frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 10 March 2025
DOI 10.3389/fsufs.2025.1485804

OPEN ACCESS

EDITED BY
Andrew John Dougill,
University of York, United Kingdom

REVIEWED BY
Mamta Mehar,
WorldFish, Malaysia
Liveness Banda,
Lilongwe University of Agriculture and Natural Resources, Malawi

*CORRESPONDENCE
Juliana Jepkemoi Cheboi
✉ juliana.cheboi@uonbi.ac.ke

RECEIVED 24 August 2024
ACCEPTED 17 February 2025
PUBLISHED 10 March 2025

CITATION
Cheboi JJ, Nkukwana T, Greathead H and Keyster M (2025) Gendered impacts of climate change on integrated crop-dairy goat farming in Kenya. *Front. Sustain. Food Syst.* 9:1485804. doi: 10.3389/fsufs.2025.1485804

Gendered impacts of climate change on integrated crop-dairy goat farming in Kenya

Juliana Jepkemoi Cheboi [1]*, Thobela Nkukwana[2], Henry Greathead [3] and Marshall Keyster [4]

[1]Department of Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya, [2]Department of Animal Sciences, University of Pretoria, Pretoria, South Africa, [3]School of Biology, University of Leeds, Leeds, United Kingdom, [4]Department of Biotechnology, University of the Western Cape, Cape Town, South Africa

Agriculture is the economic engine of Kenyan economy since it contributes to about 24% of the real GDP. However, its contribution has significantly reduced due to climate change that has impacted negatively crop production, pasture, and animals. A cross-sectional survey was undertaken among 201 households in Endo ward, Elgeyo Marakwet County to understand the effects of climate change and feed diversity. Climate change has profoundly affected individuals along the integrated value chain, with unreliable rainfall being the most significant issue, reported by 99.5% of respondents. Contrastingly, floods during the rainy season were experienced by 15.9%, while pests and diseases were reported by only 1.5% of respondents. The findings highlight a significant gender disparity in the impact of climate change along the integrated value chain resulting in shifts and challenges that impact women, men, and youth in distinct ways. Women, particularly those over 35 years, face severe consequences such as food shortages and malnutrition (56.2%), and loss of lives due to environmental disasters (39.8%). Young females bear increased domestic responsibilities, including fetching water (86.6%), which intensifies during periods of climate stress. Men over 35 years reported substantial economic losses and the impact on agricultural productivity due to pests and diseases. Although younger males are affected, their experiences are less severe compared to older males and females. In the context of dairy goat farming, there is a gender-based specialization of tasks. Men over 35 years predominantly handle activities such as shed construction (60%), marketing (54.2%), pest and disease control (57.2%), enterprise decision-making (58.7%), breeding (58.7%), and slaughtering (64.7%). Younger males, those under 35 years, are primarily responsible for transportation (62.2%). On the other hand, women under 35 are actively involved in feeding the goats (62.7%), cleaning the sheds (57.7%), and providing water (56.7%), with a notable focus on this younger age group of women. The study underscores the need for gender-sensitive adaptation strategies to address the differentiated impacts of climate change. By understanding the specific challenges faced by various demographic groups, policymakers and development practitioners can design more effective interventions to build resilience, and ensure equitable outcomes along the integrated farming system.

KEYWORDS

food systems, climate change, adaptation, resilience, gender disparity, integrated farming system

1 Introduction

Agriculture is the economic engine of Kenyan economy since it contributes to about 34% of the real GDP (Eichsteller et al., 2022). However, its contribution has significantly reduced due to climate change that has impacted negatively crop production, pasture availability, and livestock health, posing a substantial threat to food security and economic stability in Kenya (Musafiri et al., 2022).

Climate change impacts men and women differently along the integrated crop-dairy goat value chain in dry areas of Kenya. In dry areas of Kenya, the integrated crop-dairy goat value chain is particularly vulnerable to climate variability and extreme weather events. The effects of climate change are not gender-neutral; they exacerbate existing inequalities and create distinct challenges for men and women within agricultural communities (Anna Kaisa et al., 2017; Ngigi et al., 2017). Women in Kenya bear the brunt of increased workloads due to climate change. They are primarily responsible for household tasks, water collection, and caregiving. With intensified droughts and reduced water availability, women must travel further and spend more time securing these necessities, increasing their physical and emotional burden (Godoy et al., 2014). Additionally, women often have less access to critical resources such as land, credit, and agricultural inputs due to traditional gender roles and legal constraints. This limits their ability to implement effective adaptation measures and recover from climate impacts (UN-Women, 2018).

Women's livelihoods, which frequently depend on small-scale farming and livestock, are highly susceptible to climate variability. Reduced crop yields and livestock productivity can threaten household food security and income (Godde et al., 2021). Moreover, food shortages disproportionately affect women and children, leading to higher rates of malnutrition and adverse health outcomes (Beyene, 2023).

To combat these challenges, the cultivation of forage and feed crops is critical in developing resilience to climate change. Crops such as pigeon pea and orange-fleshed sweet potatoes are particularly valuable (Sapakhova et al., 2023). These crops offer multiple adaptation benefits, serving as human food, animal feed, and soil enhancers. Their versatile utility makes them ideal candidates for integrated farming systems aimed at improving climate resilience.

Men, often seen as the primary breadwinners, face increased economic pressure due to declining crop and livestock productivity. This can lead to migration in search of better opportunities, disrupting family dynamics and placing additional burdens on women (Collishaw et al., 2023). Men typically control major assets and make key agricultural decisions. Climate change challenges traditional practices, requiring new skills and adaptive strategies that must be implemented (Wang et al., 2023).The stress of dealing with economic instability and the responsibility to provide for the family can also lead to mental health issues among varied groups, compounded by the uncertainty, and unpredictability of climate impacts (Cianconi et al., 2020).

Integrating crop and dairy goat farming can enhance resilience against climate impacts. Training women in advanced livestock management practices can boost productivity and household income (Mostari et al., 2021). Community-based adaptation strategies ensure inclusive participation and knowledge sharing, with women's groups playing a pivotal role in mobilizing resources and disseminating climate-resilient practices. Developing and enforcing policies that recognize and address gender-specific vulnerabilities can enhance the effectiveness of adaptation measures, making gender mainstreaming in climate policies essential for equitable development (FAO et al., 2023). Therefore, the objective of this study is to assess the gender-differentiated impacts of climate change on integrated crop-dairy goat farming systems in Kenya, with a focus on understanding how these impacts influence labor distribution, feed diversity, and adaptation strategies.

2 Approach and methods

Recognizing the need for evidence-based strategies, a cross-sectional survey was conducted among 201 households in regions where integrated improved dairy goat and climate-smart crop farming practices are being implemented. The objective was to understand the effects of differentiated gender impacts of climate change along the integrated crop-dairy goat value chain in dry areas of Kenya and to evaluate the effectiveness of various adaptation measures. Understanding these dynamics is crucial for developing gender-sensitive strategies that enhance resilience and promote sustainable agricultural practices in these vulnerable regions.

2.1. Study site

This study was conducted in Tot Division, located in Elgeyo Marakwet County (Figure 1). Tot Division is classified as one of Kenya's ASAL (Arid and Semi-Arid Lands) zones and faces a number of difficulties, including entrenched patriarchal systems, cattle rustling, low livestock, and crop productivity. Livestock rearing and subsistence crop farming are the primary livelihoods for most households in the area.

2.2. Study design, sampling procedure, and sample size calculation

Farmers who had adopted the integrated farming system were selected to participate in the survey through a multi-stage sampling technique. The first phase involved a purposeful selection of the sub-County. Subsequently, ~201 farmers from 20 farmer's groups from four locations: Mokoro, Murkutwo, Ketut, and Chechan were randomly selected from a list of 300 farmers compiled with the help of sub-County livestock and agricultural officers. These four locations are from Endo ward, Tot division and they are the main dairy goat project beneficiaries. The 201 farmers were disaggregated based on gender and age groups comprising of 63 women (over 35 years-adults), 58 men (over 35 years-adults), 42 women (under 35 years-youth), and 38 men (under 35years-youth). The sample size was based on the Krejcie and Morgan tables. A quantitative approach was employed in this study, utilizing a

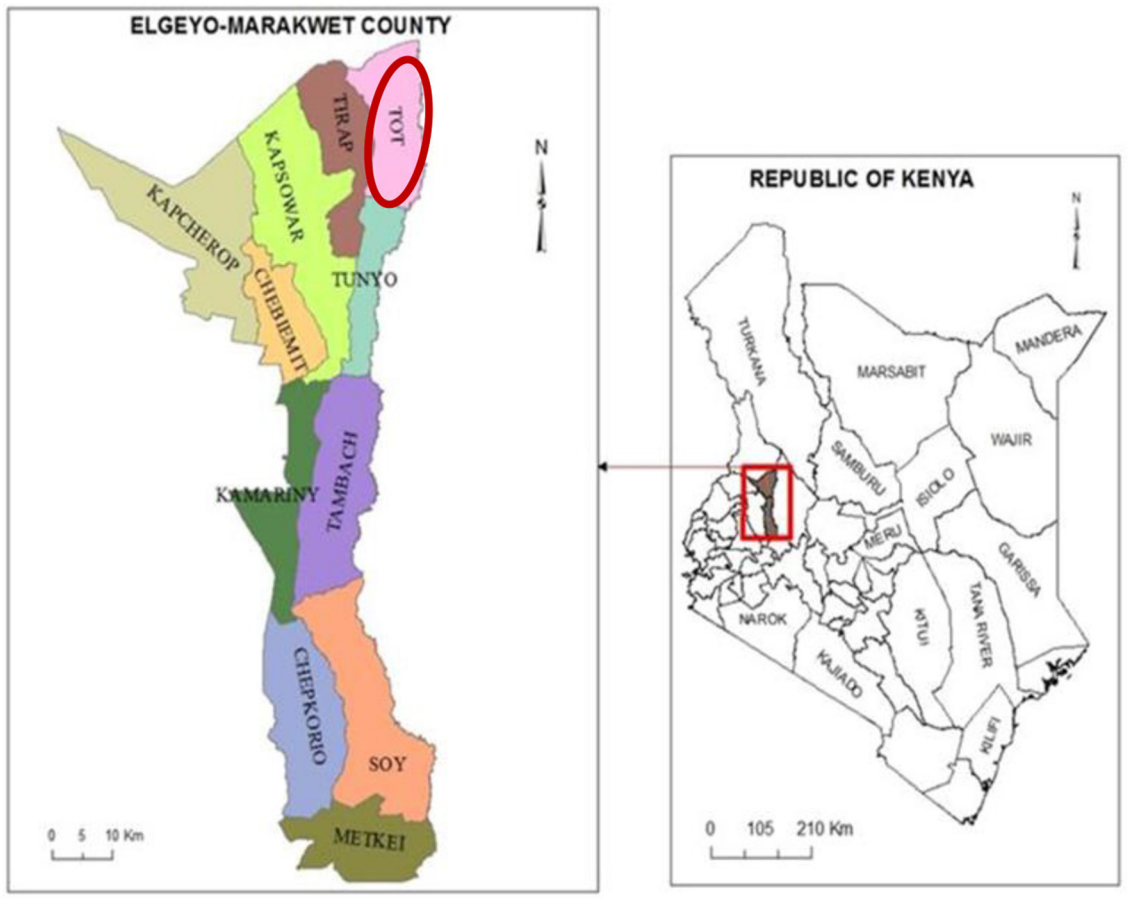

FIGURE 1
Map of the study site, Tot division. Available online at: https://www.elgeyomarakwet.go.ke/docs/HTML/toc510645892.html.

thematic questionnaire to gather data from the farmers on impacts of climate change, division of labor, and feed diversification.

2.3 Data analysis

The data were collected April 2023 and entered into Kobo then subjected to descriptive and inferential statistical analysis using SPSS software version 22.

3 Results

3.1 Impact of climate change among differentiated gender households

The respondents overwhelmingly reported significant experiences related to the effects of climate change along the integrated crop-dairy goat value chain, with 99.5% of the respondents highlighting unreliable rainfall as the most pronounced issue. In contrast, only 15.9% of households experienced floods during the 2022 rainy season, and the incidence of pests and diseases was minimal, tas reported by 1.5% of the farmers. The differentiated gender impacts of climate change and adaptation measures are detailed in Table 1. Women over 35 years were particularly affected by three climate change impacts as reported by the respondents food shortages and malnutrition (51.2%), crop and livestock losses due to increased pests and diseases (49.8%), and loss of life for both animals and humans due to floods and famine (44.3%). Younger women, under 35 years, primarily faced increased responsibilities for fetching water (86.6%) and food shortages coupled with malnutrition (56.1%). Men over 35 years reported significant losses, including wealth (80.1%), crops and livestock due to pests and diseases (69.2%), and loss of life due to floods and famine (53.2%).

3.2 Gendered division of labor in dairy goat farming

Climate change has significantly impacted gender roles and responsibilities in livestock farming, leading to shifts and challenges that affect women, men, and youth differently. In the context of dairy goat farming, there is a gender-based specialization of tasks. Men over 35 years predominantly handle activities such as shed construction (60%), marketing (54.2%), pest and disease control (57.2%), enterprise decision-making (58.7%), breeding (58.7%),

TABLE 1 Differentiated gender impact of climate change.

Impact	Female (%)		Male (%)	
	18–35 years (youth)	>35 years	18–35 years (youth)	>35 years
Loss of lives due to floods and famine	39.8%	44.3%	28.9%	53.2%
Loss of crops and livestock due to increased pest and diseases	26.4%	49.8%	33.8%	69.2%
Increased responsibility like fetching water and animal feeds collection	86.6%	39.8%	28.9%	10.4%
Loss of wealth	23.9%	36.8%	33.3%	80.1%
Food shortage and malnutrition	56.2%	51.2%	28.4%	38.8%

% denotes the percentage of respondents reporting the effects of climate change on the respective parameters.

and slaughtering (64.7%). Younger males, those under 35 years, are primarily responsible for transportation (62.2%). On the other hand, women under 35 are actively involved in feeding the goats (62.7%), cleaning the sheds (57.7%), and providing water (56.7%), with a notable focus on this younger age group of women (Table 2).

3.3 Feed diversity to sustain dairy goat farming

In dairy goat farming, a wide variety of plant materials are used as animal feed. A total of 15 plant species were reported, each contributing to the feed in different proportions (Table 3). Lucerne (100%), sweet potatoes (83.3%), Grevillea (75%), Napier grass (57.1%), and acacia pods (50%) were the most significant contributors. These plants are cultivated on a small scale, with the largest farm being 2.5 acres dedicated to Napier grass and the smallest being 0.02 acres for pigeon pea.

3.4 Feed distribution throughout the years in dairy goat farming

In dairy goat farming, the availability and distribution of feed resources throughout the year are crucial for maintaining animal health and productivity. The contributions of various feed sources fluctuate based on seasonal availability. Acacia pods (74%), crops straws (68%), and weeds (65%) were reported to moderately contribute to the feed of the dairy goats in a calendar year. While the contribution from pigeon pea and sweet potatoes was low at 62% and 69%, respectively. However, Napier grass (42%) and grass (41%) were reported to highly contribute to the animal feed throughout the year as indicated in Figure 2.

4 Discussion

4.1 Impact of climate change among differentiated gender households

As water sources become scarcer due to drought, younger women are tasked with fetching water, a responsibility that intensifies during climate stress (Rao et al., 2019). This added responsibility can take a toll on their time and health, limiting their capacity to engage in other productive activities, including education or income-generating work.

These findings corroborate existing research, emphasizing that women, particularly older women, are more vulnerable to climate change effects than men, reflecting gender inequalities in access to resources, decision-making, and responsibilities within households (UN Women, 2009). This underscores the need for gender-responsive adaptation strategies that address the specific vulnerabilities and needs of different household members.

4.2 Gendered division of labor in dairy goat farming

The division of labor revealed by this data suggests that gender-specific adaptation strategies may be necessary. For instance, women's roles in ensuring animal health and productivity might require targeted interventions that provide them with better access to resources like feed and water, as well as training in improved livestock care techniques. Meanwhile, men may need support in areas like disease control, marketing, and breeding to better manage the impacts of climate variability.

Gender-based task specialization in dairy goat farming continues to shape how different groups experience the impacts of climate change. Women, particularly young women, bear the brunt of tasks related to animal care, while men focus more on technical and market-related aspects of farming (Botreau and Cohen, 2020). These differences in roles underscore the need for gender-sensitive approaches to climate adaptation, ensuring that both men and women receive the necessary support to manage the increasing challenges in the integrated crop-livestock value chain.

4.3 Adaptation measures along the integrated crop-dairy goat value chain

The adaptation measures observed along the integrated crop-dairy goat value chain demonstrate a reliance on diverse plant species to sustain dairy goat farming, which is crucial in areas

10.3389/fsufs.2025.1485804

TABLE 2 Division of labor among different gender and age categories in dairy goat farming management practices.

Activity	Female (%)		Male (%)	
	(18–35) years	>35 years	(18–35) years	>35 years
Construction of sheds	7.0	4.5	56.7	60
Purchase of goats	7.0	19.9	40.3	49.8
Shed cleaning	57.7	45.3	9.5	17.9
Marketing	13.4	23.9	35.8	54.2
Pest and disease control	7.5	8.0	56.2	57.2
Transportation	9.0	8.0	62.2	48.8
Slaughtering	7.5	5.0	52.2	64.7
Providing water	56.7	44.8	28.9	11.4
Purchase of input	8.5	17.4	38.8	42.3
Feeding	62.7	43.8	25.4	7.5
Enterprise selection	5.5	22.9	22.4	58.7
Breeding	6.5	20.9	29.4	58.7
Control of income	22.4	34.8	27.4	39.3

% denotes the percentage of respondents reporting influence of climate change on labor distribution among diverse gender and age categories.

TABLE 3 Types of animal feeds, size of land utilized in cultivation, and their proportional contribution to the dairy goat feeding system.

Type	Proportion of contribution to feeding system	Average land space used for farming (acres)
Acacia	50.0%	0.47 ± 0.038 (0.27–1.3)
Bananas	5.0%	0.39 ± 0.027 (0.2–1)
Cassava	0 %	0.32 ± 0.26 (0.1–0.75)
Finger millet	27%	0.28 ± 0.16 (0.13–0.50)
Grevillea	75.0%	0.11 ± 0.44 (0.05–0.15)
Lantana camara	0 %	0.07 ± 002 (0.15–0.40)
Lucerne	100.0%	0.27 ± 022 (0.05–0.50)
Maize	33%	0.50 ± 0.33 (0.25–1.0)
Mangoes	0 %	0.80 ± 0.13 (0.15–0.32)
Napier grass	57.1%	0.56 ± 0.53 (0.2–2.3)
Pawpaw	0 %	0.80 ± 0.23 (0.25–1.0)
Pigeon peas	76.7%	0.29 ÷ 0.26 (0.02–0.06)
Sorghum	34.3%	0.64 ± 0.69 (0.12–2.5)
Star grass	0 %	0.20 ± 0.38 (0.25–1.4)
Sweet potatoes	83.3%	0.21 ± 0.06 (0.12–0.25)

% denotes the percentage of contribution of various animal feeds to dairy goat feeding system.

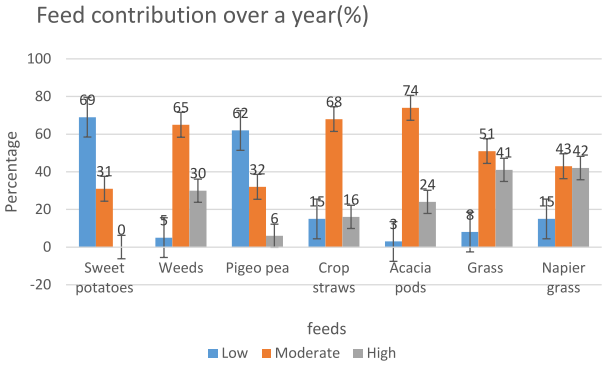

FIGURE 2
Reported contribution of varied plants to animal feeds.

affected by climate change. The use of 15 different plant species as animal feed highlights the farmers' adaptive strategies to cope with environmental challenges, ensuring that their livestock has a continuous supply of nutrition even during adverse conditions.

Lucerne, sweet potatoes, pigeon pea, Grevillea, Napier grass, and acacia pods stand out as the most significant contributors to animal feed, with Lucerne being universally used by all farmers. The prominence of these species indicates their adaptability and resilience to the local climate, making them reliable sources of feed (Vendramini et al., 2023). For instance, Lucerne is known for its high nutritional value and drought tolerance, making it an essential crop in areas prone to unreliable rainfall.

The small-scale nature of cultivation, with farm sizes ranging from 2.5 acres for Napier grass to as little as 0.02 acres for pigeon pea, reflects the constraints faced by farmers, such as limited land availability and resources. Despite these challenges, the farmers have diversified their feed sources, which is a crucial adaptation measure. This diversity reduces the risk of feed shortages, which could occur if a single crop fails due to climate variability (Vernooy, 2022).

4.4 Feed distribution throughout the years in dairy goat farming

The results highlight the importance of feed distribution throughout the year in sustaining dairy goat farming, particularly in regions where climate variability affects agricultural productivity. The data indicates that certain feed resources, such as Napier grass and regular grass, are vital in maintaining a consistent supply of nutrition for dairy goats, contributing significantly to their diet year-round. These grasses are likely favored due to their resilience and ability to grow across various seasons, ensuring a steady feed supply even during periods of climatic stress (Vendramini et al., 2023).

In contrast, other feed sources like acacia pods, crop straws, and weeds, while still contributing moderately to the diet, may be more seasonally dependent. Their availability likely fluctuates throughout the year, making them less reliable as consistent feed sources (Rojas-Downing et al., 2017). Despite their lower overall contribution, they still play a critical role in supplementing the goats' feed, especially during times when primary feed sources like grass might be less abundant.

The lower contribution from pigeon pea and sweet potatoes suggests that these feed resources are either less available or less utilized throughout the year. This could be due to their growth cycles, limited cultivation areas, or competition with human food needs. However, their inclusion in the feed, even at lower levels, provides essential variety and nutrients that contribute to the overall health of the livestock (Abebe, 2022).

5 Conclusion

These results indicate that women's roles in dairy goat farming are labor-intensive and essential to the day-to-day running of the farm, particularly in aspects of animal care that require consistent attention. Their involvement in feeding and cleaning also suggests that women are more directly engaged in tasks that contribute to the health and productivity of the livestock.

Addressing these gender-differentiated impacts requires targeted adaptation measures. Gender-specific adaptation strategies may be necessary. For instance, women's roles in ensuring animal health and productivity might require targeted interventions that provide them with better access to resources like feed and water, as well as training in improved livestock care techniques. Meanwhile, men may need support in areas like disease control, marketing, and breeding to better manage the impacts of climate variability.

The year-round distribution of feed for dairy goats in Elgeyo Marakwet County relies on a combination of high, moderate, and low-contributing feed sources. Strategic management practices are essential to maximize the utility of these feed resources, ensuring the health and productivity of dairy goats. The data highlights the importance of maintaining diverse fodder systems to cope with seasonal variations and to enhance food security for both livestock and the farming communities.

The characterization of feed utilization in dairy goat farming demonstrates a reliance on a mix of common and highly nutritious plants. While Napier grass is the most commonly used, Lucerne, sweet potatoes, Grevillea, and acacia pods contribute significantly to the diet of dairy goats, ensuring a balanced nutritional intake. The small-scale nature of farming these plants underscores the need for efficient land use and targeted agricultural practices to maximize productivity and sustainability in dairy goat farming.

Data availability statement

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

Ethics statement

The studies involving humans were approved by the University of Nairobi Ethics Committee: KNH-UoN Ethics and Research Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

JC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. TN: Conceptualization, Validation, Writing – original draft, Writing – review & editing. HG: Conceptualization, Data curation, Validation, Visualization, Writing – original draft, Writing – review & editing. MK: Conceptualization, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The research was funded by the Food Systems Research Network for Africa (FSNet-Africa). FSNet-Africa was funded by the Global Challenges Research Fund (GCRF) as a Research Excellence project under the partnership between UK Research and Innovation (UKRI) and the African Research Universities Alliance (ARUA). FSNet-Africa is a flagship project in the ARUA Centre of Excellence in Sustainable Food Systems (ARUA-SFS), which is hosted by the University of Pretoria (South Africa) in collaboration with the University of Nairobi (Grant number: ES/T015128/1).

Acknowledgments

The authors express their gratitude to FSNET-Africa for funding this research (Grant number: ES/T015128/1) and the

farmers from Endo Ward, Tot Division, for their participation in the survey.

Conflict of interest

The authors declare that this study was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Publisher's note

References

Abebe, B. (2022). The dietary use of pigeon pea for human and animal diets. *Scient. World J.* 2022:4873008. doi: 10.1155/2022/4873008

Anna Kaisa, K., Ilaria, S., and Marc Peter, S. (2017). *How to Integrate Gender Issues in Climate-Smart Agriculture Projects*. Washington, DC: World Bank Group. Available on: http://documents.worldbank.org/curated/en/586651492750796392/How-to-integrate-gender-issues-in-climate-smart-agriculture-projects-training-module (accessed October 28, 2024).

Beyene, S. D. (2023). The impact of food insecurity on health outcomes: empirical evidence from sub-saharan African countries. *BMC Public Health* 23:338. doi: 10.1186/s12889-023-15244-3

Botreau, H., and Cohen, M. J. (2020). Gender inequality and food insecurity: a dozen years after the food price crisis, rural women still bear the brunt of poverty and hunger. *Adv. Food Secur. Sustain.* 5, 53–117. doi: 10.1016/bs.af2s.2020.09.001

Cianconi, P., Betrò, S., and Janiri, L. (2020). The impact of climate change on mental health: a systematic descriptive review. *Front. Psychiatry* 11:74. doi: 10.3389/fpsyt.2020.00074

Collishaw, A., Sarah, J., Conner, M., and Hannah, C. (2023). A review of livestock development interventions' impacts on household welfare in low- and middle-income countries. *Glob. Food Sec.* 38:100704. doi: 10.1016/j.gfs.2023.100704

Eichsteller, M., Tim, N., and Elvin, N. (2022). The role of agriculture in poverty escapes in Kenya – developing a capabilities approach in the context of climate change. *World Dev.* 149:105705. doi: 10.1016/j.worlddev.2021.105705

FAO, ILRI, IFAD, and Word Bank (2023). *A Framework for Gender-Responsive Livestock Development*. Available on: http://www.fao.org/documents/card/en/c/cc7155en (accessed October 28, 2024).

Godde, C. M., Mason-D'Croz, D., Mayberry, D. E., Thornton, P. K., and Herrero, M. (2021). Impacts of climate change on the livestock food supply chain; a review of the evidence. *Glob. Food Sec.* 28:100488. doi: 10.1016/j.gfs.2020.100488

Godoy, D., Joe Dewbre, P. I. N., Cocou, J. A., Yves, Y. S., Armand, F. A., Malte, B. et al. (2014). *The Future of Food and Agriculture: Trends and Challenges*. Available at: https://www.researchgate.net/publication/

Mostari, M. P., Sadrul, S. B., Rahman, M. H., and Islam, M. S. (2021). Women empowerment and livestock development in Bangladesh: a review. *Bangladesh J. Livest. Res.* 28, 1–15. doi: 10.3329/bjlr.v28i1.72014

Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., et al. (2022). Adoption of climate-smart agricultural practices among smallholder farmers in western Kenya: do socioeconomic, institutional, and biophysical factors matter? *Heliyon* 8:e08677. doi: 10.1016/j.heliyon.2021.e08677

Ngigi, M. W., Mueller, U., and Birner, R. (2017). Gender differences in climate change adaptation strategies and participation in group-based approaches: an intra-household analysis from rural Kenya. *Ecol. Econ.* 138, 99–108. doi: 10.1016/j.ecolecon.2017.03.019

Rao, N., Lawson, E. T., Raditloaneng, W. N., Solomon, D., and Angula, M. N. (2019). Gendered vulnerabilities to climate change: insights from the semi-arid regions of Africa and Asia. *Climate Dev.* 11, 14–26. doi: 10.1080/17565529.2017.1372266

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigon, T., and Woznicki, S. A. (2017). Climate change and livestock: impacts, adaptation, and mitigation. *Clim. Risk Manag.* 16, 145–163. doi: 10.1016/j.crm.2017.02.001

Sapakhova, Z., Raissova, N., Daurov, D., Zhapar, K., Daurova, A., Zhigailov, A., et al. (2023). Sweet potato as a key crop for food security under the conditions of global climate change: a review. *Plants* 12:2516. doi: 10.3390/plants12132516

UN Women (2009). *Women, Gender Equality and Climate Change the Need for Gender Sensitive Responses to the Effects of Climate Change*. Available on: http://www.un.org/womenwatch/feature/climate_change/ (accessed October 28, 2024).

UN-Women (2018). *The-Gender-Gap-in-Agricultural-Productivity-in-Sub-Saharan-Africa-En*. Available on: www.unwomen.org (accessed October 28, 2024).

Vendramini, J. M. B., Silveira, M. L., and Moriel, P. (2023). Resilience of warm-season (C4) perennial grasses under challenging environmental and management conditions. *Anim. Front.* 13, 16–22. doi: 10.1093/af/vfad038

Vernooy, R. (2022). Does crop diversification lead to climate-related resilience? Improving the theory through insights on practice. *Agroecol. Sustain. Food Syst.* 46, 877–901. doi: 10.1080/21683565.2022.2076184

Wang, F., Harindintwali, J. D., Wei, K., Shan, Y., Zhifu, M., Costello, M. J., et al. (2023). Climate change: strategies for mitigation and adaptation. *Innov. Geosci.* 1:100015. doi: 10.59717/j.xinn-geo.2023.100015