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Communally established cattle feedlots as a sustainable livelihood option for climate change resilience and food security in sub-Saharan Africa: a systematic review

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Climate change poses a significant threat to agriculture and livestock production in sub-Saharan Africa, a region heavily reliant on livestock for smallholder farmers' livelihoods. This systematic review investigates the potential of communally established cattle feedlots as a sustainable strategy to address the interconnected challenges of climate change resilience and food security in the area. The review focuses on the intensification of climate change, marked by rising temperatures and altered precipitation patterns, posing a direct threat to the livelihoods of millions in the region. Conducting a systematic literature review, we meticulously analyzed 72 articles that centered on communally established cattle feedlots in sub-Saharan Africa. The inclusion criteria considered studies within the context of climate change resilience and food security, utilizing both qualitative and quantitative methodologies. Published articles, grey literature, and relevant reports were systematically sourced from academic databases such as PubMed, Scopus, Google Scholar and Web of Science, complemented by manual searches of journals, conference proceedings, and organizational websites. The synthesis of findings reveals a nuanced landscape of successes and challenges associated with communal feedlots. Through a narrative synthesis, studies were categorized based on key themes, unraveling the impact of communal feedlots on livestock health, economic viability, and socio-economic dynamics. The review highlights the role of communal feedlots in mitigating climate-related shocks, enhancing livestock productivity, and fostering economic opportunities for smallholder farmers. However, challenges related to land tenure, community engagement, and resource allocation emerged as critical considerations. In conclusion, communally established cattle feedlots offer a holistic and sustainable approach to address climate change challenges in sub-Saharan Africa.

KEYWORDS

cattle feedlots, climate-induced challenges, resource-poor countries, smallholder farmers, sustainable livestock production

1 Introduction

Climate change poses a critical threat to global agriculture and food security, with far-reaching consequences for ecosystems and the millions who rely on agriculture for their livelihoods (Archer et al., 2021; Zhou et al., 2022). Sub-Saharan Africa, where agriculture is integral to the economy and social well-being, is particularly vulnerable to these disruptive impacts (Oduniyi et al., 2020; Slayi et al., 2023c). Urgent action is needed to develop innovative and sustainable adaptation strategies that address both climate change resilience and food security in this region (Amamou et al., 2018; Slayi et al., 2023b). This paper focuses on one such strategy—communally established cattle feedlots—tailored to the unique circumstances of developing countries. Climate change, as outlined by the Intergovernmental Panel on Climate Change (IPCC), manifests through rising temperatures, altered precipitation patterns, and increased extreme weather events, impacting agricultural systems at various levels (Popoola et al., 2020; Slayi et al., 2023a). Livestock, crucial to the livelihoods of smallholder farmers, are especially vulnerable, posing a significant barrier to food security (Musemwa et al., 2012; Ntshangase et al., 2018).

Developing countries in the sub-Saharan Africa, home to a substantial proportion of the world's smallholder farmers, face disproportionate impacts due to limited adaptive capacity and resources (Boomiraj et al., 2010; Costa Junior et al., 2015). Trapped in a cycle of poverty and vulnerability, these farmers grapple with the dual challenge of adapting to climate change while ensuring food security (Iglesias et al., 2012; Taruvinga et al., 2013). Communally established cattle feedlots offer an innovative adaptation strategy with the potential to mitigate climate change impacts and enhance food security. This systematic review comprehensively explores the concept, dissecting its structural organization, management practices, and socioeconomic implications. Drawing on empirical evidence and literature from different countries in the sub-Saharan Africa, it highlights the advantages of communal feedlots and their potential to address climate-related shocks, enhance livestock productivity, and create economic opportunities for smallholder farmers. While contributing to mitigating greenhouse gas emissions, successful implementation requires addressing challenges such as land tenure, community engagement, and resource allocation, emphasizing the need for supportive policy frameworks and institutional mechanisms. This study aims to provide a thorough understanding of the potential of communally established cattle feedlots in addressing climate change resilience and food security challenges in sub-Saharan Africa, contributing to the discourse on climate-resilient agricultural practices.

2 Methodology

This literature survey employed a systematic review approach, chosen for its ability to ensure transparency, accuracy, and replicability, as illustrated in Figure 1. The methodology adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Cooper, 2010; Monroe et al., 2017), a framework well-established in climate science-related systematic reviews (Barth and Thomas, 2012; Berrang-ford et al., 2015). The data gathering process encompassed two primary approaches: (1) literature search and selection, and (2) data management, coding, and analysis. This methodological choice enhances the robustness and reliability of the survey findings.

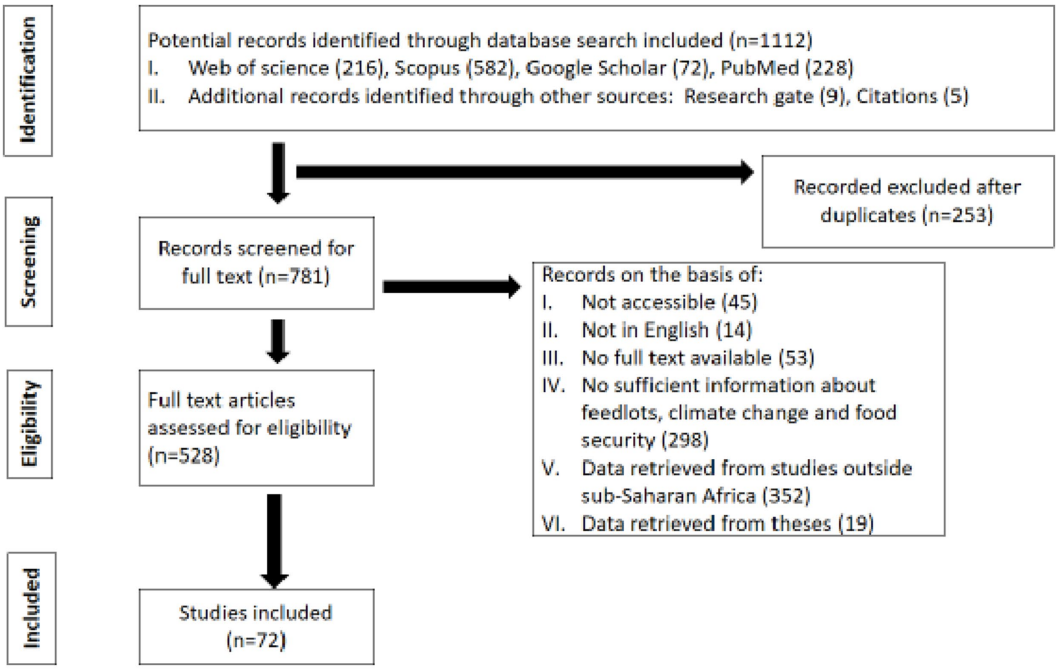

FIGURE 1
PRISMA flow diagram showing the process of identifying relevant studies for the review.

2.1 Inclusion criteria for studies

The research comprised studies that specifically concentrated on communally established cattle feedlots in sub-Saharan Africa. It encompassed investigations conducted within the context of climate change resilience and food security. The selected studies employed a range of methodologies, both qualitative and quantitative. The sources considered for this research included published articles, grey literature, and relevant reports.

2.2 Exclusion criteria for studies

The research excluded studies that were not directly pertinent to the topic of communally established cattle feedlots. It did not incorporate research conducted outside the geographical scope of sub-Saharan Africa. Studies lacking relevance to either climate change resilience or food security were not considered. Additionally, articles not available in English were excluded from the research.

2.3 Search strategy for literature retrieval

The research employed academic databases, including PubMed, Scopus, Google Scholar, and Web of Science, alongside grey literature repositories. It utilized a comprehensive search strategy involving the combination of keywords such as "communal feedlots," "livelihood," "climate change resilience," and "food security." Additionally, relevant journals, conference proceedings, and organizational websites were hand-searched to ensure a thorough exploration of the topic.

2.4 Data extraction and synthesis methods

A standardized data extraction form was created to systematically capture essential information, including study details such as author, publication year, and title. The form included fields for documenting the geographical location and characteristics of communally established cattle feedlots. It further encompassed aspects such as livelihood and economic impacts, sustainable livestock management practices, socio-economic and institutional considerations, as well as climate change resilience and food security outcomes. This structured approach ensured comprehensive and organized data collection for analysis.

2.5 Data analysis

The research undertook a narrative synthesis of findings, organizing studies based on key themes to provide a coherent and comprehensive overview. Additionally, the synthesis process included the development of summary tables to effectively present and communicate key results, enhancing the clarity and accessibility of the research findings.

3 Results and discussion

The synthesis of findings from the systematic review of communally established cattle feedlots in sub-Saharan Africa unravels a complex tapestry of insights that holds profound implications for climate change resilience and food security in the region. A meticulous analysis of 72 articles, employing a diverse range of methodologies and drawing from various sources, has laid the foundation for a comprehensive understanding of the challenges and potentials associated with this innovative adaptation strategy. As we delve into the results and discussion section, we navigate through the intricate dynamics of communal feedlots, exploring their impact on livestock health, economic viability, and the broader socio-economic landscape. This section scrutinizes the nuanced interplay of factors that shape the success and challenges of communal feedlots, shedding light on their role in mitigating climate change-induced shocks and enhancing the resilience of smallholder farmers. Through an evidence-based discussion, this paper aims to distill key insights that can inform policies, practices, and future research directions, contributing to the ongoing dialog on sustainable agricultural solutions in the face of a changing climate.

3.1 Climate change impacts on livestock and agriculture in sub-Saharan Africa

Climate change stands as a paramount global challenge, profoundly impacting agriculture and livestock production, as extensively outlined in existing literature (Escarcha et al., 2018; Talanow et al., 2021). The escalating intensification of climate change manifests through rising global temperatures, altered precipitation patterns, heightened frequency, and severity of extreme weather events, alongside shifts in the distribution of pests and diseases (Popoola et al., 2019; Oduniyi et al., 2020). The gravity of these changes reverberates worldwide, with particular repercussions for agricultural systems, especially in developing nations where agriculture predominantly relies on rain-fed practices, is resource-dependent, and serves as the cornerstone of rural livelihoods (Beauchemin and McGinn, 2005; Anderson et al., 2016; Bareki and Antwi, 2017; Tibesigwa et al., 2017). Existing research, including the compilation presented in Table 1, comprehensively highlights the multifaceted implications of climate change on global agricultural systems, shedding light on its effects on temperature and precipitation patterns that directly impact crop yields (Ntshangase et al., 2018). The identified threats, such as extreme heat and prolonged droughts, pose substantial risks to food security by diminishing crop productivity, particularly in developing nations where subsistence farming prevails, amplifying the vulnerability of local populations (Muthelo et al., 2019; Zwane, 2019; Popoola et al., 2020; Tesfuhuney and Mbeletshie, 2020).

Furthermore, the susceptibility of livestock, integral to the livelihoods of millions in sub-Saharan countries, is extensively documented in the literature (Zhou et al., 2022; Slayi et al., 2023a). Rising temperatures induce heat stress in animals, resulting in reduced productivity and increased mortality rates, a critical concern for smallholder farmers' livelihoods and the global food supply chains they contribute to (Hristov et al., 2017; Lottering et al., 2020a; Archer et al., 2021). The intricate relationship between climate change and water scarcity is also thoroughly explored, emphasizing its repercussions on agriculture and livestock (Derner et al., 2018; Oduniyi et al., 2020; Lottering et al., 2020b). Reduced water availability compromises food production by impeding crop irrigation and limiting drinking water access. Moreover, alterations in the geographic

TABLE 1 Key findings of climate change impacts, adaptive strategies and policy and investment needs on livestock and agriculture.

Category	Impacts of climate change	Adaptive strategies	Policy and investment needs	References
Reduced crop yields and food insecurity	Changes in temperature and precipitation patterns can lead to reduced crop yields, posing threats to food security.	Farmers adapt through changes in planting, diversification, and drought-resistant crop varieties.	Supportive policies, investments, and access to resources are crucial for resilience in agriculture.	Ntshangase et al. (2018); Popoola et al. (2020); Serote et al. (2023); Zwane (2019)
Livestock health and productivity	Rising temperatures can lead to heat stress in animals, reducing productivity and increasing mortality rates.	Livestock farmers adjust management practices to mitigate heat stress and disease risks.	Policies and investments in research and technology are needed to address livestock health challenges.	Zhou et al. (2022); Tibesigwa et al. (2017); Slayi et al. (2023a)
Water scarcity	Climate change exacerbates water scarcity, compromising irrigation and access to drinking water for agriculture and livestock.	Adaptive strategies may include water-efficient irrigation techniques.	Policies promoting water management and conservation are essential.	Derner et al. (2018); Slayi et al. (2023a); Archer et al. (2021); Lottering et al. (2021)
Changing pest and disease dynamics	Climate change alters the distribution of pests and diseases, affecting crop and livestock health.	Farmers adapt to changing disease dynamics through pest control measures and disease management.	Investments in research and disease surveillance, along with policy support, are necessary.	Ndiritu (2020);Tesfuhuney and Mbeletshie (2020); Theusme et al. (2020); Zhou et al. (2022)
Extreme weather events	The increasing frequency and severity of extreme weather events pose immediate risks to agriculture and livestock.	Communities and farmers may implement disaster preparedness measures and infrastructure improvements.	Policies and investments in disaster resilience and risk reduction are critical.	Lottering et al. (2020a,b); Oduniyi et al. (2020); Talanow et al. (2021)
Adaptive strategies	Farmers and communities have developed various adaptive strategies, such as changing planting dates and crop diversification.	These strategies help mitigate climate change impacts and enhance agricultural resilience.	Policies supporting farmer adaptation and knowledge sharing are important.	Taruvinga et al. (2013); Popoola et al. (2019); Ndiritu (2020); Vetter et al. (2020)
Policy and investment needs	Effective adaptation requires supportive policies, investments in research and technology, and improved access to resources.	National and international efforts are crucial for enhancing resilience and ensuring food security.	Coordinated policies, funding, and capacity-building are essential for climate adaptation.	Iglesias et al. (2012); Chatrchyan et al. (2017); Popoola et al. (2020)

distribution of pests and diseases due to climate change are identified as significant factors affecting crop and livestock health (Musemwa et al., 2012; Zhou et al., 2022). Despite the wealth of information presented, the existing literature remains silent on critical aspects. Notably, it falls short in providing a comprehensive identification of research gaps and a thorough critique of the current state of knowledge, limiting our ability to fully grasp the nuances of climate change impacts on agriculture and livestock in sub-Saharan Africa.

In response to the multifaceted challenges posed by climate change, farmers and communities in developing nations have devised various adaptive strategies. These strategies encompass alterations in planting dates, crop diversification, and the adoption of drought-resistant crop varieties (Boomiraj et al., 2010; Henry et al., 2018; Galyean and Hales, 2023). Similarly, livestock farmers may adjust their management practices to mitigate the adverse effects of heat stress and changing disease risks (Zhou et al., 2022; Slayi et al., 2023a). However, the existing literature lacks a comprehensive critique of the effectiveness of these adaptive strategies and their widespread implementation. Effective adaptation to climate change in agriculture and livestock is contingent on the formulation and implementation of supportive policies, investments in research and technology, and improved access to resources and markets (Popoola et al., 2020; Terry et al., 2020; Ridoutt et al., 2022; Ruwanza et al., 2022). Yet, there is a notable gap in the literature regarding the evaluation of the policy frameworks and the adequacy of investments and support mechanisms in facilitating successful adaptation strategies.

Recognizing the significance of national and international collaboration is crucial for enhancing resilience in agriculture and ensuring food security amidst climate change (Loerch and Fluharty, 1999; Joyce et al., 2013; Briske et al., 2015). However, the existing body of literature lacks a thorough analysis of the effectiveness of these collaborative efforts and their impact on smallholder farmers in diverse geographical and socio-economic contexts. The multifaceted and complex nature of climate change's impact on agriculture and livestock production in developing nations, as outlined by Amamou et al. (2018); Marco et al., (2018); Malusi et al. (2021), necessitates a more nuanced understanding. The identified impacts, including reduced crop yields, livestock health issues, water scarcity, changing disease dynamics, and extreme weather events, highlight the urgency of addressing these challenges through comprehensive and

context-specific approaches. Therefore, there is a notable research gap in the literature concerning the development and evaluation of holistic strategies that integrate scientific research, policy development, and community engagement to enhance resilience and ensure food security in the dynamically changing climate.

3.2 Smallholder livestock farming and vulnerability in sub-Saharan Africa

Smallholder farmers, heavily reliant on livestock as a key asset, play a pivotal role in the agriculture of many developing nations (Taruvinga et al., 2013). However, their vulnerability to the impacts of climate change is a growing concern, given their limited access to resources, technology, and adaptive capacity (Musemwa et al., 2012). This literature review scrutinizes the unique challenges faced by smallholder livestock farmers within the context of climate change, emphasizing their implications for food security. Operating on restricted land holdings and lacking access to modern farming technologies and practices, smallholders face constraints in adapting to changing climate conditions and managing climate-related shocks in sub-Saharan Africa (Escarcha et al., 2018; Archer et al., 2021). Climate variability, affecting traditional livestock management practices, poses a significant threat to smallholders (Muller and Shackleton, 2014; Dabasso et al., 2018; Nganga and Crane, 2020).

Precipitation pattern shifts leading to water scarcity and changing forage availability impact animal nutrition and health, intensifying the vulnerability of smallholder livestock farmers (Zhou et al., 2022). Given that livestock constitutes a crucial source of income and nutrition for smallholder households, climate-induced livestock losses can have severe consequences, exacerbating poverty and food insecurity (Slayi et al., 2023a). Moreover, the gender dimension in smallholder livestock farming is substantial, with women often assuming responsibility for livestock care and management (Maltitz and Bahta, 2021). Climate change, by causing livestock health issues and altering resource availability, may further amplify gender inequalities, placing an increased workload on women (Muthelo et al., 2019). The changing climate landscape also elevates the risk of livestock diseases through the altered distribution of disease vectors and pathogens (Escarcha et al., 2018). Smallholder farmers, especially those with limited access to veterinary services, face heightened vulnerability to disease outbreaks (Bocquier and González-García, 2010). Despite these challenges, smallholder livestock farmers employ adaptive strategies, including changes in grazing patterns, the introduction of drought-tolerant livestock breeds, and diversification of income sources (Zhou et al., 2022). However, the existing literature lacks a comprehensive evaluation of the effectiveness and limitations of these adaptive strategies, presenting a notable research gap. Additionally, the gender-specific impacts of climate change on smallholder livestock farming warrant further exploration and analysis in the existing literature.

Smallholder farmers often encounter barriers in accessing markets and value chains for their livestock products (Nyhodo et al., 2014). The economic prospects of these farmers are further complicated by market volatility and disruptions induced by climate change (Harrington and Lu, 2002). It is crucial for governments and development agencies to provide effective support to enhance the resilience of smallholder livestock farming (Popoola et al., 2020). Policies promoting sustainable livestock practices, facilitating access to climate information, and strengthening veterinary services can significantly reduce vulnerability (Archer et al., 2021; Zhou et al., 2022). However, the existing literature lacks a comprehensive assessment of the effectiveness of these policy interventions and their practical implications for smallholder farmers. In conclusion, smallholder livestock farmers in developing nations grapple with a myriad of challenges exacerbated by climate change. Their limited resources, reliance on livestock for income and food security, and susceptibility to climate-induced shocks underscore the pressing need for targeted interventions. While the literature acknowledges the importance of supportive policies, there is a gap in understanding the specific impacts and outcomes of these policies on smallholder livestock farming. Policymakers and development organizations must recognize the unique circumstances of smallholders and tailor climate adaptation and mitigation strategies to address their specific needs. Additionally, further research is warranted to critically evaluate the effectiveness of existing policies and identify areas for improvement. Mitigating the impacts of climate change on smallholder livestock farming is not only vital for their livelihoods but also imperative for global food security and poverty reduction efforts (Table 2).

3.3 Top of form

3.3.1 The emergence of communally established cattle feedlots

In response to the challenges posed by climate change and the vulnerability of smallholder livestock farmers in sun-Saharan Africa, communally established cattle feedlots have emerged as an innovative and context-specific adaptation strategy (Slayi et al., 2023b). This literature review critically examines the concept, development, and potential benefits of communal feedlots as an adaptation option. Communally established cattle feedlots are community-managed facilities designed to optimize cattle management and improve livestock health and productivity (Sotsha et al., 2018). In contrast to traditional extensive grazing systems, these feedlots provide controlled environments for feeding and management (Slayi et al., 2023c). However, existing research lacks a comprehensive evaluation of the effectiveness and practical implications of communal feedlots, creating a notable research gap.

The emergence of communal feedlots can be traced back to the need to address climate change impacts on livestock farming (Marandure et al., 2020). Rising temperatures, reduced forage availability, and water scarcity have prompted a reevaluation of traditional livestock management practices (Escarcha et al., 2018). Feedlots offer a way to adapt to changing conditions while maintaining livestock health and productivity (McAllister et al., 2020). Despite their potential benefits, the existing literature falls short in providing a thorough critique of communal feedlots' strengths and limitations, leaving room for further investigation. Communal feedlots, which vary in size and organization, are typically managed by community members who collectively oversee cattle feeding, health care, and record-keeping (Nyhodo et al., 2014). The infrastructure may include feeding areas, water sources, and shelter (Novelli et al., 2022). While empirical evidence from various developing nations highlights several advantages of communal feedlots, such as improved livestock health

TABLE 2 Summary of the key findings on vulnerability of smallholder farming as well as adaptive strategies and policy and institutional needs in livestock.

Category	Challenges	Adaptive strategies employed	Policy and institutional support needs	Reference
Limited resources and adaptive capacity	Smallholder farmers have limited access to land and modern farming technologies, constraining their ability to adapt to climate change.	Farmers employ adaptive strategies like resource diversification, seeking external support, and knowledge sharing	Policies should focus on resource access, technology transfer, and capacity building for smallholder livestock farmers.	Slayi et al. (2023b); Lottering et al. (2020b)
Climate variability and livestock management	Climate variability disrupts traditional livestock management practices.	Adaptive strategies include changing grazing patterns, adjusting feeding practices, and improving water resource management.	Policies should support climate-resilient livestock management practices and provide access to climate information.	Ntshangase et al. (2018); Archer et al. (2021)
Income and food security	Climate-induced livestock losses can push smallholder households deeper into poverty and food insecurity.	Diversification of income sources, crop-livestock integration, and the use of resilient livestock breeds are common adaptive strategies.	Policies should aim to protect smallholders from income shocks, enhance food security, and promote livestock resilience.	Oduniyi et al. (2020); Tibesigwa et al. (2017)
Gender dynamics	Women often play a significant role in livestock care and management. Climate change can exacerbate gender inequalities in workload and resource access.	Gender-sensitive adaptation strategies, such as providing women access to resources and climate information, help address these disparities.	Policies should integrate gender considerations and support women's empowerment in livestock farming.	Maltitz and Bahta (2021); Muthelo et al. (2019), Briske et al. (2015)
Livestock disease risks	Climate change can increase the risk of livestock diseases, particularly for smallholders with limited access to veterinary services.	Farmers employ disease prevention and management strategies, such as improved biosecurity measures and vaccination programs.	Policies should strengthen veterinary services, disease surveillance, and livestock health support for smallholders.	Zhou et al. (2022); Escarcha et al. (2018)
Market access and value chains	Smallholders often face challenges in accessing markets and value chains for their livestock products.	Adaptive strategies include participating in farmer cooperatives, building market linkages, and improving post-harvest handling practices.	Policies should support smallholders in accessing markets, enhancing value addition, and mitigating market risks.	Nyhodo et al. (2014); Harrington and Lu (2002)
Policy support	Effective support from governments and development agencies is essential for enhancing smallholder livestock farming resilience.	Policies should focus on promoting sustainable livestock practices, climate information access, and strengthening veterinary services.	Institutional support is vital to facilitate policy implementation, capacity building, and knowledge sharing among smallholder livestock farmers.	Popoola et al. (2020); Chatrchyan et al. (2017)

and weight gain, controlled feeding, and reduced exposure to climate-related stressors, the lack of a comprehensive synthesis impedes a nuanced understanding of their broader implications.

Establishing communal feedlots can create economic opportunities for smallholder farmers (Slayi et al., 2023b). By improving the growth and marketability of cattle, these feedlots enhance income generation potential and contribute to poverty reduction (Harrington and Lu, 2002; Bevans et al., 2005). However, the literature fails to provide a holistic examination of the economic impacts, leaving unexplored avenues for understanding the socio-economic dynamics associated with communal feedlots. In addition to their role in climate adaptation, communal feedlots can contribute to mitigating greenhouse gas emissions. Improved cattle management reduces methane emissions associated with enteric fermentation (Costa Junior et al., 2015). While this aligns with global efforts to reduce the environmental footprint of livestock production, a comprehensive analysis of the environmental implications of communal feedlots remains underexplored in the existing literature.

Despite their potential benefits, the establishment and successful operation of communal feedlots are not without challenges. Issues related to land tenure, resource allocation, and community participation can hinder their adoption (Sotsha et al., 2018). Additionally, the sustainability of these feedlots depends on effective management practices and ongoing support (Slayi et al., 2023c). Existing research lacks an in-depth exploration of the challenges associated with communal feedlots, making it imperative to address these gaps for a more nuanced understanding of their implementation challenges. Governments and development organizations play a crucial role in promoting the adoption of

communal feedlots (Marandure et al., 2021). However, the literature does not critically examine the policy frameworks, financial incentives, and technical support required for the successful implementation of communal feedlots, presenting a notable gap in the current understanding. In concluding this point, communally established cattle feedlots offer a promising adaptation strategy for smallholder livestock farmers in the face of climate change. Their potential to improve livestock health, increase economic opportunities, and contribute to climate mitigation makes them a compelling option. However, addressing challenges related to land tenure, resource allocation, and community engagement is essential to ensure the successful implementation and sustainability of these feedlots. Policymakers and development practitioners should consider these factors when designing strategies to enhance climate resilience and food security in developing nations. The existing literature, while providing valuable insights, leaves critical research gaps that warrant further exploration and analysis to inform effective policy and implementation strategies.

3.4 Sustainable livestock management in communal cattle feedlots

As previously discussed, communal feedlots have garnered recognition as a sustainable adaptation strategy for smallholder livestock farming within the context of climate change resilience and food security. This literature review critically examines the application of sustainable livestock management principles within communal feedlots, focusing on their contributions to environmental sustainability, animal welfare, and economic viability. Despite the growing acknowledgment of communal feedlots, the existing literature lacks a comprehensive analysis of the potential drawbacks and limitations associated with the integration of sustainable practices, highlighting a notable research gap. Communal feedlots incorporate sustainable livestock management practices into their operational framework, encompassing controlled feeding, efficient resource utilization, and waste management (Slayi et al., 2023c). While the literature acknowledges the importance of adopting sustainable principles for maximizing the benefits of communal feedlots (Nyhodo et al., 2014), it falls short in providing a nuanced critique of the practical challenges and potential trade-offs associated with their implementation.

One of the primary objectives of communal feedlots is to optimize the utilization of available resources, including feed, water, and land. Sustainable practices within these feedlots aim to ensure efficient resource use, minimize waste, and conserve natural resources (Barbero et al., 2017). While the literature highlights the positive aspects of sustainable resource management, it overlooks potential conflicts or unintended consequences that may arise, such as increased workload or conflicts over resource allocation, representing a gap in the current understanding. Sustainable livestock management principles within communal feedlots prioritize the well-being of animals, contributing to reduced stress, disease prevention, and enhanced productivity (Marandure et al., 2020). However, the literature lacks an in-depth examination of potential challenges or trade-offs associated with implementing these practices, such as the economic costs and logistical complexities of adopting improved animal health and welfare measures, presenting an avenue for further research.

Communal feedlots, often integrated with other agricultural activities, contribute to resource use efficiency and income diversification for smallholder farmers (Slayi et al., 2023b). While the literature recognizes these benefits, it fails to explore potential conflicts or challenges arising from the integration of livestock with other farming practices, such as competition for resources or increased complexity in managing integrated systems. The economic viability of communal feedlots is highlighted in the literature, emphasizing improved livestock health, increased weight gain, and higher marketability of cattle leading to increased income for smallholders (Gwiriri et al., 2019; Marandure et al., 2021). However, the existing research lacks a comprehensive economic analysis, including potential costs and risks associated with implementing sustainable livestock management practices, presenting a critical research gap. The successful implementation of sustainable livestock management in communal feedlots may require training and capacity-building for community members (Slayi et al., 2023b). Despite this acknowledgment, the literature falls short in providing a detailed analysis of the challenges related to knowledge transfer, traditional practices, and resource constraints, hindering a comprehensive understanding of the practical barriers to adoption.

Policymakers play a pivotal role in promoting sustainable livestock management in communal feedlots (Nyhodo et al., 2014). While the literature recognizes the importance of supportive policies, it lacks a critical analysis of the potential policy challenges, conflicts, or unintended consequences that may arise, presenting a research gap in the current understanding. Global initiatives, such as the Global Agenda for Sustainable Livestock, acknowledge the importance of communal feedlots in broader efforts to promote sustainability in livestock production (Rivera-Ferre et al., 2016). However, the literature does not delve into potential tensions or conflicts between global sustainability goals and local implementation challenges, leaving a gap in the assessment of the broader implications of these initiatives. In summary, while sustainable livestock management practices within communal feedlots are deemed essential for enhancing the resilience of smallholder livestock farming in the face of climate change and food security challenges, the existing literature falls short in providing a comprehensive critique and analysis. By integrating principles that prioritize environmental sustainability, animal welfare, and economic viability, communal feedlots offer a holistic approach to sustainable livestock production. Policymakers, development organizations, and local communities must collaborate to ensure the successful implementation of these practices and maximize their benefits for both farmers and the environment. However, addressing the identified research gaps is crucial for a more nuanced and informed approach to the integration of sustainable practices within communal feedlots. Future research should focus on these gaps to provide a more comprehensive understanding of the challenges and opportunities associated with sustainable livestock management in communal feedlots.

3.5 Socio-economic and institutional considerations in communal cattle feedlots

The successful establishment and operation of communal feedlots involve a nuanced interplay of socio-economic and institutional factors (Costa Junior et al., 2015). This literature review critically examines key considerations in communal feedlots, encompassing issues related to land tenure, community participation, gender dynamics, and the policy and institutional framework. Despite the

existing body of literature, several research gaps and areas for improvement within the discourse on communal feedlots are identified. Land tenure emerges as a critical factor in the establishment of communal feedlots (Nyhodo et al., 2014). However, the literature lacks a comprehensive analysis of the potential complexities arising from unclear tenure arrangements in communal lands (Marandure et al., 2021). This absence of nuanced exploration hinders a detailed understanding of the challenges and conflicts associated with land use in the context of communal feedlots, presenting a notable research gap.

Community engagement is vital for the success of communal feedlots (Gwiriri et al., 2019), with community members often playing key roles in management and decision-making processes (Slayi et al., 2023c). However, the literature falls short in providing a nuanced critique of the potential challenges and conflicts that may arise in ensuring active community involvement and ownership of feedlot initiatives, representing a research gap in the understanding of communal dynamics. Gender dynamics within communal feedlots are acknowledged, emphasizing the significant role of women in livestock management (Maltitz and Bahta, 2021). However, the literature lacks an in-depth examination of existing gender inequalities and potential barriers to women's equal access to resources, training, and decision-making opportunities within the context of communal feedlots, presenting an area for further research. Efficient resource allocation is crucial for the sustainability of communal feedlots, requiring careful planning and management (Mader et al., 2002). While the literature recognizes the importance of resource optimization, it lacks a detailed analysis of the decision-making processes regarding feed procurement, water resource allocation, and budgeting within communal feedlots, representing a gap in the current understanding.

Effective local governance structures are deemed essential for resolving conflicts and enforcing rules within communal feedlots (Slayi et al., 2023b). However, the literature lacks a critical analysis of potential challenges or conflicts that may arise in establishing and maintaining these governance structures, presenting a gap in the understanding of the practical aspects of communal feedlot management. Adequate institutional support is crucial for the establishment and success of communal feedlots, including technical assistance, training, and access to financial resources (Slayi et al., 2023c). While the literature acknowledges the importance of institutional support, it lacks a detailed exploration of potential challenges or conflicts in providing such support, hindering a comprehensive understanding of the dynamics involved in institutional backing for communal feedlots. National and regional policy frameworks are recognized as instrumental in promoting and sustaining communal feedlots (Tavirimirwa et al., 2019). However, the literature lacks an in-depth analysis of the potential tensions or conflicts between overarching policy goals and local implementation challenges, representing a research gap in the assessment of the broader implications of policy frameworks.

Access to necessary infrastructure and services is deemed essential for the economic viability of communal feedlots (Teklebrhan and Urge, 2013). While the literature recognizes the importance of improving infrastructure, it lacks a detailed analysis of potential challenges or conflicts associated with enhancing accessibility and marketability of livestock products, presenting a research gap in the understanding of economic dynamics. Training and capacity-building initiatives are considered critical for effective feedlot management (Slayi et al., 2023c). However, the literature falls short in providing a nuanced analysis of potential challenges or conflicts related to knowledge transfer and capacity-building within communal feedlots, presenting a research gap in the practical aspects of community empowerment. Robust monitoring and evaluation mechanisms are acknowledged as necessary for assessing the performance of communal feedlots (Dabasso et al., 2018). However, the literature lacks a comprehensive analysis of the practical challenges or conflicts that may arise in implementing effective monitoring and evaluation, presenting a research gap in understanding the continuous improvement processes.

In summing up, while the socio-economic and institutional aspects of communal feedlots are deemed pivotal for their sustainability and effectiveness as adaptation strategies, the existing literature falls short in providing a comprehensive critique and analysis. By addressing the identified research gaps, communal feedlots can contribute not only to climate resilience and food security but also to community empowerment and sustainable development in rural areas. Future research should focus on these gaps to provide a more nuanced and informed approach to the socio-economic and institutional considerations of communal feedlot development.

3.6 Case studies and empirical evidence of communal cattle feedlots in sub-Saharan Africa

The adoption and impact of communal cattle feedlots have been extensively examined through diverse case studies and empirical research in various developing nations (Tavirimirwa et al., 2019; Slayi et al., 2023b). While these studies contribute valuable insights into the practical application of communal feedlots as a sustainable adaptation strategy, a critical evaluation reveals areas of improvement and research gaps within the existing literature. Table 3 provides a comprehensive summary of the successes and challenges associated with the establishment of communal cattle feedlots in developing countries, drawing from a range of studies. Examining specific cases, such as Zimbabwe, reveals notable successes, including improvements in cattle health, weight gain, and increased marketability leading to enhanced income for smallholder farmers (Tavirimirwa et al., 2019). However, challenges persist, such as limited access to veterinary services and the need for sustained support and training, emphasizing the necessity for further research on effective strategies to address these issues (Dube et al., 2021).

Similar success stories are observed in Ethiopia, South Africa, Kenya, and Sudan, where communal feedlots have positively influenced cattle management practices, livestock productivity, and economic outcomes for smallholder farmers. Challenges, however, vary across regions, encompassing resource allocation, land tenure issues, access to markets, and community engagement (Babiker et al., 2009; Alemayehu and Leta, 2014; Banerjee et al., 2014; Dabasso et al., 2018; Marandure et al., 2020). The existing literature underscores the importance of addressing these challenges to maximize the benefits of communal feedlots in specific contexts. While the case studies collectively highlight the potential of communal cattle feedlots as a strategy for improving livestock health, increasing income, and enhancing resilience to climate-related challenges, a closer examination reveals certain research gaps. The literature would benefit from more in-depth analyses of the factors contributing to both the successes and challenges identified. For instance, understanding the mechanisms behind successful resource management, effective

TABLE 3 Successes and limitations of establishing communal cattle feedlots in developing countries.

Country	Success story	Challenges	References
Zimbabwe	Communal feedlots have demonstrated the potential to enhance cattle health and weight gain, thereby increasing the marketability of livestock. This has translated into improved income for smallholder farmers.	Challenges include limited access to veterinary services and the need for sustained support and training to maintain feedlot operations	Tavirimirwa et al. (2019); Dube et al. (2021); Ncube et al. (2014)
Ethiopia	Communal feedlots in Ethiopia have proven effective in improving cattle fattening practices, increasing livestock productivity, and enhancing smallholder income.	Challenges include resource allocation, land tenure issues, and access to markets. Effective resource management and market access remain key areas of concern	Teklebrhan and Urge (2013); Alemayehu and Leta (2014); Banerjee et al. (2014)
South Africa	Communal feedlots have been successful in reducing livestock vulnerability to climate variability and improving cattle growth rates	Limited access to finance and technical support for feedlot development have been identified as challenges. Collaborative efforts with government agencies and non-governmental organizations have helped address some of these challenges	Slayi et al. (2023b); Marandure et al. (2021); Sotsha et al. (2018); Marandure et al. (2020); Gwiriri et al. (2019); Nyhodo et al. (2014)
Kenya	Communal cattle feedlots in Kenya have contributed to better cattle health management and reduced exposure to climate-related stressors	Challenges include the need for continuous training and community mobilization. Ensuring community participation and adherence to sustainable practices remains an ongoing effort	Dabasso et al. (2018); Kahi et al. (2006)
Sudan	Sudan has witnessed the successful establishment of communal feedlots that have increased livestock productivity and improved the livelihoods of smallholder farmers	Resource allocation and community engagement have been challenges. Addressing resource inequities and ensuring broad community involvement are critical	Babiker et al. (2012); Babiker et al. (2009)

community mobilization, and collaborative efforts involving government agencies would provide valuable insights for tailored interventions.

Moreover, there is a need for comparative studies across multiple developing nations to elucidate the adaptability of communal feedlots in different local contexts. Climate conditions, available resources, and community dynamics play crucial roles in determining the success of communal feedlots (Dabasso et al., 2018; Gwiriri et al., 2019; Tavirimirwa et al., 2019). Examining these factors systematically across diverse regions would contribute to a more nuanced understanding of the contextual variations and inform context-specific interventions. In conclusion, while the existing literature on communal cattle feedlots provides significant insights, addressing research gaps related to the specific factors influencing successes and challenges, as well as conducting more comparative studies across diverse regions, will enhance our understanding of communal feedlots as a sustainable adaptation strategy. Policymakers, development practitioners, and communities can leverage these insights to implement effective and tailored approaches to overcome challenges and maximize the benefits of communal feedlots in diverse developing nation settings.

3.7 Conclusion and further research suggestions

This systematic review highlights the multifaceted potential of communally established cattle feedlots as a sustainable livelihood option for enhancing climate change resilience and food security in sub-Saharan Africa. The synthesis of literature reveals the significant strides made in understanding the benefits and challenges associated with these communal feedlots. Sustainable livestock management practices, economic impacts, and their role in bolstering climate resilience and food security are evident themes. The review highlights the importance of socio-economic and institutional considerations in shaping the success of such initiatives. Despite the promising aspects, challenges such as land tenure, community engagement, and resource allocation necessitate attention for successful implementation. This review emphasizes the critical need for supportive policies and institutional frameworks to address these challenges and ensure the sustained success of communally established cattle feedlots. Building on the insights gained from this systematic review, avenues for further research are identified:

I Longitudinal Studies: Conduct longitudinal studies to track the long-term impacts of communally established cattle feedlots on climate resilience and food security. This would provide a deeper understanding of their sustained effectiveness.

II Comparative Analyses: Undertake comparative analyses between different regions within sub-Saharan Africa to discern contextual variations in the outcomes of communal feedlots, accounting for diverse ecological, socio-economic, and institutional factors.

III In-Depth Socio-Economic Studies: Delve into more in-depth socio-economic studies to explore the nuanced dynamics of community engagement, gender roles, and the economic implications on individual households.

IV Policy Analysis: Evaluate existing policies and assess their effectiveness in supporting the establishment and maintenance of communal feedlots. Propose policy recommendations that can enhance their impact on climate resilience and food security.

V Climate Change Modeling: Integrate climate change modeling to forecast the future effectiveness of communally established

cattle feedlots under different climate scenarios, providing insights into their adaptive capacity.

VI Community Participation Studies: Conduct studies focused on community participation dynamics, exploring strategies to enhance local involvement and ownership in the management of communal feedlots.

In pursuing these avenues, researchers can contribute to a more comprehensive understanding of the potential and challenges associated with communally established cattle feedlots, further informing sustainable strategies for climate adaptation and food security in sub-Saharan Africa.

Author contributions

MS: Data curation, Methodology, Writing – original draft, Writing – review & editing. LZ: Conceptualization, Funding acquisition, Supervision, Writing – review & editing. PN: Writing – review & editing. IJ: Conceptualization, Methodology, Supervision, Writing – review & editing.

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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.

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References

Alemayehu, G., and Leta, S. (2014). Biosecurity practices in central Ethiopian cattle feedlots: its implication for live cattle export. *Int. J. Livestock Product.* 5, 181–187.

Amamou, H., Ben Sassi, M., Aouadi, H., Khemiri, H., Mahouachi, M., Beckers, Y., et al. (2018). Climate change-related risks and adaptation strategies as perceived in dairy cattle farming systems in Tunisia. *Clim. Risk Manag.* 20, 38–49. doi: 10.1016/j.crm.2018.03.004

Anderson, C. L., Schneider, C., Erickson, G. E., MacDonald, J. C., and Fernando, S. C. (2016). Rumen bacterial communities can be acclimated faster to high concentrate diets than currently implemented feedlot programs. *J. Appl. Microbiol.* 120, 588–599. doi: 10.1111/jam.13039

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. doi: 10.1016/j.crm.2021.100312

Babiker, A. A., Amir, M. S., and Khidir, O. A. (2009). Feedlot performance of Sudan Baggara bulls fed pelleted and Unpelleted Baggase based diets. *Pak. J. Nutr.* 8, 384–387. doi: 10.3923/pjn.2009.384.387

Babiker, A. A., Babiker, I. A., Abdelhadi, O. M. A., Elemam, M. B., and Salih, A. M. (2012). Feedlot performance and carcass characteristics of Sudan Baggara bulls fed varying levels of pelleted sorghum straw. *Online J. Anim. Feed Res.* 2, 422–426.

Banerjee, S., Ahmed, M., and Tefere, G. (2014). Studies on morphometrical traits of Boran bulls reared on two feedlots in southern Ethiopia. *Animal Genetic Resour.* 54, 53–63. doi: 10.1017/S2078633614000095

Barbero, R. P., Malheiros, E. B., Nave, R. L., Mulliniks, J. T., Delevatti, L. M., Koscheck, J. F., et al. (2017). Influence of post-weaning management system during the finishing phase on grasslands or feedlot on aiming to improvement of the beef cattle production. *Agric. Syst.* 153, 23–31. doi: 10.1016/j.agsy.2017.01.015

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.* 15, 589–603. doi: 10.15666/aeer/1504_589603

Barth, M., and Thomas, I. (2012). Synthesising case-study research—ready for the next step? *Environ. Educ. Res.* 18, 751–764. doi: 10.1080/13504622.2012.665849

Beauchemin, K. A., and McGinn, S. M. (2005). Methane emissions from feedlot cattle fed barley or corn diets1. *J. Anim. Sci.* 83, 653–661. doi: 10.2527/2005.833653x

Berrang-ford, L., Pearce, T., and Ford, J. D. (2015). Systematic review approaches for climate change adaptation research. *Reg. Envir. Ch.* 15, 755–769. doi: 10.1007/s10113-014-0708-7

Bevans, D. W., Beauchemin, K. A., Schwartzkopf-Genswein, K. S., McKinnon, J. J., and McAllister, T. A. (2005). Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. *J. Anim. Sci.* 83, 1116–1132. doi: 10.2527/2005.8351116x

Bocquier, F., and González-García, E. (2010). Sustainability of ruminant agriculture in the new context: feeding strategies and features of animal adaptability into the necessary holistic approach. *Animal* 4, 1258–1273. doi: 10.1017/s1751731110001023

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

Briske, D. D., Joyce, A. L., Polley, H. W., Brown, J. R., Wolter, K., Morgan, A. J., et al. (2015). Climate-change adaptation on rangelands: linking regional exposure with diverse adaptive capacity. *Front. Ecol. Environ.* 13, 249–256. doi: 10.1890/140266

Chatrchyan, A. M., Erlebacher, R. C., Chaopricha, N. T., Chan, J., Tobin, D., and Allred, S. B. (2017). United States agricultural stakeholder views and decisions on climate change. *WIREs Clim. Chang.* 8:469. doi: 10.1002/wcc.469

Cooper, H. M. (2010). *Research synthesis and Meta-analysis: A step-by-step approach* (Thousand Oaks: Sage).

Costa Junior, C., Cerri, C. E. P., Dorich, C. D., Maia, S. M. F., Bernoux, M., and Cerri, C. C. (2015). Towards a representative assessment of methane and nitrous oxide emissions and mitigation options from manure management of beef cattle feedlots in Brazil. *Mitig. Adapt. Strateg. Glob. Chang.* 20, 425–438. doi: 10.1007/s11027-013-9499-2

Dabasso, B. H., Wasonga, O. V., Irungu, P., and Kaufmann, B. (2018). Stratified cattle production in pastoral areas of Kenya: existing forms, driving factors and management practices. *Applied Animal Husbandry and Rural Develop.* 11, 22–31.

Derner, J., Briske, D., Reeves, M., Brown-Brandl, T., Meehan, M., Blumenthal, D., et al. (2018). Vulnerability of grazing and confined livestock in the northern Great Plains to projected mid-and late-twenty-first century climate. *Clim. Chang.* 146, 19–32. doi: 10.1007/s10584-017-2029-6

Dube, T., Sibanda, S., and Chiwara, P. (2021). Adapting peri-urban agriculture to climate change in Bulawayo, Zimbabwe: a qualitative assessment. *Cogent Soc. Sci.* 7:486. doi: 10.1080/23311886.2021.1944486

Escarcha, J. F., Lassa, J. A., and Zander, K. K. (2018). Livestock under climate change: a systematic review of impacts and adaptation. *Climate* 6:54. doi: 10.3390/cli6030054

Galyean, M. L., and Hales, K. E. (2023). Feeding management strategies to mitigate methane and improve production efficiency in feedlot cattle. *Animals* 13:758. doi: 10.3390/ani13040758

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

Harrington, L. M., and Lu, M. (2002). Beef feedlots in southwestern Kansas: local change, perceptions, and the global change context. *Glob. Environ. Chang.* 12, 273–282. doi: 10.1016/s0959-3780(02)00041-9

Henry, B. K., Eckard, R. J., and Beauchemin, K. A. (2018). Review: adaptation of ruminant livestock production systems to climate changes. *Animal* 12, s445–s456. doi: 10.1017/s1751731118001301

Hristov, A. N., Degaetano, A. T., Rotz, C. A., Hoberg, E., Skinner, R. H., Felix, T., et al. (2017). Climate change effects on livestock in the northeast US and strategies for adaptation. *Clim. Chang.* 146, 33–45. doi: 10.1007/s10584-017-2023-z

Iglesias, A., Quiroga, S., Moneo, M., and Garrote, L. (2012). From climate change impacts to the development of adaptation strategies: challenges for agriculture in Europe. *Clim. Chang.* 112, 143–168. doi: 10.1007/s10584-011-0344-x

Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., and Bailey, D. W. (2013). Climate change and north American rangelands: assessment of mitigation and adaptation strategies. *Rangel. Ecol. Manag.* 66, 512–528. doi: 10.2111/REM-D-12-00142.1

Kahi, A. K., Wasike, C. B., and Rewe, T. O. (2006). Beef production in the arid and semi-arid lands of Kenya: constraints and prospects for research and development. *Outlook on AGRICULTURE* 35, 217–225. doi: 10.5367/000000006778536800

Loerch, S. C., and Fluharty, F. L. (1999). Physiological changes and digestive capabilities of newly received feedlot cattle. *J. Anim. Sci.* 77, 1113–1119. doi: 10.2527/1999.7751113x

Lottering, S., Mafongoya, P., and Lottering, R. (2020a). Drought and its impacts on small-scale farmers in sub-Saharan Africa: a review. *South Afr. Geogr. J.* 103, 319–341. doi: 10.1080/03736245.2020.1795914

Lottering, S., Mafongoya, P., and Lottering, P. (2020b). Detecting and mapping drought severity using multi-temporal Landsat data in the uMsinga region of KwaZulu-Natal, South Africa. *Geo. Int.* 37, 1574–1586. doi: 10.1080/10106049.2020.1783580

Lottering, S., Mafongoya, P., and Lottering, P. (2021). The impacts of drought and the adaptive strategies of small-scale farmers in Umsinga, KwaZulu-Natal, South Africa. *J. Agric. Afr. Stud.* 56, 267–289. doi: 10.1177/0021909620916898

Mader, T. L., Holt, S. M., Hahn, G. L., Davis, M. S., and Spiers, D. E. (2002). Feeding strategies for managing heat load in feedlot cattle. *J. Anim. Sci.* 80, 2373–2382.

Maltitz, L. V., and Bahta, Y. T. (2021). Empowerment of smallholder female livestock farmers and its potential impacts to their resilience to agricultural drought. *AIMS Agric. Food* 6, 603–630. doi: 10.3934/agrfood.2021036

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. *Res. Policy and Pract.* 11, 1–12. doi: 10.1186/s13570-020-00186-x

Marandure, T., Bennett, J., Dzama, K., Bennet, J. E., and Mapiye, C. (2021). Drivers of low-input farmers' perceptions of sustainable ruminant farming practices in the eastern Cape Province, South Africa. *Environ. Dev. Sustain.* 23, 8405–8432. doi: 10.1007/s10668-020-00973-x

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

Marco, I., Padró, R., Cattaneo, C., Caravaca, J., and Tello, E. (2018). From vineyards to feedlots: a fund-flow scanning of sociometabolic transition in the Vallès County (Catalonia) 1860–1956–1999. *Reg. Environ. Chang.* 18, 981–993. doi: 10.1007/s10113-017-1172-y

McAllister, T. A., Stanford, K., Chaves, A. V., Evans, P. R., de Souza Figueiredo, E. E., and Ribeiro, G. (2020). "Nutrition, feeding and management of beef cattle in intensive and extensive production systems" in *Animal Agriculture*. Eds. F. W. Bazer, G. Cliff, and G. Wu (Cambridge, MA, USA: Academic Press), 75–98.

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., and Chaves, W. A. (2017). Identifying effective climate change education strategies: a systematic review of the research. *Environ. Educ. Res.* 25, 791–812. doi: 10.1080/13504622.2017.1360842

Muller, C., and Shackleton, S. (2014). Perceptions of climate change and barriers to adaptation amongst commonage and commercial livestock farmers in the semi-arid eastern Cape Karoo. *African J. Rang. For. Sci.* 31, 1–12. doi: 10.2989/10220119.2013.845606

Musemwa, L., Muchenje, V., Mushunje, A., and Zhou, L. (2012). The impact of climate change on livestock production amongst the resource-poor farmers of the third world countries: a review. *Asian J. Rural Dev.* 2, 621–631. doi: 10.22004/ag.econ.198008

Muthelo, D., Owusu-Sekyere, E., and Ogundeji, A. A. (2019). Small-holder farmers' adaptation to drought: identifying effective adaptive strategies and measures. *WaterSA* 11:2069. doi: 10.3390/w11102069

Ncube, S., Ndlovu, L. R., Tavirimirwa, B., Tambo, G., Mwembe, R., and Nyamushamba, G. B. (2014). Growth performance of ruminants fed different proportions of maize and sorghum grain. *Livest. Res. Rural. Dev.* 26:166.

Ndiritu, S. W. (2020). Beef value chain analysis and climate change adaptation and investment options in the semi-arid lands of northern Kenya. *J. Arid Environ.* 181:104216. doi: 10.1016/j.jaridenv.2020.104216

Nganga, T. W., and Crane, T. A. (2020). Social differentiation in climate change adaptation: one community, multiple pathways in transitioning Kenyan pastoralism. *Environ. Sci. Pol.* 114, 478–485. doi: 10.1016/j.envsci.2020.08.010

Novelli, T. I., Bium, B. F., Biffi, C. H. C., Picharillo, M. E., de Souza, N. S., de Medeiros, S. R., et al. (2022). Consumption, productivity and cost: three dimensions of water and their relationship with the supply of artificial shading for beef cattle in feedlots. *J. Clean. Prod.* 376:134088. doi: 10.1016/j.jclepro.2022.134088

Ntshangase, N. L., Muroyiwa, B., and Sibanda, M. (2018). Farmers' perceptions and factors influencing the adoption of no-till conservation agriculture by small-scale farmers in Zashuke, KwaZulu-Natal Province. *Sustain. For.* 10:555. doi: 10.3390/su10020555

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.

Oduniyi, O. S., Rubhara, T. T., and Antwi, M. A. (2020). Sustainability of livestock farming in South Africa. Outlook on production constraints, climate-related events, and upshot on adaptive capacity. *Sustain. For.* 12:2582. doi: 10.3390/su12072582

Popoola, O. O., Yusuf, S. F. G., and Monde, N. (2019). Perception and adaptation responses to climate change: an assessment of small-holder livestock farmers in Amathole District municipality, eastern Cape Province. *S. Afr. J. Agric. Ext.* 47, 46–57. doi: 10.17159/2413-3221/2019/v47n2a502

Popoola, O. O., Yusuf, S. F. G., and Monde, N. (2020). South African National Climate Change Response Policy Sensitization: an assessment of small-holder farmers in Amathole District municipality, Eastern Cape Province. *Sustainability* 12:2616. doi: 10.3390/su12072616

Ridoutt, B., Lehnert, S. A., Denman, S., Charmley, E., Kinley, R., and Dominik, S. (2022). Potential GHG emission benefits of *Asparagopsis taxiformis* feed supplement in Australian beef cattle feedlots. *J. Clean. Prod.* 337:130499. doi: 10.1016/j.jclepro.2022.130499

Rivera-Ferre, M. G., López-i-Gelats, F., Howden, M., Smith, P., Morton, J. F., and Herrero, M. (2016). Re-framing the climate change debate in the livestock sector: mitigation and adaptation options. *Wiley Interdiscip. Rev. Clim. Chang.* 7, 869–892. doi: 10.1002/wcc.421

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. *Landscape* 11, 159–167. doi: 10.3390/land11020159

Serote, B., Mokgehle, S., Senyolo, G., du Plooy, C., Hlophe-Ginindza, S., Mpandeli, S., et al. (2023). Exploring the barriers to the adoption of climate-smart irrigation Technologies for Sustainable Crop Productivity by smallholder farmers: evidence from South Africa. *Agriculture* 13:246. doi: 10.3390/agriculture13020246

Slayi, M., Zhou, L., and Jaja, I. F. (2023a). 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., 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). 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

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.

Talanow, K., Topp, E. N., Loos, J., and Martin-Lopez, B. (2021). Farmers' perceptions of climate change and adaptation strategies in South Africa's Western cape. *J. Rural. Stud.* 81, 203–219. doi: 10.1016/j.jrurstud.2020.10.026

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

Tavirimirwa, B., Manzungu, E., Washaya, S., Ncube, S., Ncube, S., Mudzengi, C., et al. (2019). Efforts to improve Zimbabwe communal grazing areas: a review. *African J. Range & Forage Sci.* 36, 73–83. doi: 10.2989/10220119.2019.1602566

Teklebrhan, T., and Urge, M. (2013). Assessment of commercial feedlot finishing practices at eastern Shoa, Ethiopia. *Open J. Animal Sci.* 3, 273–280. doi: 10.4236/ojas.2013.34041

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

Tesfuhuney, W. A., and Mbeletshie, E. H. (2020). Place-based perceptions, resilience and adaptation to climate change by small-holder farmers in rural South Africa. *Int. J. Agric. Res. Innov. Technol.* 10, 116–127. doi: 10.3329/ijarit.v10i2.51585

Theusme, C., Avendaño-Reyes, L., Macías-Cruz, U., Correa-Calderón, A., García-Cueto, R., Mellado, M., et al. (2020). Climate change vulnerability of confined livestock systems predicted using bioclimatic indexes in an arid region of México. *Sci. Total Environ.* 751:141779. doi: 10.1016/j.scitotenv.2020.141779

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

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

Zwane, E. M. (2019). Impact of climate change on primary agriculture, water sources and food security in Western cape, South Africa. *J. Disast. Risk Stud.* 11:7. doi: 10.4102/jamba.v11i1.562