	-0.03525	0.1550	-0.3391	0.2686			
Limpopo	-0.3704	0.1621	-0.6883	-0.05251			
North West	0.07386	0.1646	-0.2489	0.3966			
Free State	-0.1724	0.2045	-0.5734	0.2286			
FL					**0.0921**	**0.13**	**0.13**
Mpumalanga	0.2252	0.3608	-0.4829	0.9334			
Eastern Cape	-0.9643	0.3964	-1.7423	-0.1862			
Limpopo	0.9146	0.4028	0.1240	1.7052			
North West	0.3184	0.3960	-0.4589	1.0956			
Free State	-0.3833	0.4888	-1.3425	0.5760			
DO							
Mpumalanga	0.3936	0.2271	-0.05201	0.8392	**0.0926**	**0.83**	**0.27**
Eastern Cape	0.07890	0.2266	-0.3657	0.5235			
Limpopo	-0.07653	0.2412	-0.5497	0.3966			
North West	0.4069	0.2522	-0.08782	0.9017			
Free State	-0.8030	0.2893	-1.3705	-0.2354			
CI					**0.0923**	**0.92**	**0.06**
Mpumalanga	-0.1497	0.2271	-0.5952	0.2958			
Eastern Cape	-0.2402	0.2285	-0.6885	0.2082			
Limpopo	-0.4831	0.2539	-0.9811	0.01495			
North West	0.09089	0.2462	-0.3921	0.5738			
Free State	0.7949	0.2830	0.2398	1.3499			

Table S2. Cow characteristics.

Characteristics	**Frequency %**
Breed type	
Nguni type	9.37
Afrikaner type	5.32
Angus type	3.62
Beef master type	15.28
Bonsmara type	39.85
Boran type	1.95
Brahman type	3.79
Drakensberger type	4.74
Hereford type	4.74
Hugenoot type	1.28
Simbrah type	3.65
Simmental type	6.41
Age	
3	3.18
4	12.85
5	27.43
6	25.31
7	19.85
8+	11.38
Parity	
1	31.64
2	31.93
3	21.55
4	12.48
5+	2.40

Chapter 5

Critical review and conclusion

5.1 General Discussions and Recommendations

Sound reproductive performance highlights the strength of any beef cattle production and demands routine monitoring to ensure productivity and economic viability of the farm (Fernandez-Novo *et al.*, 2021). The mission of the SA Department of Agriculture Land Reform and Rural Development is to support cattle smallholder systems in moving towards sustainable farming and contribute to the economy of rural communities (Zantsi & Bester, 2019; DALRRD, 2020). Improvements, especially in reproductive performance are of utmost importance for the development and growth of any farm (Kaurivi *et al.*, 2020). For two years, the High-Value Beef Partnerships (HVBP) project has monitored reproductive performance in smallholder farms to create a unique database of key performance indicators for the assessment of herd reproductive performance. The project intended to analyse current reproductive performance, identifying achievable levels of performance and multiple factors that may negatively impact reproduction in smallholder beef cattle farms. The aim of the project was to recommend best practices for management of reproductive performance in smallholder farms. A unique feature of the current research is the development of a practical and user-friendly guidelines for reproductive performance in smallholder farms. These guidelines are compiled from findings in Chapters 3, 4 and supplementary findings in Addendum B. The guidelines are presented in Addendum C. They provide practical farm information on aspects such as breeding season, herd nutrition (BCS), oestrus behaviour and pregnancy evaluation, weaning and re-conception, breeding bull management and records keeping. For a better understanding of the study population group, the current study used a structured questionnaire (Chapter 3) to outline farmers' demographics, farming objectives and constraints in smallholder beef cattle production.

The farmers' demographics revealed that males in their 60's dominate in beef cattle farming, while young people and women make up a relatively small percentage. This is similar to research reported by Cheteni & Mokhele (2019). Although the current research has demonstrated that women engagement in agriculture is still limited, no difference in reproductive performance between female and male farmers was found in this study. As a result, this emphasizes the need for future programs to increase opportunities for female participation in smallholder beef cattle farming (Motiang & Webb, 2016).

Women in smallholder farming systems are known to be the producer of about 70% of food in Africa and generate family income (van der Walt, 2021). In Pakistan, it has been highlighted that women spent approximately 6.9 hours on livestock activities daily as compared to the two hours spent by men (Usman *et al*., 2022). Despite their commitment and determination, women in agriculture are constrained by multiple factors such as lack of land equality. Although the present study provinces do not provide information about gender-based land ownership, a recent investigation by the Northern Cape Department of Agriculture revealed that men own 73% of the land, providing insight into gender-based land ownership in SA (Maltitz & Bahta, 2021). Land equality is one of the major factors contributing to disempowerment of women according to the Women's Empowerment in Agriculture Index (A-WEAI) score (Maltitz & Bahta.2021).

A collaborative effort between United Nations women (UN Women) and Standard Bank was initiated to empower over 50,000 women farmers in Uganda, Malawi, Nigeria and SA (van der Walt, 2021). This partnership aimed to support women through climate-smart agriculture projects aiming to enhance agricultural productivity among smallholder farmers in the face of the changing climatic conditions. The project provided valuable skills and resources to enable these women to improve their productivity in farming. Since its inception, the project has made a significant impact, benefitting many women in different regions. Approximately 6,000 women in Malawi, 2,300 in Nigeria, 1,400 in Uganda and 2,753 in SA have already benefited from these various climate-smart farming projects (van der Walt, 2021). The initiative has not only improved women's livelihoods however, contributed to sustainable agriculture and pursuit of the Sustainable Development Goal 2, which aims to achieve zero hunger (Gil *et al*., 2019). Promoting gender equality as outlined in Sustainable Development Goal 5 and the provision of equal access to productive resources will move smallholder agriculture one step closer to advancing sustainable farming and addressing the global challenge of hunger (Singh *et al*., 2022; Agarwal, 2018).

The majority of farmers indicated that their primary farming objectives for beef cattle production were sales (78%) and improving their local economy (37%). This is consistent with the government's goals for the growth and transformation of local communities through smallholder farming. However, constraints observed in the study such as lack of farm information, understanding of farm business, and lack of information communicated by government may defeat this goal. All of these constraints have an impact on other important farm data, such as effective reproduction management which is a crucial element in the productivity and financial success of a cow-calf production system (Mutenje *et al.,* 2020). The reproductive performance of animals is greatly influenced by fundamental farm management knowledge (Birhan *et al*., 2023). For instance, inadequate knowledge and understanding of breeding seasons as observed in majority of farms (91%) practicing continuous grazing in the current study may result in unfavourable calving seasons, reduced calf weight and increased calf mortalities (Molefe *et al*., 2017). Additionally, lack of knowledge on proper recording of farm information including breeding dates and weaning plans in majority of farmers contributes to a prolonged inter-calving period of two years in smallholder farms (Khapayi & Celliers, 2016; Nengovhela *et al*., 2021).

Historically, reproductive performance in smallholder farms was measured through farmers' surveys focusing on a single region and in one trait (calving rate) in SA (Nowers *et al*., 2013; Nengovhela *et al*., 2021). However, the current study takes a more comprehensive approach by simultaneously monitoring reproductive performance on multiple indicators, including pregnancy rates, fetal and calf losses, days open, and calving intervals. Through analyzing on-farm cow records, the current research has contributed valuable insights into beef cattle smallholder reproductive performance, revealing at national-level reproductive norms of 50% PR, 12% FL, an average of 304 DO, and a CI of 602 days. Moreover, the study provided for the first-time benchmarks for reproductive performance for either top 25% of the lower or higher level of performance.

However, it is essential to note that the availability of reproductive data in the current study was limited for other provinces, which affected the power of statistical analysis, particularly when evaluating performance on a provincial basis to cater for the difference in geographic areas. In the second year of the study (2019), data collection was limited by a sizeable number of farmers withdrawing from the project based on either the market specifications imposed on the daily farming practices or herd health-related challenges, as outlined in Chapter 4. In response to these challenges, we aggregated data from all five provinces to estimate reproductive performance at the national level. The study employed an unconditional logistic regression model to test for the probability and variation of performance indicators between provinces (Ene *et al*., 2015). The model showed no significant difference in performance between provinces, thus validating the data.

The current reproductive performance norms of the measured indicators in smallholder farms of SA were lower than those achieved in extensive systems of other countries such as New Zealand and Australia (Kaurivi *et al.*, 2020; McCosker *et al.*, 2022). Reports originating from the Australian cash cow project have put forth recommendations regarding attainable levels for beef cattle extensive production systems in tropical countries. These recommendations include a desired pregnancy rate of ≤ 75% and a minimal foetal and calf loss rate of less than 5% (McGowan *et al.,* 2014; McCosker *et al.,* 2020). Similarly, Webb et al. (2017) have proposed a calving interval of 477 days as achievable for extensive production systems in tropical regions. However, the established benchmarks of reproductive performance in the current study suggest that there is scope for enhancing reproductive performance in smallholder farms which can aid in setting improvement goals and providing guidance for future management actions. Additionally, observations from smallholder farms in low-input countries like Bali, Chile, and Indonesia have emphasized that better management practices such as selective breeding season and feed supplementation can lead to notable improvements. These improvements include a recorded pregnancy rate of 70-80%, a reduced postpartum anestrous interval from 198 to 98 days, and a decreased duration of days open from 217 to 118 (Ratnawati *et al*., 2016; Müller-Sepúlveda *et al*., 2020).

Implementing optimal reproductive performance requires addressing risk factors that have been found to limit reproductive performance (Chapter 4). This strategy ensures that challenges affecting reproduction are identified in order to manage performance for improvement. The multilevel logistic regression model analysis for animal and management factors associated with reproductive performance (Chapter 4 & Addendum B) in this study has provided insight into understanding major determinants for reproductive performance. The main outcome emphasized that improved management on factors such as BCS, breeding season, breed type and culling of old and non-productive cows may reduce extended CL, DO, FC and increase PR in smallholder farms as these factors were found to have the most influence on reproductive performance indicators. Details on the full description of the identified factors from the model analysis are provided in Addendum B.

The model findings have led to recommendations for improving the reproductive norms in smallholder farms as per the established benchmarks identified in Chapter 4. It is recommended that increased pregnancy rate and reduced CL, DO and FL in smallholder farmers would be achieved through the use of indigenous breeds that better adapted to their local environment, keeping cows in BCS 3, implementation of a breeding season that makes use of available good quality pastures and culling of old and non productive cows (Chapter 4 & Addendum B).

The model has predicted BCS 1 and 2 to be associated with increased FL, CI and DO in the current study. Body condition score (BCS) plays a pivotal role in the reproductive performance of any beef cattle farming system (Domínguez-Muñoz *et al*., 2018). It significantly impact various aspects essential for successful reproduction including energy reserves, hormonal regulation, calving ease, postpartum recovery and milk production capacity (Wang *et al*., 2019). Important management practices such as implementing regular body condition scoring program to assess the fat cover and overall body condition of breeding cattle may assist in identifying animals that are under or over-conditioned, and allow for adjustments to feeding requirements (Addendum C) (Tait *et al*., 2017). In previous studies conducted by Akbar et al. (2015) and Nazhat et al. (2021), it was emphasized that the implementation of a successful body condition monitoring program can be achieved through strategic grouping of cows according to their nutritional status and providing them with feeds tailored to meet their specific dietary requirements. Moreover, cows in high maintenance phases such as pregnancy and lactation, along with first-calvers that require additional feeding for maintenance purposes can be grouped together. Additionally, encouraging early weaning is recommended, preferably at around seven months of age to avoid excessive feeding during winter (Burrow, 2019). Although the lack of infrastructure, financial resources, and knowledge of appropriate weaning methods may have negative consequences for farmers (Chapter 3), it is recommended that smallholder farming encourages community-driven initiatives. These initiatives should emphasize collective actions, such as resource sharing and group purchases as they can effectively assist smallholder farmers in overcoming financial and infrastructure limitations (Ratnawati *et al.,* 2019).

Interventions for optimal breeding season involves implementing measures that maximize breeding efficiency, enhance conception rates and achieve synchronized calving outcomes (Consentini *et al*., 2021). The current study highlighted an increase in the likelihoods of FC in farms without a breeding season. Therefore, the choice of a breeding season should take into account the local climate and forage availability. It is important to select a period when forage resources are abundant to ensure optimal nutrition for the breeding herd and subsequent offspring (Burrow, 2019). Moreover, synchronizing calving to coincide with forage availability and increasing the number of healthy calves born in favourable times can improve management of the offspring (Martínez *et al*., 2021). This includes enhancing aspects such as health care, weaning weight and marketing strategies (Moorey & Biase, 2020). The phenomenon was observed in a study conducted by Grobler et al. (2019), where calves born during calving season that is synchronized with good fodder availability were 6.5 kg heavier with a weaning weight of 214 kg (Moorey & Biase, 2020). Overall, it is recommended to commence breeding season following the month with the highest rainfall and it is estimated at approximately 60 to 90 days (Bergh, 2004; Mares *et al*., 2017). Neglecting to account for these practical considerations can carry significant economic implications for the herd (Mohammad *et al*., 2015). For instance, a poorly timed breeding season can lead to a higher proportion of non-pregnant animals, resulting in lost productivity, which in essence defeat the concept of a cow/calf operation (Burns, 2010).

Breed adaptation entails breeds that can thrive and reproduce in local climates, and ecological conditions (Van Marle-Köster *et al*., 2021). This includes considering factors such as heat tolerance, disease resistance, forage utilization, and reproductive efficiency (Widyas *et al.*, 2021). Breeds that are adapted to the local environment are more likely to exhibit better reproductive performance, resulting in increased conception rates and calving (Adisu & Zewdu, 2021). Moreover, the regression model in the study predicted an increase in the odds of PR on Nguni breed type. However, studies have shown that in the past centuries, the extinction of indigenous cattle amounts to 30% in Africa. The reality is that SA Sanga breeds (Chapter 2) are critically reduced due to poorly designed or unstructured crossbreeding (Nyamushamba *et al*., 2017). To date majority of non-descript breeds dominating smallholder herds (Mapiye *et al.*, 2019). That is 66% of low input herds in SA and 80% in Kenya are made up of non-descript breeds (Nyamushamba *et al.*, 2017). Raising awareness among smallholder farmers about the value and importance of indigenous cattle breeds is not only beneficial for their farming practices, however is also crucial for the preservation of the breeds (Cumbula & Taela, 2020).

Record keeping is critical for analyzing areas of concern affecting farm growth. The present study has found no record keeping in smallholder herds is associated with overly extended CI and DO. Programs such as the community-based breeding programs can initiate and promote the systematic recording of reproductive performance through educating and training smallholder farmers on the importance of keeping accurate records of calving rates and calf losses (Zoma-Traoré *et al*., 2021; Omer *et al*., 2021). This data serves as the foundation for making informed breeding decisions. Moreover, these programs offer knowledge on reproductive aspects including understanding estrus cycle, identifying signs of heat, and implementing effective breeding strategies (Ratnawati *et al*., 2019; Ouédraogo *et al*., 2021). Furthermore, the programs emphasize the importance of appropriate forage selection and feed management practices to meet the specific reproductive performance needs of an animal, primarily when feed is limited (Mtshali *et al*., 2021; Odubote, 2022).

Management strategies such as culling of aged cows eliminates poorly performing cows to maintain the productivity and profitability of the beef cow herd. This strategy should be implemented in smallholder herds as aged cows in the current study resulted in increased odds of extended days open and FC. It is recommended that farmers practices culling based on or inability to produce a calf every year or either environmental reasons e.g draught as a management strategy for reducing farming expenses (Lamega *et al*., 2021). The report by Dennis (2022) suggests that farmers can use two to three years calving data gathered for breeding cows to identify cows that are in the bottom 10 to 25% for weaning a calf every year. Such cows should be culling candidates. Alternatively, non-productive and old cows can be sold for economic benefits to the farmers.

5.2 Future studies

The current research has shown that BCS is the primary factor in influencing pregnancy rate, fetal and calf loss, days open and calving interval in smallholder farms. Therefore, future research should evaluate the mechanism of changes in body condition by evaluating factors influencing the changes during breeding and calving season. Research focusing on the economic implications of fluctuating BCS during the autumn-winter period may be significant in farm management and profitability. In particular, the New Zealand cattle breeding program is considering incorporating autumn BCS as a trait to evaluate the fluctuations in cow body reserves when feed is less abundant (Byrne *et al*., 2018). This development emphasizes the importance of monitoring body condition scores toward the end of pregnancy, calving, and drying-off, as it directly impacts feeding costs for farms and has implications for the development of smallholder farmers.

The diversity among smallholder farmers implies that not all development projects are universally suitable. Future studies should utilize surveys to understand various farmer categories and identify beneficiaries based on specific project suitability. Conducting surveys prior the main research may serve as a vital tool to ensure that proposed developmental projects align with the realities on the ground. Collecting data on farmers' existing practices and capabilities can assist in developing realistic and feasible project plans. For instance, when introducing a niche market for farmers, understanding market demands, available resources, and the farmers' skills and capabilities towards the uptake of the project specifications is important. Therefore, a preliminary investigation at a small scale, aiming to evaluate the feasibility and effectiveness of the research methods, procedures, and protocols is necessary for consistency of project data.

In Ethiopia and Kenya, questionnaire pilots are conducted with farmers as a pre-test of their data collection tool. The questionnaires are piloted to highlight the critical research deficiencies that need to be addressed and to ascertain the authenticity of the data collection tool to ensure it provides the required data (Alemayehu *et al*, 2021; Dumani *et al*., 2023). Additionally, the piloting procedure can serve as a valuable training program for farmers. An example from Thailand illustrates how farmers were trained in basic health care before implementing a longitudinal animal health monitoring system (Meemark, 1993). Ultimately, this approach aids project owners in identifying and addressing potential challenges and refining the research design, and making necessary adjustments before conducting the full-scale study.

Improving reproductive performance in smallholder beef cattle farms significantly depends on implementation of training support from governments and agricultural organizations. Governments can organize educational programs and training sessions specifically focusing on reproductive management in beef cattle. These programs can cover topics such as estrus detection and bull selection as these are major contributors to poor mating management (Peters *et al*., 2022). Farmers need to be trained in understanding the concept of estrus (heat) and its importance, behavioral signs of estrus, physical signs of estrus and follow-up actions once estrus is detected (Addendum C). The implementation of heat detection strategies and equipping dairy smallholder farmers in Rwanda with knowledge and skills in effective estrus detection resulted in an increase in AI success rate from 44.2% to 58.7% (Sibo *et al*., 2019). Moreover, developing skills in the selection of suitable bulls play a crucial role in improving the genetics and overall reproductive performance of the beef herd. Training should be provided on aspects such as bull age and maturity, physical conformation and structural soundness, bull to cow ratio, evaluation of mating behaviour and any signs of injuries prior breeding (Addendum C). With addition to traditional lectures (farmers days and workshop), practical demonstrations, group discussions and visual materials such as the guideline highlighted in Addendum C can be used to emphasis the adoption of these practices. Moreover, encourage peer learning and knowledge sharing among smallholder farmers is important. Farmers who have successfully implemented some of the practices can serve as mentors to others, sharing their experiences and best practices

Establishing a recording system for reproductive performance in smallholder farms is crucial for tracking performance and making informed decisions. However, the challenge lies not only in the act of recording itself but also in the knowledge and skills required to set up an effective recording system in smallholder farms (Staff reporter, 2022). Future studies may look into key factors in establishing an effective system for reproductive parameters in smallholder farms. Firstly, implementing a defined objective of reproductive parameters that will be recorded. This may include mating (heat detection dates, breeding dates, calving dates, and pregnancy rates) and calving records (Addendum C). Secondly, animal identification in smallholder farms is a challenge and is viewed as an expensive task that compromises tracking performance of individual animals (Coetzee *et al*., 2005). Therefore, smallholder farms require the necessary skills to assign unique identification such as ear tags or tattoos to their animals. Thirdly, a recording system requires standardized protocols and procedures to ensure consistency and accuracy into the recording system. Therefore, farmers may set a routine for data entry, either daily, weekly, or monthly, and ensure that they are dedicated to their routine to identify trends, patterns, and areas for improvement. Finally, a user-friendly recording system that is suitable for the resources and capabilities of smallholder farmers is important. This can be done manually using notebooks or electronically using spreadsheet software and mobile applications (Crooijmans, 2023).

A study on cost-benefit analysis could be conducted to determine the economic impact of different strategies to improve reproductive performance in smallholder farms. This can assist in resource allocation, decision-making, risk assessment, financial viability and securing external support for farmers. By evaluating the cost-effectiveness of different strategies, smallholder farmers can make informed decisions about which strategies or developmental projects to implement for improving their reproductive performance based on their cost-effectiveness.

For instance, farmers may choose to either apply the Australian cash cow program and the integrated Village Management systems (IVMS) applied in countries such as Indonesia, or the implementation of Assisted Reproductive Technology programs. Conducting a cost analysis for these programs is essential to evaluate their economic feasibility and potential benefits (McGowen, 2014; Dahlaludin *et al*., 2016). The cash cow and the IVMS are programs that encourage farmers to excel in basic animal husbandry and understanding their farming systems and environment. These programs encourage farmers to utilize their on-farm resources effectively to improve herd reproduction. The programs offer training on basic activities such as the importance of breeding seasons, oestrus detection, use of breeds of adaptation and the importance of supplementation using crop residues (their harvesting periods and storage). These programs have improved calving intervals from 507-486 in Indonesia (Ratnawati *et al*., 2016; Budisatria *et al.*, 2021).

The Agricultural Research Council in collaboration with the Department of Agriculture, Land Reform and Rural Development and the Technology Innovation Agency (TIA) carried out initiatives to promote assisted reproductive technologies (ART) by conducting on-farm research in smallholder farms (Mugwabane *et al*., 2019; Nengovhela *et al*., 2022). However, the adoption of ART long-term remains low in smallholder farms due to high costs and limited farm resources (Mugwabane *et al*., 2019; Kebebe, 2019). Therefore, a thorough cost analysis in the adoption of ART should involve assessing the expenses associated with acquiring the necessary equipment, infrastructure, knowledge and skills. Farmers should also be trained on discipline and determination for the effectiveness of the technologies such as following synchronization protocols (Mugwabane *et al*., 2019). The ART are essential in enhancing beef herd productivity and genetic progress especially in smallholder extensive production systems that is affected by climate change. Therefore, a collaborative long-term plan among various stakeholders, including researchers, agricultural extension agents, policymakers, and private sector entities is a matter of utmost importance in overcoming constraints on the adoption of technologies in smallholder farms. Collaborative efforts can assist in addressing challenges related to cost, knowledge, and skills by pooling resources, expertise and experiences. One of the initiatives in Botswana prior introduction of technology to cattle farmers is to evaluate the technical efficiency of farmers to support a technology. Moreover, Botswana assesses the potential for improving a farmer's productivity considering the constraints of the current technology in place (Temoso *et al*., 2018). This initiative could be a step taken by SA to promote technology adoption in smallholder farms. The current study has created a unique database of key performance indicators from on-farm records for the assessment of herd reproductive performance. This unique baseline resource could be used in longitudinal studies or national programs to continue monitoring reproductive performance over time as this may inform policy decisions and extension programs aimed at improving reproductive performance in smallholder beef cattle. These programs can provide targeted support and resources based on the specific needs identified through long-term monitoring to enhance productivity and sustainability of smallholder beef cattle farming systems.

5.3. Conclusion

Using the baseline questionnaire, the study found that the participation of women compared to man in beef cattle farming is low. Moreover, the accessibility and understanding of farm information remains a barrier for smallholder farmers, which may defeat their objectives of farming with beef cattle for sales purposes. These implications have negative effects on various aspects of smallholder beef cattle farming such as nutrition, diseases and reproduction as evident of constraining factors to majority of farmers in the study. Gender inequality in agriculture broadly represents a missed opportunity for economic development, food security, sustainability, and innovation. Addressing inequality is not only a matter of social justice, however, a key factor in ensuring the future resilience and success of agriculture.

Additionally, the study identified BCS, breed type, culling non-productive cows, record keeping, calving and breeding seasons, and bull to cow ratio as factors associated with poor reproductive performance in low input systems. An integrated approach, which accounted for herd and animal management to improve performance (50% pregnancy rate, 12% fetal and calf loss, 304 days open and 602 calving intervals) towards functional breeding systems remains a priority. Understanding the defined areas of concern provided guidelines as starting point towards functional breeding systems that may be used by extension and advisory services.

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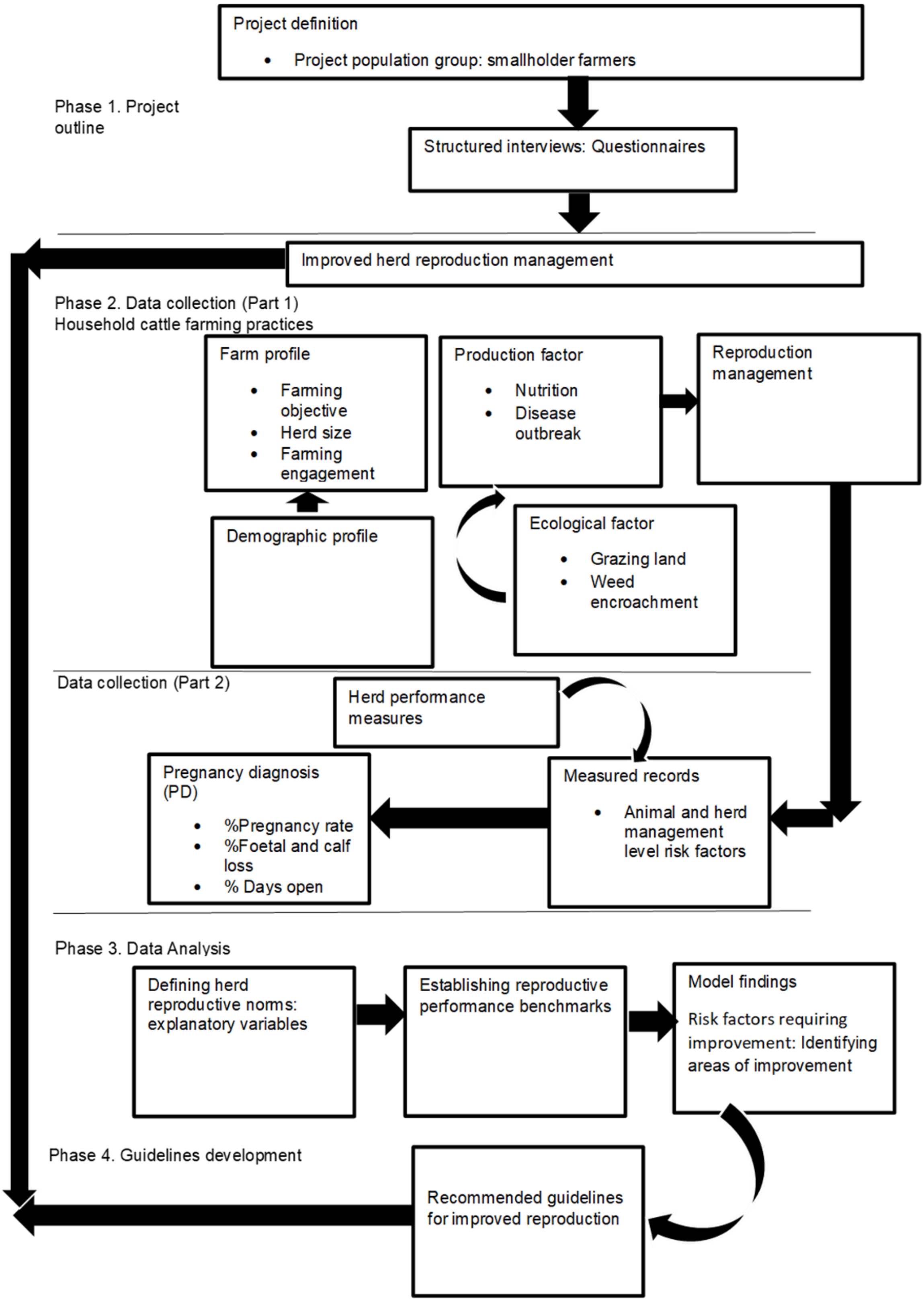
Addendum A

The work plan of the study phases is provided below:



Addendum B

Multivariate logistic regression analysis of animal and management factors associated with pregnancy (Table 1), CI (Table 2), DO (Table 3) and FC (Table 4).

Note: Animal class were categorized as follows: First calvers: cows nursing their first calf; second calvers: cows that weaned their first calf; matured cows: cows age between 5-7 years and aged cows: cows over 8 years. Breeds were recorded as ‘‘type’’ according to the strongest phenotypic characterization or resemblance of a specific breed. Insemination months were according to a farmers' management preference.

Table 1: The Binary logistic regression model summarizing herd associations between risk factors and the odds of pregnancy rate in smallholder herds.

Variable	SE	OR	95% CI of OR		*P value*
			Lower	Upper	
BCS					***<.0001***
BCS 1 vs 4	0.4283	0.260	0.081	0.833	***0.0430***
BCS 2 vs 4	0.1586	0.512	0.346	0.759	***0.2427***
BCS 3 vs 4	0.1560	1.083	0.755	1.555	***0.0003***
BCS 4	***Ref***				
Breed					***<.0001***
Beefmaster type vs Simmentaler type	0.1749	0.362	0.192	0.653	0.1768
Bonsmara type vs Simmentaler type	0.1082	0.361	0.225	0.620	0.0421
Boran type vs Simmentaler type	0.2886	0.440	0.213	0.922	0.9266
Brahman type vs Simmentaler type	0.0421	0.432	0.212	0.850	0.0990
Drakensberger type vs Simmentaler type	0.2431	0.631	0.321	1.271	1.8795
Hereford type vs Simmentaler type	0.3632	0.492	0.190	1.190	0.8546
Hogenout type vs Simmentaler type	0.3550	0.433	0.161	1.150	0.8935
Nguni type vs Simmentaler type	0.1741	1.420	0.221	0.793	0.6722
Simbrah type vs Simmentaler type	0.3519	0.590	0.262	1.351	0.4458
Simmentaler type	***Ref***				
Lactation status					***<.0001***
Dry vs Wet	0.05	1.280	1.091	1.501	0.0020
Wet	***Ref***				
Insemination months					***<.0001***
August-October vs September-December	0.4617	0.471	0.132	1.672	0.6097
Continuous vs September-December	0.123	0.390	0.181	0.840	0.0005
December-March vs September-December	0.210	3.812	0.233	0.951	0.32
January-March vs September-December	0.301	1.615	0.212	1.502	0.8356
March-June vs September-December	0.422	2.695	0.060	0.961	0.0109
November-February vs September-December	0.370	2.561	1.464	9.901	<.0001
October-March vs	0.280	0.552	0.251	1.192	0.9362

September-December baseline	***Ref***				
Veld condition					***0.0004***
Good vs Very poor	0.18	0.160	0.040	0.33	<.0001
Moderate vs Very poor	0.22	0.551	0.171	1.02	0.2375
Poor vs Very poor	0.16	0.271	0.121	0.61	0.1716
Very poor	***Ref***				
Culling old cows		4.18	0.472	0.834	<.0001
Culling non productive cows	0.20	0.47	0.302	0.670	***0.019***
Cow age class					***0.05***
First calvers vs Aged cow	0.16	0.716	0.320	0.891	0.1921
Mature cows vs Aged cow	0.13	0.959	0.401	0.821	0.2721
Second calvers vs Aged cow	0.07	1.104	0.491	0.880	0.8523
Aged cow	***Ref***				
BCS prior breeding	0.19	0.471	0.292		0.0802
Bull to cow ratio	0.486	1.242	0.832	1.841	0.0301

Statistically significant at level (p < 0.01; p < 0.05). SE = Standard Error, OR = odds ratio, CI = confidence interval.

Table 2: The cumulative logit regression model summarizing herd associations between risk factors and the odds of CI in smallholder beef cattle herds.

Variable	SE	OR	95% CI of OR		***P value***
			Lower	Upper	
BCS prior breeding					***<.0001***
BCS breeding					**<.0001**
BCS1vs 4	430.5	3.254	0.186	0.369	0.9765
BSC2vs 4	0.2981	3.775	0.010	0.739	<.0001
BCS 3vs 4	0.2538	1.694	0.137	0.603	0.1439
BCS 4	***Ref***				
Breed type					***<.0001***
Afrikaner Type vs Nguni Type	0.3733	0.849	0.469	1.538	0.5889
Angus Type vs Nguni Type	0.6679	2.350	1.033	5.343	0.2388
Beefmaster vs Nguni Type	0.2784	1.736	1.080	2.792	0.0228
Bonsmara type vs Nguni Type	0.2300	1.482	0.759	2.893	0.0461
Boran Type vs Nguni Type	0.4609	1.020	0.471	2.211	0.6478
Brahman type vs Nguni Type	0.5377	3.266	0.882	12.100	0.0765
Drakensberger type vs Nguni type	0.3124	0.664	0.376	1.173	0.1584
Hereford vs Nguni Type	0.5875	2.073	0.681	6.312	0.1995
Simmentaler Type vs Nguni Type	0.2982	0.775	0.442	1.359	0.3745
Nguni type	***Ref***				
Cow age class					***0.0071***
Aged cow vs Matured	0.1977	1.245	0.699	2.220	*0.1385*

First calvers vs Matured	0.2378	4.240	2.105	8.540	*<.0001*
Second calvers vs Matured	0.1195	1.470	0.987	2.189	*0.2873*
Matured	***Ref***				
Reason loss					***0.0171***
Aborted vs Stillborn	78.2578	1.336	0.055	32.666	0.9834
Died vs Stillborn	78.2574	0.478	0.020	11.507	0.9729
Stillborn	***Ref***				
Calving records	0.4117	3.148	1.405	7.055	0.0514
Culling Non-productive cows	0.2761	0.494	0.287	0.848	***0.0106***
Lactation Breeding	0.1012	0.797	0.536	1.185	0.2055
Bull to cow ratio	0.2784	0.481	0.277	0.833	0.0187
Calving months					***0.0006***
Autumn vs Spring	0.2111	1.836	0.179	0.669	0.0034
Winter vs Spring	0.1527	1.744	0.336	1.043	<.0001
Summer vs Spring	0.2935	0.346	0.579	1.838	0.0580
Spring	***Ref***				

Statistically significant at level ($p < 0.01$; $p < 0.05$). SE = Standard Error, OR = odds ratio, CI = confidence interval.

Table 3: The cumulative logit regression model summarizing herd-adjusted associations between risk factors and the odds of DO (overlay extended) in smallholder beef cattle herds.

Variable	**SE**	**OR**	**95% CI of OR**		***P value***
			Lower	**Upper**	
Calving season					***<.0001***
Autumn vs Spring	0.1679	1.092	0.588	2.027	0.8452
Winter vs Spring	0.1021	0.861	0.509	1.456	0.0448
Summer vs Spring	0.1095	0.730	0.428	1.244	0.0007
Spring	***Ref***				
Breed					***0.0001***
Afrikaner type vs Nguni type	0.2661	0.549	0.326	0.924	0.0241
Angus type vs Nguni type	0.3313	0.849	0.443	1.625	0.6204
Beefmaster type vs Nguni type	0.2109	0.455	0.301	0.688	0.0002
Bonsmara type vs Nguni type	0.1788	0.659	0.465	0.936	0.0198
Boran type vs Nguni type	0.3555	1.005	0.501	2.017	0.9889
Brahman type vs Nguni type	0.5449	0.318	0.370	3.135	0.8911
Drakensberger type vs Nguni type	0.2864	0.199	0.114	0.349	<.0001
Hereford type vs Nguni type	0.5336	0.262	0.092	0.745	0.0120
Simmentaler type vs Nguni type	0.2499	1.077	0.195	0.520	<.0001
Nguni type	***Ref***				

BCS Prior breeding	0.2698	0.724	0.427	1.228	0.0188
Cow age class					***0.0220***
Aged cow vs Second calvers	0.1515	1.498	0.952	2.357	0.0358
First calvers vs Second calvers	0.1797	0.785	0.465	1.326	0.1268
Mature cow vs Second calvers	0.0962	1.038	0.756	1.425	0.7808
Matured	***Ref***				
BCS breeding	0.2252	0.724	0.427	1.228	***0.030***
BCS breeding 1 vs 4	1.3337	4.792	0.351	65.422	0.2400
BCS breeding 2 vs 4	0.1299	1.094	0.848	1.411	0.4888
BCS breeding 3 vs 4	0.2196	0.523	0.990	2.341	0.0555
BSC 4	***Ref***				

Statistically significant at level (p < 0.01; p < 0.05). SE = Standard Error, OR = odds ratio, CI = confidence interval.

Table 4: The Binary logistic regression model summarizing herd associations between risk factors and the odds of FC in smallholder beef cattle herds.

Variable	SE	OR	95% CI of OR		*P value*
			Lower	Upper	
Lactation (breeding)					***<.0001***
Dry vs Wet	0.1610	0.710	0.378	1.335	0.2882
Insemination months					***<.0001***
Continuous vs September-December	38.0911	12.86	0.211	85.899	0.9656
December-February vs September-December	38.0914	1.469	0.219	9.874	0.9897
December-March vs September-December	38.0890	1.349	0.075	24.404	0.9897
January-March vs September-December	38.0918	4.250	0.664	250.172	0.9425
March-June vs September-December	38.0970	2.900	0.141	59.548	0.9736
November-February vs September-December	304.7	<0.001	<0.001	>999.999	0.9591
October-March vs September-December	38.0925	3.361	0.372	30.388	0.9706
September-December	***Ref***				
BCS at calving					***0.0246***
BCS 1 vs 4	0.2921	4.322	1.148	16.272	0.0068
BCS 2 vs 4	0.2921	3.059	0.908	10.308	0.0477
BCS 3 vs 4	0.2508	0.120	0.353	3.557	0.0255
BSC 4	**Ref**				
Veld condition					***0.0356***
Very poor vs good	1.7396	0.015	<0.001	7.070	0.3411
Moderate vs Good	0.7112	0.014	<0.001	0.674	0.0127
Poor vs Good	0.6831	0.197	0.032	1.229	0.1868
Good	***Ref***				
Cow age class					

Aged cows vs Matured	0.3103	3.827	1.263	11.591	0.0164
First calvers vs Matured	0.1991	2.218	0.701	7.021	0.5495
Second calvers vs Matured	0.2056	1.286	0.522	3.167	0.0922
Matured	***Ref***				

Statistically significant at level ($p < 0.01$; $p < 0.05$). SE = Standard Error, OR = odds ratio, CI = confidence interval.

Addendum C

Guideline of practices for optimizing reproductive performance in smallholder beef cattle farms

1. Introduction

Efficient reproduction performance requires strategic planning for a farmer to be able to produce a calf every year. Producing a calf every year for smallholder farms may improve cash income, increase marketing channels, improve economy and household nutritional outcomes. A checklist guide is provided below for improved reproductive performance in smallholder beef cattle farms.

The set of practices include:

2. Controlled breeding season

Different breeding seasons may exist for different farms, however it is best for farmers to establish a specific window in which cows will be bred so that calving can be matched with fodder availability. It is to note that this calendar may slightly differ from one area to another however, it is a guide to illustrate the essential periods of when to put in the bulls (rainy season) and the desired calving season (summer grazing). The rainy season in South Africa (SA) typically runs from the end of October to the end of March, however due to changing climate this may slightly differ from one area to another (https://journeysbydesign.com/destinations/south-africa/when-to-go). Therefore, the breeding calendar can be altered from one area to the other to match with the rainy season and fodder availability.

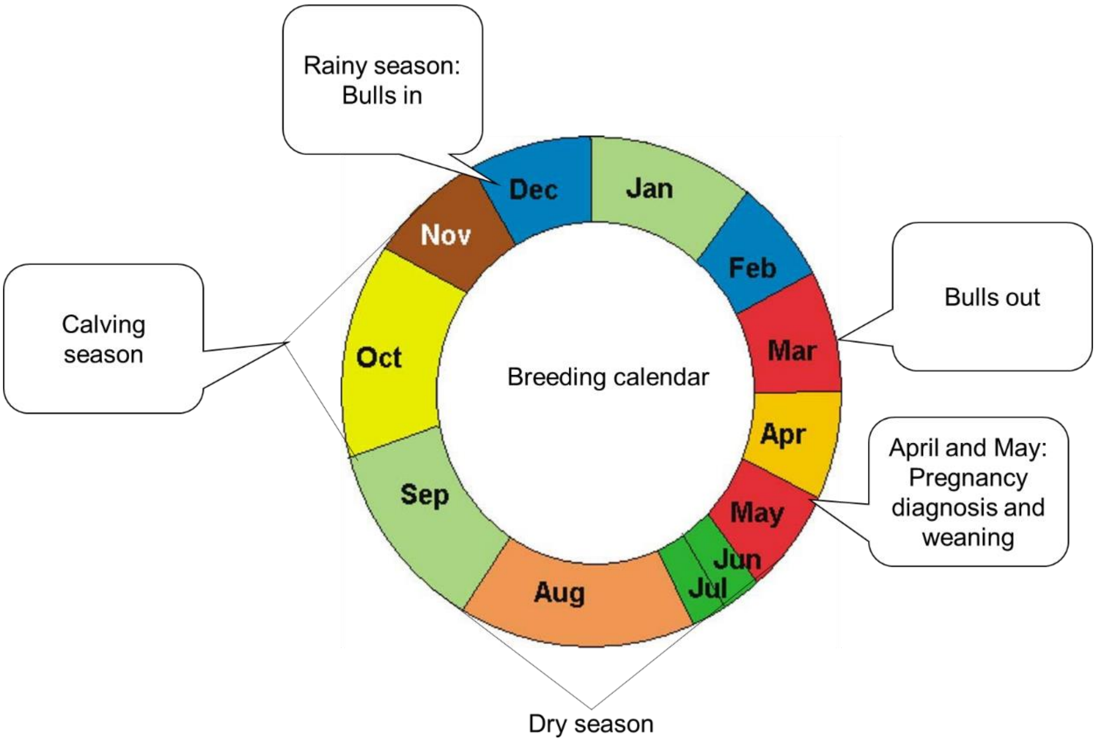
2.1. Benefit of breeding season

- ✓ Reduces cost for herd maintenance: i.e. cattle herd will be at the same physiological stage and maintenance such as feed will be controlled and uniform
- ✓ Increases herd production (i.e. infertile cows can be identified)
- ✓ Constant calving pattern

Note:

Breeding season lasts 60 to 90 days.

- ✓ 60-day breeding season (two/ three opportunities for cow to conceive).
- ✓ 90-day breeding season (three/ four opportunities for cow to conceive).



Breeding calendar

3. Body condition scores (BCS): Herd nutrition

Improved reproductive management highly depend on the assessment and management of BCS. Evaluation of BCS in breeding females is crucial as it can determine important production process such as conception and re-conception. While it is necessary to regularly evaluate the cow's condition, there are specific periods when BCS assessment becomes essential for a farmer:

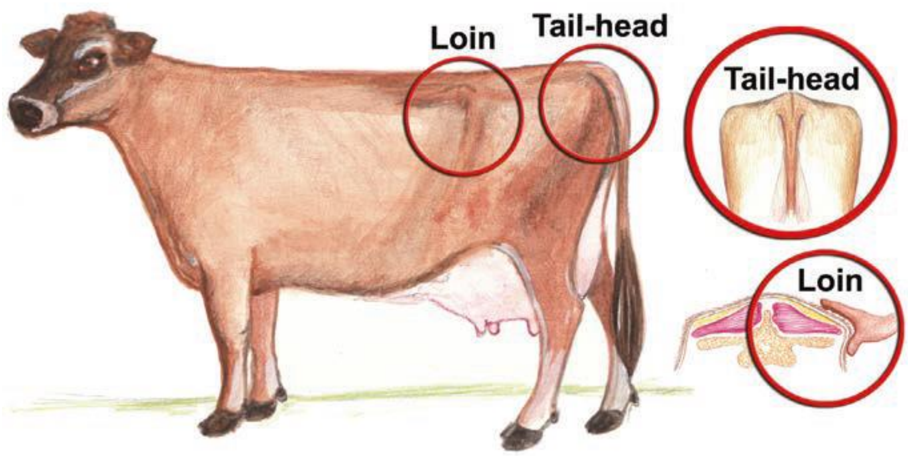
- ✓ Around 60 to 90 days before calving
- ✓ At calving
- ✓ Weaning

This is to assist with management decision on whether to improve or maintain nutrition status for re-conception.

The amount of subcutaneous fat on the left side of a cow can be measured to score the cow's body condition as the right side contains kidney fat, which can be misleading during BCS testing.

Tips on prominent areas to evaluate BCS

- ✓ The loin area: use a thumb to feel the thickness of fat over the bone by gripping the outer edges of the loin.
- ✓ Ribs (i.e use the palm of a hand to feel the thickness of the fat layer covering the bone).
- ✓ Tail head (Use fingers to assess the fat deposit around the tail head).

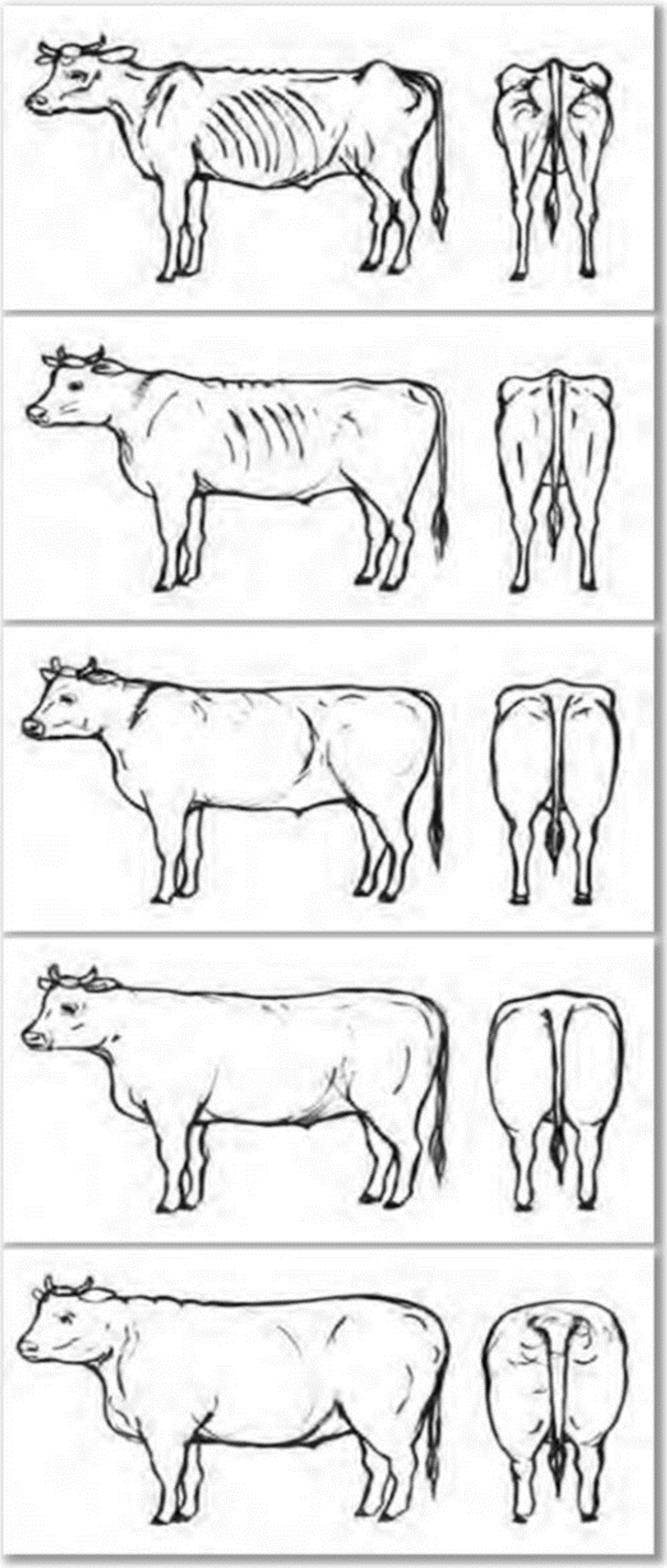


Areas for assessing BCS. Extracted from milk SA

Note: Target BCS for cows on different physiological stages

- ✓ Breeding: 3
- ✓ Calving: 2.5-3
- ✓ Weaning: 3

Below is the body condition scoring chart to guide in measuring body condition score in farm:



Cattle body condition scoring chart (Howell, 2011)

Condition score 1

Present a prominent backbone, hips, and shoulder bones. The ribs are clearly visible and the tail-head area is recessed, giving skeletal body outline.

Condition score 2

Visible backbone, hips, and shoulder bones (less prominent as score 1). Visible, however, faintly ribs and the tail-head area is slightly recessed.

Condition score 3

Hip bones are faintly visible, while the ribs are generally not visible.

Tail-head area not sunken, Body outline appears to be almost smooth.

Condition score 4

Hip bones and ribs not visible. The tail-head area appears slightly lumpy. Round body outline.

Condition score 5

The hip bones are showing a fat deposit The ribs are very well covered. The tail-head area is very lumpy.Body outline bulging.

4. Pregnancy evaluation

Pregnancy diagnosis is an important tool in beef cattle production as keeping a non-pregnant cow on the farm has negative economic implications. An empty cow requires the same cost of a pregnant cow, however, without generating any income. Pregnancy can be tested by local veterinarian and technician through:

- ✓ Rectal palpation after 35 to 90 days,
- ✓ Ultrasound examination between 30 to 90 days, or through blood analysis after 30 days.

(A) ultra sound scanner, (B) performing PD using ultrasound scanner and (C) performing PD hand palpation: Images from ARC GCRB

Benefit of pregnancy testing

- ✓ Identification of non-pregnant cows early
- ✓ Low pregnancy rates might indicate problems with an individual bull.

Tips on handling open cows

- ✓ Fatten them for sale or re-bred them
- ✓ Cull (i.e. if feed is insufficient)

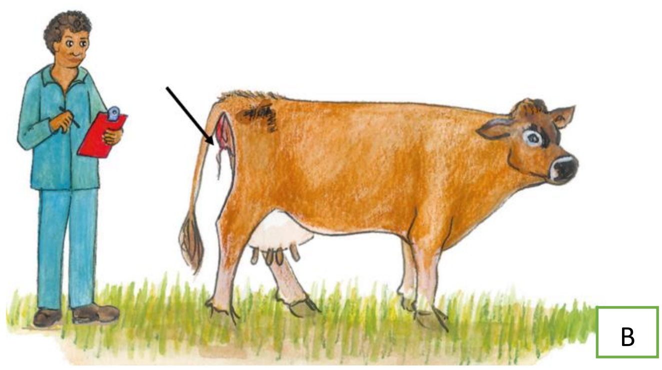
Due to limited access of extension and veterinary services in smallholder farmers, farmers may implement physical characteristics of examining not only pregnancy however, foetal or embryo loss as well.

Guide on physical exam of cows for PD

- ✓ Pregnant cows will not come to heat for the entire 285 days of pregnancy, if a cow become on heat post breeding season is not pregnant.
- ✓ Monitoring bull behaviour on the cows (i.e pheromone activity). A pregnant cow will not be followed by a bull.
- ✓ A cow that was pregnant but had an abortion might not go into estrus for a month or two after breeding season, but she will go into heat the following months.

Signs of heat

- Cows mounting each other
- Bull string.
- Swollen red vulva.
- Restless.
- Ruffled tail hair.



Cow signs of Estrus (A) cows mounting each other and (B) cow showing swollen vulva and bull string. Extracted from milk SA

Note: High conception rate is achieved when animals are bred between 4 to 14 hours after the onset of heat. Estrus need to be monitored at least for 20 minutes in the early hours of the morning and in the afternoon. Smallholder farmers who do not have breeding camps can mark breeding cows with neckbands and collars for monitoring during mating. This allows farmers to visually identify them without the need for separate camps.

5. Achieving a 365/477 day calving interval

With a 365-day calving interval, smallholder farmers can plan and anticipate a steady supply of marketable calves throughout the year. This regularity in calf production allows for a more consistent income stream which can contribute to improved financial stability and planning.

Tips in achieving a 365/477 day calving interval

- ✓ Weaning the suckled calf
- ✓ Keeping BCS 3 at calving

Guide to weaning

- ✓ Wean before the condition of the cow fall below 2.5
- ✓ At 7 to 8 months of age

- ✓ Wean prior to the onset of the dry season
- ✓ When the calve reaches the weight of 120 Kg

5.1. Common weaning methods

- ✓ Nose ring (i.e Nose ring is a recommended method on weaning in smallholder farms since majority are constraint by lack of camps, therefore separation might be a challenge)
- ✓ Fence lining: Due to limited land, fencing might not be practical to some farmers, however, in a community based breeding programs, calves can be exchanged between herd/village camps

Weaning methods (A) nose ring and (B) fencing separation. Internet source (Extracted from Walmart, Canada)

6. Managing breeding bulls

Guide to bull management

- ✓ Mating bulls should be from 2-4 years of age.
- ✓ Change bulls every 2-3 years (i.e. to avoid inbreeding).
- ✓ Ideal BCS 3.
- ✓ Exercise the bulls daily by walking (i.e in cases where bull do not walk distances for grazing)
- ✓ Identify bull desire to mating (a sexually active bull must be able to service one cow in 10 minutes).
- ✓ Bull to cow ratio (i.e. in an extensive pastoral system, one bull can service 30/35 cows)
- ✓ Physical exam such as eyes (pink eye), feet and legs (injuries on the hooks).Physical exam need to happen eight weeks prior breeding.
- ✓ Test and vaccinate bulls for reproductive diseases (i.e Trichomonas, Comphobactor or brucellosis) with the help of a state Veterinarian and animal health technician.
- ✓ If fewer than 40 cows become pregnant, replace the breeding bull for the upcoming breeding season.

7. Records

Keeping records are necessary for future reference of the production and growth of the farm. Recording herd reproductive performance provides areas that might need improvement for farm efficiency. The following information are necessary for keeping track of the farm performance:

Mating information

- ✓ Bull to cow ratio: number of bull used for breeding
- ✓ Removal date of the bulls in mating camps
- ✓ Successful parturition or loss per individual cow
- ✓ Number of cows failed to get pregnant

Calving information

- ✓ Date of birth of individual calves
- ✓ Number of calf born dead
- ✓ Abortions
- ✓ Number of calves produced per cow

Reference

Howell, A., 2011, 'Snail-borne diseases in bovids at high and low altitude in eastern Uganda: Integratedparasitological and malacological mapping', MSc dissertation, Liverpool School of Tropical Medicine

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Addendum D

Questionnaire

Please indicate (✓) if this survey is:

Code No

Self-administered: _____ Enumerator-administered: _______ Date: _____

Name of the Enumerator: ___________INTERGIS Participant Number: __________

ACIAR Behaviour Change Project 2016:
Baseline Survey

[

Disclaimer:

This is an independent survey undertaken by the ACIAR. Its aim is to learn more about the people in the area with regard to capabilities of livestock production, marketing and Social dynamics. The information given will be processed anonymously and will NOT be used for taxation or other official purposes. Please fill in one questionnaire only for each household.

Introduction to Participants

Thank you for agreeing to participate in this survey which has been specifically designed to ***help us to help you improve the profitability of your beef or poultry business***. Your responses to the survey will help us to better understand the nature of your farm business and the challenges you face in running your business. Once we understand those factors, we can then identify new ways to help you to directly address the main concerns impacting on your business.

Please be assured that your responses will be treated with absolute confidentiality. Even though your name and farm location will be recorded on the original survey document, once the information and your responses to the survey are entered onto the project database, your records will be not be identifiable other than through an anonymous identification code. So your responses are, and will remain, entirely confidential. Importantly, your survey responses will be combined with responses from all other farmers involved in the project, to enable us to identify the priority areas of greatest concern to most farmers in your region and province. This means that the issues of importance to you will never be identified back to you or your farm business.

The survey itself has been structured in a way that we are able to address the issues effectively.

Specifically, the questions in this survey will help us:

1. To understand more about your farm business and the benefits that you, members of your family and your local community receive as a direct result of your beef or poultry business;
2. To identify any concerns you have about your farm business and the environment in which it operates;
3. To identify those aspects of your farm business that you already believe you can address yourself, without the need for any outside help; and
4. To understand how you prefer to do things, as those preferences will help us to develop strategies that will make it easier for you to improve the profitability of your farm business.

Please remember there are no right or wrong answers to most of the survey questions. Rather we are interested in your personal perspectives. So you should not spend too much time thinking through those questions (other than the factual questions about your farm and farming business). Instead you should make sure you understand the question and then give the first response that comes to mind once you understand the question.

Once all of the farmers in the project have completed the survey, the results will be combined and analysed together to identify the best strategies to help you overcome the main business concerns identified by farmers in your region and province. The project's farmer support team will work with you to implement those strategies, to improve the profitability and long-term viability of your beef or poultry business.

Thank you again for agreeing to participate in this survey.

Dr Baldwin Nengovhela, Project Leader, DAFF: Animal Production
Tel: 0123197448 or 0828559476 Email: NkhanedzeniN@daff.gov.za

A – Farming Profile

A1.1

1. Indicate your type of farming 1 Crop 2 Livestock 3 Mixed 2 What type of grazing livestock do you have? 1 Cattle 2 Sheep/Goats 3 Donkeys/Horses

A1.2 How many of each of these livestock do you own? 1 Sheep 2 Goats 3 Horses 4 Donkeys

2. Indicate your farming engagement 1 Full-time 2 Part-time
3. Indicate your farm size (in ha): ______________
4. Indicate the portion of your land allocated for grazing livestock (e.g., cattle, sheep, goats, donkeys, horses) production (in ha):

A1.3 Do you have access to other land for grazing? 1 No 2 Yes

If yes, then please specify the size of the land (in ha): _________________

5. Indicate the portion of your land allocated for poultry production (in ha): _________________
6. Indicate the portion of your land allocated for crop production (in ha): ____________________
7. Total number of labourers: _____________

A1.4 What is the source of water for your farm business? 1 River 2 Bores 3 Municipal water 4 Rainwater 5 Other (specify): ____

8. Indicate the amount of water used for farming per month: _____________________
9. Do you have credit /loan that you are re-paying? 1 Yes 2 No
10. Do you have access to information? 1 Yes 2 No

If yes, please indicate the source of information: 1 Market 2 Extension 3 Financial 4 Other (specify): ____________

A2-Cattle production

A2.1 How long have you been farming with cattle (in years)? _________________

1. Indicate reasons for keeping cattle: 1 Wealth 2 Sale 3 Household consumption
2. Do you keep cattle for cultural reasons? 1 Yes 2 No

3. If yes in Q37, what are the reasons? 1 Dowry 2 Cultural festivities 3 Other (specify): _____

4. Indicate the number of cattle owned: ______

5. Indicate the number of female cattle: 1 Heifers = 2 Cows =

6. Indicate the number of male cattle: 1 Bulls = 2 Oxen = 3 Young males (Steers/Bulls) = 42 *Left BLANK. No item for this one.*

A2.2 Indicate the number of calves born each year: ____________

7. Indicate the number of cattle deaths each year: ___________

8. Number of cattle purchased each year: _______________

9. Number of cattle sold each year: _______________

A2.3 Where did you sell these cattle and how many in each category?

1 Informal market (how many=) 2 Auction (how many=) 3 Feedlot (how many=) 4 Abattoir (how many=) 5 Other (specify): ____________ (how many=) 45c What is your gross annual income from cattle sales?

1 Zero 2 R1 – R50,000 3 R51,000 – R100,000 4 over R100,000

10. Total cost of feed purchases each year: _____________ 47 Total cost of veterinary purchases each year: _____________

11. *Left BLANK. No item for this one.*

B – Expected Benefits

Please indicate how much you agree or disagree with the following statements related to your cattle/poultry farm.

Statements		Very unlikely	Moderately unlikely	Neutral	Moderately likely	Very likely
1. I will be able to earn more money.		1	2	3	4	5
2. It will benefit my community.		1	2	3	4	5
3. The local economy will improve.		1	2	3	4	5
4. I will have a more reliable source of income.		1	2	3	4	5
5. It will be beneficial to the environment.		1	2	3	4	5
6. *Left BLANK. No item for this one.*						
6b. I believe I will earn respect in my community from my cattle/poultry farming.		1	2	3	4	5

7. I believe I can meet traditional needs of my family (e.g., dowry, funeral, spiritual) from my cattle/poultry farming.		1	2	3	4	5
8. I believe that my cattle/poultry farming is allowing me to provide nutritional (healthy) food for my family.		1	2	3	4	5

C – Farming Concerns or Perceived Barriers

Please indicate the severity of the stress caused to you by each of the following events during past farming experience.

Concerns		Very l ow	Low	Moderate	High	Very high
1. Current level of debt.		1	2	3	4	5
2. Unpredictability of the weather.		1	2	3	4	5
3. Extreme weather events (e.g., drought, bushfire).		1	2	3	4	5
4. Increased workload at peak times.		1	2	3	4	5
5. Personal illness during busy times.		1	2	3	4	5
6. Few holidays away from the farm.		1	2	3	4	5
7. Complying with safety requirements.		1	2	3	4	5
8. Succession plans.		1	2	3	4	5
9. Long hours of work.		1	2	3	4	5
10. Difficulty accessing services (e.g., government agencies, health care).		1	2	3	4	5
11. Feeling alone and isolated.		1	2	3	4	5
12. Too much work and too little time.		1	2	3	4	5
13. Complying with bureaucratic or governmental regulations.		1	2	3	4	5
14. Complying with market requirements.		1	2	3	4	5

15. Lack of understanding of information communicated by government agencies.		1	2	3	4	5
16. Illness or disability or alcohol/drug dependency of a family member or workforce.		1	2	3	4	5
17. Not enough ready cash.		1	2	3	4	5
18. Dealing with government bodies.		1	2	3	4	5
19. Rise in input costs.		1	2	3	4	5
20. Concerns about being able to continue working on the farm.		1	2	3	4	5
21. Farming-related accident.		1	2	3	4	5
22. Climate change.		1	2	3	4	5
23. Uncertainty about the programs related to adoption of livestock (cattle/poultry) farming.		1	2	3	4	5
24. Lack of access to reliable markets.		1	2	3	4	5
25. Lack of fair pricing for cattle/poultry.		1	2	3	4	5
26. Cattle/poultry theft or predation.		1	2	3	4	5
27. High crime rates in the local area.		1	2	3	4	5
28. Disease outbreaks.		1	2	3	4	5
29. Concerns about availability of reliable and skilled farm labour.		1	2	3	4	5
30. Concerns about adequate supply of cattle nutrition throughout the year.		1	2	3	4	5
31. Concerns about encroachment of weeds into grazing lands.		1	2	3	4	5
32. Land degradation (e.g., soil erosion).		1	2	3	4	5
33. Reliable access to safe water for farming purposes.		1	2	3	4	5
34. Concerns about competing land use (e.g., urbanization, other agricultural uses).		1	2	3	4	5
35. Lack of access to relevant technicallyproven information about managing their farm business.		1	2	3	4	5
36. Lack of trust across all other sectors in the value chain (e.g., buyers, auctioneers, feedlots, abattoirs).		1	2	3	4	5

37. Any other concerns (specify): ____

D – Demographics

We'd like you to answer some general questions about yourself. Please remember that all your responses are confidential.

1. Province: 1 **EC** 2 **LP** 3 **KZN** 4 **FS** 5 **MP** 6 **NW** 7 **GP** 8 **NC** 9 **WC**
2. District: ____________
3. Town: ______________
4. Ward: _______________
5. GPS Co-ordinates: ________________
6. Respondent's surname & initials: __________________________
7. Gender: 1 **Male** 2 **Female**
8. Age (in years): ___________
9. Education: 1 Primary 2 Secondary 3 High School 4 College/University degree 5 No School
10. Home language(s): 1 Sepedi 2 Setswana 3 isiZulu 4 IsiXhosa 5 SeSotho 6 Xitsonga 7 Swati 8 Ndebele 9 Afrikaans 10 English
11. Venda 12 Other (specify)

11 What is the popular language in your community? _________________ 12 Indicate your mother language proficiency on a scale of 1 - 5, where:

1	2	3	4	5
Very poor	Poor	Fair	Good	Very good

Speaking: [ ] **Writing:** [ ] **Reading:** [ ]

12. Occupation: 1 Employed 2 Unemployed 3 Other (specify): ___________
13. Household position: 1 Head 2 Spouse 3 Son 4 Daughter 5 Other (Specify): ________

14b What is your role in the agriculture sector/industry in your local area? __________________

14. Race: 1 Black 2 White 3 Asian 4 Coloured
15. No of people living in your household: ________
16. Do you own the home where you are staying? 1 Yes 2 No 18 Indicate the status of your home: 1 Renting 2 Paying bond 3 Inheritance 4 Other (specify):______
17. Indicate the number of adults living in your home: __________

18. Indicate the number of children living in your home: __________
19. How long have you lived in the place in Q17? _________________
20. Do you intend to move away within the next five years? 1 Yes 2 No
21. Indicate your gross annual off-farm household income: ________________
22. Indicate the sources of off-farm household income: 1 Pension 2 Social grant 3 Employment

    4 Other (specify): ____________

24b Do you have a disability? 1 Yes 2 No

E-Herd reproductive management: survey questionnaire

E1 Breeding bulls management

23. How many breeding bulls do you have ____________
24. Do you purchase breeding bulls? Yes/No____________
25. If yes, where do you prefer buying from: 1. Neighbors, 2. Auctions
26. Do you do isolate your breeding sires from your breeding cows? Yes/No____________
27. Bull to cow ratio: 1= under, 2= Ideal, 3= Over

E2 Replacement heifer management

28. Do you perform selection for breeding heifers? Yes/No____________
29. If yes, what is the criteria for selection: 1. Animal condition or Parents breeding history____________
30. Breeding heifers: Service age____________ Weight ____________and Target calving____________
31. Do you vaccinate your breeding heifers? Yes/No____________
32. Do your heifers calf from their first service, Yes/No____________

E3 Cow management

33. Do you do measures of body condition scoring and weaning prior breeding Yes/No____________
34. Do you keep records of your calving rate? Yes/No____________
35. What is the rate of your Calving Interval: 1. calf every, 2. Calf every 2 years, 3. Calf post 3 years or more?
36. Do you experience abortions from your breeding cows? Yes/No____________
37. If Yes, how often per breeding season: 1. Consecutive breeding seasons or 2. non-consecutive breeding season
38. Control of abortions in herds: 1. Isolation 2. Selling or culling, 3. keep within the herd
39. Do you cull non-productive cows: 1. Yes, 2. No
40. Do you cull old cows: 1. Yes, 2. No

E4 Health status

41. How many times do you vaccinate your herd in a year? ____________

42. Common infections: 1. Bovine Viral Diarrhoe(BVD), 2. Infectious bovine rhinotracheitis (IBR), 2. leptospirosis, 3. Brucellosis and neosporosis
43. Do you have an animal technician in your area? Yes/No

Thank you very much for participating!