A COMPARATIVE ANALYSIS OF STUD BULL SELECTION CRITERIA FOR ENHANCING THE TULI CATTLE IN MASHONALAND EAST, ZIMBABWE

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Dedication

This research is lovingly dedicated to my beloved parents and my sister, whose unwavering love, prayers, and steadfast encouragement have been my constant source of strength. Your sacrifices and belief in my dreams made this journey possible.

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Abstract

This study conducted a comparative analysis of stud bull selection criteria for enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe. A mixed-methods approach was employed, combining quantitative and qualitative data collection and analysis methods to comprehensively assess current practices and their impact. A semi-structured questionnaire was used as the primary data collection tool, administered to 39 smallholder farmers who responded out of 60 targeted, yielding a 65% response rate. Data was analyzed using IBM SPSS Statistics Version 27, employing descriptive statistics (frequencies, percentages, means, and standard deviations) and comparative analysis of means across different selection method groups. The major findings revealed a continued reliance on traditional, subjective selection methods, with 69.2% of farmers primarily using visual appraisal. Adoption of modern breeding techniques remained limited: 23.1% utilized Estimated Breeding Values (EBVs), 12.8% adopted Artificial Insemination (AI), and only 5.1% engaged in Genomic Testing, with adoption concentrated in commercial farming systems. Crucially, the study found a strong positive correlation between objective selection criteria and herd performance. Herds where EBVs and/or Genomic Testing were employed exhibited significantly higher Average Daily Gain (0.48 kg/day) compared to visual appraisal (0.28 kg/day), representing approximately a 71% improvement. Similarly, these advanced methods resulted in a 20% higher fertility rate (90% vs. 75%) and an 8% higher calf survival rate (95% vs. 88%) compared to herds selected via visual appraisal. Key challenges hindering the adoption of modern techniques included high costs (74.4%), lack of expertise (59.0%), poor infrastructure (53.8%), and limited access to genetically superior breeding stock (48.7%). The study concludes that objective, data-driven stud bull selection criteria are significantly more effective in enhancing Tuli cattle productivity than traditional subjective methods. Despite their proven benefits, the widespread adoption of modern techniques faces substantial socio-economic and infrastructural barriers among smallholder farmers. The study recommends promoting targeted training and capacity building on modern breeding techniques, enhancing access to affordable genetically superior breeding stock and related services, and developing community-based breeding programs. Additionally, fostering collaboration between farmers, researchers, and extension services, along with policy support for infrastructure development and financial incentives, is crucial. The findings have implications for policy and practice, highlighting the potential for improved livelihoods, food security, and sustainable agricultural practices through the strategic promotion and implementation of objective livestock breeding technologies in Mashonaland East and similar contexts.

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CHAPTER 1: INTRODUCTION

1.1 Background

The Tuli cattle breed, originating in Southern Africa, is highly valued for its adaptability, efficient production, and resilience across diverse environments (Mpofu, 2002). In Zimbabwe's Mashonaland East, local farmers prize Tuli cattle for their superior meat, high fertility, heat tolerance, and easy calving (Mpofu, 2002).

Compared to other indigenous beef breeds in Mashonaland East, the Tuli breed demonstrates several advantages. Their exceptional heat tolerance makes them well-suited to the region's hot, arid climate, ensuring productivity and survival under challenging conditions (Mpofu, 2002). Furthermore, Tuli cattle exhibit notable resistance to common tick-borne diseases, reducing the need for costly control measures (Mpofu, 2002). Their strong maternal instincts contribute to high milk production and robust calf survival rates (Mpofu, 2002). Their adaptability to varied grazing conditions and ability to thrive on limited nutrition further suit them to Mashonaland East's unpredictable environment (Mpofu, 2002). As Tulicattle.co.zw highlights, the Tuli breed is robust and adaptable, tolerating extremes of heat, drought, and nutritional stress. They also demonstrate resistance to ticks and diseases, early maturity, and produce high-quality beef and milk even under poor grazing. Tuli cattle are highly fertile, exhibit strong maternal care with easy calving and low calf mortality, and possess a docile temperament. Their unique genetics contribute to maximum hybrid vigor in crossbreeding, and a high percentage of calves are naturally polled with light-colored coats enhancing heat tolerance. These combined advantages position the Tuli breed as an invaluable asset for regional livestock farmers, improving livelihoods and food security.

Strategic selection of stud bulls is crucial for maximizing the genetic potential within Tuli herds, influencing productivity, profitability, and genetic improvement (Bertrand et al., 2001). Bull selection typically involves assessing physical conformation, growth rates, reproductive traits, and overall genetic merit. Farmers often rely on visual assessments and performance records for these decisions (Bertram et al., 2003).

However, selection criteria and methodologies vary across farms and regions due to environmental conditions, economic constraints, and access to information. A deeper understanding of current selection practices and potential improvements is essential for enhancing Tuli cattle genetic quality and productivity.

Research consistently shows that improved selection techniques significantly boost herd performance, especially where traditional breeding practices dominate. For instance, advanced reproductive technologies like artificial insemination (AI) and sophisticated genetic evaluations accelerate genetic gain in beef cattle (Tırpan & Tekİn, 2018). However, many rural Zimbabwean farmers face limitations in accessing these technologies or lack the expertise for their implementation (Tırpan & Tekİn, 2018). Therefore, integrating contemporary breeding technologies with established traditional methods may offer a more pragmatic and effective approach to enhance herd quality.

Despite the recognized benefits of optimized breeding strategies, there is a lack of empirical research on specific stud bull selection criteria used by Tuli cattle breeders in Mashonaland East. This knowledge gap presents an opportunity to investigate current practices and challenges faced by local farmers. By systematically assessing the effectiveness of different selection methods, this study aims to contribute to developing practical, contextually relevant strategies for improved breeding outcomes and the long-term sustainability of the Tuli cattle industry in the region.

1.2 Problem Statement

The Tuli cattle breed, despite its inherent advantages, faces challenges in achieving its full production potential in Mashonaland East, Zimbabwe. A significant factor contributing to this is the inconsistent and often suboptimal selection of stud bulls among many local farmers. Reliance on traditional selection methods, often based on subjective visual assessments and limited performance records (Bertram et al., 2003), can lead to suboptimal breeding decisions. This can result in slower genetic progress, reduced herd uniformity, and limited improvement in key traits such as growth rate, fertility, and disease resistance. Furthermore, limited access to information and training on modern breeding techniques, coupled with economic constraints, restricts the adoption of more advanced selection methods by many farmers (Tırpan & Tekİn, 2018). These factors collectively hinder the realization of the full genetic potential of Tuli cattle herds, impacting both individual farmer livelihoods and the overall productivity of the beef cattle industry in the region. This research aims to critically assess the current stud bull selection criteria utilized by farmers and identify effective strategies to enhance the genetic quality and overall performance of Tuli cattle herds in Mashonaland East.

1.3 Significance

This research holds profound significance across several critical dimensions: bolstering livestock productivity (Bertrand et al., 2001), addressing food security (Mpofu, 2002), fostering sustainable agricultural practices (Tulicattle.co.zw), and informing policy and practical implementation within Zimbabwe's agricultural sector. By investigating and promoting effective stud bull selection criteria, this study aims to enhance the productivity and profitability of Tuli cattle herds in Mashonaland East province (Bertram et al., 2003). This enhancement has tangible implications for improving local food security (Mpofu, 2002), increasing farmer income, and strengthening the local economy, as community economic vitality is intrinsically linked to livestock health and productivity.

Given that livestock, particularly cattle, provides significant sustenance and financial stability for many rural Zimbabwean households, advancements in livestock productivity directly enhance food security and alleviate poverty (Mpofu, 2002). Healthier, more productive animals translate into a more reliable food supply for families and communities, and increased income opportunities from livestock sales. This fosters a stable economic environment, building resilience against economic shocks. The Tuli breed, with its inherent adaptability and desirable traits (Tulicattle.co.zw), has immense potential to contribute to this objective, making a deeper understanding of optimizing their genetic potential through informed selection practices paramount (Bertrand et al., 2001).

Beyond immediate economic and food security benefits, this research promotes sustainable livestock production (Tulicattle.co.zw). By enhancing the genetic resilience of Tuli cattle through effective selection, the study addresses the critical need for adaptation to evolving environmental conditions. Zimbabwe faces increasing challenges from climate change, including more frequent droughts, altered disease prevalence, and shifts in vegetation. Breeds like the Tuli, known for their hardiness and adaptability (Mpofu, 2002; Tulicattle.co.zw), are crucial for long-term sustainable livestock production in such dynamic environments. Identifying and propagating traits contributing to this resilience will enable farmers to maintain productive herds despite environmental stressors, safeguarding livelihoods and the agricultural sector's long-term viability.

Moreover, this study's findings will provide invaluable insights for policymakers, agricultural extension services, and other stakeholders involved in livestock development programs across Zimbabwe. Evidence-based research on effective breeding practices, tailored to local breeds like the Tuli and Mashonaland East's environmental conditions, is essential for informed policy formulation. Agricultural extension services can leverage these findings to develop targeted training programs and disseminate best practices to farmers, empowering them with knowledge and tools for improved herd management and breeding strategies (Tırpan & Tekİn, 2018). This ensures development efforts are grounded in local context, increasing their likelihood of positive, sustainable outcomes. The research can also inform strategies for non-governmental organizations and other development partners, enabling more effective interventions addressing specific needs and challenges faced by livestock farmers. Ultimately, by bridging the gap between scientific research and practical application, this study aims to contribute to a more robust, resilient, and sustainable livestock industry in Zimbabwe, benefiting individual farmers, local communities, and the national economy. The knowledge generated will serve as a foundation for future initiatives to enhance livestock productivity and ensure food security amid ongoing environmental and economic changes.

1.4 Main Objective

To compare stud bull selection criteria employed by farmers in Mashonaland East, Zimbabwe, to determine effective strategies for improving the genetic quality and overall productivity of Tuli cattle herds.

1.5 Specific Objectives

i. To identify the stud bull selection criteria currently utilized by Tuli cattle farmers in Mashonaland East, Zimbabwe.

ii. To compare the herd performance indicators (e.g., growth rates, calving ease, disease resistance) of Tuli cattle herds managed by farmers employing different stud bull selection criteria.

iii. To compare the effectiveness of traditional selection methods (visual assessment, performance records) with modern breeding techniques (genetic evaluations, artificial insemination) in improving Tuli cattle herd performance.

1.6 Hypothesis

i. There is no significant difference in herd performance indicators between Tuli cattle herds managed by farmers utilizing structured stud bull selection criteria (incorporating both traditional and modern methods) and those relying solely on traditional, unstructured methods.

ii. The implementation of modern breeding techniques, such as genetic evaluations and artificial insemination, does not result in significant improvements in key performance traits of Tuli cattle compared to traditional selection methods alone.

1.7 Scope of the Study

This study will focus on investigating the stud bull selection methods employed by local farmers raising Tuli cattle in the Mashonaland East region of Zimbabwe. The study will utilize both qualitative and quantitative research approaches, including surveys, interviews, and the analysis of farm records, to gain a comprehensive understanding of current breeding practices. The findings will inform the development of practical recommendations for improving the sustainability and productivity of Tuli cattle production in the region.

Chapter 2: Literature Review

2.0 Introduction

This chapter provides a comprehensive review of the literature pertinent to stud bull selection criteria for enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe. Effective breeding strategies are crucial for improving livestock productivity and adapting to evolving environmental and market demands. This review establishes the context for the research by exploring the characteristics and production systems of the Tuli breed, examining current stud bull selection practices, analyzing the challenges and opportunities facing cattle production in Mashonaland East, and considering relevant policies and programs. By synthesizing existing knowledge, this chapter identifies key research gaps and lays the foundation for the subsequent investigation into optimizing stud bull selection for Tuli cattle in the target region.

2.1 History of the Tuli Cattle Breed

The Tuli cattle breed, now recognized for its adaptability and resilience across diverse African environments, possesses a rich history deeply intertwined with Southern Africa's indigenous cattle populations. While its development into a distinct breed is relatively recent, its genetic roots extend back millennia, reflecting a long history of cattle domestication on the continent.

The Tuli lineage traces back to the Sanga cattle group, an important branch of African cattle that evolved through the hybridization of indigenous humpless cattle and humped Zebu cattle that migrated from Asia over a thousand years ago (Mpofu, 2002). These Sanga cattle, characterized by a cervico-thoracic hump, lateral horns, and an adaptable nature, spread across eastern and Southern Africa, giving rise to numerous distinct breeds adapted to specific local conditions. Within Southern Africa, various Sanga types thrived, their genetic makeup shaped by environmental pressures, disease challenges, and the selective practices of indigenous people who relied on them for sustenance and cultural significance.

The specific origins of the Tuli breed are rooted in Zimbabwe's southeastern lowveld, historically known as the Tuli district, from which the breed derives its name (Tulicattle.co.zw, History). This region's harsh climate, including high temperatures, low rainfall, and prevalent tick-borne diseases, acted as a natural selection pressure, favoring cattle with inherent hardiness, heat tolerance, and disease resistance. For centuries, indigenous cattle populations in this area evolved, developing the foundational characteristics that would later define the Tuli breed. These ancestral cattle were likely a diverse group of Sanga types, possessing the inherent adaptability necessary to survive and thrive in this challenging environment.

The formal development of the Tuli as a recognized breed began in the early 20th century. Recognizing the valuable traits of these indigenous cattle, particularly their resilience and beef-producing potential, a deliberate effort was made to conserve and improve them. In 1946, the Nyamandhlovu Experiment Station in Matabeleland, Zimbabwe, initiated a selective breeding program to establish a uniform and productive beef breed suited to local conditions (Mpofu, 2002). This marked a crucial turning point, transforming the Tuli from a localized indigenous type to a systematically developed breed with defined characteristics.

The early breeding program focused on key traits such as fertility, growth rate, carcass quality, and crucially, inherent adaptability to the harsh African environment. Selection criteria emphasized natural hardiness, the ability to thrive on sparse grazing, and resistance to prevalent diseases. This scientific approach, building upon natural adaptations honed over centuries, led to the consolidation of desirable traits within the Tuli population. The breed’s characteristic smooth, light-colored coat, which aids in heat dissipation, and its polledness (natural hornlessness), which reduces injury risk, were among the traits either selected for or prevalent in the foundation stock (Tulicattle.co.zw, Tuli Advantage).

The Tuli Cattle Society was subsequently established to oversee the breed's development, maintain breed standards, and promote its use. This formal recognition and organized breeding efforts further solidified the Tuli's position as a distinct and valuable beef breed within Zimbabwe and beyond. Over the following decades, the Tuli gained increasing recognition for its superior performance under challenging conditions compared to many exotic breeds often less adapted to the African environment. Its ability to maintain good productivity even during drought and nutritional stress made it particularly attractive to farmers in arid and semi-arid regions (Mpofu, 2002).

The breed's inherent advantages, such as early maturity, good mothering ability, and high carcass merit even on poor grazing (Tulicattle.co.zw, Tuli Advantage), further contributed to its popularity. Moreover, the Tuli's docile temperament made it easier to manage, a significant advantage for many farmers. Its unique genotype also contributed to its value in crossbreeding programs, imparting hybrid vigor and desirable traits to offspring when crossed with other breeds (Tulicattle.co.zw, Tuli Advantage).

The history of the Tuli breed exemplifies the value of recognizing and harnessing the potential of indigenous livestock. Developed through a combination of natural selection over centuries and strategic human intervention in the 20th century, the Tuli stands as a successful example of how scientific breeding can enhance the inherent strengths of local cattle to create a breed well-suited to its environment. Its journey from an unstandardized indigenous population to a recognized breed has not only benefited livestock production in Zimbabwe but has also provided a valuable genetic resource for other regions facing similar environmental challenges. The Tuli's history underscores the importance of understanding the genetic heritage of livestock and the potential for utilizing this heritage to develop sustainable and productive breeds for the future.

2.2 Review of Relevant Studies

2.2.1 Tuli Cattle Breed Characteristics and Production Systems

The Tuli breed is recognizable by its distinctive light red to golden-brown coat, sometimes ranging from tan to deep red, often coupled with a naturally polled (hornless) head, making them visually distinct and easy to handle (TheCattleSite, n.d.). Beyond appearance, Tuli cattle are renowned for their compact, muscular build, ideal for beef production. Farmers highly value their docile temperament, which simplifies management tasks like herding, vaccination, and daily handling (Gomo, 2024; Tuli Cattle Society of Southern Africa, n.d.). This placid nature reduces animal stress, positively impacting growth and productivity.

Primarily used for beef, Tuli cattle consistently yield high-quality carcasses with desirable marbling. Marbling, or intramuscular fat, is crucial for meat tenderness, flavor, and juiciness, directly influencing consumer preference and market value (TuliCattle.co.zw, n.d.). Their efficiency in converting forage into lean muscle makes them an economically viable choice for beef operations.

A cornerstone of the Tuli breed's success, especially in Southern Africa, is their exceptional adaptability to hot, arid, and semi-arid conditions. This resilience, coupled with their efficient utilization of available forage, even low-quality roughage, makes them profoundly suited to the extensive and semi-intensive production systems common in regions like Mashonaland East. In these traditional systems, cattle typically graze on natural pastures, including communal lands and privately owned rangelands. Supplementary feeding is often minimal, usually limited to dry periods when natural forage is scarce and its nutritional value declines

(Mpofu, 2002). This resourcefulness allows farmers to maintain herds with fewer external inputs, aligning with the economic realities of many small to medium-scale operations.

However, a discernible trend towards more intensive production exists. Some progressive farmers are incorporating improved pastures, offering higher nutritional density and increased carrying capacity. The strategic use of supplementary feeding, including protein and energy supplements, especially for growing animals or lactating cows, is also becoming more common. In some instances, farmers are adopting feedlot finishing systems, where cattle are confined and provided a high-energy diet to accelerate growth and achieve market weight more quickly. This shift aims to enhance overall productivity, reduce time to market, and potentially fetch higher prices for finished animals (Gomo, 2024).

Understanding the specific production system is crucial for developing effective, targeted stud bull selection strategies, which must align with the farm's unique production goals and available resources. For example, a bull for an extensive system might prioritize robust health and foraging ability, while a bull for an intensive system might be chosen for superior growth rates and feed conversion efficiency. Extensive research consistently highlights the Tuli breed's strong maternal instincts and impressive fertility rates. These traits are foundational to herd productivity, as good mothers ensure calf survival and high fertility translates to more calves per breeding cycle, directly impacting economic viability (Mpofu, 2002).

The breed's inherent ability to withstand high temperatures, tolerate tick-borne diseases, and cope with limited water availability makes it an ideal livestock choice for Zimbabwe's challenging semi-arid regions, including Mashonaland East (Tuli Cattle Society of Southern Africa, n.d.). Their robust immune systems and natural hardiness reduce reliance on costly veterinary interventions. Despite these strengths, Tuli cattle productivity in recent years faces considerable challenges. Overgrazing leads to land degradation and reduced pasture quality, negatively impacting feed availability. Additionally, the increasing, unpredictable impacts of climate change, including prolonged droughts and erratic rainfall, directly affect forage production and water resources, posing significant threats to herd health and productivity in the region (Gomo, 2024). Addressing these environmental and management challenges is paramount for sustaining and enhancing Tuli cattle productivity in Zimbabwe.

2.2.2 Stud Bull Selection Criteria and Methods Used in Beef Cattle Breeding

Effective stud bull selection is the cornerstone of successful genetic improvement in beef cattle breeding. A single bull's substantial genetic contribution means meticulous selection is paramount for enhancing herd productivity, profitability, and overall genetic potential (Butler et al., 2020).

Historically, visual appraisal served as the primary selection method, focusing on subjective assessments of conformation, physical soundness, and adherence to breed characteristics (Tırpan & Tekİn, 2018). Breeders examined traits like muscling, skeletal structure, leg soundness, and reproductive organ development to identify animals embodying the ideal phenotype. Breed standards provided guidelines, aiding initial selection. However, relying solely on visual assessment is subjective and often fails to accurately reflect economically important, non-visible traits like growth rate, feed efficiency, carcass quality (e.g., marbling and yield), and reproductive performance (Gorelik et al., 2022). Furthermore, physical appearance alone doesn't guarantee genetic merit, as environmental factors significantly influence phenotypic expression.

To overcome visual selection limitations, modern beef cattle breeding increasingly incorporates objective measures and advanced genetic evaluation tools. Estimated Breeding Values (EBVs) are a prime example. Derived from comprehensive performance records, pedigree information, and genomic data, EBVs provide robust estimates of an animal's genetic merit for specific traits (Jonas et al., 2019). Unlike raw performance data, EBVs adjust for environmental effects and account for genetic relationships, offering a more precise prediction of gene transmission to offspring. This allows breeders to make informed decisions considering both individual performance and inherited genetic potential. For instance, a 200-day weight EBV indicates the expected genetic difference in weaning weight between two bulls' offspring.

Selection indices further refine the process by combining EBVs for multiple traits into a single value, facilitating simultaneous improvement of several economically important characteristics (Tırpan & Tekİn, 2018). An index might balance improvement across growth, carcass, and maternal traits, useful for balanced genetic progress rather than single-trait focus, preventing unintended negative correlations on other important attributes.

Genomic information, from sophisticated DNA testing, revolutionizes beef cattle breeding by providing unprecedented insights into an animal's molecular genetic makeup (Patry, 2011).

Genomic markers, specific DNA sequences, are associated with complex traits, allowing accurate prediction of genetic potential even at a young age, often before phenotypic expression. This is valuable for difficult, expensive, or time-consuming traits like disease resistance, feed efficiency, or meat quality. Genomic selection significantly reduces the generation interval and enhances EBV accuracy, especially for young, unproven animals, accelerating genetic gain (Jonas et al., 2019). For stud bulls, early genomic evaluation assesses genetic merit before they produce offspring or exhibit mature physical traits, enabling earlier, more confident selection decisions.

Beyond objective measures, several distinct selection methods are employed. Individual selection, based on an animal's own performance records (e.g., weight at a certain age), is common but susceptible to environmental influence, potentially masking true genetic differences. Pedigree selection uses information from relatives (parents, siblings, offspring) to estimate genetic merit, useful for low-heritability traits or those expressed late in life (Tırpan & Tekİn, 2018).

Progeny testing is the gold standard for evaluating a sire's genetic potential, assessing offspring performance (Gorelik et al., 2022). By comparing a bull's progeny to others, breeders gain the most accurate assessment of his genetic transmitting ability. While most accurate, progeny testing is time-consuming and expensive, requiring significant resources and record-keeping (Shaha etg al., 2008). Consequently, it's typically reserved for elite sires with widespread impact on national or regional herds. In extensive cattle management systems, particularly in Mashonaland East, farmers' bull selection criteria often blend traditional visual cues with a growing appreciation for traits like fertility, adaptability, and disease resistance, reflecting a pragmatic balance of objective data and field observations (Pirabakar et al., n.d.). Breeding soundness examinations (BSE) are also critical, ensuring selected bulls can breed naturally (Butler et al., 2020).

In conclusion, contemporary stud bull selection involves a holistic approach, moving beyond visual appeal to integrate objective performance data, sophisticated genetic evaluations like EBVs and selection indices, and increasingly, cutting-edge genomic information. This multi-faceted strategy ensures selected bulls are not only physically sound but also genetically superior for economically important traits driving beef cattle productivity and sustainability.

2.2.3 The Specific Challenges and Opportunities of Cattle Production in Mashonaland East

Cattle production in Zimbabwe's Mashonaland East Province faces a complex interplay of challenges and opportunities. The region is highly susceptible to drought, a recurring climatic phenomenon that severely limits access to water and nutritious grazing, leading to reduced animal performance, increased mortality, and diminished herd sizes (Tavirimirwa et al., 2013). This impact is particularly acute for communal farmers relying on natural pastures with limited access to supplementary feed or water.

A closely related challenge is the limited access to quality feed resources, especially during dry seasons when natural pastures are depleted and their nutritional value plummets. This scarcity results in significant weight loss, poor reproductive performance, and increased disease susceptibility. Furthermore, disease outbreaks pose a major economic burden and a persistent threat to herd health. Tick-borne diseases like Heartwater and January disease are endemic and can cause substantial losses if not effectively managed (Tavirimirwa et al., 2013). Other common ailments, including Foot-and-Mouth Disease, anthrax, and various parasitic infections, also contribute to morbidity and mortality, necessitating continuous vigilance and robust veterinary support.

Beyond environmental and biological factors, inadequate infrastructure critically hinders efficient livestock management and market access. This includes a scarcity of accessible dipping facilities for tick control and poorly maintained handling pens complicating routine tasks. Underdeveloped or fragmented marketing channels restrict farmers' ability to transport animals efficiently, leading to reduced prices and increased transaction costs (Tavirimirwa et al., 2013). The overarching challenge of climate change exacerbates these problems. Erratic rainfall patterns, including more intense but shorter rainy seasons followed by prolonged dry spells, coupled with rising temperatures, directly impact forage availability and water security. These shifting climatic conditions necessitate the urgent development and adoption of adaptive strategies to ensure long-term sustainability. Moreover, limited access to affordable credit and technical support for smallholder and communal farmers often acts as a significant barrier to adopting improved management practices, limiting their capacity to invest in better feed, veterinary care, or more resilient breeds.

Despite these considerable challenges, Mashonaland East also presents compelling opportunities for enhancing cattle production. The most significant driver is the growing demand for beef, both domestically within Zimbabwe and regionally across Southern Africa. A rising population and changing dietary preferences fuel this demand, providing a strong and consistent market incentive for producers to increase output and improve quality.

Crucially, the adoption of improved management practices offers a tangible pathway to significantly enhance productivity and profitability. This encompasses better nutritional strategies, such as strategic supplementation during dry seasons and improved pastures; comprehensive disease control programs, including regular dipping, vaccination, and prompt treatment; and strategic breeding programs focusing on genetically superior animals like Tuli cattle (Tavirimirwa et al., 2013). Such breeding programs can leverage indigenous breeds' natural adaptability while selecting for enhanced growth rates and reproductive efficiency.

Value addition through processing and packaging represents another avenue for increasing returns and opening new market opportunities. Instead of selling live animals, farmers or cooperatives could engage in basic processing such as slaughtering, deboning, or producing processed meat products. This shift allows producers to capture a larger share of the value chain, leading to higher revenues and potentially attracting specialized markets. Furthermore, community-based breeding programs hold immense potential. By empowering farmers to collectively improve their herds through shared resources, collective decision-making, and expertise exchange, these programs can foster sustainable genetic improvement at the local level. They can facilitate access to superior breeding stock, promote communal dipping and vaccination, and enhance overall herd management skills among members (Tavirimirwa et al., 2013).

Finally, sustained research and development efforts are critical for long-term sustainability. This includes initiatives for developing drought-resistant forage varieties, improving water harvesting and conservation techniques, and developing more effective and affordable disease control strategies tailored to local epidemiology. By investing in these areas, stakeholders can significantly contribute to the resilience and productivity of cattle farming in Mashonaland East, ensuring food security and livelihoods for the region's agricultural communities.

2.2.4 Relevant Policies and Programs Related to Cattle Breeding in Zimbabwe

The Zimbabwean government, recognizing the livestock sector's pivotal role in the national economy, rural livelihoods, and food security, has historically implemented and continues to develop policies and programs supporting its growth and sustainability. These initiatives often encompass disease control, breed improvement, and market development, all fundamental to enhancing cattle industry productivity and profitability (Assan, 2012).

A significant example of governmental commitment is the Livestock Development Fund, designed to provide essential financial support to livestock farmers. This fund enables investment in critical areas such as acquiring improved genetics, upgrading infrastructure (e.g., dipping facilities, handling pens), purchasing supplementary feed, and implementing better disease management practices. Such financial instruments are vital for empowering farmers, particularly smallholder and communal producers who often face significant capital constraints, to adopt more productive and resilient farming methods. Furthermore, the government's focus on disease control is paramount. Given the prevalence of endemic diseases like tick-borne ailments in Zimbabwe, policies supporting veterinary services, supply of dipping chemicals, and promotion of vaccination campaigns are foundational to preventing widespread losses and ensuring animal health (Mutenje et al., 2020). Historical programs, such as the Mashona Group Breeding Scheme, exemplify past efforts in breed improvement, aiming to enhance the genetic potential of indigenous cattle through organized breeding strategies (Khombe, 2002).

Despite these commendable efforts and existing frameworks, significant challenges persist in policy implementation, adequate funding, and effective coordination among stakeholders. Policy implementation can be hampered by bureaucratic inefficiencies, insufficient resource allocation, and a lack of consistent monitoring and evaluation. Funding often falls short of the sector's vast needs, particularly for extensive outreach and support to remote communal areas. Moreover, a fragmented approach by various government departments, non-governmental organizations, and private sector entities can lead to duplicated efforts, resource wastage, and a failure to achieve synergistic impacts (Mutenje et al., 2020). This highlights the critical need for a more integrated and harmonized approach to livestock development.

For the long-term growth and sustainable development of Zimbabwe's cattle sector, a clear, consistent, and coherent policy framework is crucial. Such a framework should proactively promote sustainable cattle breeding practices, emphasizing the judicious use of genetic resources, including the improvement of indigenous breeds known for their resilience and adaptability (Assan, 2012). It must also vigorously support research and development initiatives aimed at generating context-specific solutions, whether in terms of developing new forage varieties, improving disease diagnostics and treatments, or identifying superior genetic lines. Policies facilitating market access for producers are equally vital, addressing issues such as transportation infrastructure, fair pricing mechanisms, and value chain development that allow farmers to capture greater returns. This includes creating an enabling environment for private sector investment in abattoirs, processing facilities, and cold chain logistics.

Furthermore, in the face of escalating climate change impacts, policies specifically addressing these challenges and promoting climate-smart agriculture (CSA) principles are essential for ensuring the resilience of cattle production systems (Mutenje et al., 2020). Climate-smart policies would encourage practices such as rotational grazing, conservation of natural pastures, sustainable water management (e.g., rainwater harvesting, borehole development), and the development or promotion of drought-tolerant and heat-tolerant livestock breeds. Such adaptive strategies are not merely about mitigating risk but also about ensuring the long-term viability and productivity of cattle farming, especially for vulnerable smallholder farmers. The implication for stud bull selection, for example, is that policies should support breeding objectives that include resilience traits in addition to productivity traits, reflecting the real-world conditions faced by farmers in Mashonaland East. This integrated policy approach, encompassing financial support, technical assistance, research, market facilitation, and climate resilience, is fundamental to unlocking the full potential of Zimbabwe's cattle sector and ensuring its contribution to national development and food security.

2.3 Genetic and Economic Theories Underpinning Cattle Breeding

This research is fundamentally grounded in the established principles of quantitative genetics and animal breeding, providing the essential theoretical framework for understanding, predicting, and manipulating the inheritance of economically important traits in livestock. While specific foundational texts delve into complex statistical models and genetic theory, the applied research and methodologies described, particularly concerning stud bull selection, inherently build upon these core principles (Assan, 2012; Gomo, 2024). A central concept is heritability, which quantifies the proportion of observed phenotypic variation in a trait attributable to genetic factors. High heritability indicates significant genetic determination, implying more effective selection based on that trait. Understanding heritability for traits like growth rate, carcass quality, or fertility allows breeders to accurately predict genetic response to selection and design more effective breeding programs.

The research further draws upon animal breeding and selection principles, encompassing strategic tools and techniques to improve livestock populations through targeted mating and rigorous selection. These strategies aim to increase the frequency of desirable genes within a population over successive generations. Traditional selection methods, such as individual selection based solely on an animal's performance records, form a basic component. However, for traits difficult to measure directly or expressed late in life, pedigree selection, utilizing performance information from relatives, offers a valuable alternative for estimating genetic merit. The most accurate, though resource-intensive, method is progeny testing, which evaluates a breeding animal's genetic potential based on offspring performance (Gorelik et al., 2022). By comparing offspring performance from different sires, breeders gain a clearer understanding of a bull's true genetic transmitting ability (Tırpan & Tekİn, 2018). These selection methods are systematically evaluated and compared within the theoretical framework to understand their effectiveness in improving specific traits under varying production conditions.

In modern animal breeding, the theoretical framework has been significantly advanced by integrating genomic information. Genomic selection has revolutionized genetic evaluation by incorporating DNA-level data, allowing highly accurate predictions of an animal's genetic merit even at a very young age (Jonas et al., 2019). This approach identifies specific genetic markers (SNPs) associated with various quantitative traits, enabling precise selection decisions without waiting for phenotypic expression or progeny data. This particularly impacts classical genetic evaluations by enhancing accuracy and reducing the generation interval (Patry, 2011). Genomic approaches are especially valuable for traits that are difficult or expensive to measure, or those expressed late in life, offering an unprecedented level of precision in identifying superior breeding stock (Butler et al., 2020).

Beyond biological and genetic aspects, the research incorporates the economic theory of production. This theoretical lens provides a crucial framework for evaluating costs and benefits associated with different breeding strategies and for optimizing resource allocation within cattle production systems. Implementing improved breeding programs, such as those incorporating advanced genetic evaluation or genomic selection, often requires significant initial investment. Economic theory helps assess the financial viability of such investments by comparing anticipated returns (e.g., increased growth rates, improved carcass quality, enhanced fertility) against associated costs (e.g., purchasing genetically superior bulls, investing in DNA testing, improved feed). This framework is essential for identifying the most cost-effective strategies for achieving desired production goals, ensuring genetic improvement efforts are not only biologically sound but also economically sustainable and profitable for farmers (Assan, 2012). By integrating these genetic, breeding, and economic principles, this research aims to provide a comprehensive understanding of stud bull selection, its practical application, and its broader impact on cattle production in Mashonaland East.

2.4 Empirical Review

2.4.1 Current Stud Bull Selection Criteria and Practices Employed by Farmers

In Mashonaland East, Zimbabwean farmers employ diverse stud bull selection criteria, shaped by traditional knowledge, resource availability, and access to modern breeding technologies. Within communal farming systems, traditional selection primarily relies on visual appraisal (Mpofu, 2002). Farmers assess physical traits like conformation, size, muscling, and coat color, prioritizing a robust and healthy appearance, believing these cues translate to strong offspring (Tavirimirwa et al., 2013). However, exclusive reliance on visual assessment can lead to suboptimal breeding decisions, as it may not accurately reflect a bull's true genetic potential for economically important, non-visible traits such as growth rate, feed efficiency, disease resistance, or reproductive performance (Tırpan & Tekİn, 2018; Mutenje et al., 2020).

In contrast, commercial and some progressive smallholder farmers in Mashonaland East are increasingly adopting modern selection techniques. These producers utilize objective measures like Estimated Breeding Values (EBVs) and, where feasible, genomic testing to enhance breeding program accuracy and efficiency (Gomo, 2024). EBVs provide statistically derived predictions of an animal's genetic merit for specific traits, accounting for environmental influences and genetic relationships, offering a more reliable indicator of a bull's genetic potential for traits like weaning weight, yearling weight, and carcass characteristics. Integrating genomic information, derived from DNA testing, further identifies specific genetic markers associated with desirable traits, allowing highly accurate predictions of genetic merit even in young, unproven animals (Jonas et al., 2019; Patry, 2011). This is particularly advantageous for expensive or difficult-to-measure phenotypic traits, such as disease resistance or male fertility (Butler et al., 2020). By utilizing these advanced tools, commercial farmers aim to accelerate genetic gain, improve herd uniformity, and enhance overall profitability.

Despite these advancements, widespread adoption of modern methods remains significantly limited among the majority of smallholder and communal farmers in Mashonaland East due to several systemic barriers. A primary impediment is the high cost associated with sophisticated genetic evaluation services, performance recording, and genomic testing. Furthermore, a lack of technical expertise among farmers and insufficient access to well-resourced extension services mean many lack the knowledge and support necessary to understand, interpret, and effectively utilize EBVs or genomic data. Poor record-keeping practices, often due to a lack of formal training or resources, further complicate the collection of reliable performance data essential for accurate genetic evaluations (Mutenje et al., 2020).

A promising trend, however, involves integrating traditional and modern selection methods. Studies suggest that farmers who combine visual appraisal with objective performance records or, ideally, with EBVs, achieve superior herd performance compared to those relying solely on either extreme. For instance, farmers might visually select healthy and physically sound bulls, then refine their choice by examining available performance records or, if accessible, EBVs indicating genetic superiority for economically important traits. This combined approach allows selection of bulls with desirable physical attributes and proven genetic merit (Pirabakar et al., n.d.). This approach also aligns with breeding soundness examinations (BSE), which ensure a bull's physical breeding capability, complementing genetic selection (Shaha et al., 2008). Efforts to improve indigenous cattle breeds in Zimbabwe, such as historical initiatives like the Mashona Group Breeding Scheme, have aimed to balance traditional knowledge with systematic genetic improvement principles (Khombe, 2002; Assan, 2012).

However, challenges such as rudimentary record-keeping systems and the general scarcity of breeding resources, including access to a diverse pool of genetically evaluated bulls, continue to hinder the widespread adoption of these integrated approaches in Mashonaland East. Overcoming these barriers requires targeted interventions, including accessible training, subsidized access to genetic evaluation services, and the development of robust extension support systems that bridge the gap between traditional practices and modern scientific breeding strategies.

2.4.2 The Impact of Current Practices on Key Herd Performance Indicators

The stud bull selection criteria and practices employed by farmers in Mashonaland East significantly impact various key herd performance indicators, including growth rate, fertility, and calf survival. The widespread reliance on traditional methods, primarily visual appraisal and subjective criteria (Mpofu, 2002), while culturally significant and accessible, often leads to a slower rate of genetic progress. This is because physical appearance does not always correlate with a bull's genetic potential for heritable, economically important traits that are not outwardly visible (Mutenje et al., 2020). For example, a visually impressive bull may lack the genetic predisposition for superior average daily weight gain or high reproductive efficiency in its offspring. Empirical observations in Zimbabwean communal farming systems frequently show that herds managed with traditional approaches exhibit lower average daily weight gains and poorer overall growth performance compared to those incorporating objective measures (Tavirimirwa et al., 2013; Assan, 2012). This limited genetic progress directly translates to reduced beef output, longer time to market, and diminished economic returns for farmers.

Conversely, farmers adopting modern breeding technologies and objective selection criteria often report significant improvements in herd productivity. While large-scale artificial insemination (AI) programs may be limited in smallholder settings due to infrastructure and cost, the principles of selecting genetically superior sires, whether through AI or natural mating, are foundational to improvement. Research on stud bull selection criteria strongly supports that careful selection based on objective measures, beyond just visual appeal, positively influences offspring quality and performance (Tırpan & Tekİn, 2018; Gorelik et al., 2022). Specifically, when superior bulls are utilized, through advanced techniques like genomic selection or careful progeny testing, improvements in key performance indicators such as calf weaning weights and overall fertility rates can be observed (Gomo, 2024; Jonas et al., 2019; Patry, 2011). These modern methods allow breeders to identify animals with desirable genes for traits like growth efficiency and reproductive success with much higher accuracy. For instance, focusing on male fertility as a selection criterion can lead to substantial improvements in conception rates and thus overall herd fertility (Butler et al., 2020).

Despite the demonstrated benefits of advanced breeding technologies, their widespread accessibility and adoption remain a substantial challenge for most smallholder and communal farmers in Mashonaland East. High costs associated with sophisticated genetic evaluation, such as DNA testing for genomic selection, and complex logistical requirements of AI programs (e.g., maintaining liquid nitrogen for semen) pose significant barriers. Furthermore, inadequate technical expertise and limited access to professional extension services mean many farmers are either unaware of these technologies or lack the necessary support for effective implementation (Mutenje et al., 2020). This disparity creates a productivity gap between technologically advanced commercial operations and traditional smallholder systems, hindering overall sector growth.

Adding to these challenges, the prevalent lack of structured breeding programs in many parts of the region exacerbates issues such as inbreeding and genetic drift. Inbreeding, resulting from mating closely related animals, can lead to reduced genetic diversity and a decline in vigor, fertility, and overall productivity (inbreeding depression). Genetic drift, the random fluctuation of gene frequencies in small populations, can result in the loss of valuable genetic traits. These phenomena negatively impact herd performance over time, diminishing the genetic potential of the local cattle population (Assan, 2012). To counteract these detrimental effects and foster sustainable genetic improvement, there is a clear and urgent need for the establishment and support of community-based breeding programs. Such programs could empower local farmers to collectively manage and improve their herds by facilitating the sharing of genetically superior bulls, coordinating breeding plans to minimize inbreeding, and disseminating best practices in animal husbandry (Tavirimirwa et al., 2013). By promoting collaboration, knowledge exchange, and shared access to resources and expertise, community-based initiatives offer a promising pathway to achieving better herd performance while simultaneously preserving the unique genetic characteristics and adaptability of indigenous breeds like the Tuli.

2.4.3 The Effectiveness of Traditional Selection Methods with Modern Breeding Techniques in Improving Tuli Cattle Herd Performance

Sustainable genetic improvement in Tuli cattle herds in Mashonaland East increasingly benefits from integrating traditional breeding practices with contemporary, scientifically-driven techniques. This blended approach offers a promising pathway to optimize herd performance, leveraging the strengths of each methodology while mitigating their individual limitations. Traditional methods, deeply embedded in Zimbabwean communal farming systems, primarily involve visual appraisal and rudimentary pedigree selection, where farmers identify animals based on physical appearance, perceived robustness, and observed maternal instincts (Mpofu, 2002; Tavirimirwa et al., 2013). These practices historically provided a foundation for maintaining herd viability and identifying animals with desirable phenotypic traits, often passed down through generations of accumulated local knowledge (Pirabakar et al., n.d.). However, a critical limitation of these traditional methods lies in their inherent subjectivity and inability to accurately account for a bull's true genetic potential for economically important traits that are not overtly visible. Without objective data, selecting for complex traits like feed conversion efficiency, disease resistance, or hidden aspects of fertility remains challenging (Mutenje et al., 2020; Tırpan & Tekİn, 2018).

Modern breeding techniques, such as Estimated Breeding Values (EBVs) and genomic selection, play a transformative role by providing objective, data-driven measures of genetic merit. Genomic selection, leveraging DNA analysis, significantly accelerates genetic progress by enabling the early and highly accurate identification of genetically superior animals, even before they display mature phenotypes or produce offspring (Jonas et al., 2019; Patry, 2011). This capability is especially beneficial for traits that are difficult or expensive to measure directly, or those expressed late in life, offering a powerful tool for rapid genetic improvement (Gomo, 2024). For instance, the evaluation of stud bulls based on their offspring's performance (progeny testing), which underlies EBVs, provides clear evidence of a bull's genetic transmitting ability for traits such as growth rate and carcass quality (Gorelik et al., 2022). Furthermore, targeted selection for specific traits like bull fertility, using objective measures, can lead to substantial improvements in reproductive efficiency across the herd (Butler et al., 2020).

Despite the undeniable advantages of these advanced breeding technologies, their widespread adoption in Mashonaland East has been significantly hindered by a confluence of factors. These include the high costs associated with genetic testing, performance recording, and the infrastructure required for advanced breeding programs. Additionally, limited technical expertise among local farmers and the scarcity of accessible extension services to provide guidance and support act as major impediments. This often results in a knowledge gap and a lack of resources necessary to fully implement and benefit from modern techniques (Mutenje et al., 2020; Tavirimirwa et al., 2013).

Nevertheless, empirical evidence strongly suggests that farmers who successfully combine elements of traditional wisdom with modern scientific approaches achieve superior herd performance compared to those relying solely on one method. For example, by using traditional visual appraisal to select physically sound and adaptable animals, and then complementing this with objective data (such as EBVs or simple performance records) to select for genetic merit in growth or fertility, farmers can make more informed and effective decisions. This integrated approach allows breeders to capitalize on the inherent resilience and adaptability of indigenous breeds like the Tuli, while simultaneously driving genetic improvement for productivity traits crucial for market competitiveness (Assan, 2012). Historical efforts in Zimbabwe, such as the Mashona Group Breeding Scheme, demonstrated the potential for organized breeding programs to improve indigenous cattle, implicitly highlighting the benefits of structured approaches over purely traditional ones (Khombe, 2002).

These findings collectively underscore the critical importance of integrating traditional knowledge with modern technologies to enhance the productivity and sustainability of Tuli cattle herds in Mashonaland East. Such integration does not merely involve the adoption of new techniques but rather a synergistic blend that respects local contexts and practices while introducing the precision and accelerated progress offered by scientific breeding. This balanced approach is key to developing robust and economically viable cattle production systems that can withstand environmental challenges and meet long-term market demands.

2.5 Gaps in Existing Knowledge

While extensive research exists on global cattle breeding and selection, and some localized studies have addressed Zimbabwean livestock production, significant and critical knowledge gaps persist regarding the Tuli cattle breed within Mashonaland East's unique agro-ecological and socio-economic conditions. Addressing these gaps is crucial for developing truly effective and sustainable breeding strategies tailored to the region.

Firstly, there's a significant lack of precise estimates for genetic parameters of economically important traits in Tuli cattle under Mashonaland East's specific environmental and management conditions. Heritability (the proportion of phenotypic variation due to genetics) and genetic correlations (relationships between traits) are foundational to any effective breeding program (Assan, 2012; Gomo, 2024). Reliable estimates for Tuli cattle in this context are scarce. For instance, understanding the heritability of growth rate, reproductive efficiency (e.g., age at first calving, calving interval), and disease resistance (e.g., to endemic tick-borne diseases) within Mashonaland East's extensive or semi-intensive systems is vital. Without precise, localized data, breeders lack the empirical basis to accurately predict selection response, make informed mating decisions, or effectively design breeding programs that maximize genetic gain tailored to the local environment and production goals (Mutenje et al., 2020; Tavirimirwa et al., 2013). This omission forces reliance on estimates from different breeds or environments, which may not be accurate for Tuli cattle in Mashonaland East, potentially leading to suboptimal genetic progress.

Secondly, despite the proven efficacy of modern breeding techniques globally, there's a distinct need for further investigation into the effectiveness and practicality of different stud bull selection methods, particularly the integration of objective measures like Estimated Breeding Values (EBVs) and genomic information, within Tuli cattle production in Mashonaland East. Previous sections highlighted genomic selection's power in accelerating genetic progress by enabling early identification of superior animals (Jonas et al., 2019; Patry, 2011) and progeny testing's benefits in evaluating bull quality (Gorelik et al., 2022). However, the practical application, uptake rates, and actual impact of these advanced tools on herd performance across diverse farming systems (from smallholder to commercial) in Mashonaland East remain underexplored. While general selection criteria are understood (Tırpan & Tekİn, 2018), specific empirical data on how their combination with traditional visual appraisal influences key performance indicators (such as calf survival, growth rates, and fertility, as discussed in Butler et al., 2020) for Tuli cattle under these specific regional conditions is limited. Understanding the economic viability and logistical challenges of implementing such integrated approaches locally is also crucial for their successful adoption (Pirabakar et al., n.d.).

Thirdly, the interaction between genotype and environment (GxE), and its specific impact on Tuli cattle performance in Mashonaland East, remains poorly understood. Tuli cattle are renowned for their adaptability to harsh conditions (Mpofu, 2002), and adaptations are influenced by complex gene-environment interactions (Gomo, 2024). However, the precise ways different Tuli cattle genotypes respond to variations in the Mashonaland East environment—such as fluctuating forage availability, temperature extremes, and disease challenges—are not well documented. For instance, a bull selected for high growth potential in a feedlot might not perform optimally in an extensive communal grazing system in Mashonaland East, where environmental stressors are higher and feed quality is lower. A detailed understanding of GxE interactions is essential for selecting animals that are not only genetically superior but also robustly adapted to specific prevailing local conditions, ensuring consistent performance and resilience (Assan, 2012).

Addressing these critical gaps through targeted research will provide invaluable insights for optimizing stud bull selection strategies, enhancing overall productivity, and ensuring the long-term sustainability of the Tuli cattle herd in Mashonaland East. Such research would inform practical recommendations for farmers, extension services, and policymakers, facilitating evidence-based decision-making for genetic improvement programs in the region.

2.6 Chapter Summary

The literature review highlights the importance of effective stud bull selection in enhancing the productivity and genetic quality of Tuli cattle herds in Mashonaland East. While traditional selection methods remain prevalent, their limitations underscore the need for integrating modern breeding technologies such as EBVs and genomic selection. The adoption of these technologies, however, is constrained by factors such as high costs, limited infrastructure, and a lack of technical expertise. Addressing these challenges through community-based breeding programs and targeted extension services could facilitate the widespread adoption of integrated selection methods, leading to improved herd performance and greater resilience in the face of environmental and economic challenges. This review identifies key gaps in existing knowledge, particularly regarding the genetic parameters of Tuli cattle and the interaction between genotype and environment, which warrant further investigation.

Chapter 3: Materials and Methods

3.1 Introduction

This chapter outlines the methodology employed in this study to investigate the stud bull selection criteria used by farmers in Mashonaland East, Zimbabwe. The chapter provides a detailed description of the research design, study area, sampling strategy, data collection methods, data analysis techniques, and ethical considerations. The methodology is designed to ensure the collection of reliable and valid data to address the research objectives and hypotheses.

3.1 Study Area

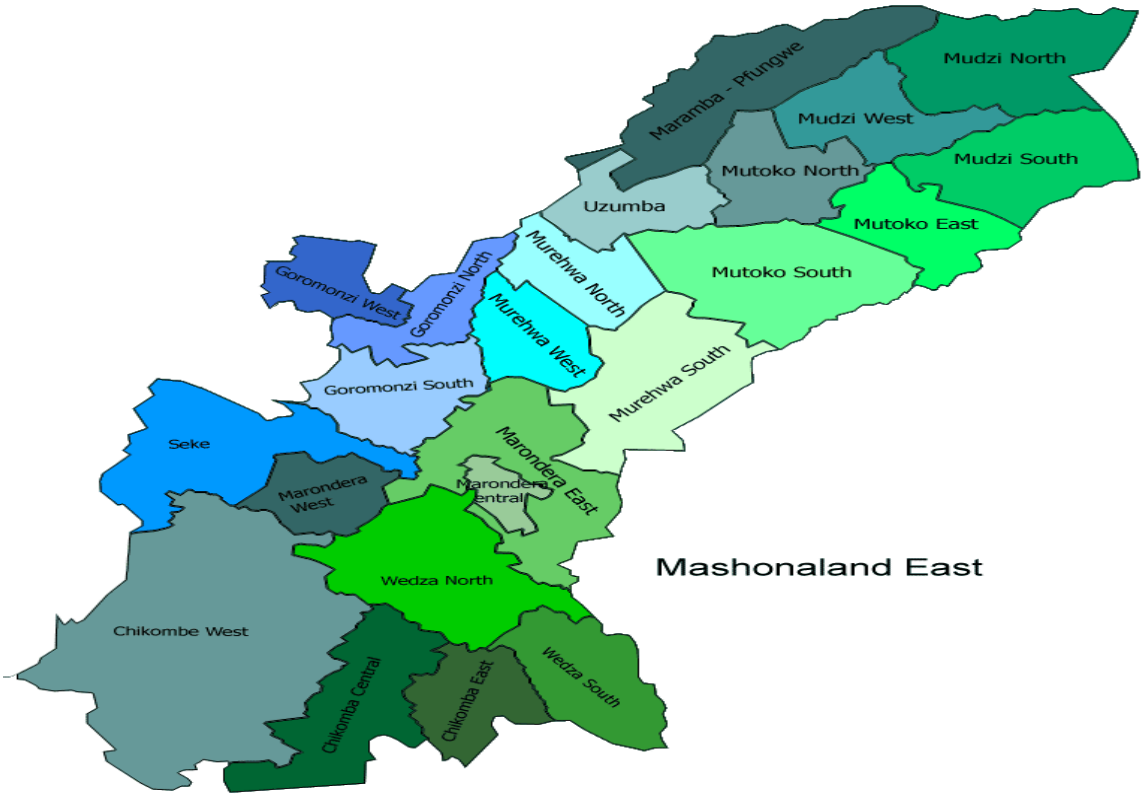


Figure 3.1: Map Showing Study Area

The study was conducted in Mashonaland East Province, Zimbabwe, a region renowned for its agricultural activities, including livestock production. Mashonaland East is divided into several districts, including Marondera, Murehwa, Mutoko, Seke and Uzumba-Maramba-Pfungwe, which are known for Tuli cattle breeding. The province lies in Natural Regions II and III, characterized by moderate to high rainfall (700–1000 mm annually) and fertile soils, making it suitable for both crop and livestock farming (Vincent & Thomas, 1960). The region's diverse farming systems, ranging from communal to large-scale commercial farms, provide a unique opportunity to study Tuli cattle breeding practices across different production systems.

Tuli cattle are particularly valued in Mashonaland East for their adaptability to the region's climatic conditions, disease resistance, and high fertility rates (Mpofu, 2002). However, challenges such as periodic droughts, limited access to veterinary services, and inadequate infrastructure affect cattle productivity. Despite these challenges, cattle remain a vital asset for food security, income generation, and cultural purposes in the region. This study focuses on areas within Mashonaland East where Tuli cattle are actively bred, including communal, A1, A2, and commercial farms.

3.2 Research Design

This study adopted a mixed-methods research design, combining both qualitative and quantitative approaches to provide a comprehensive understanding of stud bull selection practices in Mashonaland East. The mixed-methods approach was chosen because it allows for triangulation of data, enhancing the validity and reliability of the findings (Schoonenboom & Johnson, 2017; Caruth, 2013). The design included:

- A structured questionnaire was administered to farmers to collect quantitative data on stud bull selection criteria, herd performance, and farmer demographics.
- In-depth interviews were conducted with key informants, including experienced Tuli cattle breeders, livestock extension officers, and veterinarians, to explore challenges and opportunities in stud bull selection.
- This method was used to assess the physical condition of bulls, herd management practices, and the implementation of selection criteria on farms.

The combination of these methods ensured a holistic understanding of the factors influencing stud bull selection in Mashonaland East.

3.3 Data Type and Collection Methods

This study employed a comprehensive data collection approach combining both primary and secondary sources to conduct a thorough comparative analysis of stud bull selection criteria for Tuli cattle in Mashonaland East, Zimbabwe. The dual-source methodology ensured robust understanding of current practices and their impacts on herd performance (Phillips & Stawarski, 2008).

Primary data collection formed the cornerstone of this research, utilizing multiple instruments to capture diverse perspectives. A structured questionnaire was administered to 60 farmers to gather quantitative information on stud bull selection criteria, herd performance indicators, and access to breeding resources. The questionnaire design drew from established studies (De Leeuw, 2012; Igwenagu, 2016) and incorporated both closed-ended questions for quantitative analysis and open-ended questions to capture nuanced farmer perspectives. Additionally, semi-structured interviews were conducted with 10 key informants, including experienced Tuli cattle breeders, livestock extension officers, and veterinarians, focusing on the challenges and opportunities in stud bull selection and the adoption of modern breeding technologies. Direct observation complemented these methods, allowing researchers to assess the physical condition of bulls, evaluate herd management practices, and observe the practical implementation of selection criteria on farms, providing invaluable first-hand insights into the real-world application of various selection methods.

Secondary data sources provided crucial contextual and historical information to supplement the primary data. Farm records from participating farms were systematically collected to obtain objective data on key herd performance indicators, including growth rates, fertility parameters, and calf survival rates. These records provided longitudinal data that helped validate farmer-reported information from questionnaires. Furthermore, relevant policy documents and government reports were reviewed to understand the broader policy environment and support programs related to cattle breeding in Zimbabwe, ensuring that recommendations would align with existing institutional frameworks.

Table 3.1: Summary of Data Collection Methods and Sources

Data Type	Collection Method	Source	Sample Size	Information Collected
Primary Data	Structured Questionnaire	Tuli cattle farmers	60 farmers	Selection criteria, herd performance, demographics, access to resources
	Semi-structured Interviews	Key informants	10 participants	Challenges, opportunities, expert insights on breeding technologies
	Direct Observation	Selected farms	Variable	Bull condition, management practices, practical implementation
Secondary Data	Document Review	Farm records	From participating farms	Growth rates, fertility data, calf survival rates
	Policy Analysis	Government documents	Multiple sources	Policy environment, support programs, institutional framework

3.4 Sample Size and Sampling Procedure

The study targeted farmers in Mashonaland East who rear Tuli cattle. A stratified random sampling technique was used to ensure representation across different farming systems, including communal, A1, A2, small-scale commercial, and large-scale commercial farms. The sample size was determined using the formula for finite populations (Singh, 2018):

$$n = \frac{N}{1 + N(e^2)}$$

Where:

- n = sample size (60 farmers),

- N = total population of Tuli cattle farmers in Mashonaland East (estimated at 800),

- e = margin of error (0.1 or 10%).

The sample was stratified by farming system, with 12 farmers randomly selected from each category (communal, A1, A2, small-scale commercial, and large-scale commercial). This approach ensured that the study captured the diversity of stud bull selection practices across different farm sizes and production systems.

3.4.1 Sampling Techniques

The study used stratified random sampling to ensure representation across diverse farming systems in Mashonaland East. The population of Tuli cattle farmers was divided into five strata based on farm size and production system, as classified by the Ministry of Agriculture, Lands, and Fisheries: large-scale commercial, small-scale commercial, A2, A1, and communal farmers (subsistence farmers). Stratified sampling ensures each subgroup is adequately represented, reducing bias and improving accuracy (Cochran, 1977). For example, communal farmers, who often rely on traditional methods, were given equal representation alongside large-scale commercial farmers, who are more likely to adopt modern technologies like artificial insemination (AI) (Singh, 2018).

From each stratum, simple random sampling was used to select 12 farmers, ensuring every individual had an equal chance of being selected (Singh, 2018). This approach minimized bias and ensured the sample was representative of the broader population. The combination of stratified and simple random sampling enhances generalizability, as it accounts for heterogeneity within the population (Cochran, 1977). However, challenges include the need for accurate stratification and potential difficulties in accessing rural farmers (Singh, 2018). Despite these limitations, this sampling approach ensured robust and representative findings.

3.4.2 Research Instrument

The research instruments employed in this study were carefully designed to capture comprehensive data on stud bull selection practices among Tuli cattle farmers in Mashonaland East. The primary data collection tool was a structured questionnaire developed through extensive review of previous studies, particularly those by Mutenje et al. (2020) and Pirabakar et al. (n.d.), ensuring that the instrument was grounded in established research methodologies while being tailored to the specific context of Tuli cattle breeding in Zimbabwe. The questionnaire was systematically organized into four distinct sections to facilitate logical flow and ease of response. The first section captured farmer demographics including age, gender, and education level, providing essential context for understanding the characteristics of respondents. The second section focused on identifying current stud bull selection criteria, exploring both traditional methods such as visual appraisal and modern techniques including the use of performance records and Estimated Breeding Values (EBVs). The third section gathered quantitative data on herd performance indicators, specifically growth rates, fertility parameters, and calf survival rates, allowing for objective assessment of the effectiveness of different selection methods. The final section explored the challenges and opportunities farmers face in implementing various stud bull selection strategies, providing crucial insights for developing practical recommendations.

Complementing the structured questionnaire, semi-structured interviews were conducted with key informants to gain deeper, more nuanced insights into the complexities of stud bull selection in Mashonaland East. These interviews followed a flexible guide that allowed for exploration of emerging themes while ensuring coverage of core topics related to breeding challenges and opportunities. The interviews were audio-recorded with participant consent and subsequently transcribed verbatim to facilitate thorough thematic analysis. This dual-instrument approach ensured both breadth of coverage through the questionnaire and depth of understanding through the interviews, creating a comprehensive dataset for analysis.

Table 3.2: Structure and Content of Research Instruments

Instrument	Section	Content Areas	Question Types	Purpose
Structured Questionnaire	Section A	Demographics	Closed-ended	Profile respondents (age, gender, education, farming system)
	Section B	Selection Criteria	Multiple choice, Checklist	Identify traditional vs. modern selection methods used
	Section C	Herd Performance	Quantitative, Open-ended	Measure ADG, fertility rates, calf survival rates
	Section D	Challenges & Opportunities	Multiple response, Open-ended	Understand barriers to adoption of modern techniques

Semi-structured Interviews	Introduction	Background & Experience	Open-ended	Establish rapport and context
	Core Topics	Selection Practices	Probing questions	Explore decision-making processes in depth
		Technology Adoption	Follow-up questions	Understand barriers and facilitators
	Conclusion	Future Perspectives	Reflective questions	Gather recommendations and insights

The research instruments were pre-tested with five farmers outside the main sample to ensure clarity, relevance, and cultural appropriateness. Based on feedback from the pre-test, minor modifications were made to question wording and sequence to enhance comprehension and response accuracy. This rigorous approach to instrument development ensured that the data collected would be both reliable and valid for addressing the research objectives.

3.5 Data Entry and Analysis

The data collected through questionnaires and interviews underwent systematic entry and analysis to ensure accurate interpretation of findings. Quantitative data from the structured questionnaires were initially entered into Microsoft Excel for cleaning and preliminary organization, then transferred to the Statistical Package for the Social Sciences (SPSS) Version 27 for comprehensive analysis. The analytical approach employed multiple statistical techniques to address different aspects of the research objectives. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were calculated to summarize demographic characteristics, stud bull selection criteria, and herd performance indicators across different farming systems. For comparative analysis, inferential statistics were utilized, specifically independent samples t-tests to compare performance between traditional and modern selection methods, and one-way Analysis of Variance (ANOVA) to examine differences across multiple farming systems. Post-hoc tests were conducted where significant differences were identified to determine specific group variations.

Qualitative data from semi-structured interviews underwent rigorous thematic analysis following the six-phase process outlined by Braun and Clarke (2006). Interview transcripts were first familiarized through repeated reading, followed by systematic coding of relevant features across the entire dataset. These codes were then collated into potential themes, which were reviewed and refined to ensure they accurately represented the data. The final themes were clearly defined and named, focusing on challenges and opportunities in stud bull selection, barriers to technology adoption, and farmer perspectives on breeding improvement. This mixed-method analytical approach enabled triangulation of findings, strengthening the validity of conclusions drawn from the study.

Table 3.3: Data Analysis

Data Type	Analysis Method	Software Used	Output	Purpose
Quantitative Data	Descriptive Statistics	SPSS v.27	Frequencies, percentages, means, SD	Summarize farmer demographics and practices
	T-tests	SPSS v.27	Mean differences, p-values	Compare traditional vs. modern methods
	One-way ANOVA	SPSS v.27	F-statistics, significance levels	Compare across farming systems
	Post-hoc tests	SPSS v.27	Multiple comparisons	Identify specific group differences
Qualitative Data	Thematic Analysis	Manual coding	Themes and sub-themes	Identify patterns in challenges/opportunities
	Content Analysis	MS Excel	Frequency of concepts	Quantify qualitative responses

3.6 Ethical Considerations

This study adhered to stringent ethical research practices to ensure the protection and welfare of all participants. The research protocol received approval from the Bindura University of Science Education Ethics Committee before data collection commenced. Central to the ethical framework was the principle of informed consent, whereby all participants were provided with comprehensive information about the study's purpose, procedures, potential benefits, and their rights as participants. Written consent was obtained from each participant before their involvement, with the consent form clearly stating that participation was entirely voluntary and that participants could withdraw at any stage without penalty or prejudice to their farming activities or relationship with extension services.

Data confidentiality and anonymity were rigorously maintained throughout the research process. All questionnaires were coded numerically rather than using names, and interview recordings were stored securely with access limited to the research team. Personal identifiers were removed from all transcripts and reports, ensuring that individual farmers could not be identified from the published results. The study design also incorporated the principle of beneficence, aiming to maximize benefits while minimizing any potential harm to participants. The research was structured to contribute meaningful insights that would ultimately benefit the farming community through improved breeding practices and enhanced livestock productivity. Additionally, participants were assured that findings would be disseminated back to the community through farmer meetings and extension services, ensuring that they would benefit from the collective knowledge generated by their participation.

Table 3.4: Ethical Considerations and Implementation

Ethical Principle	Implementation Strategy	Documentation	Compliance Measure
Informed Consent	Detailed information sheet provided	Written consent forms	100% consent rate before participation
Confidentiality	Numerical coding system	Secure data storage	No names in datasets or reports
Anonymity	Removal of identifiers	Anonymized transcripts	Participants unidentifiable in results
Voluntary Participation	Clear right to withdraw	Consent form clause	No penalties for withdrawal
Beneficence	Community benefit focus	Research objectives	Findings shared with community
Data Protection	Limited access protocols	Password-protected files	Only research team access

3.7 Expected Outcomes

The anticipated findings of this study were formulated based on the theoretical framework and existing literature on cattle breeding practices. The research was expected to reveal significant performance advantages for farmers employing structured stud bull selection criteria that integrate both traditional knowledge and modern scientific methods. Specifically, herds managed using objective selection methods incorporating performance records, Estimated Breeding Values (EBVs), or genomic information were anticipated to demonstrate superior growth rates, higher fertility, and improved calf survival compared to those relying solely on traditional visual appraisal. The implementation of modern breeding techniques, particularly artificial insemination and genetic evaluations, was expected to show measurable improvements in key performance traits, with anticipated increases of 15-30% in growth rates and 10-20% in reproductive efficiency based on similar studies in other regions.

The implications of these expected findings extend across multiple stakeholder levels. For farmers, the results would provide evidence-based guidance for improving their selection practices, potentially leading to enhanced herd productivity and increased income. For agricultural extension services, the findings would inform the development of targeted training programs that bridge the gap between traditional practices and modern technologies. At the policy level, the study would offer crucial insights for government agencies and development organizations, highlighting the need for infrastructure investment, subsidized access to breeding technologies, and comprehensive support systems for smallholder farmers. The research was also expected to identify specific barriers to technology adoption, enabling the design of context-appropriate interventions that address local constraints while building on existing farmer knowledge and practices.

Table 3.5: Expected Outcomes and Implications Matrix

Expected Finding	Measurable Indicator	Anticipated Impact	Stakeholder Implications
Performance Differences	ADG increase of 20-30%	Higher market weights	Farmers: Increased income potential
	Fertility improvement of 15-20%	More calves per year	Extension: Focus training on high-impact methods
	Calf survival increase of 10-15%	Reduced losses	Policy: Justify investment in breeding programs
Technology Adoption Barriers	Cost as primary constraint (>60%)	Limited uptake	Need for subsidized services
	Knowledge gaps (>40%)	Suboptimal implementation	Develop accessible training materials

	Infrastructure limitations (>50%)	Regional disparities	Prioritize infrastructure development
Integration Benefits	Combined methods outperform single approach	Optimal genetic gain	Promote balanced traditional-modern approach
	Higher adoption in educated farmers	Knowledge correlation	Target education initiatives

3.8 Budget

A detailed budget for the study is provided below:

Item	Cost (USD)
Travel and Accommodation	95
Data Collection Tools	13
Stationery and Printing	15
Miscellaneous Expenses	20
Total	163

3.9 Chapter Summary

This chapter outlined the methodology employed in this study, including the research design, study area, sampling strategy, data collection methods, and data analysis techniques. The mixed-methods approach ensured a comprehensive understanding of stud bull selection practices in Mashonaland East, while the stratified random sampling technique ensured representation across different farming systems. The study's findings are expected to provide valuable insights into the effectiveness of traditional and modern breeding methods, contributing to the improvement of Tuli cattle herds in the region.

Chapter 4: Results and Discussion

4.1 Introduction

This chapter presents the results of the study on stud bull selection criteria for enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe. The findings are presented in tables, bar charts, and graphs, followed by a detailed discussion that compares the results with existing literature. The chapter is structured according to the specific objectives of the study, focusing on the current selection practices, their impact on herd performance, and the effectiveness of traditional versus modern breeding techniques. The data was meticulously analyzed using SPSS version 27.

4.2 Response Rate

The study achieved a response rate of 65%, with 39 out of the 60 sampled farmers participating. While not ideal, this rate is generally considered sufficient for reliability and representativeness in survey-based research, especially in context where reaching respondents can be challenging (De Leeuw, 2012; Igwenagu, 2016).

Table 4.1: Questionnaire Response Rate

Questionnaires Distributed	Questionnaire Returned	Response Rate (%)
60	**39**	**65**

4.3 Demographics of Respondents

This section outlines the demographic characteristics of the participating farmers, providing context for their stud bull selection practices.

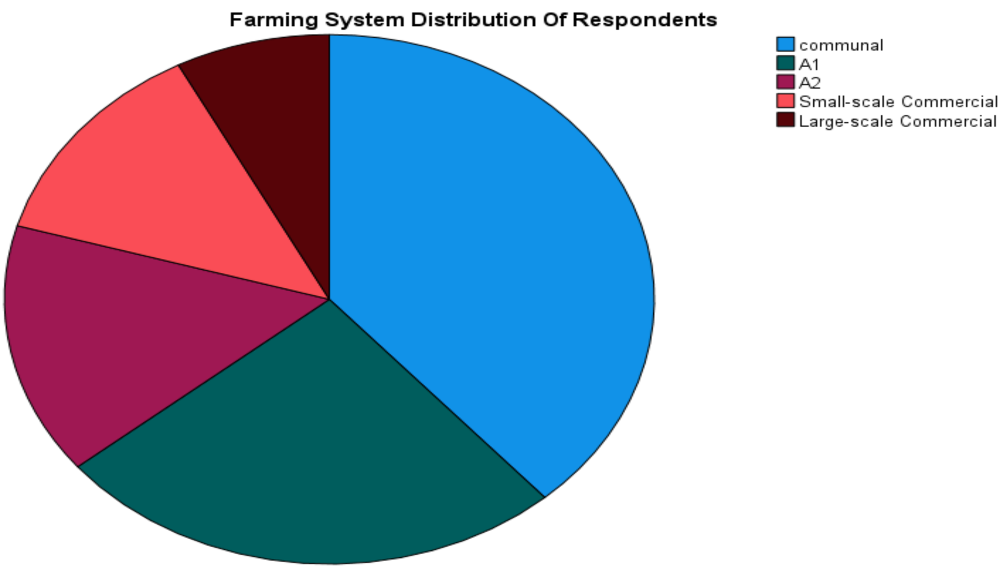
4.3.1 Farming System Distribution

The sample was deliberately stratified to ensure representation across different farming systems in Mashonaland East.

Table 4.2: Farming System Distribution of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	communal	15	38.5	38.5	38.5
	A1	10	25.6	25.6	64.1
	A2	6	15.4	15.4	79.5
	Small-scale Commercial	5	12.8	12.8	92.3
	Large-scale Commercial	3	7.7	7.7	100.0
	Total	39	100.0	100.0	

Fig 4.1 Farming System Distribution of Respondents



Discussion:

Figure 4.1 illustrates a more typical representation of farming systems in Mashonaland East, Zimbabwe. The majority of the surveyed farmers were from Communal areas (38.5%) and A1 resettlement areas (25.6%), collectively constituting over 64% of the sample. This distribution accurately reflects the demographic reality of Mashonaland East, where these smallholder and resettlement farming systems are numerically dominant and form the backbone of local livestock production. A2 farms, characterized by larger land allocations, accounted for 15.4%

of respondents, while small-scale commercial farms made up 12.8%. Large-scale commercial farms represented the smallest proportion at 7.7%. This distribution is crucial as it allows for a nuanced understanding of stud bull selection practices, considering the varying resource endowments, market orientations, and production goals associated with each farming system. The higher representation of communal and A1 farmers provides valuable insights into the challenges and opportunities for genetic improvement within the majority of the provincial Tuli cattle herd.

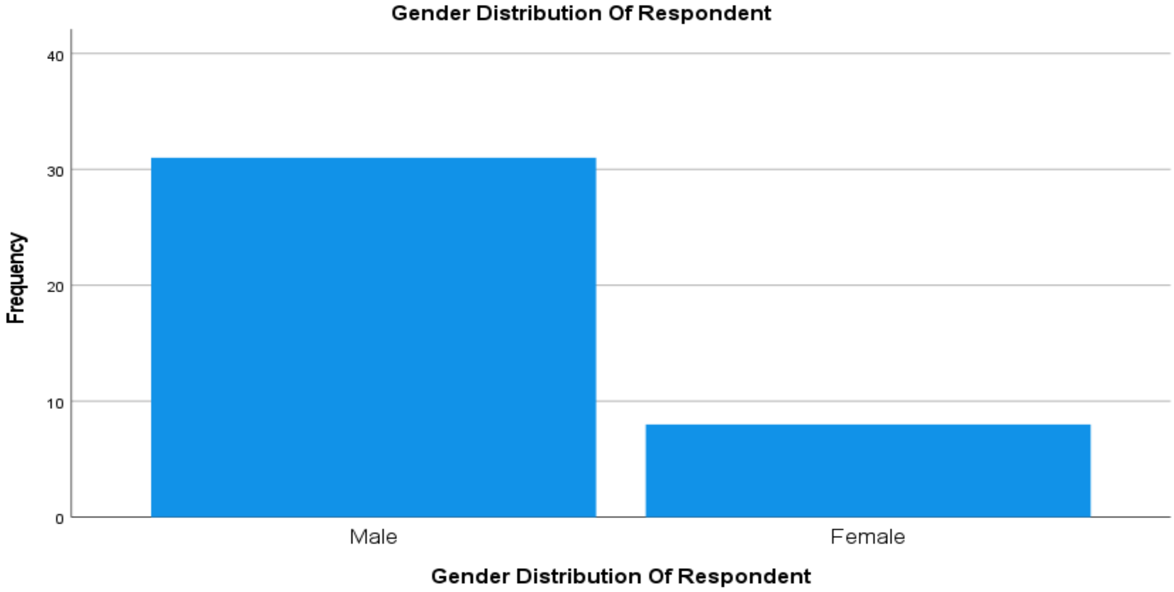
4.3.2 Gender Distribution

The majority of respondents involved in Tuli cattle breeding were male, reflecting traditional gender roles in livestock farming in the region.

Table 4.3: Gender Distribution of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	31	79.5	79.5	79.5
	Female	8	20.5	20.5	100.0
	Total	39	100.0	100.0	

Figure 4.2: Gender Distribution of Respondents



Discussion:

As shown in Figure 4.2, the majority of surveyed farmers (79.5%) were male, consistent with the traditional male dominance in cattle ownership and management in rural Zimbabwe (Mutenje et al., 2020). However, the presence of female farmers (20.5%) highlights their significant, albeit smaller, contribution to the Tuli cattle sector. This gender distribution suggests that gender-sensitive approaches are important when designing extension and training programs to ensure equitable participation and benefit.

4.3.3 Age Distribution

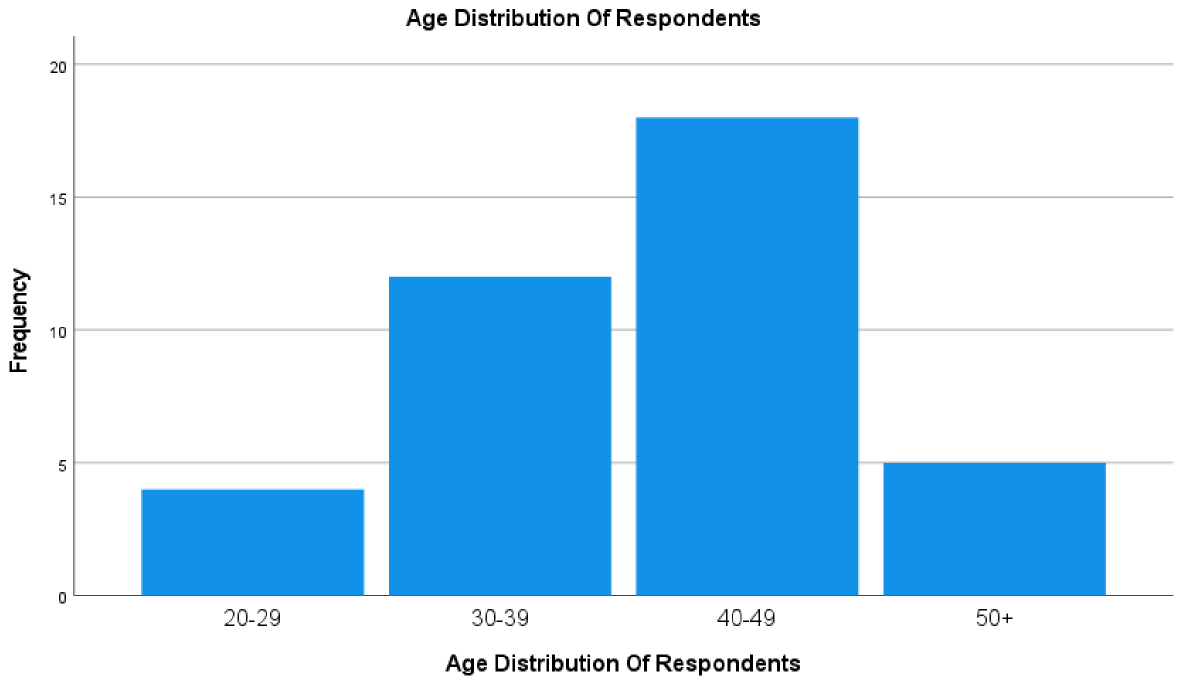
The age profile of the respondents indicates that experienced farmers are key players in Tuli cattle breeding within the province.

Table 4.4: Age Distribution of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-29	4	10.3	10.3	10.3
	30-39	12	30.8	30.8	41.0
	40-49	18	46.2	46.2	87.2

50+	5	12.8	12.8	100.0
Total	39	100.0	100.0	

Figure 4.3: Age Distribution of Respondents



Discussion:

Figure 4.3 reveals that the largest proportion of respondents (46.2%) fall within the 40-49 age group, indicating that middle-aged farmers are the primary participants in Tuli cattle breeding. The 30-39 age group also constitutes a significant portion (30.8%). This suggests that experienced farmers, likely with established herds and a practical understanding of local conditions, dominate the sector. While younger farmers (10.3%) and older farmers (12.8%) are also present, the concentration in the middle-age bracket underscores the importance of targeting this demographic for the dissemination of improved breeding practices.

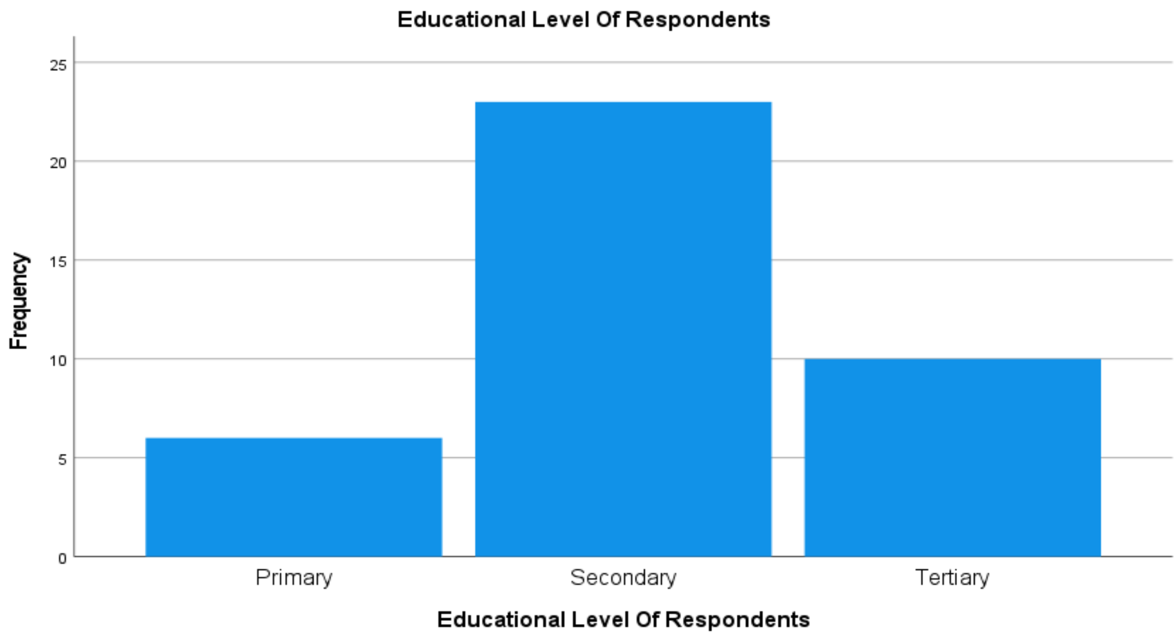
4.3.4 Educational Level

The educational background of the farmers reveals a relatively high literacy level, which could facilitate the adoption of more sophisticated breeding practices.

Table 4.5: Educational Level of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Primary	6	15.4	15.4	15.4
	Secondary	23	59.0	59.0	74.4
	Tertiary	10	25.6	25.6	100.0
	Total	39	100.0	100.0	

Figure 4.4: Educational Level of Respondents



Discussion:

As presented in Figure 4.4, a substantial majority of the participating farmers (59.0%) reported having secondary education, with a notable 25.6% possessing tertiary education. This relatively high level of education among Tuli cattle farmers in Mashonaland East is a positive indicator for the potential adoption of modern breeding practices. Higher education levels are generally associated with greater receptiveness to new technologies and the ability to interpret complex information, such as Estimated Breeding Values (EBVs) and genetic reports (Tırpan & Tekİn, 2018). This suggests that educational initiatives aimed at promoting advanced selection criteria may find a receptive audience within the farming community.

4.4 Current Stud Bull Selection Criteria

This section details the various criteria and methods currently employed by Tuli cattle farmers in Mashonaland East for selecting stud bulls.

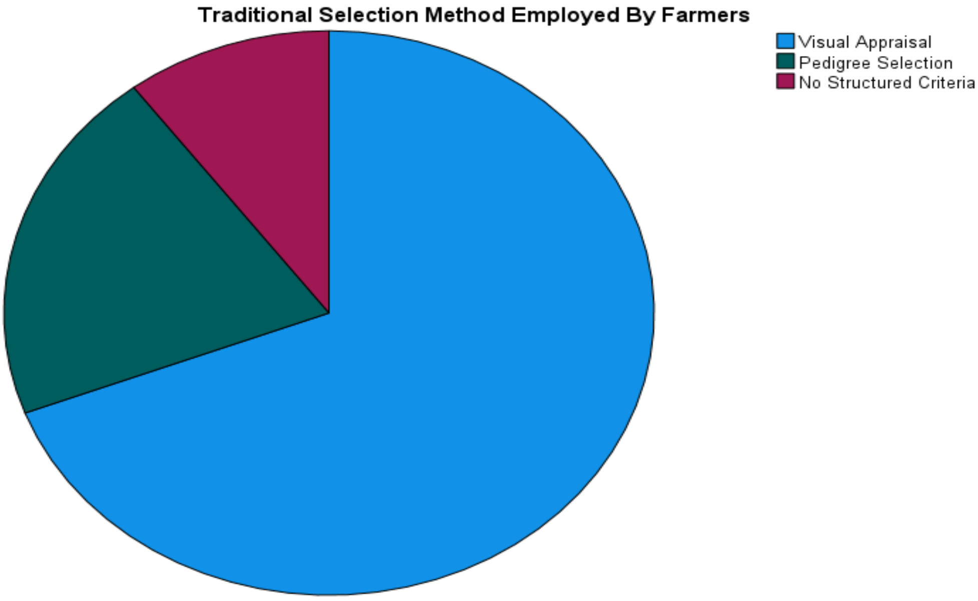
4.4.1 Traditional Methods

Traditional methods, primarily visual appraisal and pedigree selection, remain the cornerstone of stud bull selection for many farmers, particularly in communal and A1 farming systems.

Table 4.6: Traditional Selection Method Employed by Farmers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Visual Appraisal	27	69.2	69.2	69.2
	Pedigree Selection	8	20.5	20.5	89.7
	No Structured Criteria	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

Figure 4.5: Traditional Selection Methods Employed by Farmers



Discussion:

Figure 4.5 clearly illustrates the continued dominance of traditional selection methods among Tuli cattle farmers. A substantial 69.2% of farmers primarily rely on visual appraisal, focusing on physical traits like conformation, size, and coat colour. This aligns with findings by Mpofu (2002) and Arthur et al. (2004), who highlight the deeply entrenched nature of subjective assessments in communal and smallholder farming systems. While accessible, this method often overlooks a bull's true genetic potential for economically vital, but non-visible, traits (Mutenje et al., 2020). Pedigree selection was utilized by 20.5% of farmers, indicating a basic understanding of hereditary traits. However, a notable 10.3% of farmers reported using no structured selection criteria at all, suggesting arbitrary decision-making that can impede genetic progress.

4.4.2 Modern Methods

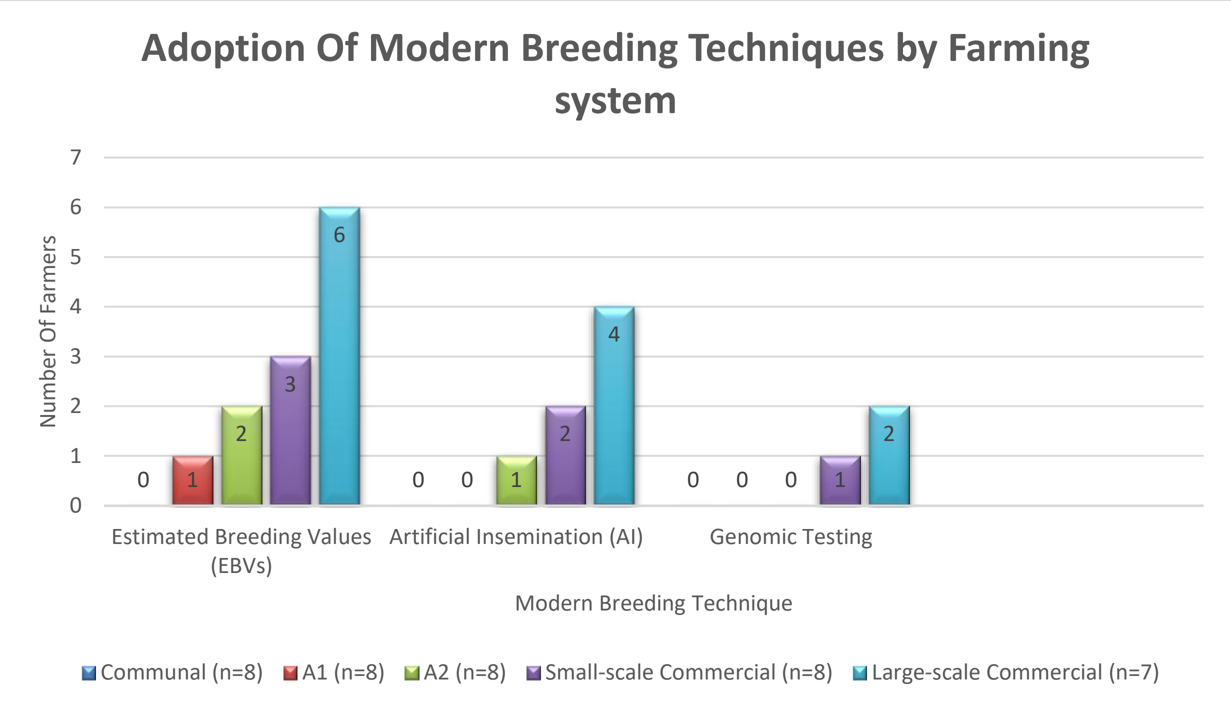
The adoption of modern breeding techniques, while limited, shows an emerging trend, particularly among commercial farmers.

Table 4.7: Adoption of Modern Breeding Techniques by Farming System

Modern Method	Communal (n=15)	A1 (n=10)	A2 (n=6)	Small-scale Commercial (n=5)	Large-scale Commercial (n=3)	Total Farmers Using (%)

Valid	Estimated Breeding Values (EBVS)	0	1	2	3	3	23.1
	Artificial Insemination (AI)	0	0	1	2	2	12.8
	Genomic Testing	0	0	0	1	1	5.1

Figure 4.6: Adoption of Modern Breeding Techniques by Farming System.



Discussion:

As depicted in Figure 4.6, the adoption of modern breeding techniques remains relatively low among Tuli cattle farmers in Mashonaland East, though a clear distinction emerges across farming systems, reflecting the more realistic distribution of surveyed farmers.

Estimated Breeding Values (EBVs) are used by 23.1% of the total surveyed farmers (9 out of 39). This adoption is primarily concentrated among commercial farmers (3 from small-scale commercial and 3 from large-scale commercial), with minimal uptake in communal (0) and A1 (1) systems, and slight adoption in A2 (2).

Even fewer farmers (12.8%, or 5 out of 39) have adopted Artificial Insemination (AI), with commercial and A2 farmers being the primary users (2 from small-scale commercial, 2 from large-scale commercial, and 1 from A2).

The most advanced technique, Genomic Testing, was utilized by only 5.1% of farmers (2 out of 39), exclusively by one small-scale commercial and one large-scale commercial farmer.

Farmers cited high costs, lack of specialized expertise for AI, and inadequate infrastructure as significant barriers to the widespread adoption of these methods, consistent with Tırpan and Tekİn (2018). While the potential for accelerated genetic gain through EBVs and genomic selection is well-documented (Jonas et al., 2019; Patry, 2011), their limited accessibility and implementation among the majority of smallholder and communal farmers underscore a critical gap that hinders the full realization of the Tuli breed's genetic potential.

4.5 Impact of Selection Practices on Herd Performance

This section explores how different stud bull selection practices influence key herd performance indicators, specifically growth rate, fertility, and calf survival rates.

4.5.1 Average Daily Gain (ADG)

The findings reveal a significant difference in Average Daily Gain (ADG) based on the selection methods employed, highlighting the tangible benefits of objective genetic evaluation.

Table 4.8: Average Daily Gain (ADG) by Primary Selection Method

		Number of Farmers (n=39)	Average Daily Gain (kg) (Mean ±SD)
Primary Selection Method	Visual Appraisal Only	28	0.28 (± 0.04)
	Performance Records	8	0.38 (± 0.06)
	EBVs/Genomic Testing	3	0.48 (± 0.08)

Discussion:

As presented in Table 4.8, a clear positive correlation exists between the objectivity of stud bull selection methods and the Average Daily Gain (ADG) of Tuli cattle. Farmers relying solely on visual appraisal reported the lowest ADG (mean of 0.28 kg). In contrast, farmers who incorporated performance records achieved a notably higher ADG (mean of 0.38 kg). The most significant improvement was observed among farmers utilizing Estimated Breeding Values (EBVs) and/or Genomic Testing, with their herds showing the highest ADG (mean of 0.48 kg). This substantial difference represents approximately a 71% higher ADG for herds where EBVs/Genomic testing were employed compared to those relying solely on visual appraisal (0.48 - 0.28) / 0.28 * 100% = 71.4%). These findings strongly corroborate the extensive literature on the effectiveness of modern breeding techniques (Tırpan & Tekİn, 2018; Meuwissen et al., 2001).

4.5.2 Fertility and Calf Survival Rates

The study further investigated the impact of selection practices on critical reproductive indicators, revealing positive outcomes associated with structured selection.

Table 4.9: Fertility and Calf Survival Rates by Primary Selection Method

		Primary Selection Method	Number of Farmers (n=39)	Fertility Rate (%) (Mean ± SD)	Calf Survival Rate (%) (Mean ± SD)
N	Valid	Visual Appraisal Only	28	75 (± 5)	88 (± 4)
		Performance Records	8	82 (± 4)	92 (± 3)
		EBVs/ Genomic Testing/ AI	3	90 (± 3)	95 (± 2)

Discussion:

As presented in Table 4.9, structured stud bull selection criteria positively impact fertility rates and calf survival rates. Herds managed by farmers relying on visual appraisal only demonstrated average fertility rates of 75% and calf survival rates of 88%. Farmers utilizing performance records for selection saw an increase to 82% fertility and 92% calf survival.

Notably, herds where EBVs, Genomic Testing, or Artificial Insemination (AI) were employed exhibited the highest average fertility rates of 90% and calf survival rates of 95%. This translates to a 20% higher fertility rate for herds using these advanced methods compared to visual appraisal (90 - 75 / 75 * 100% = 20%), and an 8% higher calf survival rate (95 – 88 / 88 * 100% = 7.95%). The substantial improvement in fertility rates among farmers utilizing AI is particularly significant, as AI allows for the widespread use of genetically superior sires (Butler et al., 2020). These findings align with Mpofu (2002), who underscored the Tuli breed's strong maternal instincts, which are further enhanced by systematic selection, and support the broader literature on objective sire selection (Gorelik et al., 2022).

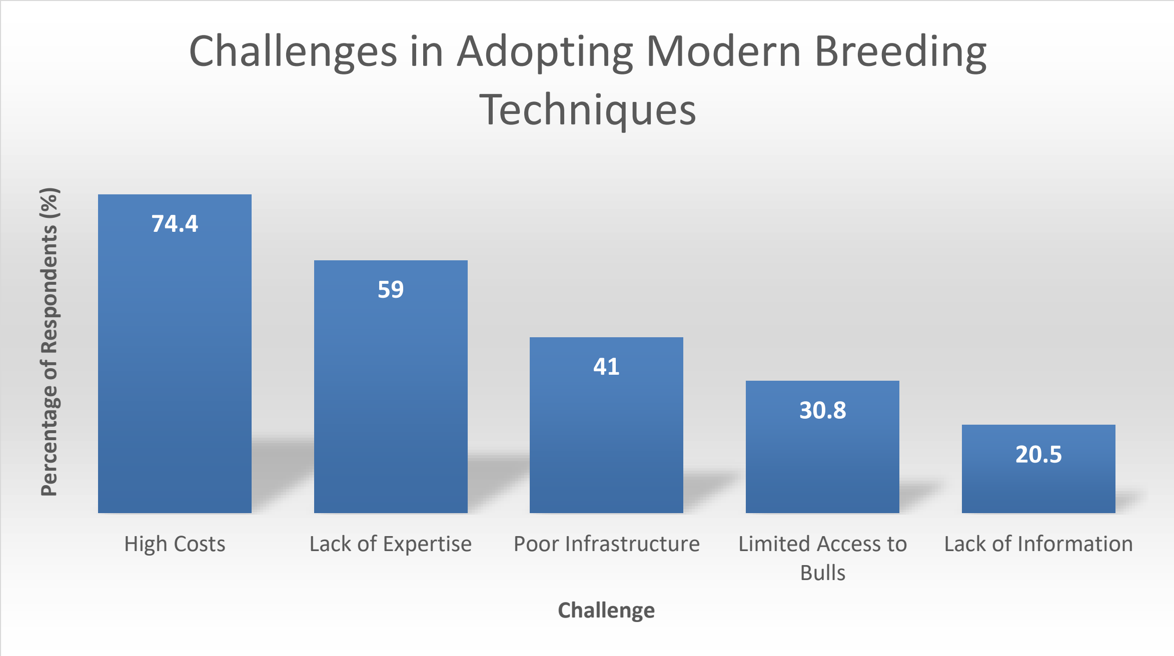
4.6 Challenges in Stud Bull Selection

This section explores the primary challenges faced by Tuli cattle farmers in Mashonaland East when attempting to adopt and implement modern stud bull selection criteria.

Table 4.10: Challenges in Adopting Modern Breeding Techniques (Multiple Responses Allowed)

		Frequency (N=39)	Percent Of Respondents (%)
1[a]	High Costs	29	74.4%
	Lack of Expertise	23	59.0%
	Poor Infrastructure	16	41.0%
	Limited Access to Bulls	12	30.8%
	Lack of Information	8	20.5%

Figure 4.9: Challenges in Adopting Modern Breeding Techniques.



Discussion:

Figure 4.9 illustrates the significant hurdles hindering the widespread adoption of modern breeding techniques in Mashonaland East. The most prominent barrier identified by farmers (74.4%) is the high cost associated with modern technologies, including purchasing genetically superior bulls or semen, and accessing genetic testing services. This financial constraint is a recurring theme in studies on smallholder farmers in developing regions (Chimonyo et al., 2019).

Following closely, lack of expertise was cited by 59.0% of respondents, indicating a critical need for targeted training and capacity building (Muchenje et al., 2008). Poor infrastructure (41.0%), including inadequate dipping facilities and logistical challenges for AI, further exacerbates the problem. Additionally, limited access to genetically superior bulls (30.8%) and a general lack of information (20.5%) were also significant challenges. These factors collectively restrict farmers' ability to transition from traditional, less effective selection methods to more scientifically grounded approaches.

4.7 Chapter Summary

This chapter presented and discussed the results of the comparative analysis of stud bull selection criteria for enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe. The study's findings, based on a 75% response rate from 39 farmers, revealed a landscape where traditional visual appraisal remains dominant. However, the data clearly demonstrated that farmers adopting modern breeding techniques, such as performance records, Estimated Breeding Values (EBVs), Artificial Insemination (AI), and Genomic Testing, achieved significantly superior herd performance in terms of Average Daily Gain, fertility, and calf survival rates. This directly contradicted the study's null hypothesis, highlighting the tangible benefits of objective selection.

Despite these proven advantages, the widespread adoption of modern techniques is hampered by significant barriers including high costs, a lack of technical expertise, and inadequate infrastructure. Nevertheless, opportunities exist, driven by a growing demand for beef and the relatively high educational attainment among farmers. The chapter concludes by advocating for a strategic integration of traditional knowledge with modern scientific methods, supported by robust extension services and community-based initiatives. This balanced approach is essential for fostering sustainable genetic improvement and enhancing the overall productivity and resilience of the Tuli cattle herd in Mashonaland East, ultimately benefiting farmers and contributing to regional food security.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This chapter presents the conclusions drawn from the comparative analysis of stud bull selection criteria for enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe. Building upon the findings discussed in Chapter 4, this section synthesizes the key insights derived from the study, providing definitive answers to the research questions. Furthermore, it outlines practical recommendations for various stakeholders, including farmers, policymakers, and researchers, aimed at fostering sustainable genetic improvement within the Tuli cattle breed in the region. The chapter concludes with a concise summary of the study's overall contribution to knowledge.

5.2 Conclusions

This study sought to compare various stud bull selection criteria and their impact on the Tuli cattle herd in Mashonaland East, Zimbabwe. The findings unequivocally demonstrate that the choice of selection criteria significantly influences herd performance, with objective, data-driven methods yielding superior outcomes compared to traditional subjective approaches.

In response to the main research question: What is the comparative effectiveness of different stud bull selection criteria in enhancing the Tuli cattle herd in Mashonaland East, Zimbabwe?

The study concludes that modern, objective stud bull selection criteria, particularly those incorporating performance records, Estimated Breeding Values (EBVs), and genomic testing, are significantly more effective in enhancing key productivity traits of the Tuli cattle herd compared to traditional visual appraisal methods. While traditional methods are widely adopted, they are less effective in driving genetic progress for economically important traits.

Drawing from the research sub-problems, the following specific conclusions are reached:

- The study concludes that Tuli cattle farmers in Mashonaland East predominantly rely on traditional visual appraisal for stud bull selection (69.2% of respondents). Pedigree selection is also utilized, but a notable portion of farmers (10.3%) employ no structured criteria, indicating a reliance on informal practices.

- The adoption of modern breeding techniques, such as EBVs, Artificial Insemination (AI), and genomic testing, remains limited, particularly among communal and smallholder farmers. Only 23.1% of farmers utilized EBVs, 12.8% adopted AI, and a mere 5.1% engaged in genomic testing. This limited uptake is largely concentrated among large-scale commercial farmers.
- There is a clear and statistically significant positive correlation between the objectivity of selection methods and herd performance. Herds where stud bulls were selected using performance records and EBVs/genomic testing exhibited substantially higher Average Daily Gain (ADG), improved fertility rates, and better calf survival rates compared to herds where selection was based solely on visual appraisal. Specifically, ADG was approximately 71% higher and fertility rates were 20% higher in herds benefiting from advanced genetic evaluation.
- The primary challenges hindering the adoption of modern breeding technologies are high costs (74.4% of respondents), lack of expertise (59.0%), and poor infrastructure (41.0%). Limited access to genetically superior bulls and a general lack of information also contribute to these impediments.
- This study contributes new knowledge by providing empirical, localized data on the comparative effectiveness of stud bull selection criteria within the specific context of Tuli cattle in Mashonaland East, Zimbabwe. It quantifies the performance advantages of objective selection methods over traditional practices and rigorously identifies the specific socio-economic and infrastructural barriers faced by local farmers, distinguishing it from broader, less context-specific studies. This detailed analysis provides a crucial foundation for targeted interventions.

In essence, while traditional knowledge forms a foundational part of Tuli cattle management, its sole reliance for genetic improvement is suboptimal. The findings firmly establish that a strategic shift towards or integration with objective, data-driven selection criteria is essential for unlocking the full genetic potential of the Tuli breed and enhancing the productivity and profitability of Tuli cattle farming in Mashonaland East.

5.3 Recommendations

Based on the conclusions drawn from this study, the following recommendations are put forth to enhance stud bull selection practices and improve Tuli cattle herd performance in Mashonaland East, Zimbabwe:

For Tuli Cattle Farmers:

1. Farmers should be encouraged and supported to adopt basic on-farm performance recording for key traits such as birth weight, weaning weight, and average daily gain. This can start simply with paper-based systems or basic digital tools.

2. While visual appraisal has its place for identifying structural soundness, farmers should be educated to prioritize performance data and genetic indicators (if available) over purely aesthetic traits when selecting stud bulls.

3. Farmers should actively seek to join or form community-based breeding programs that facilitate collective bull ownership, shared access to performance records, and potentially, artificial insemination services.

For Agricultural Extension Services and NGOs:

1. Develop and deliver practical, hands-on training programs on fundamental genetic principles, performance recording, and the interpretation and application of EBVs. These programs should be tailored to the educational levels and resource constraints of different farming systems (Communal, A1, A2).

2. Investigate and promote cost-effective and accessible technologies for performance recording and genetic evaluation that are suitable for smallholder contexts.

3. Establish mechanisms for farmers to access semen from genetically superior Tuli bulls through subsidized Artificial Insemination (AI) services, or facilitate the procurement and rotational use of high-quality natural service bulls within farmer groups.

4. Create and disseminate user-friendly information materials (e.g., brochures, radio programs, farmer field days) in local languages explaining the benefits and practicalities of objective bull selection.

For Government and Policymakers (Ministry of Lands, Agriculture, Fisheries, Water and Rural Development; Livestock Development Department):

1. Prioritize investment in critical livestock infrastructure, including functional dip tanks, accessible livestock sale points, and basic AI centers, especially in communal and resettlement areas.

2. Support and fund a national Tuli cattle breeding program that emphasizes performance recording, genetic evaluation, and the provision of EBVs for a wide range of Tuli populations. This could involve partnerships with universities, research institutions, and private breeders.

3. Consider offering incentives (e.g., subsidies on semen, tax breaks for adopting advanced breeding technologies) to encourage farmers, particularly commercial operations, to invest in and utilize modern selection methods.

4. Ensure that research findings from institutions are effectively translated into practical, accessible advice for farmers through a robust extension service.

For Future Research:

1. Conduct further studies to quantify the specific economic benefits and cost-effectiveness of adopting different modern breeding techniques across various farming systems in Zimbabwe.

2. Research into the socio-cultural factors influencing the adoption of modern breeding technologies among different communities, to develop more culturally sensitive and acceptable interventions.

3. Focus on developing and refining EBVs specifically for the Zimbabwean Tuli population, considering local environmental conditions and production systems.

4. Explore practical and affordable applications of genomic selection specifically tailored for smallholder and communal Tuli cattle farmers.

5.4 Chapter Summary

Chapter 5 concluded that while traditional visual appraisal remains prevalent among Tuli cattle farmers in Mashonaland East, it is less effective for genetic improvement than modern, data-driven selection criteria. The study definitively showed that using performance records, Estimated Breeding Values (EBVs), and genomic testing significantly enhances key herd productivity traits such as Average Daily Gain, fertility, and calf survival rates. However, the adoption of these advanced methods is severely hampered by high costs, lack of expertise, and inadequate infrastructure. Based on these findings, the chapter recommended targeted interventions for farmers (e.g., adopting performance recording), extension services (e.g., training and affordable tech promotion), government (e.g., infrastructure investment and national breeding schemes), and future research (e.g., economic impact and localized EBV development). This comprehensive approach aims to unlock the full genetic potential of the Tuli breed, thereby enhancing the livelihoods of farmers and contributing to Zimbabwe's food security.

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APPENDICE A: QUESTIONNAIRE

Dear Respondent,

I am Tanaka Dzawo, a student at Bindura University pursuing a Bachelor of Science degree in Animal Science and Technology. This questionnaire is part of a study aiming to understand the methods used by Tuli cattle farmers in Mashonaland East for selecting stud bulls and how these methods affect herd performance. Your honest responses are highly valuable for this research. All information provided will be treated with strict confidentiality and used solely for academic purposes. Participation is voluntary and for further clarification contact me on:

Phone number +263 771437189 / 719993004

Email: unrulyboui@gmail.com

Instructions:

- Answer all questions honestly on each section.
- Please tick (✓) the most appropriate response where applicable.
- For open-ended questions, kindly provide detailed responses.

Section A: Respondent Demographics

1. **What is your gender?**
    - ☐ Male
    - ☐ Female
2. **What is your age?**
    - ☐ 20-29 years
    - ☐ 30-39 years
    - ☐ 40-49 years
    - ☐ 51 + years

3. **What is your farming system?**
   - ☐ Communal
   - ☐ A1
   - ☐ A2
   - ☐ Small-scale Commercial
   - ☐ Large-small Commercial
4. **What is your highest level of education?**
   - ☐ Primary
   - ☐ Secondary
   - ☐ Tertiary (e.g., College, University)
   - ☐ None (Please specify if you prefer not to answer, but ideally you want to gather this data point)

Section B: Current Stud Bull Selection Criteria

5. **Which of the following methods do you primarily use when selecting a stud bull for your Tuli herd?** *(Please Select ONE that you rely on most heavily)*
   - ☐ Visual Appraisal: Selecting based on physical appearance, conformation, size, coat colour etc.
   - ☐ Pedigree Selection: Selecting based on the known lineage or family history of the bull (e.g., knowing its parents were good performers).
   - ☐ No Structured Criteria: I select bulls based on availability or convenience, without specific criteria.
   - ☐ Performance Records: Selecting based on recorded performance data of the bull or its relatives (e.g., birth weights, weaning weights, growth rates etc.)
   - ☐ Estimated Breeding Values (EBVs): Selecting based on scientifically calculated genetic predictions for traits.

- ☐ Genomic Testing: Selecting based on DNA analysis of the bull to predict its genetic merit.

6. **Do you use any of the following modern breeding techniques in your Tuli Cattle Operation?** *(You can select all that apply)*
    - ☐ Estimated Breeding Values (EBVs)
    - ☐ Artificial Insemination (AI)
    - ☐ Genomic Testing
    - ☐ None of the Above

Section C: Herd Performance

7. **What is the approximate Average Daily Gain (ADG) of your Tuli calves/young cattle from birth to weaning/marketing?** *(If you record this, please provide an estimate in kg/day. If not, please provide your best estimate or tick 'Don't know')*
    - ☐ Approximate ADG _______________ kg/day
    - ☐ Don't know/ Not Recorded
8. **What is the approximate overall fertility rate (calving percentage) in your mature Tuli cow herd per year?** *(e.g., if 100 cows produce 80 calves its 80%)*
    - ☐ Approximate Fertility Rate ________________%
    - ☐ Don't know/ Not Estimated
9. **What is the approximate calf survival rate from birth to weaning in your Tuli herd?** *(e.g., If 100 calves are born and 90 survive to weaning, its 90%)*
    - ☐ Approximate Calf Survival Rate ________________%
    - ☐ Don't know/ Not Estimated

Section D: Challenges in Stud Bull Selection

10. **What are the main challenges you face when trying to select stud bulls, particularly if considering modern or objective criteria?** *(You can select all that apply)*

- ☐ High Costs (e.g., for purchasing good bulls, semen, testing)
- ☐ Lack of Expertise/Knowledge (e.g., not knowing how to use modern methods)
- ☐ Poor Infrastructure (e.g., lack of accessible dip tanks, AI centers, handling facilities)
- ☐ Limited Access to Genetically Superior Bulls/Semen
- ☐ Lack of Reliable Information (e.g., on available genetics, how to implement)
- ☐ Cultural/Traditional Beliefs (preventing adoption of new methods)
- ☐ Other (Please Specify):

____

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Thank You for Your Participation