Effects of climate-induced drought on livestock production and market dynamics in Mazabuka District of Zambia

frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 02 March 2026
DOI 10.3389/fsufs.2026.1776530

OPEN ACCESS

EDITED BY
Cornelia F. A. van Wesenbeeck,
Vrije Universiteit Amsterdam,
Netherlands

REVIEWED BY
Alpha Kargbo,
University of the Gambia, Gambia
Takunda Shabani,
Local Initiatives and Development Agency, Zimbabwe

*CORRESPONDENCE
Oliver J. Hasimuna
oliverhasimuna@gmail.com

RECEIVED 27 December 2025
REVISED 28 January 2026
ACCEPTED 02 February 2026
PUBLISHED 02 March 2026

CITATION
Shanzuwa S, Bwalya C, Taimolo L, Mwamba F, Mweemba M, Chibesa M, Nkweto E, Mulwanda C, Mweetwa HM, Tembo B, Sianangama PC, Munkombwe J, Siankwilimba E, Maulu S and Hasimuna OJ (2026) Effects of climate-induced drought on livestock production and market dynamics in Mazabuka District of Zambia. *Front. Sustain. Food Syst.* 10:1776530. doi: 10.3389/fsufs.2026.1776530

Effects of climate-induced drought on livestock production and market dynamics in Mazabuka District of Zambia

Stacey Shanzuwa[1], Chewe Bwalya[2], Lawrencia Taimolo[3], Francis Mwamba[3], Malawo Mweemba[3,4,5], Moses Chibesa[2], Emmanuel Nkweto[1], Christopher Mulwanda[1,6], Hansel M. Mweetwa[7], Brian Tembo[8], Pharaoh C. Sianangama[8], Joshua Munkombwe[8], Enock Siankwilimba[9], Sahya Maulu[10,11] and Oliver J. Hasimuna[1,10,12]*

[1]Department of Agriculture and Aquatic Sciences, Kapasa Makasa University, Chinsali, Zambia, [2]Department of Zoology and Aquatic Sciences, School of Natural Resources, Copperbelt University, Kitwe, Zambia, [3]Department of Plant and Environmental Sciences, School of Natural Resources, Copperbelt University, Kitwe, Zambia, [4]Department of Biomaterials Sciences and Technology, School of Natural Resources, Copperbelt University, Kitwe, Zambia, [5]Chair of Environment and Development, Oliver R. Tambo Africa Research Chairs Initiative, Copperbelt University, Kitwe, Zambia, [6]Centre for Environment Justice, Lusaka, Zambia, [7]Independent Researcher, Choma, Zambia, [8]Department of Animal Science, School of Agricultural Sciences, Palabana University, Lusaka, Zambia, [9]Graduate School of Business, University of Zambia, Lusaka, Zambia, [10]Department of Aquaculture and Fisheries Sciences, School of Agricultural Sciences, Palabana University, Lusaka, Zambia, [11]Faculty of Science and Engineering, School of Biological and Marine Sciences, University of Plymouth, Plymouth, United Kingdom, [12]Department of Geography and Environmental Sciences, School of Archaeology, Geography and Environmental Science, University of Reading, Reading, United Kingdom

Livestock production is a central pillar of Zambia's food system, contributing to food security, incomes, and rural livelihoods. However, increasing frequency and intensity of climate-induced droughts pose significant risks to livestock productivity, market stability, and household resilience. This study examined the effects of climate-induced drought on livestock production outcomes, market dynamics, and farmer adaptation responses in Mazabuka District, Zambia, using a climate-smart food systems perspective. Data were collected from 95 randomly selected livestock farmers through semi-structured questionnaires and analysed using descriptive statistics, chi-square tests, and binary logistic regression in SPSS Statistics Version 29 (IBM Corp., Armonk, NY, USA), at a 0.05 significance level. The findings indicated that drought impacts were primarily manifested through water scarcity, reduced grazing availability, increased disease incidence, and declines in dairy production. Regression analysis identified livestock diseases, mortality, and reduced productivity as key predictors of farmers' perceived severity of drought impacts. Market effects were pronounced, with 96% of farmers associating poor animal body condition with declining livestock prices, highlighting strong production–market linkages within the local food system. Coping strategies were largely reactive, dominated by herd reduction and seasonal migration in search of grazing resources. Farmers expressed strong demand for systemic support, particularly training in climate-smart livestock practices, subsidised feed and water interventions, and livestock insurance schemes. These results underscore the need for integrated policy responses that strengthen climate resilience across production, animal health, and market subsystems. Aligning livestock development strategies with climate-smart agriculture principles, social protection mechanisms, and inclusive market policies is essential for advancing Sustainable

Development Goals related to zero hunger, poverty reduction, and climate action in drought-prone regions of Southern Africa. Future research should prioritise longitudinal and experimental approaches to quantitatively assess the effectiveness, economic feasibility, and sustainability of climate-smart livestock adaptation strategies under varying drought intensities such as strengthening livestock system resilience. This requires integrated, policy-supported interventions that expand climate-smart livestock training, subsidise drought-responsive feed and water inputs, scale up accessible livestock insurance schemes, and reinforce veterinary and market linkages. Advancing these measures is essential for safeguarding rural livelihoods, stabilising livestock markets, and supporting inclusive, climate-resilient food systems in Zambia.

KEYWORDS

adaptation strategies, climate-induced drought, climate-smart agriculture, livestock production, livestock resilience, market dynamics, smallholder farmers, Zambia

1 Introduction

Livestock production, defined as the breeding, rearing, and management of animals such as cattle, goats, sheep, pigs, and poultry for food, fibre, draught power, and income generation, is a cornerstone of global and regional food systems (Mozumdar, 2012; Volk and Walubita, 2024). Globally, the livestock sector contributes substantially to food and nutrition security, rural livelihoods, and agricultural gross domestic products by supplying high-quality animal-source proteins and supporting value chains that employ millions of people (Grote, 2014; Michalk et al., 2019; Defe et al., 2024). According to the FAO (2024), global meat production increased by approximately 1.7% in 2024, driven by rising population demand, intensification of production systems, and improved market integration (FAO, 2024; Muchhadiya et al., 2024; Prasad, 2025). Despite this growth, livestock systems are increasingly constrained by climate-induced shocks, including droughts, floods, heatwaves, and extreme weather events, which threaten productivity, animal welfare, and the stability of food systems worldwide (Escarcha et al., 2018; Bogale and Erena, 2022; Tofu, 2024; Anuta et al., 2025).

In Zambia, livestock production plays a critical role in national development by contributing to food security, employment creation, and household income diversification, particularly in rural areas (Wezi et al., 2023; Erdaw, 2023; Volk and Walubita, 2024). The sector comprises both large-scale commercial ranching and predominantly smallholder systems producing cattle, goats, sheep, pigs, and poultry (Thornton et al., 2024). Recent estimates indicate that Zambia hosts approximately 4.7 million cattle, with over 70% of milk production supplied by smallholder farmers, underscoring the sector's importance for livelihoods and nutrition (Kapende, 2024). Consequently, livestock production contributes directly to several Sustainable Development Goals (SDGs), particularly poverty reduction (SDG 1), zero hunger (SDG 2), and decent work and economic growth (SDG 8) (Phiri et al., 2020; Wattiaux, 2023; Hasimuna et al., 2025a).

The growth and resilience of Zambia's livestock sector have been supported by policy frameworks and development programmes, including the National Livestock Development Policy (2020), the Farmer Input Support Programme (FISP), and the Eighth National Development Plan (8NDP, 2022–2026), which emphasise improved breeds, extension services, veterinary support, and market access (Kuteya et al., 2025; Wezi et al., 2023). Complementary support from institutions such as the Ministry of Fisheries and Livestock and international partners, including IFAD, has further strengthened technical capacity and value chain development (Sibhatu et al., 2022; Wezi et al., 2023; Jerie et al., 2025). However, these gains remain fragile in the face of accelerating climate change.

Anthropogenic climate change, driven by greenhouse gas emissions and altered land-use systems has intensified the frequency and severity of climate-induced disasters, particularly droughts, across sub-Saharan Africa (Escarcha et al., 2018; Maulu et al., 2021; Siankwilimba et al., 2025; Soeder, 2025). These changes disrupt hydrological cycles, reduce pasture availability, increase disease pressure, and undermine livestock productivity and market stability (Thornton et al., 2009; Sivakumar, 2020; Kalaignazhal et al., 2025). Climate projections indicate that drought events in Zambia and the wider region are likely to become more frequent and severe, with disproportionate impacts on smallholder livestock systems that rely heavily on rain-fed grazing and surface water sources (Omokpariola et al., 2025; Mamba et al., 2025).

Zambia's 2023–2024 agricultural season was recorded as the driest in more than four decades, largely attributed to El Niño conditions compounded by long-term anthropogenic climate change (Ghosh et al., 2025). Similar drought episodes during the 2015–2016 and 2018–2019 seasons resulted in widespread crop failures, water shortages, and humanitarian emergencies, highlighting systemic vulnerabilities in agri-food systems (de Boer et al., 2024; Lembani, 2024; Ghosh et al., 2025). Southern Province, particularly Mazabuka District, has been repeatedly affected by erratic rainfall and prolonged dry spells, leading to depleted water sources, reduced pasture regeneration, declining livestock body condition, and increased exposure to disease risks.

While several studies have examined climate change impacts on crop production in Zambia, empirical evidence linking climate-induced droughts to livestock production outcomes, market dynamics, and farmer adaptation strategies remains limited. Understanding these interlinked dimensions is essential for designing climate-smart food system interventions that enhance resilience, protect livelihoods, and stabilise markets. Against this background, the present study aimed to (i) assess the effects of climate-induced drought on livestock production, (ii) examine drought-related impacts on livestock market

dynamics, particularly dairy products, and (iii) identify adaptation and coping strategies employed by livestock farmers in Mazabuka District. By situating livestock production within a food systems and policy-relevant framework, this study contributes evidence to inform climate-smart livestock development strategies aligned with national priorities and global sustainability goals.

2 Methodology

2.1 Study site

The study was conducted in Mazabuka District, located in Zambia's Southern Province (15.856° S, 27.748° E), a region characterised by mixed crop–livestock systems dominated by cattle, goats, and poultry alongside extensive sugarcane production. Zambia is broadly classified into three agro-ecological zones based on long-term rainfall patterns. Agro-ecological Zone I is the driest, receiving less than 800 mm of annual rainfall and accounting for approximately 12% of national precipitation. Zone II receives between 800 and 1,000 mm annually and contributes about 42% of total rainfall, while Zone III is the wettest zone, receiving 1,000–1,500 mm and accounting for roughly 46% of national rainfall (Makondo et al., 2014; Maulu et al., 2024). Mazabuka District falls within Agro-ecological Zone IIb, which is characterised by high interannual rainfall variability and recurrent drought events (Figure 1). Socio-economically, Mazabuka District is predominantly rural, with livelihoods largely dependent on smallholder agriculture, livestock rearing, and employment in the sugar industry. Livestock production plays a central role in household income generation, food security, draft power, and asset accumulation. The district exhibits marked income inequality, with commercial sugarcane estates co-existing alongside resource-constrained smallholder farmers who face limited access to markets, veterinary services, and financial credit. These socio-economic conditions, combined with climate variability, heighten household vulnerability to drought shocks and influence livestock management practices and market participation. Consequently, the district provides an appropriate setting for examining drought impacts on livestock production systems and associated market dynamics. These climatic conditions make the district particularly vulnerable to climate-induced droughts, thereby providing an appropriate setting for examining drought impacts on livestock production systems and associated market dynamics.

2.2 Sampling procedure and rationale

The study targeted small-scale livestock farmers registered with local agricultural authorities in Mazabuka District. From a sampling frame of 126 registered livestock farmers, a sample of 95 respondents was selected. The sample size was determined using the formula proposed by Yamane (1973), assuming a 95% confidence level, a 5% margin of error, and a population proportion of 0.5 to maximise statistical power.

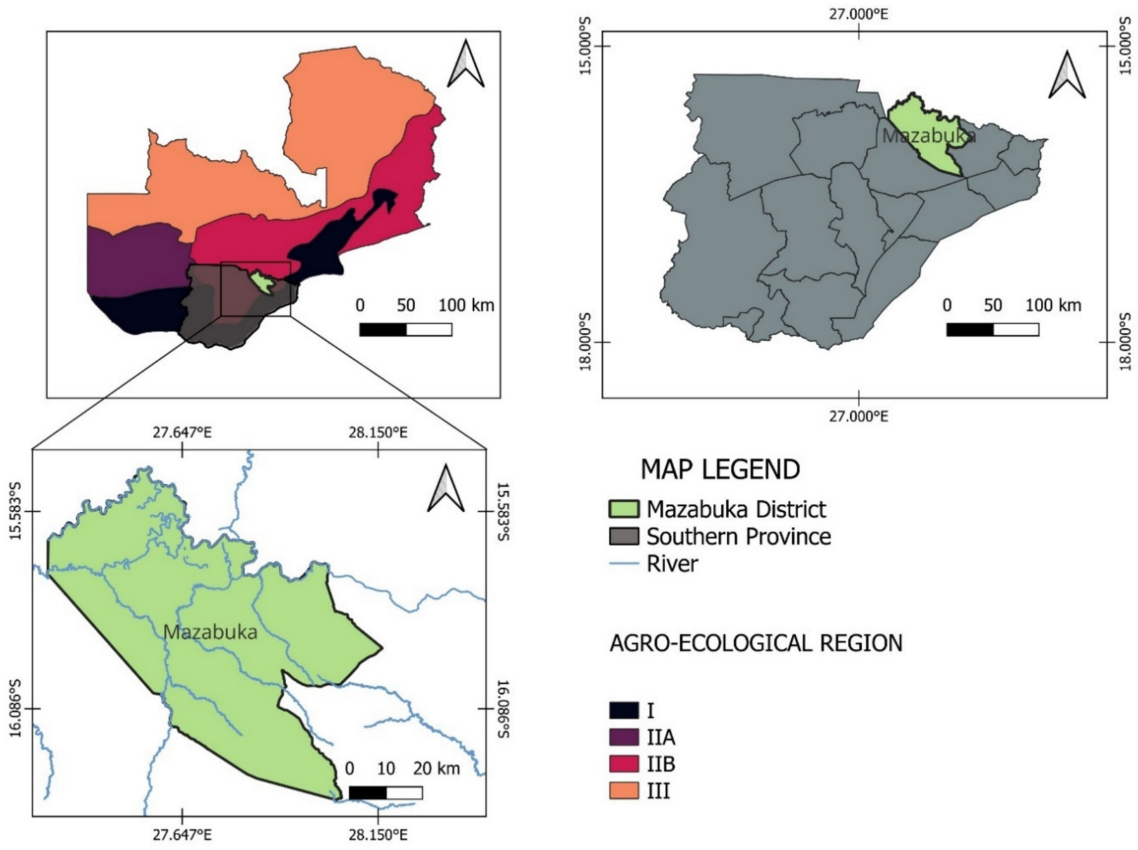

FIGURE 1
Geographic location of Mazabuka District, Southern Province, Zambia.

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

where n is the sample size, N is the population size, and e is the margin of error.

A probability-based sampling approach was employed to ensure representativeness. The first household was randomly selected from the sampling frame, after which systematic sampling was applied by selecting every fourth household until the target sample size was reached. This approach balanced randomness with field practicality and is widely applied in farm-level socio-economic studies where complete household listings are available (Mulwanda et al., 2022).

2.3 Data collection

Primary data were collected between April and June 2025 using a semi-structured questionnaire administered to household heads. The questionnaire captured information on household socio-demographic characteristics, perceived impacts of climate-induced drought on livestock production, effects on livestock market dynamics, and adaptation strategies and support needs. The questionnaire was pretested among a small group of livestock farmers in the study area to ensure clarity, internal consistency, and contextual relevance (Maulu et al., 2024; Hasimuna et al., 2025a, 2025b). Minor adjustments were made to improve question wording and sequencing prior to the main survey. Data collection was conducted through face-to-face interviews by the research team and trained research assistants, with questionnaires administered in English and translated into local languages where necessary. Verbal informed consent was obtained from all participants prior to interviews, consistent with local cultural norms and ethical research practice (Mphande et al., 2023; Mwamba et al., 2025). Data entry and management were facilitated using the Kobo Toolbox platform, which enhanced accuracy and data integrity. This study involved human participants through questionnaire-based interviews with livestock farmers. Prior to data collection, verbal informed consent was obtained from all respondents after explaining the purpose of the study and their right to decline participation, though none did. Participation was voluntary, and no personally identifiable information was collected. The study followed ethical principles applicable to social science and agricultural related research and posed minimal risk to participants (Mulwanda et al., 2022).

2.4 Data analysis

Quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS), version 29 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequencies and percentages, were used to summarise household characteristics, drought impacts, adaptation strategies, and support needs. Associations between demographic characteristics and perceived drought impact severity were examined using appropriate exact tests where contingency table assumptions were not met. Drought impact severity, measured as an ordinal outcome with three ordered categories (minimal, moderate, and severe), was analysed using ordinal logistic regression to identify factors associated with increasing severity of climate-induced drought impacts on livestock production. Predictor variables included livestock disease incidence, mortality, reduced productivity, grazing constraints, and water shortages. Prior to model estimation, predictors were assessed for multicollinearity, and model fit was evaluated using appropriate goodness-of-fit diagnostics. All statistical tests were conducted at a 5% significance level. Interview transcripts were first transcribed and read repeatedly to ensure familiarity with the data. The data were then coded by identifying meaningful units related to the study objectives. Similar codes were grouped into categories and further developed into themes representing key patterns in participants' responses. These themes were interpreted in relation to the research questions and supported with representative quotations.

2.5 Research ethics

Ethical considerations were carefully observed throughout the study to protect the rights, dignity, and welfare of all participants. Prior to data collection, ethical approval was obtained from the relevant institutional authorities. All participants were fully informed about the purpose of the study, the procedures involved, and their right to decline participation or withdraw at any time without any negative consequences. Informed consent was obtained before administering questionnaires and conducting interviews. Confidentiality and anonymity were ensured by not recording participants' names or identifying information and by storing all data securely. The collected data were used strictly for academic purposes, and participants were assured that their responses would be treated with honesty, respect, and confidentiality.

3 Results

3.1 Demographic information of respondents

The demographic information of livestock farmers in Mazabuka District (Table 1) revealed that the majority of farmers in the district were male (68%), while females were 32%. The age distribution revealed that the largest proportion of farmers (42%) was aged between 46–60 years, followed by those aged 31–45 years (35%). Farmers who were above 60 years constituted 13%, while the youngest group (18–30 years) represented 11% of the respondents. In terms of level of education among livestock farmers, secondary education was the most common level of education attained (48%), followed by primary education (31%), tertiary education (15%), and no formal education (6%). Experience in livestock farming was fairly distributed, with 34% having 11–20 years of experience, while farmers with 5–10 years and 11–20 years of experience were both 31%. Only 4% livestock farmers had less than 5 years of farming experience.

3.2 Livestock kept

The type of Livestock kept by livestock farmers in the present study varied (Figure 2). The most commonly kept livestock per farmer were goats (98%), followed by cattle (95%), sheep (56%), and poultry (53%), while pigs were the least kept by only 7% of the livestock farmers.

3.3 Impacts of drought on livestock

Several impacts of climate-induced droughts on livestock in Mazabuka District were recorded among the farmers covered in the study (Figure 3). The majority (96%) of farmers reported that they

10.3389/fsufs.2026.1776530

TABLE 1 Demographic characteristics of respondent livestock farmers in Mazabuka District, Zambia.

Variable	Category	Percentage (%)
Gender	Female	32
	Male	68
Total		100
Age group	31–45 years	35
	Above 60 years	13
	18–30 years	11
	46–60 years	41
Total		100
Level of education	Secondary education	48
	Primary education	31
	Tertiary education	15
	No formal education	6
Total		100
Years of experience in livestock farming	11–20 years	34
	20 years and above	31
	5–10 years	31
	Less than 5 years	4
Total		100

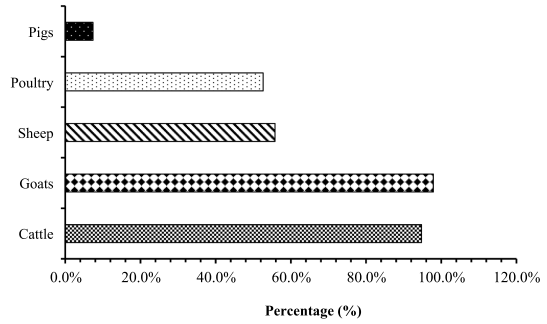

FIGURE 2
The most frequently kept type of livestock among farmers in Mazabuka, District of Zambia.

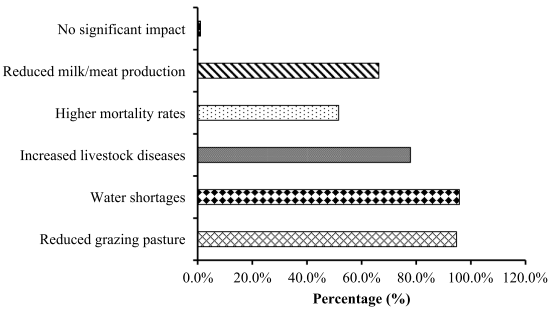

FIGURE 3
The impact of climate-induced drought on livestock production in Mazabuka District of Zambia.

experienced water shortage for livestock consumption. Followed by reduced grazing pasture areas (95%), an increase in incidence of livestock disease cases (78%), high mortality rates (52%), and reduced milk and meat production (66%). Only 1% of the farmers reported not being impacted significantly by the drought conditions.

3.4 Relationship between impact and the severity of climate-induced drought

The relationship between the impact that livestock farmers faced and the severity of climate-related droughts on livestock production being severe was assessed using Ordinal logistic regression analysis (Table 2). The indicated that increased livestock disease incidence, higher mortality rates, and reduced milk or meat production were significantly associated with higher levels of perceived drought impact severity among livestock farmers impacts ($p = 0.981$ and $p = 0.278$, respectively). In contrast, water shortages and reduced grazing availability were not significantly associated with increasing severity levels. The observed large coefficient estimates for some predictors likely reflect sparse-data effects and strong clustering of severe outcomes among affected households; therefore, results are interpreted as associative rather than causal relationships. Increased livestock diseases ($p = 0.001$), higher mortality rates ($p = 0.003$), and reduced milk or meat production ($p = 0.001$) were all significantly associated with droughts, having severe impacts on livestock production.

3.5 Impact of drought leading to dairy price reduction

The Impact of drought on livestock production, which led to a reduction in the price of dairy products in Mazabuka District, are shown in Figure 4. Results indicate that the majority of farmers (96%) perceived that climate-induced drought led to poor body condition of their livestock. Additionally, 35% recorded a reduction in livestock demand from buyers on the market, while 12% of farmers cited an increase in the cost of feed and accessing water.

TABLE 2 Ordinal logistic regression results for factors associated with severity of climate-induced drought impacts on livestock production in Mazabuka District.

Predictor	Coefficient (B)	Standard error	*z*	*p*	-2 Log-Likelihood	Cox and Snell R^2
					57.06	0.54
Reduced grazing pasture	0.12	5.03	0.02	0.981		
Water shortages	1.92	1.77	1.09	0.278		
Increased livestock diseases	5.24	1.49	3.52	0.001		
Higher mortality rates	3.34	1.13	2.97	0.003		
Reduced milk/meat production	4.65	1.19	3.91	0.001		

Coefficient estimates represent associations with increasing levels of drought impact severity (minimal, moderate, severe).

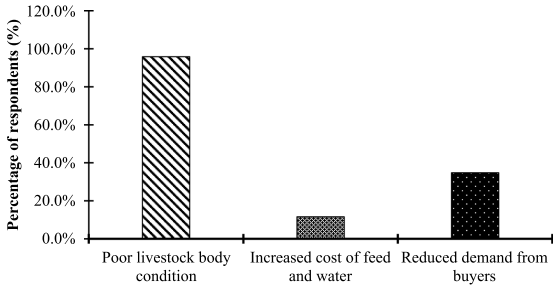

FIGURE 4
The impact of climate-induced droughts on livestock production in Mazabuka District of Zambia.

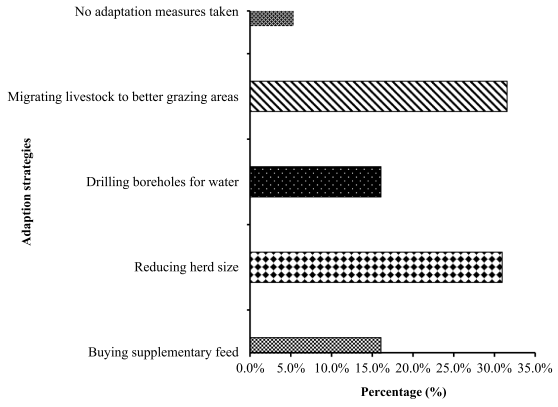

FIGURE 5
The adaptation strategies adopted by livestock farmers during the climate-induced drought periods in Mazabuka District.

3.6 Adaptation strategies

Several adaptation strategies were reportedly adopted by livestock farmers in Mazabuka District (Figure 5). The majority adopted migrating livestock to better grazing areas (32%) or reducing herd size (31%). Some farmers reported buying supplementary feed and drilling boreholes for water (16%) while another 5% reported not taking any adaptation measures to prevent the effects of the droughts. The reduced number of farmers adopting strategies such as buying feed and drilling boreholes was mainly attributed to high costs involved and limited access to financial resources, making them less feasible for most smallholder farmers compared to low-cost options like migration and herd reduction.

3.7 Association of the impact of climate-induced drought and demographics

The impact of climate-induced drought was significantly associated with the age group of livestock farmers in Mazabuka District ($\chi^2 = 18.646$; $p = 0.005$; Table 3). Severe impact was most frequently reported among livestock farmers aged 46–60 years (33.7%) than those aged 31–45 years (29.5%). In contrast, only 6.3% of livestock farmers aged 18–30 years and 11.6% of those above 60 years perceived climate-related drought to have had severe impact. Impact among other age groups was more moderate and was reported to be by 8.4% of livestock farmers aged 46–60 years, 5.3% of those aged 31–45 years, 2.1% of those aged 18–30 years, and 1.1% of those above 60 years. Minimal impact was reported solely among younger livestock farmers aged 18–30 years (2.1%). Due to small expected cell counts in some categories, exact tests were applied to assess the association between age group and perceived drought impact severity.

3.8 Support needed for drought resilience

Livestock farmers in Mazabuka District pleaded for support to increase resilience against climate-induced drought (Table 4). The majority of livestock farmers pleaded to be trained in climate-smart agriculture (77%) or to be provided with Government subsidies to enable them have access to feed and water (76%). Additionally, other forms of needed support cited by livestock farmers included insurance against livestock losses 55%, improved veterinary services (46%), and better market access (43%).

4 Discussion

4.1 Demographic information of respondents

The findings indicate that livestock production in Mazabuka District is predominantly undertaken by male farmers, a pattern consistent with previous studies from Zambia and the wider Southern African region (Machina and Lubungu, 2019; Odubote et al., 2023). This gender imbalance reflects entrenched socio-cultural norms that shape access to productive resources. In many rural settings, men retain greater control over land, livestock assets, and financial capital, enabling sustained engagement in livestock production relative to

TABLE 3 Association between the impact of climate-induced drought and the age group of respondent livestock farmers in Mazabuka District.

Impact	Age group				Total
	31–45 years	Above 60 years	18–30 years	46–60 years	
Minimal impact	0 (0.0%)	0 (0.0%)	2 (2.1%)	0 (0.0%)	2 (2.1%)
Moderate impact	5 (5.3%)	1 (1.1%)	2 (2.1%)	8 (8.4%)	16 (16.8%)
Severe impact	28 (29.5%)	11 (11.6%)	6 (6.3%)	32 (33.7%)	77 (81.1%)
Total	33 (34.7%)	12 (12.6%)	10 (10.5%)	40 (42.1%)	95 (100.0%)

Chi-square tests	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	18.646	6	0.005
Likelihood ratio	10.802	6	0.095
N of valid cases	95		

TABLE 4 Support needed by livestock farmers for climate-induced drought resilience in Mazabuka District.

Support needed	Percentage (%)
Training on climate-smart farming	77
Government subsidies for feed and water	76
Insurance for livestock losses	55
Improved veterinary services	46
Better market access	43

women (Munawar et al., 2013; Lubungu and Birner, 2021; Njiru et al., 2026). Such structural disparities have implications for equitable participation in climate adaptation initiatives and access to institutional support.

The age distribution of respondents was skewed toward the 46–60-year category, supporting earlier evidence that middle-aged farmers form the backbone of livestock production systems in Zambia (Hichaambwa and Jayne, 2014; Kapende, 2024). This cohort typically combines accumulated experience, financial capacity, and social networks that are critical for managing livestock under increasing climatic variability. However, the limited involvement of younger household members in livestock decision-making raises concerns about generational renewal and long-term sector sustainability, particularly under escalating climate stress.

Educational attainment among respondents was largely concentrated at the secondary school level, contrasting with findings by Wezi et al. (2023), who reported primary education as the dominant level among livestock farmers in other regions of Zambia. Limited progression to tertiary education may be linked to early involvement of youth in herding and farm labour, often during school-going years, which constrains long-term educational advancement (Mwaura et al., 2025). This has direct implications for farmers' capacity to interpret climate information, adopt climate-smart technologies, and engage effectively with formal extension and insurance schemes. Most respondents reported 10–20 years of livestock farming experience, suggesting that entry into the sector often occurs after households accumulate sufficient capital and social standing. While this reflects stability within the farming population, it also underscores barriers to entry for younger or resource-poor households. Goats, cattle, poultry, and sheep were the most commonly kept species, consistent with previous studies in Southern Province (Wezi et al., 2023; Bwalya et al., 2024). These species are favoured for their adaptability to drought-prone environments, tolerance to feed scarcity, and cultural and economic significance. In this context, resilience is understood as the capacity of livestock species to withstand climatic stressors and disease pressures while maintaining productive functions, a critical attribute under recurrent climate-induced droughts.

4.2 Impacts of climate-induced drought on livestock production

The study identified water scarcity and reduced grazing availability as the primary drought-related constraints affecting livestock production in Mazabuka District. This finding aligns with evidence from across sub-Saharan Africa indicating that prolonged droughts severely limit both the availability and quality of drinking water and forage resources for livestock (Tulu et al., 2024; Sintayehu et al., 2025; Ngongolo and Gayo, 2025). Declining pasture productivity and degradation of rangelands during extended dry periods reduce dietary intake and compromise animal hydration, with cascading effects on health and productivity (Giridhar and Samireddypalle, 2015; Ludgate et al., 2025).

Beyond these immediate constraints, increases in livestock diseases, mortality rates, and reduced productivity emerged as the strongest predictors of perceived drought severity. Similar patterns have been reported by Ngongolo and Gayo (2025), highlighting that while water and feed shortages are widely recognised, it is the downstream biological and economic consequences that farmers experience as most severe. Compromised nutrition weakens immune responses, increases susceptibility to disease, and elevates mortality risk,

ultimately translating into reduced marketable output and income losses (Bett et al., 2017; Dzavo et al., 2019). These findings underscore the interconnected nature of climatic, biological, and economic stressors within livestock-based food systems.

4.3 Adaptation strategies among livestock farmers

In response to drought conditions, most livestock farmers reported reducing herd sizes or migrating animals to areas with better grazing. These strategies are consistent with adaptation patterns observed in other drought-prone regions of Southern and Eastern Africa (Abazinab et al., 2022; Dzavo et al., 2019). Herd reduction lowers pressure on limited feed and water resources and may reduce disease transmission, while migration enables access to higher-quality forage, supporting animal body condition and market value (Gardner et al., 2002; Næss and Bårdsen, 2013; Kupczyński et al., 2024). However, these strategies are not without trade-offs, as herd reduction constrains overall production potential and migration can disrupt breeding cycles and limit access to veterinary services. The adoption of more anticipatory measures, such as feed conservation, fodder banks, and livestock insurance, remained limited. Barriers include high upfront costs, limited access to credit, insecure land tenure, and inadequate technical knowledge for forage production and storage (Abazinab et al., 2022; Dzavo et al., 2019). Although index-based livestock insurance schemes have been piloted in Zambia, uptake remains low due to affordability concerns, limited awareness, and mistrust of payout mechanisms. Consequently, farmers favour immediate, low-cost coping strategies despite their limited long-term sustainability under recurrent drought conditions.

4.4 Demographic influences and farmer priorities for climate adaptation

The analysis further indicated a significant association between drought impacts and farmer age, with middle-aged farmers experiencing heightened vulnerability. This group often manages larger herds and has greater financial exposure, making drought-related losses particularly consequential. Their production systems may also be less flexible than those of smaller-scale operators, constraining rapid adjustment during extreme climatic events. However, farmers overwhelmingly expressed the need for training in climate-smart agriculture, government support for feed and water, and access to livestock insurance. This reflects recognition that knowledge, inputs, and risk-transfer mechanisms are essential for building resilience in livestock systems, consistent with findings from Ethiopia and Eswatini where extension services and insurance improved adaptive capacity (Kalimba and Culas, 2019; Singh and Hlophe, 2017). The expressed willingness to engage with insurance schemes suggests an opportunity for policy interventions that address affordability, trust, and institutional design. While this study identifies farmer-reported priorities for strengthening drought resilience, the findings should be interpreted in light of the study's cross-sectional and perception-based design. The analysis does not provide quantitative estimates of the effectiveness, costs, or long-term sustainability of proposed adaptation measures. As such, the policy implications presented here should be viewed as indicative and exploratory, highlighting areas for targeted intervention and future empirical evaluation rather than definitive policy prescriptions.

4.5 Limitations and future research directions

While this study provides valuable insights into the effects of climate-induced drought on livestock production and market dynamics in Mazabuka District, several limitations warrant consideration. First, the reliance on cross-sectional, self-reported data captures perceptions at a single point in time and may be influenced by recall bias or recent climatic events. Longitudinal studies integrating household surveys with climatic, hydrological, and production data would better capture temporal variability and recovery trajectories.

Second, the study focused primarily on livestock producers and did not incorporate perspectives from traders, processors, or other value-chain actors. This limits a comprehensive understanding of how drought shocks propagate through livestock markets. Future research adopting a value-chain lens would enhance understanding of price formation, supply stability, and income distribution under climatic stress.

Third, although adaptation strategies were identified, their effectiveness, costs, and long-term sustainability were not quantitatively assessed. Experimental or quasi-experimental studies evaluating climate-smart livestock practices, insurance mechanisms, and targeted feed and water subsidies across varying drought intensities would strengthen the evidence base for scaling up interventions. Addressing these gaps will support the design of integrated, policy-relevant strategies that enhance drought resilience, safeguard livestock-dependent livelihoods, and strengthen sustainable food systems in Zambia and comparable drought-prone regions.

5 Conclusion

This study demonstrates that climate-induced droughts pose systemic constraints to livestock-based food systems in Mazabuka District by disrupting water availability, grazing resources, animal health, and market functioning, with disease incidence, mortality, and declining body condition emerging as the most consequential drivers of production losses and price instability. While livestock production is dominated by experienced, middle-aged male farmers, their relatively larger herd investments heighten vulnerability to drought-related shocks. In response, farmers primarily adopt short-term coping strategies such as herd reduction and livestock migration, reflecting limited access to climate-resilient technologies and financial risk-transfer mechanisms.

6 Recommendations

Future research should prioritise longitudinal and experimental approaches to quantitatively assess the effectiveness, economic feasibility, and sustainability of climate-smart livestock adaptation strategies under varying drought intensities such as strengthening livestock system resilience therefore requires integrated, policy-supported

interventions that expand climate-smart livestock training, subsidise drought-responsive feed and water inputs, scale up accessible livestock insurance schemes, and reinforce veterinary and market linkages. Advancing these measures is essential for safeguarding rural livelihoods, stabilising livestock markets, and supporting inclusive, climate-resilient food systems in Zambia, while contributing directly to progress on SDGs 1 (No Poverty), 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 13 (Climate Action).

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 participants provided verbal informed consent to participate in this study.

Author contributions

SS: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Writing – original draft. CB: Data curation, Formal analysis, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. LT: Validation, Writing – original draft, Writing – review & editing. FM: Formal analysis, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MM: Data curation, Funding acquisition, Validation, Visualization, Writing – original draft, Writing – review & editing. MC: Data curation, Funding acquisition, Validation, Visualization, Writing – original draft, Writing – review & editing. EN: Validation, Writing – original draft, Writing – review & editing. CM: Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. HM: Resources, Validation, Writing – original draft, Writing – review & editing. BT: Validation, Writing – original draft, Writing – review & editing. PS: Validation, Visualization, Writing – original draft, Writing – review & editing. JM: Validation, Writing – original draft, Writing – review & editing. ES: Conceptualization, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. SM: Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. OH: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Acknowledgments

The authors thank the participating farmers for their cooperation. We are grateful to the Ministry of Fisheries and Livestock, Mazabuka District, for their support. We also acknowledge the reviewers for their valuable feedback.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Abazinab, H., Duguma, B., and Muleta, E. (2022). Livestock farmers' perception of climate change and adaptation strategies in the Gera district, Jimma zone, Oromia regional state, Southwest Ethiopia. *Heliyon* 8. doi: 10.1016/j.heliyon.2022.e12200

Anuta, A., Wang, X., and Kinay, P. (2025). The impacts of climate change on livestock: an interdisciplinary, scoping review of health, production, and adaptation strategies. *Climate Smart Agriculture* 2:100082. doi: 10.1016/j.csag.2025.100082

Bett, B., Kiunga, P., Gachohi, J., Sindato, C., Mbotha, D., Robinson, T., et al. (2017). Effects of climate change on the occurrence and distribution of livestock diseases. *Prev. Vet. Med.* 137, 119–129. doi: 10.1016/j.prevetmed.2016.11.019

Bogale, G. A., and Erena, Z. B. (2022). Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-ecological zones of Ethiopia. *J. Appl. Anim. Res.* 50, 471–489. doi: 10.1080/09712119.2022.2103563

Bwalya, B., Chiluba, B. C., and Mwanza, K. (2024). Livestock ownership among smallholder farming households in eastern Zambia: a gendered pathway for enhancing climate resilience? *Front. Sustainable Food Systems* 8:1487798. doi: 10.3389/fsufs.2024.1487798

de Boer, T., Mutenje, M., Nohayi, N., Kasoma-Pele, W., Arretche, C., and Jaime, C. (2024). Food and water security, early warning, early action and response in Western Province, Zambia: Retrospective analysis of the 2018–2020 humanitarian food and water crisis in Western Province, Zambia. International Water Management Institute (IWMI). (73 pp.). CGIAR Initiative on Fragility, Conflict, and Migration. Available online at: https://hdl.handle.net/10568/173317

Defe, R., Matsa, M., and Shabani, T. (2024). Resilience-building interventions to manage climate induced livestock poverty and deaths in southern Zimbabwe. *Nature-Based Solutions* 6:100151. doi: 10.1016/j.nbsj.2024.100151

Dzavo, T., Zindove, T. J., Dhliwayo, M., and Chimonyo, M. (2019). Effects of drought on cattle production in sub-tropical environments. *Trop. Anim. Health Prod.* 51, 669–675. doi: 10.1007/s11250-018-1741-1

Erdaw, M. M. (2023). Contribution, prospects and trends of livestock production in sub-Saharan Africa: a review. *Int. J. Agric. Sustain.* 21:2247776. doi: 10.1080/14735903.2023.2247776

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

FAO (2024). *Meat market review: Emerging trends and outlook in 2024*. Rome: Food and Agriculture Organization.

Gardner, I. A., Willeberg, P., and Mousing, J. (2002). Empirical and theoretical evidence for herd size as a risk factor for swine diseases. *Anim. Health Res. Rev.* 3, 43–55. doi: 10.1079/AHRR200239

Ghosh, S., Kour, S., Taron, A., Kaywala, K., and Rajakaruna, P. (2025). Assessing El Niño-induced drought in Zambia and its effects using earth observation data. *Nat. Hazards* 121, 4505–4530. doi: 10.1007/s11069-024-06976-5

Giridhar, K., and Samireddypalle, A. (2015). "Impact of climate change on forage availability for livestock" in *Climate change impact on livestock: Adaptation and mitigation* (New Delhi: Springer India), 97–112.

Grote, U. (2014). Can we improve global food security? A socio-economic and political perspective. *Food Secur.* 6, 187–200. doi: 10.1007/s12571-013-0321-5

Hasimuna, O. J., Mphande, J., Lengwe, M., Siavwapa, S., Bbole, I., Bwalya, H., et al. (2025b). An assessment of government-funded small-scale cage fish farming in Siavonga District, Zambia: performance, challenges and opportunities. *Front. Sustain. Food Syst.* 9:1629414. doi: 10.3389/fsufs.2025.1629414

Hasimuna, O. J., Mphande, J., Maulu, S., Chibesa, M., Siankwilimba, E., Mumbula, I., et al. (2025a). The status, challenges, and potential opportunities of fish seed production in Zambia. *Aquac. Int.* 33, 1–19. doi: 10.1007/s10499-025-02073-x

Hichaambwa, M., and Jayne, T. S. (2014). Can increasing smallholder farm size broadly reduce rural poverty in Zambia? *Department of Agricultural, Food, and Resource Economics*. doi: 10.22004/ag.econ.171876

Jerie, S., Shabani, T., Manyakaidze, P., and Shabani, T. (2025). Towards boosting adoption of circular integrated solid waste management to achieve sustainable development goal 13 (climate action) in southern Africa. *Circ. Econ. Sustain.* 5, 6593–6606. doi: 10.1007/s43615-025-00655-8

Kalaignazhal, G., Silpa, M. V., Shashank, C. G., Devaraj, C., Rebez, E. B., Rajkumar, R. S., et al. (2025). "Impact of climate change on livestock production and mitigation strategies in coastal region" in *Advances in Agri-food systems: Volume I* (Singapore: Springer Nature Singapore), 99–119.

Kalimba, U. B., and Culas, R. J. (2019). Climate change and farmers' adaptation: Extension and capacity building of smallholder farmers in sub-Saharan Africa. Global climate change and environmental policy: Agriculture perspectives, eds. V. Venkatramanan, S. Shah and R. Prasadeds (Springer). 379–410. doi: 10.1007/978-981-13-9570-3_13

Kapende, C. (2024). *An examination of the impediments to profitability of smallholder dairy farmers in Palabana dairy cooperative* Doctoral dissertation (Master's thesis, The University of Zambia). Lusaka: The University of Zambia. Available online at: https://dspace.unza.zm/handle/123456789/8915

Kupczyński, R., Bednarski, M., Sokołowski, M., Kowalkowski, W., and Pacyga, K. (2024). Comparison of antibiotic use and the frequency of diseases depending on the size of herd and the type of cattle breeding. *Animals* 14:1889. doi: 10.3390/ani14131889

Kuteya, A. N., Kalinda, T. H., and Kuntashula, E. (2025). Impact of Zambia's farmer input support program E-voucher system on smallholder farmers' food security. *Agrekon*, 64, 1–17. doi: 10.1080/03031853.2025.2515877

Lembani, D. K. (2024). A critical analysis of food security situation amidst epoch of drought & flooding in Zambia. *Int. J. Agric. Earth Sci.* 10, 150–175. doi: 10.56201/ijaes.v10.no5.2024.pg150.175

Lubungu, M., and Birner, R. (2021). Gender relations in smallholder cattle production in Zambia. *World Development Perspectives* 22:100309. doi: 10.1016/j.wdp.2021.100309

Ludgate, N., Umutoni, C., Vyas, D., Serra, R., Adeoti, T. M., Bonna, A. S., et al. (2025). Transforming livestock systems with better feeds: a triple win for food and nutrition security, climate resilience, and women and youth empowerment in low-and lower-middle-income countries. *Annual Review Animal Biosciences* 14, 181–206. doi: 10.1146/annurev-animal-111523-102141

Machina, H., and Lubungu, M. (2019). Understanding intra-household gender disparities of smallholder livestock production in Zambia. *J. Gender Agricul. Food Secur.* 4, 11–24. doi: 10.22004/ag.econ.301203

Makondo, C. C., Chola, K., and Moonga, B. (2014). Climate change adaptation and vulnerability: a case of rain dependent small-holder farmers in selected districts in Zambia. *Am. J. Clim. Chang.* 3, 388–403. doi: 10.4236/ajcc.2014.34034

Mamba, S. F., Ncube, M., Ndlovu, S., Ndlovu, N., Moyo, F., Dube, Z. L., et al. (2025). Climate-induced displacement and migration – implications on poverty and household food security in southern Africa. *J. Asian Afr. Stud.*:00219096251319226. doi: 10.1177/00219096251319226

Maulu, S., Hasimuna, O. J., Chibesa, M., Bbole, I., Mphande, J., Mwanachingwala, M., et al. (2024). Perceived effects of climate change on aquaculture production in Zambia: status, vulnerability factors, and adaptation strategies. *Front. Sustain. Food Syst.* 8:1348984. doi: 10.3389/fsufs.2024.1348984

Maulu, S., Hasimuna, O. J., Haambiya, L. H., Monde, C., Musuka, C. G., Makorwa, T. H., et al. (2021). Climate change effects on aquaculture production: sustainability implications, mitigation, and adaptations. *Front. Sustain. Food Syst.* 5:609097. doi: 10.3389/fsufs.2021.609097

Michalk, D. L., Kemp, D. R., Badgery, W. B., Wu, J., Zhang, Y., and Thomassin, P. J. (2019). Sustainability and future food security—a global perspective for livestock production. *Land Degrad. Dev.* 30, 561–573. doi: 10.1002/ldr.3217

Mozumdar, L. (2012). Agricultural productivity and food security in the developing world. *Bangl. J. Agric. Econ.* 35, 53–69. doi: 10.22004/ag.econ.196764

Mphande, J., Hasimuna, O. J., Kikamba, E., Maulu, S., Nawanzi, K., Phiri, D., et al. (2023). Application of anaesthetics in fish hatcheries to promote broodstock and fish seed welfare in Zambia. *Cogent Food Agric.* 9:2211845. doi: 10.1080/23311932.2023.2211845

Muchhadiya, R. M., Gohil, B., Yadahalli, V., Hm, A. U. R., Siddiqua, A., Khayum, A., et al. (2024). Feeding the world: agronomic innovations to meet the challenges of a growing population. *Int. J. Res. Agron.* 7, 790–802. doi: 10.33545/2618060X.2024.v7.i7j.1133

Mulwanda, C., Nyirenda, V. R., and Namukonde, N. (2022). Perceived social-ecological benefits of insect pollinators in Mufulira mining district of Zambia. *Int. J. Trop. Insect Sci.* 42, 3245–3252. doi: 10.1007/s42690-022-00759-w.

Munawar, M., Safdar, U., Luqman, M., Butt, T. M., Hassan, M. Z. Y., and Khalid, M. F. (2013). Factors inhibiting the participation of rural women in livestock production activities. *J. Agricult. Res.* 51, 213–220.

Mwamba, F. K., Taimolo, L., Chinyanta, S., Mphande, J., Siankwilimba, E., Sianangama, P. C., et al. (2025). Exploring tomato farmers' knowledge and adaptation practices to climate change: insights from Chinsali district, Zambia. *Cogent Food Agric.* 11:2547315. doi: 10.1080/23311932.2025.2547315

Mwaura, H. K., Wakhu, S., and Kanyingi, B. (2025). The effects of cattle rustling on children's educational outcomes in sub-Saharan Africa. *Glob. Change Peace Secur.* 36, 207–225. doi: 10.1080/14781158.2025.2542737

Næss, M. W., and Bårdsen, B. J. (2013). Why herd size matters–mitigating the effects of livestock crashes. *PLoS One* 8:e70161. doi: 10.1371/journal.pone.0070161

Ngongolo, K., and Gayo, L. (2025). Climate change impacts and mitigation strategies in sub-Saharan Africa's livestock production sector. A brief review. *Pastoralism Res. Policy Pract.* 15:14225. doi: 10.3389/past.2025.14225

Njiru, N., Omia, D., Galiè, A., Loriba, A., and Cislaghi, B. (2026). Gender norms and implications on women's empowerment within the livestock and vaccines delivery systems: a multisite qualitative study in the upper east region of northern Ghana. *Heliyon* 12:10.1016/j.heliyon.2026.e44514. doi: 10.1016/j.heliyon.2026.e44514

Odubote, I. K., Musimuko, E., Rensing, S., Schmitt, F., and Kapotwe, B. (2023). Genetic survey in smallholder dairy production system of southern province of Zambia. *J. Anim. Breed. Genet.* 140, 235–252. doi: 10.1111/jbg.12749

Omokpariola, D. O., Agbanu-Kumordzi, C., Samuel, T., Kiswii, L., Moses, G. S., and Adelegan, A. M. (2025). Climate change, crop yield, and food security in sub-Saharan Africa. *Discov. Sustain.* 6:678. doi: 10.1007/s43621-025-01580-4

Phiri, J., Malec, K., Majune, S. K., Appiah-Kubi, S. N. K., Gebeltová, Z., Maitah, M., et al. (2020). Agriculture as a determinant of Zambian economic sustainability. *Sustainability* 12:4559. doi: 10.3390/su12114559

Prasad, N. (2025). "Energy efficiency in the livestock sector" in *Energy efficient Technologies for Food Safety, quality, and security* (IGI Global Scientific Publishing), 87–98.

Siankwilimba, E., Hiddlestone-Mumford, J., Hoque, M. E., Hang'ombe, B. M., Mumba, C., Hasimuna, O. J., et al. (2025). Effects of systemic challenges on agricultural development systems: a systematic review of perspectives. *Cogent Food Agriculture* 11:2480266. doi: 10.1080/23311932.2025.2480266

Sibhatu, K. T., Arslan, A., and Zucchini, E. (2022). The effect of agricultural programs on dietary diversity and food security: insights from the smallholder productivity promotion program in Zambia. *Food Policy* 113:102268. doi: 10.1016/j.foodpol.2022.102268

Singh, A. S., and Hlophe, N. M. (2017). Factors affecting adoption of livestock insurance: a case study of livestock farmers in Manzini region, Swaziland. *Research J. Agricul. Forest. Sci.* 2320:6063.

Sintayehu, D. W., Alemayehu, S., Terefe, T., Tegegne, G., Engdaw, M. M., Gebre, L., et al. (2025). Effects of drought on livestock production, market dynamics, and pastoralists' adaptation strategies in semi-arid Ethiopia. *Climate* 13:65. doi: 10.3390/cli13040065

Sivakumar, M. V. (2020). Climate extremes and impacts on agriculture. *Agroclimatology* 60, 621–647. doi: 10.2134/agronmonogr60.2016.0003

Soeder, D. J. (2025). "Greenhouse gas and climate change" in *Energy futures: The story of fossil fuel, greenhouse gas, and climate change* (Cham: Springer Nature Switzerland), 97–141.

Thornton, P. K., van de Steeg, J., Notenbaert, A., and Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. *Agric. Syst.* 101, 113–127. doi: 10.1016/j.agsy.2009.05.002

Thornton, P.K., Wollenberg, E.K., and Cramer, L. (2024). Livestock and climate change: Outlook for a more sustainable and equitable future. *International Livestock Research Institute (ILRI)*. Available online at: https://hdl.handle.net/10568/172688

Tofu, D. A. (2024). Evaluating the impacts of climate-induced East Africa's recent disastrous drought on the pastoral livelihoods. *Sci. Afr.* 24:e02219. doi: 10.1016/j.sciaf.2024.e02219

Tulu, D., Hundessa, F., Gadissa, S., and Temesgen, T. (2024). Review on the influence of water quality on livestock production in the era of climate change: perspectives from dryland regions. *Cogent Food Agriculture* 10:2306726. doi: 10.1080/23311932.2024.2306726

Volk, J., and Walubita, K. M. (2024). The livestock sector in Zambia. The Oxford handbook of the Zambian Economy, Oxford University Press. 384. doi: 10.1093/oxfordhb/9780192864222.013.20

Wattiaux, M. A. (2023). Sustainability of dairy systems through the lenses of the sustainable development goals. *Front. Anim. Sci.* 4:1135381. doi: 10.3389/fanim.2023.1135381

Wezi, K., Mataa, L., Lubungu, M., Chongwe, A., Simwanza, C., Chiluba, C., et al. (2023). A comprehensive study on the livestock sub-sector analysis and its role in fostering sustainable development in Zambia: insights from the 2022 livestock survey report. *J Research Applied Sciences Biotechnology* 2, 78–82. doi: 10.55544/jrasb.2.5.12

Yamane, T. (1973). Statistics: An introductory analysis. 3rd Edition, Harper and Row, New York.