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Climate variability and the pastoralist's dilemma: socio-economic impacts on livestock systems in East Africa

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Climate variability poses a significant threat to livestock production and livelihoods in Tanzania, Kenya, and Uganda. This paper uses a cross-sectional study and systematic literature review to investigate the socio-economic effects of various climate stressors, including rainfall variability, increasing temperatures, and frequent drought events, on livestock production in these countries from 2021 through to 2025. The results suggest that high temperature-humidity indices (THIs), coupled with fluctuating rainfall patterns, impact animal health. This leads to reduced milk production, low fertility rates, poor physical condition, and increased mortality due to dehydration and energy deficiency. These biophysical effects result in economic losses, malnutrition, loss of resources and increased conflict among pastoral communities, thus exacerbating the 'pastoralist's dilemma'. Although pastoral communities employ adaptive strategies such as mobility, herd diversity, and livelihood diversification, these measures are increasingly challenged by the limited availability of resources. It is ultimately argued that indigenous knowledge alone is insufficient for the long-term sustainability of adaptation efforts, and that there is a need to develop climate-smart pastoralism. This would involve adopting indigenous practices alongside modern innovations such as early warning systems, satellite technology for vegetation monitoring, index-based livestock insurance and efficient water supply systems.

KEYWORDS
adaptation strategies, climate change, East Africa, livestock production, pastoralism

Introduction

Climate variation and climate change are major concerns that continue to shape pastoral systems in East African countries such as Tanzania, Kenya and Uganda, where people rely heavily on climate-sensitive resources for their livelihoods (Hassan et al., 2026; Ndesanjo et al., 2023). ASALs dominate East Africa's geography and pastoralism remains the primary livelihood system, providing an important source of food security, income generation and social cohesion (Mayanja et al., 2022; Scoones, 2023). However, the increased incidence of climatic shocks, including unreliable precipitation, rising temperatures, recurring droughts and water shortages, is making it increasingly difficult for pastoralists to maintain productive activities (Moti and Liwenga, 2025; Kirui et al., 2022). Researchers acknowledge that variations in rainfall are one of the key climatic factors impacting pastoral ecosystems. Unpredictable rainfall affects the growth and regeneration cycles of pastures, resulting in

lower quantities of pasture plants and ecosystem deterioration (Moti and Liwenga, 2025; Ndesanjo et al., 2023). Poor food availability in turn causes malnutrition among cattle and other animals, negatively influencing their health, productivity, growth, reproductive capabilities and other essential characteristics (Kirui et al., 2022; Bostedt et al., 2023). According to various studies, increasing rainfall variability makes ensuring the sustainability of rangelands challenging (Kotikot et al., 2024; Bostedt et al., 2023).

Apart from variations in rainfall, higher temperatures pose serious challenges to the welfare and performance of livestock. High temperatures can cause heat stress in livestock, affecting physiological processes such as metabolism, feeding and reproduction (Sejian et al., 2025; Campos et al., 2022). Studies have demonstrated that heat stress reduces milk production, reproductive capacity, and weight gain, while simultaneously increasing susceptibility to disease and parasitism (Campos et al., 2022; Moti and Liwenga, 2025). In East Africa, THI values have risen above the levels required for optimal livestock productivity, causing physiological stress and reducing performance (Moti and Liwenga, 2025). Drought is another climate hazard whose occurrence in East Africa appears to be increasing over time. Drought leads to water scarcity and a shortage of pasture, causing livestock deaths and economic losses (Kirui et al., 2022; Waiswa and Günlü, 2022). Pastoralists may have to travel long distances to find water and grazing land during droughts, which increases their energy expenditure and reduces the chances of their livestock surviving (Hassan et al., 2026; Leal Filho et al., 2023). Droughts affect herd recovery, disrupt production systems and increase vulnerability (Mayanja et al., 2022).

In addition to these biophysical effects, variations in climate have several socio-economic consequences in pastoral areas. Low productivity in the livestock sector leads to low income for pastoralists from the sale of livestock and reduced milk production. This limits their economic options and makes them more vulnerable (Zane and Pica-Ciamarra, 2021; Kirui et al., 2022). Secondly, low production levels lead to food shortages within the community as milk is an essential part of their diet (Moti and Liwenga, 2025; Mayanja et al., 2022). Food crises caused by climate change have also necessitated reliance on food aid and assistance from others among pastoral communities (Moti and Liwenga, 2025; Hassan et al., 2026). Climate variability is another factor that exacerbates social and institutional problems. Disputes over limited supplies of water and grazing land have been found to cause instability in pastoralist societies (Konaka, 2021; Hassan et al., 2026). Furthermore, the resilience of pastoralist societies is never uniform as it is affected by socioeconomic differences relating to issues such as gender, access to resources and institutions (Ash et al., 2025; Bostedt et al., 2023). Pastoral societies have implemented various adaptation methods to enhance their resilience to the above challenges. These methods include livestock mobility and diversification, such as adopting breeds of livestock that can tolerate drought conditions, such as goats and camels. Other methods include diversifying livelihoods from pastoralism to other forms (Bostedt et al., 2023; Kirui et al., 2022). Furthermore, combining indigenous knowledge with technology, such as climate early warning systems, has had a positive influence on decision-making amid climatic uncertainty (Hassan et al., 2026; Rotich et al., 2023). However, despite the implementation of these measures, their effectiveness has been inconsistent due to various challenges (Ash et al., 2025; Mayanja et al., 2022).

Research gap and statement of the problem

However, despite the increase in studies in this area, little work has been done to integrate biophysical and socio-economic dimensions when analysing the impact of climate change on livestock productivity and pastoral livelihoods (Moti and Liwenga, 2025; Kirui et al., 2022). Separating the two aspects makes it difficult to establish an integrated perspective on the interactions between climatic stress and its influence on livestock production and socioeconomic conditions among pastoral communities. Furthermore, the integration of the socio-biological aspect—specifically, the effects of environmental stress on livestock behaviour and its impact on productivity—has received less attention in current studies. Meanwhile, livestock mobility, diversity and early warning systems have been extensively analysed in various contexts in terms of their effectiveness in increasing adaptive capacity and mitigating climate change (Bostedt et al., 2023; Hassan et al., 2026; Muricho et al., 2018). However, the influence of social differences based on gender, access to resources and institutional support has yet to be adequately addressed (Ash et al., 2025).

Research objectives

The primary objective of this research is to investigate the impact of climate variability on livestock production and pastoral livelihoods in East Africa. More specifically, the study will examine the impact of climate-related stresses, such as rainfall variability, rising temperatures, droughts, and water scarcity, on livestock performance, including body condition, fertility, milk production, and mortality. The research will also investigate the biophysical consequences of climate impacts relating to pasture access, grazing, water scarcity and energy balance. Furthermore, the study will examine the economic consequences of lower livestock productivity, including income loss, food insecurity, asset sustainability, market participation, and poverty cycles. The study will also identify and classify social consequences such as conflicts and migration arising from scarce resources. Other objectives include identifying and classifying the various adaptation strategies used by pastoralists, and assessing the efficacy of these strategies and the constraints to them.

Conceptual framework/institutional context

The assessment of climate adaptation capacity in the region of interest uses a socio-ecological systems approach, associating environmental challenges with the national institutional arrangements designed to respond to them. Despite having similar semi-arid ecologies, pastoral populations in Tanzania, Kenya and Uganda face different political environments, resulting in varying levels of resilience to the adverse effects of climate change. Kenya has adopted devolution and sophisticated ASAL policies to support regional drought resilience and index-based livestock insurance. Conversely, Uganda's political structure emphasises the sedentarisation and modernisation of customary

systems, such as those in the Karamoja sub-region, intending to transform them into commercial agropastoral production systems. Tanzania has a decentralised policy strategy for climate change, whereby adaptation measures in districts such as Hai and Manyara are supported by agricultural development plans. This socio-ecological systems analysis examines how unique institutional structures can either enhance or hinder adaptation efforts in the face of similar climatic changes, such as increased temperature-humidity indices (THI) and pasture shortages.

Target population and production systems

Within the study area, the target population has adopted different livestock production practices according to their respective micro-ecological environments, indicating a well-defined continuum of climatic adaptations within the East African Cattle Corridor. In Tanzania, however, production dynamics differ significantly from one district to another. In the mountainous Hai District of Tanzania's northern plains, where crops coexist at high altitudes, the predominant production system is dairy-intensive agro-pastoralism due to demand and proximity to mountain resources (Swai et al., 2014). In contrast, the semi-arid Manyara district is still dominated by the extensive pastoral practices of the Maasai (Galaty, 1982; Homewood et al., 2009). However, internationally, there are some changes happening with respect to traditional boundaries. For example, in Uganda's Karamoja subregion, the traditional distinction between settled agriculture (ere) and mobile cattle keeping (awi) is gradually merging into mixed agro-pastoral systems (Rugadya, 2006).

Materials and methods

Study design

A comparative, cross-sectional scoping review design was used to explore the socio-economic effects of climate variability on livestock productivity in Tanzania, Kenya and Uganda through the pastoralist system. This design incorporated qualitative and quantitative research evidence obtained from peer-reviewed articles and institutional documents published between 2021 and 2025. The search strategy involved using major scientific databases and grey literature to collect data, while the PRISMA-ScR criteria were used to select the articles. The study design incorporated a combination of narrative synthesis and comparative analysis to analyse the relationship between climate stress factors, such as rainfall variability, drought and rising temperatures, and the productivity levels of milk yield, fertility and livestock mortality. Furthermore, the socio-economic consequences of factors such as income changes, food insecurity, asset sustainability and conflict were examined. The comparative analysis facilitated by the study design will identify similarities and differences among the cases studied. This will provide a comprehensive understanding of the system and its resilience strategies.

Keywords and search strategy

This study employed a scoping review method. This was designed to provide an overview of existing studies on the effects of climate change, adaptation challenges and nature-based approaches in sub-Saharan Africa. A thorough search was conducted across various electronic databases, including Scopus, Web of Science, ScienceDirect, Google Scholar. To enhance clarity and replicability, a specific search string comprising certain keywords and Boolean operators was created for each database. These search strings are presented below: ("Climate variability" or "climate change") and ("livestock productivity" or "pastoral system" or "livestock production") and ("East Africa" or "Tanzania" or "Kenya" or "Uganda").

("Rainfall variability" or "drought" or "temperature increase" or "heat stress") and ("livestock performance" or "milk yield" or "mortality" or "fertility").

("pastoral livelihoods" or "household income" or "food security" or "asset sustainability") and ("climate impact" or "climate shock").

("adaptation strategy" or "resilience" or "coping mechanism") and ("pastoralists" or "livestock mobility").

The search period was from 2021 to 2025, taking into account the current climate conditions in East Africa, including recent drought cycles and experiences of heat stress. To obtain a holistic picture of the topic from both academic and practical standpoints, peer-reviewed journal articles and grey literature were used. Studies with the following characteristics were considered eligible for inclusion: (1) studies conducted in Tanzania, Kenya, Uganda or other parts of East Africa; (2) English-language papers; (3) studies published between 2021 and 2025; and (4) studies involving one of the following topics: climatic challenges, cattle productivity, socio-economic implications or adaptation strategies. Articles addressing issues related to non-pastoral cattle rearing systems were excluded as they were not relevant to the study. The screening process comprised three steps: the title screening stage, the abstract reading stage and the full article screening stage.

Study area

This study examines the ASAL regions of East Africa, with a particular focus on the semi-arid ecological zones of the East African Cattle Corridor. This corridor cuts through the territories of Tanzania, Kenya, and Uganda (Figure 1). Such places are ecologically marked by irregular rainfall, frequent droughts, and an increased temperature-humidity index (THI), which pose challenges to the productivity and viability of livestock. In Tanzania, the study focuses on the northern and central plains, specifically the Hai and Manyara districts. In Kenya, the focus is on both the northern and southern rangelands, where pasture shortages are more pronounced. In Uganda, the corridor encompasses regions from the south-west to the north-east, including the Karamoja region, where pastoral production systems are becoming mixed. These countries have been selected because they have similar ecologies and are economically dependent on livestock and livestock-based

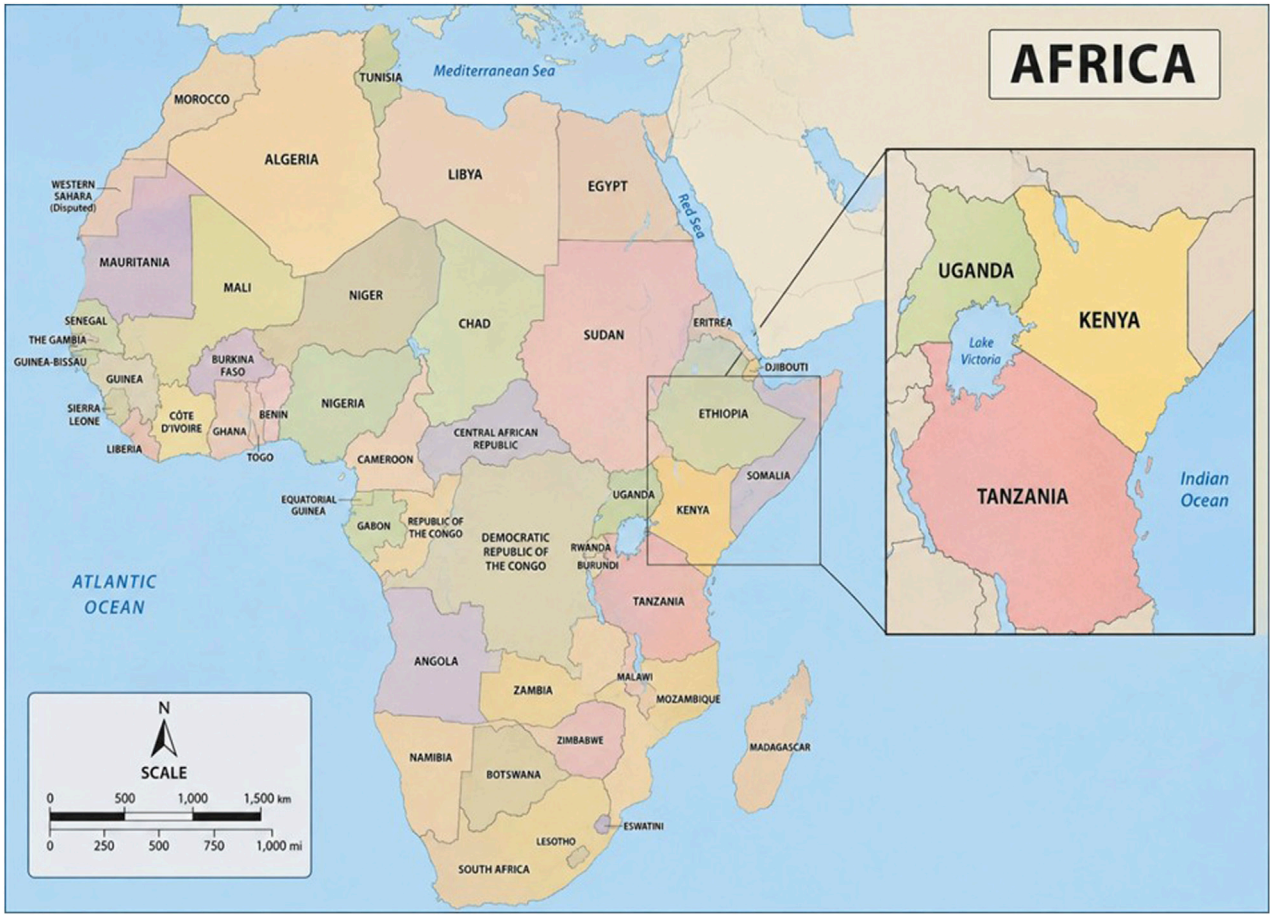

FIGURE 1
Geographical location of Tanzania, Kenya, and Uganda in Africa.

activities for people's incomes and GDP, but have different levels of adjustment to climate-related stress.

Inclusion and exclusion criteria

To ensure relevance and reliability, the inclusion criteria considered context and methodology. Four main requirements for selecting studies were established. Firstly, research works dealing with semi-arid areas in Tanzania, Kenya, and Uganda were limited based on the nature and socio-economic features of the East African Cattle Corridor. Secondly, the review considered literature from 2021 to 2025, as this period reflected recent climatic changes, including severe droughts and high temperature–humidity index (THI) events. This made the review policy-relevant and up to date. Nonetheless, works from before 2021 were also considered if they contributed to our understanding of climate trends, based on baseline or longitudinal findings. Thirdly, studies were included if they demonstrated an empirical link between climatic stressors (e.g., rainfall variability and the THI) and livestock production, as well as socio-economic factors such as income and food security. Lastly, only scientific studies with a valid methodology could be included. It was also important to establish some criteria for excluding certain studies. Specifically, literature dealing with intensive livestock farming, geographically irrelevant regions, or lacking socio-economic links was not analysed. Furthermore, non-peer-reviewed or anecdotal sources were rejected unless they provided essential baseline data.

Screening process

The PRISMA-ScR approach was used to screen the literature, achieving consistency and objectivity throughout the process (Figure 2). To increase the validity of the study, two reviewers conducted the analysis independently and resolved any discrepancies through discussion. An extensive literature search was conducted using the major scientific databases available, including Google Scholar, Scopus, Web of Science and ScienceDirect. Keywords relating to climate change, THI, livestock productivity, pastoralism, food security and the targeted countries (Tanzania, Kenya and Uganda) were combined using Boolean operators (AND/OR). The years under consideration were 2021–2025.

Data synthesis

These papers have been synthesised using thematic and comparative approaches, in line with the aims of this study. The findings were grouped under the following three main themes: (1) the impact of climate variation and an increase in THI on livestock productivity and health; (2) the coping strategies of pastoralists and

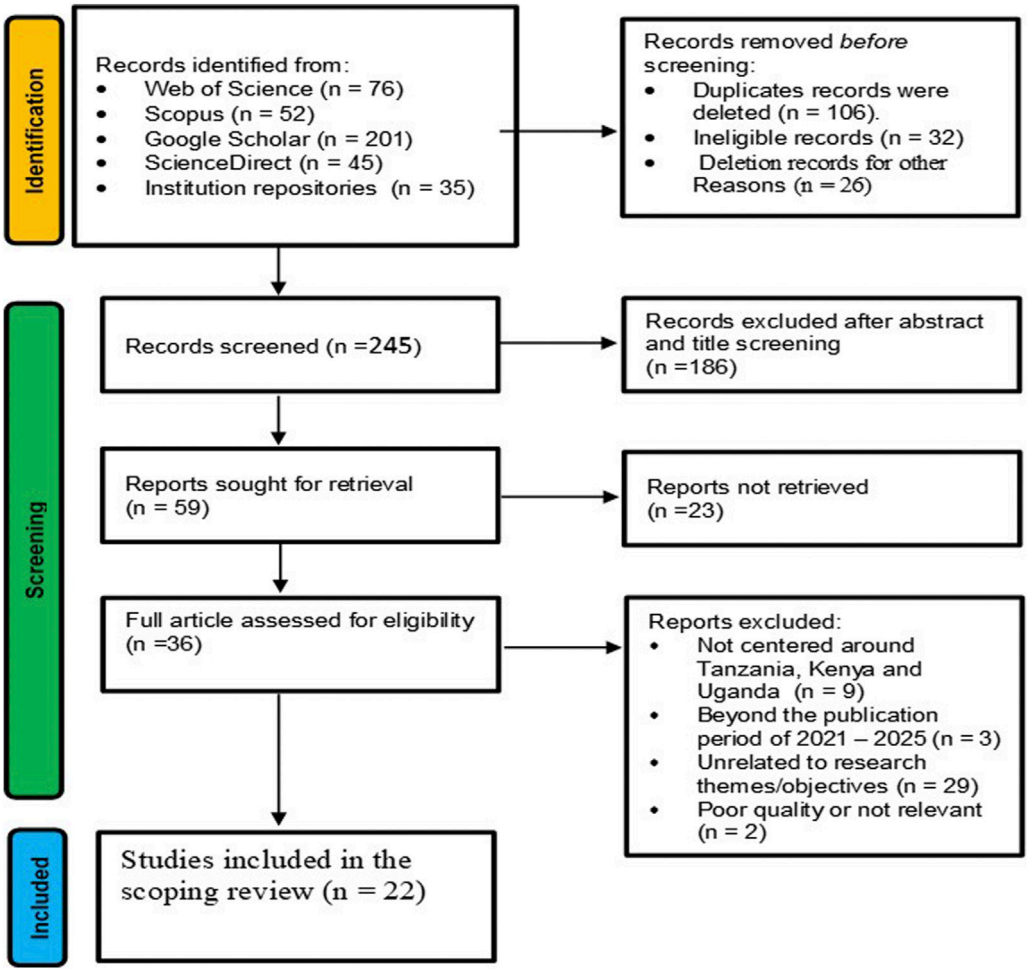

FIGURE 2
PRISMA-ScR flow diagram outlining the study selection process, including identification, screening, eligibility, and inclusion stages for literature on climate stressors, livestock system vulnerability, and adaptation strategies in the East African Cattle Corridor (Tanzania, Kenya, and Uganda), covering publications from 2021 to 2025.

the challenges they face in adapting to climatic conditions in semi-arid areas; and (3) the impact on livelihoods of climatic stressors. A narrative synthesis approach was used to analyse the literature, given the diversity in design, data type, and methods employed in the papers. Regarding Theme 1, emphasis was placed on the impact of changes in rainfall patterns, drought events, and heat stress on cattle productivity, reproduction, and death rates. The second theme focuses on the challenges faced by pastoral communities in adapting to climate stressors, particularly the lack of access to water sources and pastures, institutional constraints, and restricted mobility. The third theme examines the impact of climatic stressors on livelihoods, including the influence of livestock death rates on resilience and food security.

Results

The following PRISMA-ScR process was used to screen the selected studies. Initially, 409 records were found in various databases and institutional libraries (Figure 2). Of these, 60 (14.7%) were duplicates and were therefore eliminated, leaving 349 (85.3%) studies. Of these, 240 records (58.7%) were excluded as irrelevant to the study topic during the screening based on titles and abstracts, leaving 109 records (26.6%) for further examination of the full texts. Finally, all 109 articles were scrutinised for eligibility according to specific inclusion and exclusion criteria. However, 87 studies (21.3%) were found not to meet all the necessary conditions for inclusion in the review. These were primarily due to geographic irrelevance, insufficient consideration of the link between livestock and climate change, and poor methodology. Therefore, 22 studies (5.4%) passed all steps and were accepted for analysis.

Climatic stressors and livestock system vulnerability

Stress caused by environmental factors has an adverse effect on biological and economic performance. The data

TABLE 1 Climate-related vulnerabilities and impact on livestock production in East Africa.

S/N	Key issue	Description	Country	Citation
1	Rainfall variability and pasture scarcity	Erratic rainfall reduces pasture availability and grazing patterns, leading to feed shortages and livestock weight loss	Tanzania	Moti and Liwenga (2025)
		Unpredictable rainfall disrupts pasture regeneration cycles and increases grazing pressure	Kenya	Kirui et al. (2022)
		Delayed rainfall seasons reduce pasture growth and livestock productivity	Uganda	Diem et al. (2017)
2	Rising temperatures and heat stress	Increased temperatures reduce feed intake, fertility, and milk yield in livestock	Tanzania	Habimana et al. (2024)
		Heat stress increases livestock disease vulnerability and reduces productivity	Kenya	Filho et al. (2023)
		Elevated temperatures reduce grazing time and increase water demand	Uganda	Auma and Badr (2022)
3	Drought frequency and livestock mortality	Recurrent droughts cause herd losses and reduced livestock productivity	Tanzania	Moti and Liwenga (2025)
		Prolonged drought leads to large-scale livestock deaths and economic losses	Kenya	Kirui et al. (2022)
		Repeated dry spells reduce water and pasture availability, increasing mortality	Uganda	Waiswa and Günlü (2022)
4	Water scarcity and resource depletion	Drying water sources forces livestock to travel long distances, reducing productivity	Tanzania	Anyango et al. ((2019)
		Competition over limited water sources intensifies pressure on livestock systems	Kenya	Njiru. (2012)
		Limited access to water reduces livestock survival and productivity	Uganda	Nalwanga et al. (2025)

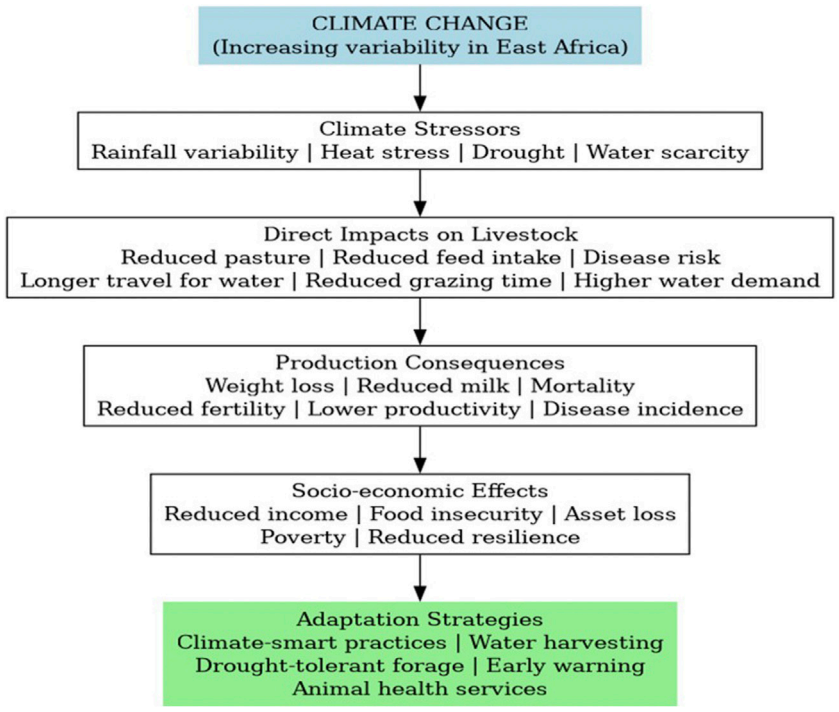

FIGURE 3
Conceptual pathway illustrating the impacts of climate change on livestock systems and livelihoods in East Africa.

TABLE 2 Socio-Economic impacts of climate change on livestock-dependent households in East Africa.

S/N	Key issue	Description	Country	Citation
1	Decline in household income	Reduced livestock productivity lowers income from milk and livestock sales	Tanzania	Zane and Pica- Ciamarra (2021)
		Livestock losses reduce household earnings and market participation	Kenya	Kirui et al. (2022)
		Reduced herd sizes limit income opportunities for pastoral households	Uganda	Waiswa and Günlü (2022)
2	Food insecurity and nutrition	Reduced milk production leads to poor household nutrition	Tanzania	Moti and Liwenga (2025)
		Drought increases dependence on food aid and relief programs	Kenya	Huho and Mugalavai (2010)
		Declining livestock output contributes to household food shortages	Uganda	Omona (2023)
3	Asset depletion and poverty	Loss of livestock assets reduces long-term economic resilience	Tanzania	Zane and Pica-Ciamarra (2021)
		Distressed livestock sales during drought deepen poverty levels	Kenya	Kirui et al. (2022)
		Repeated climate shocks erode household assets and coping capacity	Uganda	Waiswa and Günlü (2022)
4	Resource conflict and social instability	Migration leads to conflicts over land and water resources	Tanzania	Ndimbo and Sanga (2026)
		Scarcity of resources intensifies inter-community conflicts	Kenya	Vundi and Koome (2023)
		Competition for grazing land leads to local disputes	Uganda	Raycraft, et al. (2025)

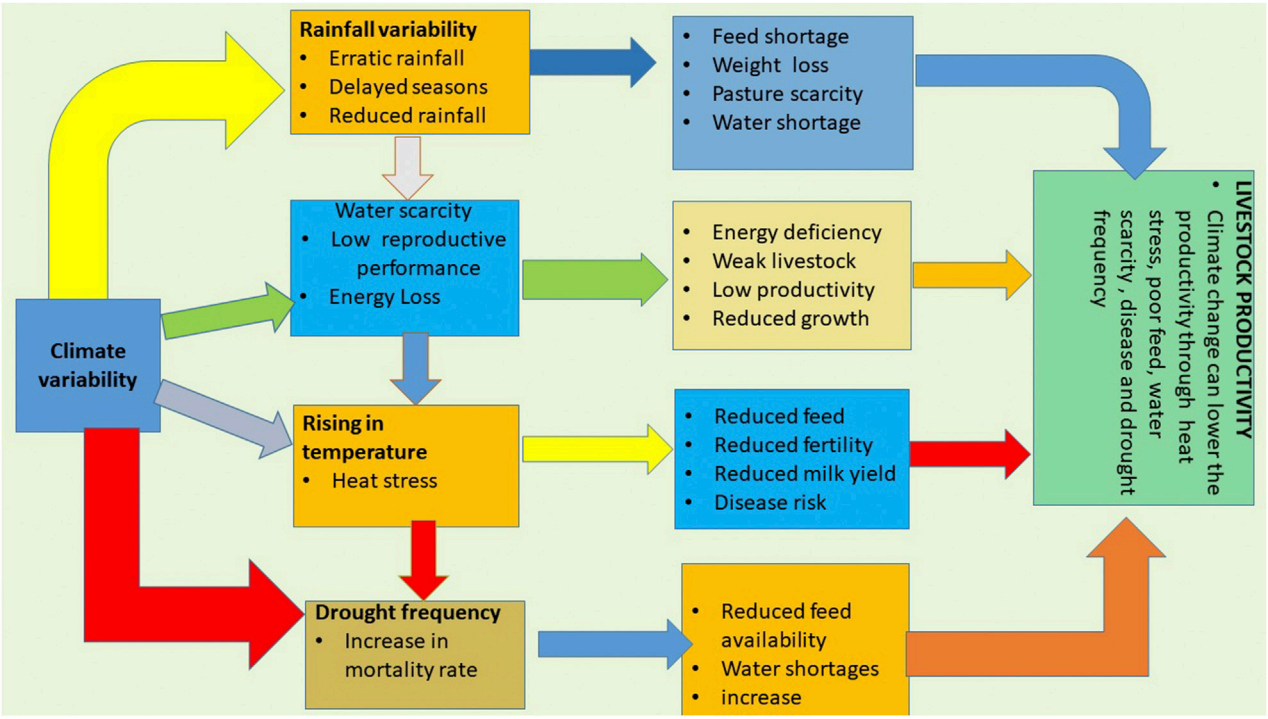

FIGURE 4
Climate vulnerability and its effects on livestock productivity.

reveal that changes in rainfall patterns and pasture availability result in regular fluctuations in body mass and suboptimal performance (Table 1). High levels of heat stress in recent years, such as in 2024 and 2025, also affect fertility rates and milk yield. The data show that when drought becomes frequent, livestock mortality rates increase significantly. Additionally, increased distances to water sources represent another source of stress, causing energy deficiency (Figure 3). Overall, studies

TABLE 3 Adaptation strategies and resilience mechanisms in East African livestock systems.

S/N	Key issue	Description	Country	Citation
1	Livestock mobility and migration	Seasonal migration is used to access pasture and water resources	Tanzania	Mwanga et al. (2025)
		Transhumance helps pastoralists cope with climate variability	Kenya	Vundi and Koome (2023)
		Movement to wetter regions sustains livestock during drought	Uganda	Byenkya et al. (2014)
2	Livestock diversification	Shift to drought-resistant livestock improves resilience	Tanzania	Kichamu et al. (2024)
	Livestock diversification	Adoption of camels and goats enhances adaptation to arid conditions	Kenya	Watson et al. (2016)
		Integration of small ruminants reduces climate risks	Uganda	Waiswa and Günlü (2022)
3	Livelihood diversification	Engagement in non-livestock activities supplements income	Tanzania	Moti and Liwenga (2025)
		Diversification into trade and wage labor reduces vulnerability	Kenya	Kirui et al. (2022)
		Mixed farming systems improve resilience to climate shocks	Uganda	Bashiri and Oseni (2025)
4	Indigenous and modern adaptation strategies	Use of indigenous knowledge enhances climate resilience	Tanzania	Filho et al. (2023)
		Adoption of early warning systems supports climate adaptation	Kenya	Kiptum et al. (2025)
		Improved breeds and water management practices enhance productivity	Uganda	Waiswa and Günlü (2022)

by Moti and Liwenga (2025), Kirui et al. (2022), and others from various countries demonstrate the urgent need for adaptive practices within the agricultural industry to protect rural economies.

Socio-economic consequences and community resilience

As shown in Table 2, climate instability in Tanzania, Kenya, and Uganda has triggered a series of socio-economic crises. These include reduced household income due to low productivity and increased livestock mortality, resulting in decreased dairy production and market attendance (Figure 4). Furthermore, climate instability is associated with food insecurity, as decreased harvests affect household nutrition and increase the need for food aid from outside sources, as reported by Moti and Liwenga (2025).

Furthermore, the findings reveal that economic instability is caused by continuous asset loss, as people sell livestock during droughts (Kirui et al., 2022). Finally, social instability is another consequence of climate change in East Africa. This is due to conflicts arising between migrating communities competing for scarce water supplies and grazing fields. Overall, it should be acknowledged that climate instability affects not only agriculture but also society and the economy.

Strategic adaptation and resilience building in pastoral communities

As can be seen in Table 3, various methods have been used by pastoralists in Tanzania, Kenya, and Uganda to adapt to climate-related hazards. One key approach evident is the ability of pastoralists to move their herds to locations with water and grass in the face of harsh conditions. Additionally, the data suggest a trend of livestock diversification through breeding animals adapted to dry environments, such as camels and goats. Furthermore, livestock owners are venturing into diversified livelihood activities, such as trading, wage employment, and mixed farming, in addition to their livestock businesses. The table shows the importance of combining local knowledge with technological advances when adopting new techniques for early warnings and breeding. By combining various strategies, such as geographical movement, biological breeding, and economic adaptation, a sustainable approach has been developed.

Discussion

The effect of climatic variability in East Africa has not only continued, but also intensified, adversely affecting livestock production and the lives of herders. High temperatures and erratic rainfall resulting from climate change have increased the temperature humidity index (THI), which has compromised the fertility, milk production and weight of livestock (Moti and Liwenga, 2025; Kirui et al., 2022; Sejian et al., 2025; Campos et al., 2022). Evidence gathered in Bagamoyo, Tanzania, suggests that 74% of pastoralists have observed suboptimal performance in their cattle due to stress from heat and humidity (Moti and Liwenga, 2025). A similar trend has been observed in Kenya and Uganda due to recurring droughts and variable rainfall.

These stresses are exacerbated by the long distances travelled in search of water and pasture, resulting in low energy levels and increased livestock losses (Hassan et al., 2026; Leal Filho et al., 2023). Poor livestock productivity therefore contributes to what

is referred to as the 'pastoralists' dilemma', whereby poor productivity threatens the survival of pastoralist households. This can lead to low incomes, limited market participation, food insecurity and the loss of assets through the sale of distressed livestock (Zane and Pica-Ciamarra, 2021; Kirui et al., 2022; Mayanja et al., 2022).

Impact of climate variability on livestock productivity and pastoral livelihoods

It should be noted that the conclusions drawn from the research findings presented above are strongly supported by the empirical evidence provided by Moti and Liwenga (2025), Kirui et al. (2022) and other relevant sources. This evidence supports the idea that climate variability is one of the main causes of livestock decline in East Africa, affecting both biology and the economy. Increased temperatures coupled with unpredictable rainfall patterns lead to higher temperature-humidity index (THI) values in cattle, resulting in adverse biological outcomes such as reduced reproductive success, decreased milk production and even death (Campos et al., 2022). For example, Moti & Liwenga. (2025) found that 74 per cent of pastoralists in Bagamoyo, Tanzania, reported decreased cattle productivity due to high thermal and humidity effects. Similarly, in Kenya and Uganda, the variable nature of rainfall was found to reduce pasture production and increase the risk of disease in cattle herds (Diem et al., 2024; Ndesanjo et al., 2023; Kirui et al., 2022).

The impact of environmental stress on livestock productivity, food security, and asset sustainability

The current analysis revealed that environmental stressors lead to serious socio-economic consequences, creating the 'pastoralists' dilemma', whereby poor livestock production performance endangers their survival. As has been observed in northern Kenya, transformations in pastoral livelihoods have been shown to be fragile. Many households have had to abandon pastoral activities or revert to poverty and subsistence practices due to consistent livestock losses and minimal market participation (Kirui et al., 2022; Hassan et al., 2026). Such volatility directly leads to food insecurity, as lower milk production becomes the main source of nutrition for families, who then rely heavily on food assistance from outside sources (Moti and Liwenga, 2025; Mayanja et al., 2022). Although climate change-driven mobility is a traditional adaptation technique practised by pastoralists, it leads to competition for resources and increases the likelihood of conflicts between communities over grazing areas and water points (Vundi and Koome, 2023; Konaka, 2021). Frequent drought-related shocks also prompt the distress sale of livestock, thereby undermining household capital and pushing communities into greater poverty (Waiswa and Günlü, 2022; Zane and Pica-Ciamarra, 2021). Without technology integration alongside indigenous knowledge, the further erosion of pastoralists' livestock systems seems inevitable.

This study shows that decreased productivity resulting from environmental factors has a significant impact on the socioeconomic outcomes of pastoralists in East Africa. The effects of rainfall variability, drought and elevated temperatures significantly impact animal productivity, reducing body weight, fertility rates and milk yields (Moti and Liwenga, 2025; Kirui et al., 2022; Sejian et al., 2025; Ndesanjo et al., 2023). Such effects have an adverse economic impact on pastoralists, since reduced milk production means that families will earn fewer funds. Additionally, the death of livestock increases expenses related to replacement and decreases herd size (Waiswa and Günlü, 2022; Zane and Pica-Ciamarra, 2021). These factors limit access to markets, making pastoralists vulnerable.

Furthermore, these climatic conditions reduce the sustainability of assets over time, increasing the risk of poverty among pastoralists (Hassan et al., 2026; Kirui et al., 2022). Research conducted under experimental conditions highlights the importance of improved feeding and management practices, as more productive livestock in laboratories can offset losses caused by climate change (Lijalem and Zereu Hadgu, 2024).

Climate-induced livelihood vulnerability and the efficacy of pastoralist adaptation strategies

In addition to the drop in income levels, there is also evidence of a link between reduced livestock productivity and issues of food security and asset sustainability. A decrease in milk production negatively impacts the nutritional status of households in pastoralist settings, given that milk is a core component of their diet. Thus, decreased livestock productivity exposes households to food insecurity, as evidenced by Moti and Liwenga (2025). Furthermore, recurring droughts exacerbate food insecurity by forcing the sale of assets such as livestock, leading to poverty and a reduced ability to cope (Kirui et al., 2022; Waiswa and Günlü, 2022). This makes it difficult to achieve asset sustainability in pastoralist settings. This is because livestock provides income and assets that sustain the lives of pastoralists. Another consequence of climate change for livestock is the forced movement of animals to other areas in search of resources (Leal Filho et al., 2023).

However, there are different degrees of success among adaptation and coping measures that have been used by pastoralists in East Africa as ways of dealing with climate change vulnerabilities. Migration is one of these approaches, which allows pastoralists to get access to pasture and water in case of shortages, thus preventing the death of livestock during droughts (Vundi and Koome, 2023). Another strategy that has worked effectively includes livestock diversification, especially through the inclusion of drought-resilient species like goats and sheep, which can provide food security for pastoralists and additional income sources (de Glanville et al., 2020; Sewando et al., 2016). The use of early warning systems, combined with traditional knowledge about changes in precipitation and temperature, increases the ability of herders to make informed decisions regarding weather patterns (Waiswa and Günlü, 2022).

Nevertheless, implementing such strategies is hindered by a number of economic and environmental constraints. Diversifying sources of livelihood to include non-livestock activities is an effective way to ensure stable livelihoods, particularly when the performance of livestock deteriorates due to climatic impacts such as heat stress and drought (Kirui et al., 2022). However, the high costs associated with acquiring inputs such as veterinary support can hinder profitability and resilience (Waiswa and Günlü, 2022). Furthermore, the increasing trend in heat stress levels, as evidenced by changes in THI thresholds (Besteiro et al., 2025), necessitates more advanced solutions, such as breeding new cattle strains and providing cooling systems.

Conclusion

This literature review reveals that climate variability, particularly in the form of rising temperatures, unpredictable rainfall, and recurring droughts, has had a significant impact on livestock productivity and pastoral livelihoods in Tanzania, Kenya, and Uganda. The research shows that an increase in the temperature-humidity index (THI), coupled with water scarcity, negatively affects livestock health, resulting in low milk production, reduced fertility, and a high mortality rate. This has many socio-economic implications, including income reduction, food insecurity, asset depletion, and resource-based conflicts, which contribute to the 'pastoralist's dilemma'.

While some adaptive measures employed by pastoralists include livestock mobility, herd diversification, and diversification of livelihoods, the effectiveness of these coping strategies is diminishing due to extreme weather conditions and inadequate institutional support. Furthermore, the findings reveal that the use of indigenous knowledge to mitigate the impacts of climate change is inadequate, particularly in light of recent challenges experienced in 2024–25. In this context, resilience would generally involve combining traditional knowledge with climate-smart innovations.

Recommendations and way forward

To enhance the resilience of the pastoral system in East Africa, the following activities should be carried out: Involve the relevant stakeholders, such as the Ministries of Livestock and Agriculture in Tanzania, Kenya and Uganda, the Intergovernmental Authority on Development (IGAD), the International Livestock Research Institute (ILRI), the Consultative Group on International Agricultural Research (CGIAR), the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the United States Agency for International Development (USAID), private insurance firms and local pastoral cooperatives. They should focus on promoting climate-smart pastoralism, integrating indigenous knowledge such as migration, the pastoral calendar, and diversified herds, with advanced technology. Technological innovations to be introduced should include satellite forage management, early warning systems, and climate advisory services to assist with migration and grazing planning. Pastoralists could also introduce drought-resistant animal species, such as Boran cattle, East African Zebu, Galla goats, and Somali camels.

In order to mitigate vulnerability, governments and their partners need to increase uptake of index-based livestock insurance schemes, such as the Kenya Livestock Insurance Programme (KLIP) and IBLI (Index-Based Livestock Insurance), which protect pastoral resources from the risk of drought. Community-level strategies should involve implementing sustainable measures, such as using solar power to dig boreholes and harvest rainwater, as well as building water reservoirs. Transboundary agreements on grazing should also be established to avoid conflicts. Lastly, processing milk to add value will promote the diversification and sustainability of pastoral livelihoods.

Limitations of the study

Although the current study provides a detailed cross-border assessment of the East African Cattle Corridor, certain limitations arise from its nature. Firstly, due to the corridor's extensive geographic scope, variations in the level of data reporting can be expected across Tanzania, Kenya, and Uganda. As such, disparities in historical climatic information and veterinary records may influence THI measurements. Secondly, the current analysis is based on a single time point at which both livestock production levels and pastoral adaptations were analysed. Long-term climate shifts and rapid social and political changes occurring over several decades cannot be accounted for at a single point in time. Thirdly, it is difficult to distinguish the impact of community-level adaptations from the implementation of state policies because, in many cases, pastoralists adapt to changing conditions out of immediate economic necessity, regardless of existing state policies, and *vice versa*.

Author contributions

The conception of the study idea, design of the research, and writing of the manuscript were conducted by KN. Literature review was coordinated, findings on climate variability, livestock productivity, and socio-economic effects were synthesized, and the majority of the manuscript, including the introduction, results, and discussion, was written by him. AS made considerable contributions to the study design and analytical techniques. AS was involved in the collection of data from the literature review process in addition to providing technical expertise in relation to climate resiliency and climate-smart pastoralism in East Africa. In addition, he provided guidance in formulating policy-relevant recommendations and critically reviewed the manuscript. DM contributed immensely to socio-economic analyses in addition to improving the manuscript through extensive editing. Socio-economic effects and adaptation

mechanisms were analyzed by her, and she contributed to manuscript improvement through drafting of sections on socio-economic effects. All authors reviewed and approved the final version of the manuscript.

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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.

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