frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 20 November 2024
DOI 10.3389/fsufs.2024.1452447

OPEN ACCESS

EDITED BY
Niaz Ali,
Hazara University, Pakistan

REVIEWED BY
Tanda Sahat Sastradarmaja Panjaitan,
National Research and Innovation Agency (BRIN), Indonesia
Tomas Gabriel Bas,
Catholic University of the North, Coquimbo, Chile

*CORRESPONDENCE
Mhlangabezi Slayi
✉ mslayi@ufh.ac.za

RECEIVED 20 June 2024
ACCEPTED 04 November 2024
PUBLISHED 20 November 2024

CITATION
Slayi M, Zhou L and Jaja IF (2024) Assessing the multidimensional impact of community-based cattle feedlot programs in the Eastern Cape, South Africa.
Front. Sustain. Food Syst. 8:1452447.
doi: 10.3389/fsufs.2024.1452447

Assessing the multidimensional impact of community-based cattle feedlot programs in the Eastern Cape, South Africa

Mhlangabezi Slayi[1]*, Leocadia Zhou[1] and Ishmael Festus Jaja[2]

[1]Centre for Global Change (CGC), Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa, [2]Department of Livestock and Pasture Science, University of Fort Hare, Alice, South Africa

Traditional cattle farming in the region faces numerous challenges, including limited market access, inadequate nutrition, and poor herd management, which hinder productivity and the livelihoods of farmers. This research explores whether structured feedlot programs can address these issues by enhancing agricultural productivity and improving farmer livelihoods. The study utilized quantitative data from 250 respondents and regression models to compare changes before and after participation in the feedlot programs. The findings reveal significant improvements in herd dynamics, with average herd size increasing by 40% and calving rates rising from 60 to 80%. Mortality and morbidity rates decreased by 50 and 47%, respectively. Regression analysis showed a positive impact on herd size ($\beta = 20.00$, $p < 0.001$) and a notable reduction in mortality ($\beta = -0.30$, $p = 0.050$). Animal performance also improved, with average daily gain (ADG) increasing by 60% and feed conversion ratio (FCR) improving by 25%. Health status was enhanced, indicated by a 50% reduction in disease incidence and an 80% increase in vaccination coverage. Regression results supported these improvements, showing significant positive effects of feedlot participation on ADG ($\beta = 0.50$, $p < 0.001$) and health status ($\beta = -0.10$, $p < 0.005$). Socio-economic benefits were also substantial, with household income increasing by 67% and new employment opportunities emerging. Food security improved significantly, with 85% of households reporting better access to food, and the average sales price per cattle increased by 50%. Regression analysis indicated strong positive impacts on household income ($\beta = 1{,}500$, $p < 0.001$) and food security ($\beta = 300$, $p = 0.010$). Factors influencing farmer participation in the feedlot programs included perceived benefits ($\beta = 0.80$, $p < 0.001$), access to training ($\beta = 0.50$, $p < 0.005$), and market access ($\beta = 0.70$, $p < 0.001$), while the cost of participation negatively affected involvement ($\beta = -0.002$, $p = 0.050$). Overall, the study demonstrates that community-based cattle feedlot programs significantly enhance herd dynamics, animal performance, and socio-economic conditions for farmers in the Eastern Cape Province, offering a viable strategy for improving rural livelihoods and agricultural productivity.

KEYWORDS

custom feeding schemes, stakeholder engagement, cattle farmers, food security, logistic regression

1 Introduction

Livestock farming plays a crucial role in South Africa's agricultural sector, significantly contributing to the national economy and the livelihoods of rural communities (Zhou et al., 2022; Malusi et al., 2021). In the Eastern Cape Province, cattle farming is particularly vital, providing a primary source of income, food security, and cultural heritage for many residents (Slayi et al., 2023a). Approximately 60% of cattle farming in South Africa relies on natural resources for feed and sustenance, with smallholder farmers encouraged to contribute to national food, nutrition, and income security through participation in formal markets (Ruwanza et al., 2022). However, these farmers face significant challenges, including limited access to markets, inadequate livestock support services, and insufficient adoption of improved livestock technologies (Slayi et al., 2024). Traditional cattle farming practices often suffer from inadequate nutrition and poor herd management, which negatively impact herd dynamics and overall animal performance (Lubing et al., 2018; Khapayi and Celliers, 2016).

The sustainability and productivity of communal cattle herds are increasingly threatened by environmental stressors such as heat stress, drought, and nutritional deficiencies (Archer et al., 2021; Boomiraj et al., 2010; Tibesigwa et al., 2017; Mpofu et al., 2023; Vetter et al., 2020; Bareki and Antwi, 2017). These stressors compromise animal health and welfare and undermine the resilience and prosperity of dependent communities (Ruwanza et al., 2022; Taruvinga et al., 2013). The Eastern Cape is particularly vulnerable to climate change, with changing rainfall patterns, prolonged droughts, and rising temperatures causing significant cattle losses (Slayi et al., 2023a; Taruvinga et al., 2013). The impacts of climate variability on livestock are often severe, as demonstrated by the 2015 agricultural drought in South Africa, which caused economic damage estimated at USD 2 billion, an 8.4% decline in agricultural output, and a 15% reduction in the national cattle and sheep herds (Vetter et al., 2020). The drought also led to a 1.21% compound annual growth rate decrease in the number of livestock, from 44.4 million in 2012 to 42.3 million in 2016 (Marandure et al., 2016a). These challenges highlight the urgent need for innovative adaptation strategies to enhance the resilience of livestock farming.

Community-based cattle feedlot programs have emerged as a promising solution to these challenges (Wurzinger et al., 2021; Marandure et al., 2016b). These programs aim to improve the productivity and profitability of smallholder cattle farming by providing centralized facilities where cattle are collectively fed and managed. Benefits of these feedlots include enhanced feed efficiency, improved animal health and growth rates, and better market access through collective bargaining power. In the Eastern Cape, a collaborative initiative between the Department of Rural Development and Land Reform (DRLDR) and the National Agricultural Marketing Council (NAMC) has piloted these community-based feedlots in 11 towns. Designed with an average stocking capacity of 2,000 cattle, these facilities provide farmers with a controlled environment where animals can be managed more effectively (Nyhodo et al., 2014). Farmers participate by sending their cattle to the feedlots and paying a fee to the institution after the animals are sold (Sotsha et al., 2018; Marandure et al., 2016c; Terry et al., 2021). This approach enables farmers to benefit from the feedlot system without the need to establish large-scale feedlots individually, thereby offering an economically viable and environmentally sustainable option (Gwiriri et al., 2019).

Unlike conventional feedlots managed by commercial entities, community-based feedlots are situated within communal areas and actively involve local community members in their design, operation, and management (Slayi et al., 2023c). This localized approach fosters community engagement and ensures that management practices are tailored to the specific needs of the farmers, contributing to improved livestock conditions and enhanced productivity. The Eastern Cape, characterized by its diverse agricultural landscape, has increasingly focused on these community-based feedlot programs to enhance local livestock production and improve socio-economic conditions. By optimizing herd dynamics and equipping farmers with the necessary resources and knowledge, these initiatives foster sustainable agricultural practices that can significantly transform the livelihoods of rural communities dependent on livestock farming.

This study aims to evaluate the impact of community-based cattle feedlot programs on herd dynamics and socio-economic outcomes in the Eastern Cape. By examining changes in herd composition, health, productivity, and the economic benefits accrued by participating farmers, the research seeks to provide insights into the effectiveness of these programs. It hypothesizes that participation in community-based feedlot initiatives leads to improved herd management practices and increased income levels for farmers. Additionally, the study will explore the broader implications of these programs on community cohesion and food security, addressing critical questions regarding their sustainability amid environmental and economic challenges. Through a comprehensive analysis of both qualitative and quantitative data, this research aims to contribute to the existing body of knowledge on agricultural development in the region and inform policymakers on strategies that can bolster rural economies through effective livestock management.

2 Materials and methods

2.1 Site description

The research project was conducted in two community-based cattle feedlots located in Tsomo and Centane, within the Eastern Cape Province of South Africa. The study area includes five villages surrounding each feedlot, totaling 10 villages. In Centane, the selected villages are Holela, KwaZingxala, Jojweni, Mapondweni, and KwaMaxhama. In the Tsomo area, the villages include Komkhulu, Gxwalibomvu, Qombolo, KuHange, and EsiXhotyeni (Figure 1). These villages fall under the Mnquma and Intsika-Yethu Local Municipalities, respectively, which are part of the broader Eastern Cape Province that comprises 37 district municipalities. Centane is situated at 32.18° S latitude and 28.02° E longitude, with an elevation of 501 meters above sea level. Tsomo, on the other hand, lies at 31.93° S latitude and 27.64° E longitude, with an elevation of 1,083 meters above sea level. Both towns face significant socio-economic challenges, including high youth unemployment rates and a heavy reliance on government social grants for support. Subsistence livestock farming and crop cultivation are primary sources of income in these resource-constrained communities, playing critical roles in sustaining the local population. Indigenous cattle breeds and sheep are highly valued and preferred among residents in both areas, highlighting their significance in the local livestock industry (Slayi et al., 2023b). Notably, the feedlots in Gxwalibomvu and Holela contribute to the agricultural

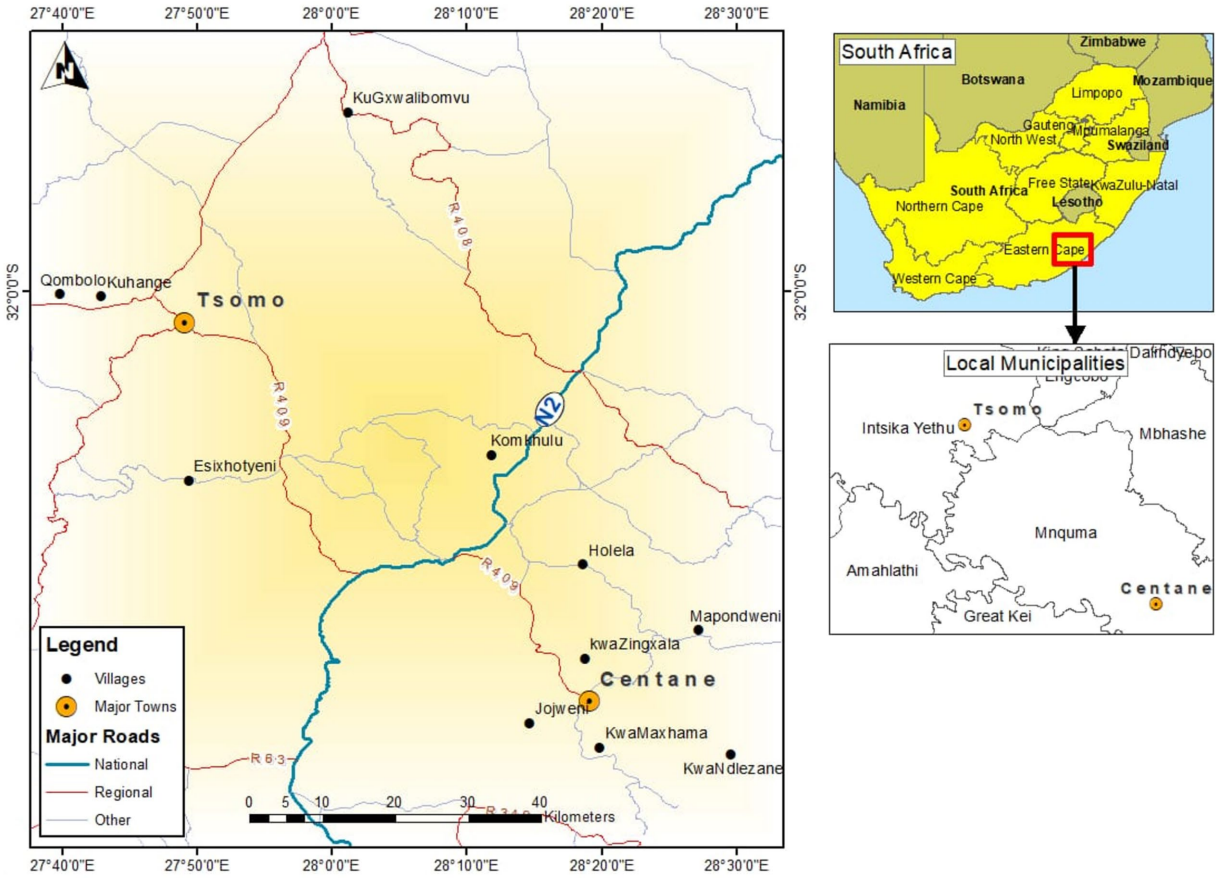

FIGURE 1
Map showing the 10 villages hosting the two community-based cattle feedlots.

landscape of these towns, offering enhanced opportunities for livestock management and marketing, and potentially improving the economic prospects of local farmers (Slayi et al., 2023c; Nyhodo et al., 2014). The region is characterized by climate variability, including droughts and floods, with livestock heavily dependent on natural pastures for grazing and feed. The climate features moderately hot summers, high humidity throughout the year, and erratic rainfall patterns. The average annual rainfall is 473.2 mm, occurring primarily between November and April. Maximum daily temperatures average 25.8°C, while minimum temperatures are around 11.2°C. Humidity remains consistently high, averaging 72.1% annually. The area experiences four distinct seasons: the post-rainy season (March to May), cold-dry season (June to August), hot-dry season (September to November), and hot-wet season (December to February). These seasonal variations significantly influence local agricultural activities and farming practices. The landscape is characterized by lowlands interspersed with steep, isolated mountains and is dominated by Bhisho Thornveld vegetation. The region supports a variety of trees, shrubs, and grasses, including species such as *Acacia karroo*, *Themeda triandra*, *Panicum maximum*, *Digitaria eriantha*, Eragrostis spp., *Cynodon dactylon*, and *Pennisetum clandestinum* (Mucina and Rutherford, 2011; Acocks, 1988). The soils in the area are primarily sedimentary, consisting of sand and mudstones, but also exhibit heterogeneity due to intrusions of igneous rock (doleritic dykes and sheets), resulting in patches of red soils (Nciizha and Wakindiki, 2012).

2.2 Ethical considerations

The study was conducted in compliance with the ethical standards set forth by the Research Ethics Committee of the University of Fort Hare, which granted ethical clearance under the reference number JAJ051SMPO01. This approval ensured that the research adhered to established ethical guidelines aimed at protecting the rights, safety, and well-being of all participants. To safeguard participants' rights, informed consent was obtained from all participating cattle farmers before their involvement in the study. This process included providing detailed information about the study's purpose, procedures, potential risks, and benefits, ensuring that participants were fully aware and voluntarily agreed to participate. To uphold confidentiality, several measures were implemented throughout the study. Participants' identities were anonymized, and no personally identifiable information was included in the data analysis or reporting phases. Data were handled and stored securely, with access restricted to authorized personnel only, further ensuring that the privacy of the participants was maintained.

2.3 Study design

A mixed-methods approach was employed, combining quantitative and qualitative data collection and analysis. This

approach provided a comprehensive understanding of the multifaceted contributions of community-based cattle feedlot programs.

2.4 Sample selection

The study employed a purposive sampling strategy to select 150 households involved in community-based cattle feedlot programs and 100 households not participating (control group). The total number of households involved in the feedlot programs was approximately 178, providing a comprehensive pool from which the sample was drawn. The decision to select 150 households was informed by power calculations to ensure adequate statistical power to detect meaningful differences between participating and non-participating households. This sample size was also aligned with previous studies on livestock interventions, which suggest that similar sample sizes are sufficient to achieve reliable and generalizable results in community-based agricultural research (Myeki et al., 2014; Lubing et al., 2018). Households were selected based on their active involvement in cattle farming and their accessibility, ensuring that the sample was representative of the broader target population. This approach allowed for the inclusion of diverse household characteristics, such as farm size, herd composition, and socio-economic status, providing a robust basis for comparison between participating and control groups.

2.5 Data collection

A mixed-methods approach was employed, combining quantitative and qualitative data collection and analysis. This approach facilitated a comprehensive understanding of the multifaceted contributions of community-based cattle feedlot programs. The primary data collection methods included structured questionnaires, focus group discussions (FGDs), and direct observations:

A Structured questionnaires

Structured questionnaires were administered to both participating and non-participating households to gather quantitative data on herd dynamics, animal performance, and socio-economic outcomes. Key metrics included herd size, calving rates, mortality and morbidity rates, average daily gain (ADG), feed conversion ratio (FCR), health status, household income, employment, and food security. Each interview took approximately 45 min. This quantitative data provided a detailed analysis of the changes associated with feedlot participation.

B Focus group discussions (FGDs)

FGDs were conducted exclusively with participating farmers, community leaders, and feedlot managers at two different feedlots. This qualitative component provided in-depth insights into the perceived benefits, challenges, and communal experiences associated with the feedlot programs. The selection of these participants was deliberate to capture a range of perspectives directly linked to the operation and impact of the feedlots. Each FGD lasted around 90 min and was structured to explore themes such as community cohesion, barriers to participation, and adaptive strategies. This component enriched the data by capturing the socio-cultural dimensions of the feedlot programs, which might not be fully captured through quantitative measures.

C Direct observations

Researchers conducted direct observations at the feedlots to assess management practices, animal health and performance, and overall operational efficiency. Each observation session lasted about 2 h and allowed researchers to validate data obtained from interviews and FGDs. Observations provided context for understanding the operational realities of the feedlots, including feed management, animal handling practices, and infrastructure conditions.

The key variables measured included herd size, calving rates, mortality and morbidity rates, ADG, FCR, health status, household income, employment creation, and food security. The combination of these data collection methods ensured a comprehensive analysis of the impact of community-based cattle feedlot programs on various aspects of herd dynamics, animal performance, and socio-economic outcomes.

2.6 Data analysis

Quantitative data were analyzed using R software (version 3.4.2) to perform descriptive statistics and regression analysis (R Core Team, 2017). The regression models assessed the impact of feedlot participation on herd dynamics, animal performance, and socio-economic outcomes. Descriptive Statistics: Summarized the basic features of the data, including means, standard deviations, and frequencies. Regression Analysis: Used to determine the relationships between feedlot participation (independent variable) and the key outcome variables (dependent variables). The models included control variables such as household size, access to veterinary services, and baseline socio-economic status.

The regression equations took the form:

$$Yi = \beta 0 + \beta 1X1i + \beta 2X2i + \ldots + \beta kXki + \in i$$

Where Yi represents the outcome variables (e.g., herd size, ADG, household income), X_{1i}, X_{2i}, …, X_{ki} are the independent variables (e.g., feedlot participation, access to training), and ϵ_i is the error term.

3 Results and discussion

3.1 Herd dynamics

Community-based feedlot programs play a pivotal role in enhancing herd dynamics by offering structured management practices and access to necessary resources. Our analysis of herd dynamics before and after feedlot participation revealed notable improvements across several key parameters (Table 1). The average herd size increased by 40%, from 50 to 70 cattle, a change attributable to the controlled feeding environment and management practices inherent to feedlot systems. Such environments reduce mortality rates and bolster reproductive success, aligning with findings by Sotsha

TABLE 1 Herd dynamics before and after feedlot program participation.

Parameter	Non-participating herds	Before feedlot program	After feedlot program	% Change
Average herd size	52	50	70	+40%
Calving rate (%)	58	60	80	+33%
Inter-calving interval (months)	19	18	14	−22%
Mortality rate (%)	12	10	5	−50%
Morbidity rate (%)	16	15	8	−47%

TABLE 2 Impact of feedlot program on herd dynamics.

Variable	Coefficient (β)	Standard error (SE)	*t*-statistic	*p*-value	R^2
Intercept	40.00	5.00	8.00	0.000	0.65
Feedlot participation (1 = Yes)	20.00	3.00	6.67	0.000	
Calving rate (%)	0.50	0.10	5.00	0.001	
Mortality rate (%)	−0.30	0.15	−2.00	0.050	
Morbidity rate (%)	−0.25	0.12	−2.08	0.045	

et al. (2018) and Nyhodo et al. (2014), who reported that structured feedlot systems contribute significantly to improved reproductive performance and overall herd management. Further supporting these findings, the calving rate rose from 60 to 80%, and the inter-calving interval decreased by 22%, from 18 to 14 months. These reproductive improvements are crucial, as they directly enhance herd productivity and efficiency (Lubing et al., 2018; Wurzinger et al., 2018). Additionally, mortality and morbidity rates dropped by 50 and 47%, respectively, indicating significant health benefits, which are consistent with research demonstrating the positive impacts of feedlot systems on cattle health and survival rates. Regression analysis confirmed these observations, showing a significant positive coefficient for herd size ($\beta = 20.00$, $p < 0.001$), alongside reductions in mortality ($\beta = -0.30$, $p = 0.050$) and morbidity ($\beta = -0.25$, $p = 0.045$; Table 2). These results underscore the efficacy of feedlot programs in fostering healthier, more productive herds.

3.2 Animal performance

Feedlot programs also significantly improve animal performance metrics. As shown in Table 3, the average daily gain (ADG) increased by 60%, from 0.5 kg/day to 0.8 kg/day, primarily due to the controlled nutrition and feeding regimes provided in feedlot environments. These findings are supported by Slayi et al. (2023b), who highlighted the role of structured feeding programs in optimizing growth rates. The feed conversion ratio (FCR) also improved by 25%, from 8:1 to 6:1, reflecting more efficient feed utilization, which is critical for the economic sustainability of cattle operations (Marandure et al., 2016b; Myeki et al., 2014). Health improvements were equally notable, with disease incidence halving from 20 to 10% and vaccination coverage increasing from 50 to 90%, representing an 80% improvement. These enhancements highlight the comprehensive health management practices within feedlots, which are designed to optimize animal welfare and performance (Mpofu et al., 2023; Slayi et al., 2023b). Regression analysis further substantiated these performance gains, showing significant positive coefficients for ADG ($\beta = 0.50$, $p < 0.001$) and health status ($\beta = -0.10$, $p < 0.005$; Table 4). These outcomes demonstrate the value of feedlot programs in promoting robust animal health and performance.

3.3 Socio-economic outcomes

The socio-economic impacts of community-based feedlot programs are profound, particularly in rural areas where agriculture is a primary source of income. Table 5 illustrates that average household income rose by 67%, from ZAR 3000 to ZAR 5000 per month. This increase is directly linked to the enhanced productivity and market access afforded by feedlot programs, as supported by Marandure et al. (2020) and Marandure et al. (2016a). Additionally, feedlot programs contributed to local economic development by creating 15 new jobs within participating communities, reflecting their role in boosting rural economies (Gwiriri et al., 2019; Ntombela et al., 2013). Food security also improved significantly, with the proportion of households reporting better access to food increasing from 60 to 85%, a 42% improvement. Furthermore, the average sales price per cattle increased by 50%, from ZAR 5000 to ZAR 7500, which not only enhanced farmers' incomes but also contributed to greater economic stability (Lubing et al., 2018; Sotsha et al., 2018). Regression analysis highlighted strong positive impacts on household income ($\beta = 1{,}500$, $p < 0.001$), employment ($\beta = 200$, $p < 0.001$), and food security ($\beta = 300$, $p = 0.010$; Table 6). These findings underscore the broader socio-economic benefits of feedlot programs beyond mere livestock management.

3.4 Farmer participation

The success of community-based feedlot programs is heavily dependent on active farmer participation and engagement from all stakeholders. As shown in Table 7, satisfaction levels are high, with 85% of respondents expressing satisfaction with the program, and 90% indicating a willingness to continue participation. Improved market

TABLE 3 Animal performance metrics.

Metric	Traditional farming	Feedlot program	% Improvement
Average daily gain (kg/day)	0.5	0.8	+60%
Feed conversion ratio (FCR)	8:1	6:1	+25%
Health status (incidence of disease %)	20	10	−50%
Income over feed cost (IOFC, ZAR/cattle)	1,500	2,500	+67%
Vaccination coverage (%)	50	90	+80%

TABLE 4 Impact of feedlot program on animal performance.

Variable	Coefficient (β)	Standard error (SE)	*t*-statistic	*p*-value	R^2
Intercept	0.30	0.05	6.00	0.000	0.70
Feedlot participation (1 = Yes)	0.50	0.07	7.14	0.000	
Feed conversion ratio (FCR)	−0.05	0.02	−2.50	0.020	
Health status (incidence of disease %)	−0.10	0.03	−3.33	0.005	
Vaccination coverage (%)	0.02	0.01	2.00	0.050	

TABLE 5 Socio-economic outcomes.

Indicator	Before feedlot program	After feedlot program	% Change
Average household income (ZAR/month)	3,000	5,000	+67%
Employment created (number of jobs)	0	15	N/A
Food security level (% of households)	60	85	+42%
Average sales price per cattle (ZAR)	5,000	7,500	+50%

TABLE 6 Impact of feedlot program on socio-economic outcomes.

Variable	Coefficient (β)	Standard error (SE)	*t*-statistic	*p*-value	R^2
Intercept	2,000	500	4.00	0.000	0.75
Feedlot participation (1 = Yes)	1,500	300	5.00	0.001	
Employment created (number of jobs)	200	50	4.00	0.000	
Food security level (%)	300	100	3.00	0.010	
Average sales price per cattle (ZAR)	1,000	200	5.00	0.001	

TABLE 7 Stakeholder perceptions and participation.

Perception/Participation factor	Positive responses (%)	Negative responses (%)
Satisfaction with feedlot program	85	15
Willingness to continue participation	90	10
Perceived improvement in market access	80	20
Challenges faced (e.g., logistics, cost)	30	70

access was reported by 80% of respondents, highlighting the perceived benefits of feedlot participation. However, 30% of participants faced challenges such as logistics and costs, which indicate areas needing improvement to ensure broader adoption and sustainability. Factors influencing farmer participation include perceived benefits ($\beta = 0.80$, $p < 0.001$), access to training ($\beta = 0.50$, $p < 0.005$), and market access ($\beta = 0.70$, $p < 0.001$). Conversely, the cost of participation had a negative impact ($\beta = -0.002$, $p = 0.050$; Table 8). These results suggest that targeted training and capacity-building initiatives are essential to empower farmers with the knowledge and skills necessary to manage feedlot operations effectively (Sotsha et al., 2018; Myeki et al., 2014; Ntombela et al., 2013). Furthermore, addressing cost-related barriers is crucial for sustaining high levels of farmer participation.

3.5 Best practices proposed by stakeholders to better the functioning of cattle feedlots

Stakeholders have proposed several best practices to enhance the effectiveness of feedlot programs (Table 9). Centralized veterinary services, such as regular check-ups and vaccinations, are anticipated to improve animal health and reduce mortality rates, consistent with findings by Mpofu et al. (2023) and Slayi et al. (2023b). Additionally, collective bargaining for feed purchases could lead to increased feed

TABLE 8 Factors influencing farmer participation in feedlot programs.

Variable	Coefficient (β)	Standard error (SE)	*t*-statistic	*p*-value	R^2
Intercept	1.00	0.20	5.00	0.001	0.60
Perceived benefits (1 = Yes)	0.80	0.10	8.00	0.000	
Access to training (1 = Yes)	0.50	0.15	3.33	0.005	
Cost of participation (ZAR)	−0.002	0.001	−2.00	0.050	
Market access (1 = Yes)	0.70	0.12	5.83	0.000	

TABLE 9 Best practices and recommendations.

Best practice/ recommendation	Description	Expected impact
Centralized veterinary services	Providing regular veterinary check-ups and vaccinations at feedlot centers	Improved animal health and reduced mortality rates
Collective bargaining for feed purchases	Organizing bulk purchases of feed to reduce costs	Increased feed efficiency and reduced costs
Training programs for farmers	Offering regular training on best cattle management and feedlot practices	Enhanced farmer knowledge and improved animal performance
Market linkage initiatives	Establishing direct links with large meat processors and retailers	Better market access and higher sales prices for farmers

efficiency and significant cost savings, as supported by Lubing et al. (2018). Training programs focused on best cattle management practices are expected to further enhance animal performance (Slayi et al., 2024), while establishing direct market linkages could improve market access and increase sales prices, aligning with the recommendations of Malusi et al. (2021). However, challenges such as initial capital investment and operational costs remain barriers that must be addressed to ensure the broader participation and sustainability of feedlot programs. Supportive policies and financial mechanisms are essential to facilitate entry and continued participation in these initiatives, thereby maximizing their potential impact on livestock productivity and community welfare.

3.6 Limitations and future research directions

While the findings of this study highlight significant benefits of community-based feedlot programs on herd dynamics, animal performance, and socio-economic outcomes, there are several limitations that warrant consideration. First, the data were primarily derived from regions where feedlot programs are well-established, which may not fully capture the variability of outcomes in different ecological or socio-economic contexts. Variations in regional infrastructure, climate, and market access could influence the effectiveness of feedlot programs, limiting the generalizability of the results. Future research should aim to include a broader range of geographical regions and settings to provide a more comprehensive understanding of feedlot program impacts across diverse environments. Another limitation is the reliance on self-reported data for some socio-economic measures, such as household income and food security levels. Self-reported data can be subject to biases, including recall bias and social desirability bias, which could affect the accuracy of the findings. To address this, future studies should incorporate more objective measures, such as longitudinal tracking of income and market transactions, to validate self-reported outcomes.

The study also primarily focused on quantitative metrics to evaluate the impacts of feedlot programs. While this approach provides valuable insights into measurable changes, it may overlook qualitative aspects, such as farmer perceptions, cultural attitudes, and community dynamics that influence participation and program success. Future research should integrate qualitative methodologies, such as focus groups and interviews, to capture these nuanced factors and provide a richer understanding of the challenges and opportunities associated with feedlot programs. Moreover, the analysis did not extensively explore the environmental impacts of feedlot operations, such as greenhouse gas emissions, water usage, and land degradation. Given the increasing emphasis on sustainable agricultural practices, future research should assess the environmental footprint of feedlot programs and explore strategies to mitigate potential negative impacts. This could include evaluating the integration of sustainable feed sources, waste management practices, and the potential for regenerative agricultural approaches within feedlot systems. Additionally, the study identified cost and logistical barriers as significant challenges for farmer participation in feedlot programs. However, a more detailed economic analysis is needed to understand the cost–benefit ratios and financial viability of feedlot operations for smallholder farmers. Future studies should conduct comprehensive economic evaluations, including cost analyses, profitability assessments, and the exploration of financial support mechanisms that can make feedlot programs more accessible and sustainable for small-scale producers. Finally, while this study highlights the positive outcomes associated with feedlot programs, it also underscores the need for tailored support and capacity-building initiatives to sustain farmer participation. Future research should explore the effectiveness of different training and extension service models, particularly those that incorporate technology and digital tools to enhance knowledge transfer and decision-making among farmers.

4 Conclusion

This study demonstrates that community-based feedlot programs can significantly improve herd dynamics, animal performance, and socio-economic outcomes for smallholder farmers. By providing structured management practices, consistent feeding, and better access to veterinary care, feedlot programs have led to substantial increases in

herd size, calving rates, and average daily gain, while reducing mortality, morbidity, and inter-calving intervals. The resulting enhancements in productivity have not only bolstered household incomes but also improved food security and created new employment opportunities within rural communities. The findings align with existing literature that underscores the benefits of feedlot systems in optimizing livestock management and economic viability. The positive impacts observed in animal health and performance metrics reflect the effectiveness of controlled feeding regimes and comprehensive health management, reinforcing the potential of feedlot programs to address key challenges in traditional livestock farming. However, the study also highlights the importance of addressing barriers such as initial capital investment, operational costs, and logistical challenges that may hinder broader participation. Additionally, the need for tailored training and capacity-building initiatives is evident to empower farmers with the necessary skills and knowledge for effective feedlot management. Ensuring that these programs are accessible and sustainable for smallholder farmers is crucial for maximizing their impact. While the results are promising, several limitations, including regional variability, reliance on self-reported data, and the need for a deeper exploration of environmental impacts, suggest areas for further investigation. Future research should aim to broaden the geographical scope, incorporate qualitative insights, and conduct detailed economic and environmental assessments to enhance our understanding of feedlot programs' broader implications.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Research Ethics Committee of the University of Fort Hare (JAJ051SMPO01). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MS: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. LZ: Writing – review & editing, Funding acquisition. IJ: Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. Financial support received from the National Research Foundation, grant number TS64 (UID: 99787), is acknowledged.

Acknowledgments

The authors are grateful to the Centre for Global Change (CGC) and Department of Livestock and Pasture Science at University of Fort Hare for assisting in research logistics and cattle farmers in Tsomo and Centane who participated in the study. Deepest gratitude is given to enumerators for their help during data collection.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Acocks, J. P. H. (1988). "Veld types of South Africa" in *Memoirs of botanical survey of South Africa*. *3rd* ed (Pretoria, South Africa: Government Printer), 1–146.

Archer, E. R. M., Landman, W. A., Malherbe, J., Maluleke, P., and Weepener, H. (2021). Managing climate risk in livestock production in South Africa: how might improved tailored forecasting contribute? *Clim. Risk.* 32, 100312–100317. doi: 10.1016/j.crm.2021.100312

Bareki, N. P., and Antwi, M. A. (2017). Drought preparedness status of farmers in the Nguni cattle development project and the sire subsidy scheme in north West Province, South Africa. *Appl. Ecol. Environ. Res.* 2017, 589–603. doi: 10.15666/aeer/1504_589603

Boomiraj, K., Wani, S. P., Aggarwal, P. K., and Palanisami, K. (2010). Climate change adaptation strategies for agro-ecosystem–a review. *J. Agrometeorol.* 12, 145–160. doi: 10.54386/jam.v12i2.1297

Gwiriri, L. C., Bennett, J., Mapiye, C., Marandure, T., and Burbi, S. (2019). Constraints to the sustainability of a 'systematized' approach to livestock marketing amongst smallholder cattle producers in South Africa. *Int. J. Agric. Sustain.* 17, 189–204. doi: 10.1080/14735903.2019.1591658

Khapayi, M., and Celliers, P. R. (2016). Factors limiting and preventing emerging farmers to progress to commercial agricultural farming in the king William's town area of the eastern Cape Province, South Africa. *South Afr. J. Agric. Exten.* 44, 25–41. doi: 10.17159/2413-113221/2016/v44n1a374

Lubing, M., Mazibuko, N, and Sotsha, K., (2018). "Comparing prices received by participating and non- participating farmers in the custom feeding initiative of the National red Meat Development Programme: a case of KwaZulu Natal Province," in *30th International Conference of Agricultural Economics, no. March, 2018*.

Malusi, N., Falowo, A. B., and Idamokoro, E. M. (2021). Herd dynamics, production and marketing constraints in the commercialization of cattle across Nguni cattle project beneficiaries in eastern cape, South Africa. *Pastoralism* 11, 1–12. doi: 10.1186/s13570-020-00186-x

Marandure, T., Bennett, J., Dzama, K., Gwiriri, L. C., Bangani, N., and Mapiye, C. (2016a). Envisioning more effective delivery of custom feeding programs using participatory approaches: lessons from eastern Cape Province, South Africa. *Outlook Agric.* 48, 157–166. doi: 10.1177/0030727019843135

Marandure, T., Bennett, J., Dzama, K., Makombe, G., Gwiriri, L., and Mapiye, C. (2020). Advancing a holistic systems approach for sustainable cattle development programmes in South Africa: insights from sustainability assessments. *Agroecol. Sustain. Food Syst.* 44, 827–858. doi: 10.1080/21683565.2020.1716130

Marandure, T., Mapiye, C., Makombe, G., Nengovhela, B., Strydom, P., Muchenje, V., et al. (2016b). Determinants and opportunities for commercial marketing of beef cattle raised on communally owned natural pastures in South Africa. *Afr. J. Ran. For. Sci.* 33, 199–206. doi: 10.2989/10220119.2016.1235617

Marandure, T., Mapiye, C., Makombe, G., Nengovhela, B., Strydom, P., Muchenje, V., et al. (2016c). Beef traders' and consumers' perceptions on the development of a natural pasture-fed beef brand by smallholder cattle producers in South Africa. *Afr. J. Ran. For. Sci.* 33, 207–214. doi: 10.2989/10220119.2016.1235616

Mpofu, B. I., Slayi, M., Mutero, G., Mlahlwa, S., and Jaja, I. F. (2023). Assessing body condition scores, weight gain dynamics, and fecal egg counts in feedlot and non-feedlot cattle within high throughput abattoirs of the eastern Cape Province. *Front. Anim. Sci.* 4:1302320. doi: 10.3389/fanim.2023.1302320

Mucina, L., and Rutherford, M. C. (2011). *The vegetation of South Africa, Lesotho and Swaziland*. Pretoria, South Africa: SANBI, 513.

Myeki, L., Mmbengwa, V., and Ngqangweni, S. (2014). Assessing the use of communal feedlot in empowering women farmers: a case of mount frere cattle. *Int. J. Sustain. Dev.* 7, 11–18.

Nciizha, A. D., and Wakindiki, I. I. C. (2012). Particulate organic matter, soil texture and mineralogy relations in some eastern cape ecotopes in South Africa. *S. Afr. J. Plant Soil* 29, 39–46. doi: 10.1080/02571862.2012.688882

Ntombela, S., Myeki, L, and Nyhodo, B. (2013). Mainstreaming subsistence farmers through communal feedlot: case of Umzimvubu custom feeding program in mount frere, researchgate.net, no. September, p. 13, 2013. Available at: https://www.researchgate.net/profile/MyekiLindikaya/publication/312554593 (Accessed April 28, 2024).

Nyhodo, B., Mmbengwa, V. M., Balarane, A., and Ngetu, X. (2014). Formulating the least cost feeding strategy of a custom feeding programme: a linear programming approach. *Int. J. Sustain. Dev.* 7, 85–92.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.R-project.org/ (Accessed March 4, 2024).

Ruwanza, S., Thondhlana, G., and Falayi, M. (2022). Research progress and conceptual insights on drought impacts and responses among small-holder farmers in South Africa: a review. *Land* 11, 159–167. doi: 10.3390/land11020159

Slayi, M., Zhou, L., and Jaja, I. F. (2023a). Exploring farmers' perceptions and willingness to tackle drought-related issues in small-holder cattle production systems: a case of rural communities in the eastern cape, South Africa. *Appl. Sci.* 13:7524. doi: 10.3390/app13137524

Slayi, M., Zhou, L., and Jaja, I. F. (2023b). Smallholder farmers' adoption and perception of communally established cattle feedlots for climate change resilience in the eastern cape, South Africa. *Front. Sustain. Food Syst.* 7:1239766. doi: 10.3389/fsufs.2023.1239766

Slayi, M., Zhou, L., and Jaja, I. F. (2023c). Constraints inhibiting farmers' adoption of cattle feedlots as a climate-smart practice in rural communities of the eastern cape, South Africa: an in-depth examination. *Sustain. For.* 15:14813. doi: 10.3390/su152014813

Slayi, M., Zhou, L., Nyambo, P., Jaja, I. F., and Muchaku, S. (2024). Communally established cattle feedlots as a sustainable livelihood option for climate change resilience and food security in sub-Saharan Africa: a systematic review. *Front. Sustain. Food Syst.* 7:1325233. doi: 10.3389/fsufs.2023.1325233

Sotsha, K., Fakudze, B., Khoza, T., Mmbengwa, V., Ngqangweni, S., Lubinga, M. H., et al. (2018). Factors influencing communal livestock farmers' participation into the National red Meat Development Programme (NRMDP) in South Africa: the case of the eastern Cape Province. *OIDA Int. J. Sustain. Dev.* 11, 73–80.

Taruvinga, A., Muchenje, V., and Mushunje, A. (2013). Climate change impacts and adaptations on small-scale livestock production. *Int. J. Dev. Sust.* 2, 664–685.

Terry, S. A., Basarab, J. A., and McAllister, T. A. (2021). Strategies to improve the efficiency of beef cattle production. *Can. J. Anim. Sci.* 101, 1–19. doi: 10.1139/cjas-2020-0022

Tibesigwa, B., Visser, M., and Turpie, J. (2017). Climate change and South Africa's commercial farms: an assessment of impacts on specialised horticulture, crop, live-stock and mixed farming systems. *Environ. Dev. Sustain.* 19, 607–636. doi: 10.1007/s10668-015-9755-6

Vetter, S., Goodall, V. L., and Alcock, R. (2020). Effect of drought on communal livestock farmers in KwaZulu-Natal, South Africa. *Afr. J. Ran. For. Sci.* 37, 93–106. doi: 10.2989/10220119.2020.1738552

Wurzinger, B., Nukarinen, E., Nägele, T., Weckwerth, W., and Teige, M. (2018). The SnRK1 kinase as central mediator of energy signaling between different organelles. *Plant Physiol.* 176, 1085–1094.

Wurzinger, M., Gutiérrez, G. A., Sölkner, J., and Probst, L. (2021). Community-based livestock breeding: coordinated action or relational process? *Front. Vet. Sci.* 8:613505. doi: 10.3389/fvets.2021.613505

Zhou, L., Slayi, M., Ngarava, S., Jaja, I. F., and Musemwa, L. (2022). A systematic review of climate change risks to communal livestock production and response strategies in South Africa. *Front. Anim. Sci.* 3:868468. doi: 10.3389/fanim.2022.868468