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Assessment of Reproductive Dynamics and Production Efficiency among Communal Sheep Flocks in the Free State Province, South Africa: A Comparative Study

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ABSTRACT

Sheep farming plays a significant role in generating economic opportunities and employment on a global scale. It is a vital support system for rural economies, mainly where agricultural alternatives are scarce, like farmers living in arid and semiarid areas. This article aims to investigate and promote sustainable communal sheep farming practices and examine the significance of the weaning percentage and how it determines the communal wool industry's success, economic viability, and sustainability. Additionally, the article will address the challenges these farmers face in sweet-, sour- and mixed grass veld types. Furthermore, the article will explore the impact of lambing seasons and flock structures on ewe productivity and identify strategies to mitigate adverse effects in communal sheep flocks. Lastly, the article will discuss management practices in sheep production systems, considering their economic and environmental sustainability. The mean weaning percentage, a critical indicator of reproductive success and productivity, was 48.78%, reflecting substantial dispersion within a sample population of 9 603 sheep across 351 farmers' interviews. Pure breeding exhibits a 5.6% higher weaning percentage than crossbreeding. In cases where there was inbreeding, the weaning percentage was 11.3% lower than that of flocks using unrelated rams. Statistical analysis further underscores the substantial influence ($p<0.001$) of consistent dissemination of production and reproduction technical information, facilitated through governmental initiatives and stakeholder engagements, in driving these improvements. Best sheep and health management practices are

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paramount for enhancing the weaning percentage of sheep flocks. The quality of grazing and the utilisation of well-adapted breeding stock are pivotal factors. Statistical analysis reveals a significant impact ($p<0.05$) of rotational grazing with a herding effect (extensive grazing) compared to free grazing (continuous grazing) with minimal management. Integrating labourers into communal sheep enterprises profoundly influences various operations, notably sheep herding, where they safeguard animals, identify health issues, and guide flock movements to optimal grazing areas, enhancing nutrition and weaning percentages.

Keywords: Continuous Grazing, Management Practices, Weaning Percentage, Wool Sheep

1. INTRODUCTION

Sheep farming plays a significant role in generating economic opportunities and employment on a global scale (Paraskevopoulou *et al*., 2020). It is a vital support system for rural economies, mainly where agricultural alternatives are scarce, like farmers living in arid and semiarid areas (Halimani *et al*., 2021; Taruvinga *et al*., 2022). The livelihoods of farmers and numerous individuals engaged in the sheep farming supply chain, including farm workers (stockmen), wool brokers and processors, mutton processors and various stakeholders within the industry, such as animal health and feed companies, heavily rely on its presence. By fostering these economic avenues, sheep farming contributes to the overall socioeconomic development of communities and sustains the well-being of those involved in the industry (Hajdu, Neves & Granlund, 2020).

The vast grass field of the Free State province, consisting of 87 000 km^2 and its favourable climate, makes it ideal for the 4 486 000 sheep, 2 130 000 cattle and 215 000 goats, contributing to 30% of the gross agricultural income. Although the cultivated land consists of only 32 000 km^2, it contributes almost 60% of the gross agricultural income, with horticulture generating the balance (South African Yearbook, 2022).

Households engaged in agricultural activities, especially livestock farming, can reduce food insecurity in communal households. Sadly, these households decreased by 19.1% in only two years during the drought of 2014/2015. During 2011 – 2016, the number of households engaged in agricultural activities decreased by 600 000 (2.9 million to 2.3 million) (Statistics South Africa, 2019). When the frequency of droughts increases due to climate change (food scarcity for livestock), the risk increases to have a devastating effect on the livelihoods of communal households (Samuels *et al*., 2022).

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The weaning percentage determines the key to success (economic viability and sustainability) in sheep farming. Where various stakeholders, government initiatives and industry organisations, like the National Wool Growers Association (NWGA), were actively involved in the training, research and technical assistance to improve best management practices, infrastructure assistance, the introduction of superior rams and the selling of their wool through formal auctions (earning foreign currency), their income increased markedly with 18% in only five years—enhancing the overall competitiveness of the communal wool farmers in the wool industry (Henderson, 2015). Merino sheep's adaptability to South African conditions and high wool production and quality make it one of the various sheep breeds suitable for the Free State Province (Sankatane, 2018).

Enhanced management practices in sheep production systems (such as feedlot, intensive, and semi-intensive systems) have the potential to generate greater economic profitability. However, these systems often rely heavily on external resources, particularly non-renewable resources derived from fossil energy. This dependence significantly burdens the natural environment and contributes to an unsustainable biophysical state in the long run (Rojas-Moreno *et al*., 2022). By promoting biodiversity, farms can reduce their ecological footprint, enhance their resilience to climate-related challenges, and establish transparent and trustworthy consumer relationships (Dominati *et al*., 2019).

Sustainable agriculture, specifically livestock production, refers to a purposeful and conscious approach by livestock farmers to produce agricultural products like mutton and fibre while implementing best management practices to safeguard the natural resources utilised in farming. This approach is that food production is sustainable, enabling future generations to survive and thrive. Aspiring farmers must effectively manage the natural resources available (such as grassland or meadow) to support the biological activities involved in animal breeding. This, in turn, allows for profitable outcomes both economically, benefiting the farm and loan providers, and environmentally, by maintaining a harmonious farm ecology. These practices should align with best management practices (Nkamisa, 2020).

This article aims to investigate and promote sustainable communal sheep farming practices and examine the significance of the weaning percentage and how it determines the success, economic viability and sustainability of the communal wool sheep industry. Additionally, the article will address the challenges these farmers face in sweet-, sour- and mixed grass veld types. Furthermore, the article will explore the impact of genetic-, socioeconomic-, and infrastructure factors on ewe productivity and identify strategies to mitigate adverse effects in communal sheep flocks. Lastly, the

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article will discuss management practices in sheep production systems, considering their economic profitability and environmental sustainability.

2. MATERIALS AND METHODS

Ethical clearance was obtained from the University of the Free State Research Ethics Committee for this project (UFS-HSD2021/0422/21).

2.1. Study Area

The study was conducted in the Thaba Nchu-Botshabelo area of the Mangaung district in the Free State Province, South Africa. This region has flat, rolling grasslands, crop fields, isolated sandstone kopjes and mountains. The province is a crop and livestock production area divided into five districts: Mangaung, Xhariep, Lejweleputswa, Fezile Dabi, and Thabo Mofutsanyana. However, focus groups for personal communication and training were canvassed in the Thaba Nchu and Botshabelo areas in the Mangaung district, where most communal farmers are situated (Figure 1). The Thaba Nchu and Botshabelo area has 40 communities (59 957 ha grazing area). Of these communities, 21 (53%) (30 182 ha grazing) obtain an even location distribution through the Thaba Nchu and Botshabelo area, with different vegetation types, namely sweet grass veld, sour grass veld and mixed sour grass veld (Van der Westhuizen, Snyman & Fouché, 2018). The climate is characterised by cold winters with a daily minimum average of -0.6 °C with frost and hot summers with a daily maximum average of 33.6 °C) (ARC-NRE, 2023). The long-term annual rainfall (06 June 2012 – 29 January 2022) for the Botshabelo and Thaba Nchu area is 546 mm. Most of the yearly rain (>70%) is received in the summer from November to March (Fouché, De Jager & Opperman, 1985). The Free State Department of Agriculture and Rural Development (FSDARD) (DAFF, 2018) recommends a long-term grazing capacity of 6 ha per Large Stock Unit (LSU) for the Botshabelo and Thaba Nchu area (Meissner *et al*., 1983).

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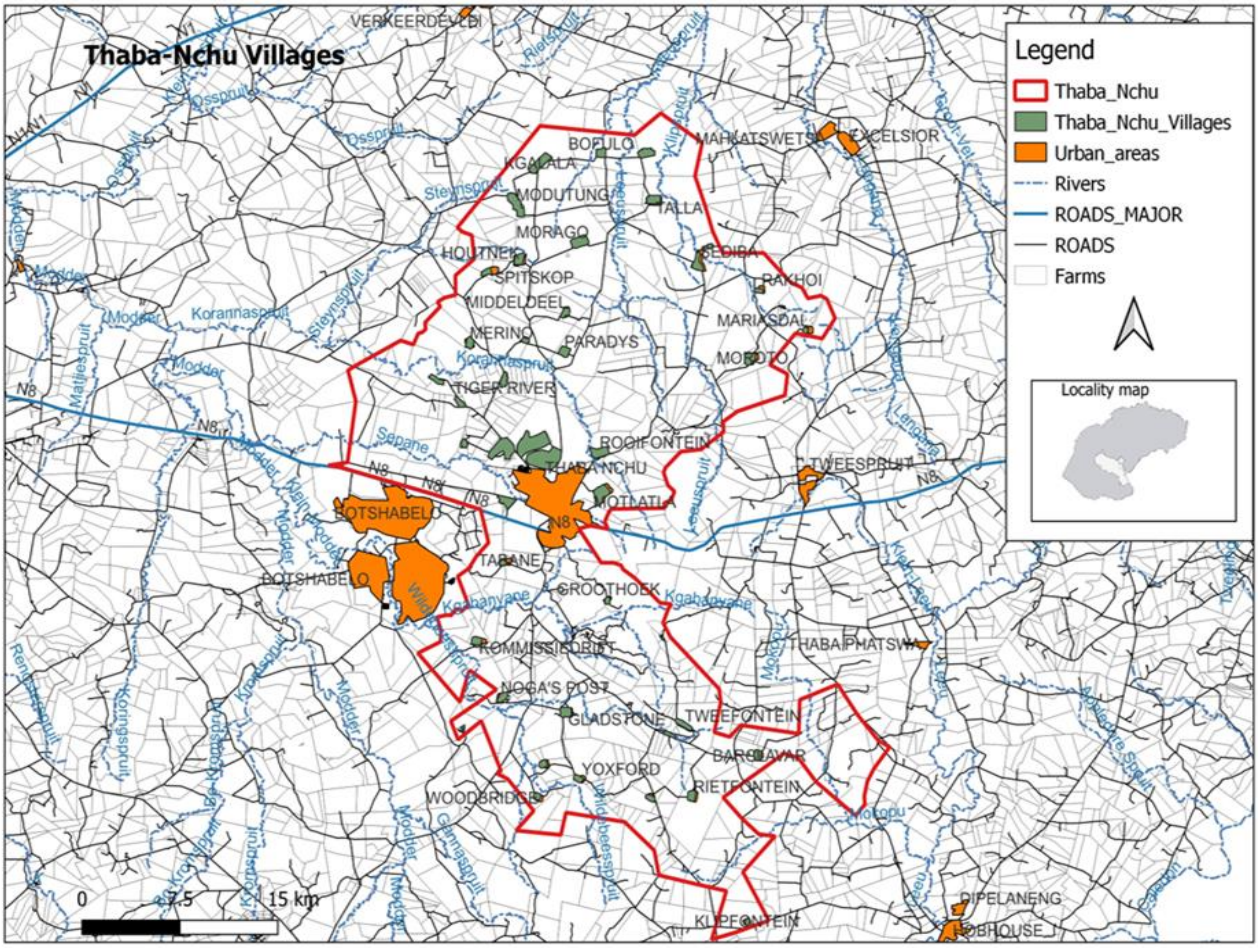

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FIGURE 1: Information from Communities in the Thaba Nchu and Botshabelo Areas in the Mangaung District in the Southeastern Part of the Free State Province, South Africa.

2.2. Sampling Procedure

The participants were selected via a non-random, purposive, convenience sampling method to reach the communal wool farmers in the Mangaung district. Approximately 1255 small-stock communal farmers are in the Mangaung district (Mocwiri, 2022). A sample size calculator (Rao, 1991) was used to determine the sample size to generalise the population. For this study, 295 or more observations have a confidence level of 95%, with the actual value within ±5% of the observation value.

2.3. Data Collection Procedure

A structured closed-ended questionnaire, created using the EvaSys software, was used in one-on-one interviews to obtain quantitative data on weaning percentages. The questionnaire captures different aspects of sheep management such as reproduction, record keeping, grazing systems, education and

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technical information obtained, genetic factors and infrastructure. While the survey was in English, all interviews took place in the participants' native languages following the interpretation of the English version. Throughout the data collection phase, supervisors systematically observed enumerators to maintain uniformity, detect outliers, and ensure the precision of the gathered data. The researcher disseminated the questionnaire to respondents and assured them their data would be confidential.

Extension officers recruited participants (David, 2022; Khwidzhili & Worth, 2016) using an inclusion criteria list. Small stock includes wool sheep, dual-purpose sheep, mutton sheep and goats. Although there are approximately 1255 small-stock farmers, only participants farming with wool-type sheep were included. Data was collected from November 2021 until February 2022, when most of the ewes would have lambed and the lambs weaned (Strauss, Avenant & De Waal., 2021). The data collected (e.g., farmer demographics, livestock numbers, reproduction, management) included one year's data (2021/2022).

The weaning percentage over 12 months was the questionnaire's dependent variable affecting livestock owners and agricultural reproduction in general. The following independent (explanatory) variables explain or predict changes in a dependent variable, namely the weaning percentage:

- Genetic factors (breeding methods and origin of breeding animals, flock structure).
- Socioeconomic factors (level of education, labourers, funding, land tenure security, technical information).
- Farm infrastructure (absence or condition of fences and kraals, water reticulation, woolshed, agricultural equipment, own transport, generator).
- Management (belongs to an organisation, including lambing seasons, record keeping, and grazing systems).

2.4. Data Management and Analysis

The SPSS (Version 29) program processed and analysed the data. Scanned completed questionnaires identify outliers and potential errors. The mean values for missing observations are added to calculate the sum in each category. ANOVAs were done on averages to determine significant differences. R-squared analysis was done for descriptive statistics to assess how well the independent variables included in the regression model explain the variability observed in the dependent variable, namely the weaning percentage. The analysed data will follow in the form of tables, graphs, and text.

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3. RESULTS AND DISCUSSION

3.1. Structure of the Sheep Flocks in the Study Area

In the Thaba Nchu region, communal sheep farming constitutes a significant agricultural activity characterised by notable variability in production metrics. The mean weaning percentage, a critical indicator of reproductive success and productivity, was 48.78 ± 46.88, reflecting substantial dispersion within a sample population of 9603 sheep across 351 farmers' interviews. The average flock size per farmer, standing at 27.36 ± 32.11 sheep, underscores the modest scale of operations, where the impact of individual events, such as the loss or gain of a single lamb, can disproportionately affect the overall weaning percentage.

3.2. Reproductive Management Factors Impacted Communal Sheep Flocks

Pure breeding exhibits a 5.6% higher weaning percentage than crossbreeding. In cases where there was inbreeding, the weaning percentage was 11.3% lower than in flocks using unrelated rams. However, if not appropriately managed for genetic relationships, the skewed ram-to-ewe ratio (17.03%) in communal flocks can elevate the risk of inbreeding. Inbreeding poses significant threats, leading to increased genetic disorders and undesirable traits, ultimately impeding the flock's long-term health and productivity, such as the weaning percentage. Implementing a well-structured breeding program with clear objectives mitigates these risks. Such a program should prioritise long-term goals, as genetic enhancement of breeding traits is a time-intensive process (David, 2022; Khwidzhili & Worth, 2016).

TABLE 1: Reproductive Management Factors Impacted Communal Sheep Flock Weaning Percentages

		Weaning % (mean)	**ANOVA results**	
			***F*-statistic**	***p*-value**
Breeding method	Pure breeding	53,32		
	Inbreeding	41,98	1,55	0,21
	Crossbreeding	48,06		
Origin of breeding animals	Acknowledged breeder	39,13		
	Self-bred	55,63		
	Acknowledged breeder and self-bred	51,53	2,44	0,06
	None of the above	41,54		

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Moreover, the origin of breeding animals emerged as a significant factor. While procuring sheep from acknowledged breeders is commonly presumed to enhance flock quality, this study revealed nuanced outcomes. Self-bred flocks demonstrated a remarkable 16.5% higher weaning percentage (Table 1), suggesting potential challenges in adapting acknowledged breeder stock to local conditions or fertility issues. Notably, the full impact of acknowledged breeder stock might not have manifested within the scope of this one-year data, underscoring the need for longitudinal analysis to comprehensively assess breeding practices' efficacy.

3.3. Socioeconomic Factors Impacted Communal Sheep Flocks

Introducing labourers into sheep management practices can lead to tangible benefits, as evidenced by the observed significant difference in weaning percentage ($p<0.05$) compared to enterprises without labourers, with a notable 17.1% increase in weaning percentage (Table 2). This underscores labourers' pivotal role in optimising sheep enterprises' performance and profitability.

Education among farmers markedly contributes to enhancing the sustainability of their agricultural enterprises. Weaning percentages reveal a noteworthy increase from the segment of farmers who have never received formal schooling to those with the highest educational qualifications, despite a decline observed within the certificate/diploma/degree group. This highlights the profound impact of educational attainment on farm performance metrics, particularly concerning livestock productivity. Statistical analysis further underscores the substantial influence ($p<0.001$) of consistent dissemination of production and reproduction technical information, facilitated through governmental initiatives and stakeholder engagements, in driving these improvements.

TABLE 2: Socioeconomic Factors Impacted Communal Sheep Flock Weaning Percentages

		Weaning % (mean)	**ANOVA results**	
			***F*-statistic**	***p*-value**
Level of education	Never been to school	37,50		
	Completed some primary school	43,93		
	Completed some high school	50,19		
	Completed matric	57,69	0,94	0,45
	Completed a certificate/ diploma/ degree	41,31		
	Completed a postgraduate degree	58,34		

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Total number of workers	No workers 1-2 workers More than two workers	47,23 44,72 64,32	**3,21**	**0,04**
Funding	None External funding Self-funding Both	49,66 38,35 55,87 39,72	0,92	0,43
Security of land tenure	Not secure Secure to an extent	46,62 49,68	0,48	0,63
Technical information	Never received technical information Sometimes/ regularly receive technical information	39,35 58,81	**3,83**	**<0,001**

3.4. Infrastructure that Impacted Communal Sheep Flocks

The condition of a wool shed and chaff cutter influenced the weaning percentage, with those having this infrastructure working to an extent having a statistically significant higher weaning percentage than those who did not have the necessary infrastructure ($p < 0,05$), accordingly intervention in this sector is of critical importance (Figure 2). Enhancing the productivity and sustainability of small-scale farmers necessitates significant improvements in infrastructure and extension services' capabilities, as Myeni *et al.* (2019) emphasised. This assertion underscores the critical role of governmental intervention in fostering these enhancements. For the rural and under-resourced areas in South Africa, the infrastructure section has been allocated R600 million for project development (Ramaphosa, 2023).

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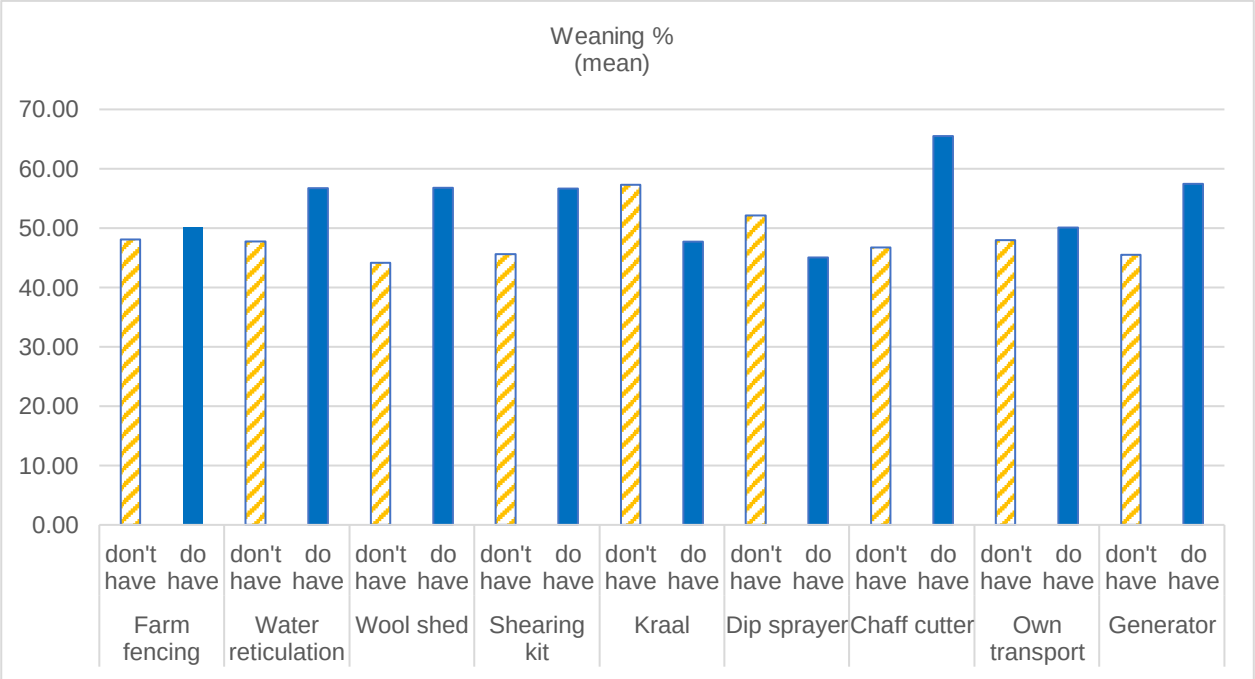

FIGURE 2: Infrastructure That Impacted Communal Sheep Flock Weaning Percentages

3.5. Management Practices That Impacted Communal Sheep Flocks

Best sheep and health management practices are paramount for enhancing the weaning percentage of sheep flocks. The quality of grazing and the utilisation of well-adapted breeding stock are pivotal factors. Statistical analysis reveals a significant impact ($p<0.05$) of rotational grazing with a herding effect (extensive grazing) compared to free grazing (continuous grazing) with minimal management. With herding practices, rotational grazing offers a promising solution to enhance production and reproduction in sheep flocks within communal grazing areas like Thaba Nchu and Botshabelo. Despite challenges such as fragmented land ownership and inadequate infrastructure, this approach utilises large land areas efficiently, promoting natural flock behaviours and optimising resource utilisation. By facilitating efficient flock management and movement, extensive grazing with herding effect addresses these challenges while improving overall productivity and reproductive outcomes in communal grazing contexts (Van der Westhuizen *et al*., 2018).

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TABLE 3: Management Practices That Impacted Communal Sheep Flock Weaning Percentages

		Weaning % (mean)	t-test results	
			t-value	*p*-value
Belong to an organisation	Do not belong to an organisation	48,30	0,12	0,91
	Do you belong to an organisation	48,91		
Lambing seasons	No	56,45	**2,47**	**0,01**
	Yes	43,44		
Record keeping	Do not keep records	48,90	0,14	0,89
	Keep records	48,19		
Grazing system	Intensive (Rotational grazing augmented with planted oats and maise)	47,09	**5,29**	**0,01**
	Extensive (Rotational grazing with herding effect)	57,24		
	Continuous grazing	40,37		

Rotational grazing, facilitated by more than two labourers (Table 2), enables better identification of sick sheep and flock issues. While no specific lambing season significantly influenced ($p<0.05$) weaning percentage, most ewes are typically mated in autumn, aligning with the natural breeding season (Table 3). Nonetheless, farmers adhering to a strict 36-day breeding season potentially disadvantage ewes not in optimal condition due to food shortage during this limited period compared to continuous mating practices. The impact of the lambing season on ewe productivity reveals that year-round lambing treatment resulted in the lowest conception rates (58.4%) and weaning percentage (65.7%), along with a relatively high lamb mortality rate (34.7%), which peaked during the summer months. These combined factors can detrimentally affect the productivity of communal flocks engaged in year-round lambing. Mapiliyao *et al*. (2012) indicated conception (49%) and mortality (22%) rates in the sourveld (Sompondo) regions of the Eastern Cape. Msuntsha & van Zyl (2019) also reported high mortalities (42.4%) in the sandy sourveld of Northern KwaZulu-Natal. The negative impact of the year-round lambing season on ewe productivity (weaning %, 65.3%) would

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be exacerbated by higher stocking rates commonly observed in communal grazing systems (Magawana *et al*., 2021).

4. CONCLUSION

Integrating labourers into communal sheep enterprises profoundly influences various operations, notably sheep herding, where they safeguard animals, identify health issues, and guide flock movements to optimal grazing areas, enhancing nutrition and weaning percentages. Elevating farmers' and labourers' expertise in animal care, grazing, and herding techniques is pivotal for achieving higher weaning percentages. Knowledge transfer mechanisms, including educational programs and dissemination strategies, empower farmers with essential skills and insights for adopting more sustainable practices, crucial for fostering agricultural sustainability and productivity within communal farming communities, emphasising the critical role of continuous learning and knowledge exchange in optimising weaning percentages in communal sheep flocks. Extension services play a significant role in enhancing the weaning percentage by providing technical advice on sheep management.

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6. AUTHORS CONTRIBUTION

AJ. Strauss collected the data for this study, interpreted the results, and wrote the initial draft manuscript. M. de Bruin conducted the statistical analysis. JW. Swanepoel and JJE. Cloete assisted with the final manuscript. All authors have read and approved the finalised manuscript.

7. CONFLICT OF INTEREST DECLARATION

FSDARD employs AJ. Strauss, who did the research with the University of the Free State. RUFORUM was responsible for the funding.

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