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Development Studies Research

An Open Access Journal

ISSN: 2166-5095 (Online) Journal homepage: www.tandfonline.com/journals/rdsr20

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To cite this article: Hawah Nabweteme, Göran Bostedt & Alice Turinawe (2025) Livelihood security shocks and coping strategies in the drylands of Kenya and Uganda – a seasonal analysis, Development Studies Research, 12:1, 2516434, DOI: 10.1080/21665095.2025.2516434

To link to this article: https://doi.org/10.1080/21665095.2025.2516434

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Published online: 17 Jun 2025.

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DEVELOPMENT STUDIES RESEARCH
2025, VOL. 12, NO. 1, 2516434
https://doi.org/10.1080/21665095.2025.2516434

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Livelihood security shocks and coping strategies in the drylands of Kenya and Uganda – a seasonal analysis

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ABSTRACT

Recurrent shocks and crises cause significant threats to household livelihood security in dryland Sub-Saharan Africa. In absence of social protection and institutional support, households resort to potentially problematic coping strategies that could trap them in a vicious cycle of livelihood insecurity. This study employs a unique panel data set from 698 households in the drylands of the Karamoja border region of Uganda and Kenya, to assess variations in shocks experienced by households and evaluate coping strategies. Findings indicate that shock incidences are significantly higher in Uganda's drylands compared to Kenya, particularly during wet seasons. The extent, direction, and significance of influence differ across countries and study locations. However, findings from the multivariate probit model suggest that households led by women, larger households, and those situated in Uganda's drylands are more susceptible and more likely to decrease their food consumption. Reducing food consumption, relying on savings, seeking assistance or loans, and selling livestock are commonly adopted strategies across all shock types. This study advocates strengthening social protection programs and agro-pastoral systems, and prioritizing climate-smart agricultural practices. Financial inclusion, access to extension services, organization of communities into beneficial groups and cooperatives, and human capital investment are recommended, with government and institutional support.

ARTICLE HISTORY
Received 11 February 2025
Accepted 31 May 2025

KEYWORDS
Drylands; livelihood security; shocks; coping strategies; Uganda; Kenya

1. Introduction

Drylands are undergoing rapid changes due to multiple interacting pressures. These areas, characterized by significant annual rainfall variability and extreme seasonality, cover about 41% of the Earth's surface, support millions of people, and account for 50% of the world's livestock (Galvin 2021). Many of the dryland inhabitants face severe challenges such as poverty, food insecurity, malnutrition, limited access to healthcare, poor governance, economic hardship, and marginalization (Stringer et al. 2021). About half of all dryland residents, approximately one billion people, live in poverty and are often overlooked in development efforts, earning the moniker 'the forgotten billion' (Middleton 2018; Middleton and Sternberg 2013). Formal institutions like finance, credit, and insurance are often underdeveloped, and land and water resources are frequently vulnerable and unequally distributed (Galvin 2021). These issues are compounded by various shocks and crises, including land degradation, flooding, drought, famine, epidemics, conflicts, locust invasions, cattle raids, and flash floods (Akall 2021; Obwocha et al. 2022; Opiyo, Wasonga, and Nyangito 2014; Stringer et al. 2021). Sub-Saharan African drylands are particularly vulnerable due to low adaptive capacity, sensitivity to projected changes, poor coping mechanisms, and heavy reliance on weather-sensitive agricultural systems (Akall 2021; Badolo and Kinda 2012; Galvin 2021; Obwocha et al. 2022; Opiyo, Wasonga, and Nyangito 2014; Shehu and Sidique 2015; Stringer et al. 2021). The vulnerability of these communities means that shocks can severely affect household welfare, potentially trapping households in cycles of poverty and insecurity. In pastoral and agro-pastoral regions heavily reliant on livestock, shocks like drought, livestock diseases, and inter-community conflict can severely affect livestock performance, which is vital for household income and livelihood security (Akwango et al. 2017; Muricho, David, and Willis 2018).

Shocks – defined as any event that disrupts the normal functions of socioeconomic agents or their activities – pose challenges and threaten livelihoods (Ansah, Gardebroek, and Ihle 2021). Shocks can be

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idiosyncratic (affecting individual households) or covariate (affecting entire communities) (Pradhan and Mukherjee 2018). Households generally cope better with idiosyncratic shocks through community support (Shehu and Sidique 2015), while covariate shocks undermine social protection mechanisms (Basu and Wong 2015). Research further shows that the impacts of shocks and crises on households vary depending on type and severity of the shocks, socioeconomic characteristics of the households, and the coping strategies they adopt (Guloba 2014; Lawson and Kasirye 2013; Yilma et al. 2014). While some households can recover quickly from shocks, others may experience prolonged crises that hinder their ability to bounce back. Distinguishing between human crises and the triggering events, such as floods, droughts, earthquakes, or conflicts, is crucial for analyzing and anticipating crisis trajectories, since the speed at which crises follow shocks depends on the nature of both the shock and the crisis, as well as their impact on different people (Levine et al. 2020). For this study, the terms 'shocks' and 'crises' will be used interchangeably.

Climate change is expected to worsen conditions in African drylands, leading to reduced agricultural productivity and increased food insecurity (Galvin 2021). Existing literature on climate change suggests that seasonal patterns will likely shift as global temperatures rise (IPCC 2007). Seasonality is a significant stressor for poor rural communities, with shifts potentially being positive (increased precipitation) or negative (shorter rainy seasons). African farmers and herders have reported changes in seasonality and rainfall that are either more erratic or less predictable (Tirado et al. 2015). Drylands are particularly vulnerable to climate change because most of their populations rely directly on a highly variable natural resource base for their livelihoods (Middleton and Sternberg 2013). Notable impacts include reduced agricultural productivity, crop failures, human disease outbreaks, water shortages, food scarcity at the household level, and food insecurity (Ubisi et al. 2017). Mekuyie (2021) and Obwocha et al. (2022) show that changing rainfall patterns and rising temperatures negatively affect food production and livestock. Seasonal temperature changes have also been found to influence the frequency of intercommunal and non-state conflicts by exacerbating social divisions between pastoral and farming communities in the developing world (Landis 2014). Communal conflicts are common in the Sahel, particularly in years of extremely high or low rainfall, due to increased competition for water and land between herders and farmers (Hendrix and Brinkman 2013). In northern Kenya, movement towards areas with relatively more water than the dry grasslands is leading to resource competition and conflict among pastoralist groups and between pastoralists and farmers (Sax et al. 2022). Additionally, cattle raiding has increased due to the scarcity of natural resources induced by climate change.

Households adopt various coping strategies to mitigate the impact of multiple shocks on livelihood security. The choice of coping strategies depends on the type of crisis, available options, household income diversity, and socio-economic characteristics (Berman, Quinn, and Paavola 2015; Bostedt et al. 2023; Olawuyi, Fola, and Mufutau Oyedapo 2011). In developing countries, savings and credit are attractive responses to crises, as they help transfer assets across seasons (Basu and Wong 2015). However, imperfections in savings and credit markets can hinder consumption smoothing. In the absence of well-functioning savings and credit markets, households may resort to informal risk-sharing mechanisms, which can be less effective, especially during widespread shocks (Shehu and Sidique 2015). Other coping strategies include disinvestment, such as selling livestock and assets (Helgeson, Dietz, and Hochrainer-Stigler 2012), reducing nutrient intake, and withdrawing children from school (Olawuyi, Fola, and Mufutau Oyedapo 2011; Rupa 2019). These strategies can deplete household capital and human resources, reducing their capacity to generate income and potentially leading to chronic poverty and livelihood insecurity.

The primary aim of this study is to examine the factors influencing which coping strategies households use in response to shocks in the drylands of northeastern Uganda and northwestern Kenya, part of what is known as the Karamoja cluster. Specifically, we identify variations in shocks experienced by households and the coping strategies they adopt, considering differences by country and agricultural season and analyse the factors that determine the coping strategies households employ in response to shocks.

This study makes several contributions to the literature. It is the first to systematically examine the factors that influence coping strategies among pastoralist households facing multiple shocks in the drylands of East Africa. Previous research on response to shocks in rural areas and low-income countries has typically relied on data from large-scale national surveys, which include few pastoralists (e.g. Guloba 2014; Lawson and Kasirye 2013; Lokonon 2022; and Nkurunziza, Kabanda, and McSharry 2023), or has focused on local studies of farming households, using relatively small samples (e.g. Ashraf, Routray, and Saeed 2014; Berman, Quinn, and Paavola 2015; and Mehar, Mittal, and Prasad 2016). This study fills these gaps by focusing specifically on pastoralists, using a larger sample. Furthermore, by empirically examining two countries – Uganda and Kenya – that

have distinct land tenure systems, population structures, and governance frameworks, across two agricultural seasons and four sites with diverse livelihood strategies, the findings contribute to development literature by facilitating comparisons across multiple dimensions.

In the remainder of the paper, section 2 contains the conceptual framework, which summarizes the relationship between coping strategy choices and shock characteristics, institutional factors, and socio-economic demographics. Section 3 explains the materials and methods used. This is followed by the results in section 4. The paper ends with a discussion in section 5, concluding remarks in section 6, and policy implications in section 7.

2. Conceptual framework

This study aims to understand the determinants of household coping strategies in response to livelihood security shocks in the drylands of Uganda and Kenya. Livelihood security, encompassing economic, food, nutrition, health, and habitat security (Chambers and Conway 1992; Frankenberger and McCaston 1998), is particularly precarious in dryland environments characterized by high climate variability and resource scarcity. Households in these regions frequently face various shocks, which for this particular study are categorized into crop shocks, livestock shocks, and general shocks, based on their similarities.

Drawing on the random utility model, when confronted with shocks, households are assumed to make rational choices from a set of available coping strategies with the aim of maximizing expected utility (McFadden 1978) and safeguard essential household objectives, such as livelihood security, consumption, health, and status (Adams, Cekan, and Sauerborn 1998). These strategies can include consumption smoothing through savings or borrowing (Basu and Wong 2015), asset depletion such as selling livestock (Rupa 2019), and reliance on social networks for support (Nikoloski, Christiaensen, and Hill 2017).

The selection of these strategies is not random; rather it is influenced by a complex interplay of factors including socio-economic factors, such as gender, age, and household size (Berman, Quinn, and Paavola 2015; Lawson and Kasirye 2013; Nkurunziza, Kabanda, and McSharry 2023). Gender, for instance, often dictates access to and control over resources, influencing the choice and effectiveness of coping strategies (Nkurunziza, Kabanda, and McSharry 2023). The age of the household head affects labor availability and risk preferences (Magal 2016). Household size influences both labor supply and consumption demand (Lokonon 2022; Magal 2016), while the size of land holdings and livestock ownership provide crucial assets for buffering against shocks (Lawson and Kasirye 2013).

Institutional factors such as access to credit, land tenure systems, and location also play a significant role (Berman, Quinn, and Paavola 2015; Guloba 2014; Nguyen, Nguyen, and Grote 2020). Additionally, the characteristics of the shocks are critical determinants of coping strategies. For instance, the type of shock dictates the immediate impact and relevant strategies. When faced with multiple shocks, households often rely on multiple rather than a single type of strategy to offset shocks and minimize their impact on livelihood security (Yilma et al. 2014). Moreover, the timing of the shock, particularly in relation to agricultural cycles, can significantly influence household coping decisions (Nkurunziza, Kabanda, and McSharry 2023).

The conceptual framework in Figure 1 summarizes the relationship between dependent variables (coping strategy choices) and independent variables (shock characteristics, institutional factors, and socio-economic demographics).

Shock types serve as the primary explanatory variables, measured by the occurrence of self-reported shocks experienced by a household. Shock events can be categorized into three groups based on their similarities:

1. Crop shocks: crop pests, drop in crop sale prices, rise in agricultural input prices, and reduced crop harvest.
2. Livestock shocks: livestock illnesses, livestock raids, rise in livestock input prices, drop in livestock sale prices, death of livestock, and loss of productivity.
3. General shocks: floods, drought, wildfires, loss of salaried employment, locust invasions, loss of land due to erosion, family illness, land grabbing, lack of food access, dwelling damage or destruction, and insecurity due to violent conflicts in the region.

In summary, the conceptual framework, represented in Figure 1, demonstrates that household responses to livelihood security shocks in the drylands of Uganda and Kenya are a function of an interaction between the characteristics of the shocks experienced, the socio-economic demographics and the prevailing institutional factors. Understanding these relationships is crucial for developing effective interventions aimed at enhancing the resilience of vulnerable households in these dynamic and risk-prone environments.

3. Material and methods

3.1. Study area

The study took place in the Karamoja cluster, focusing on the border region between northeastern Uganda

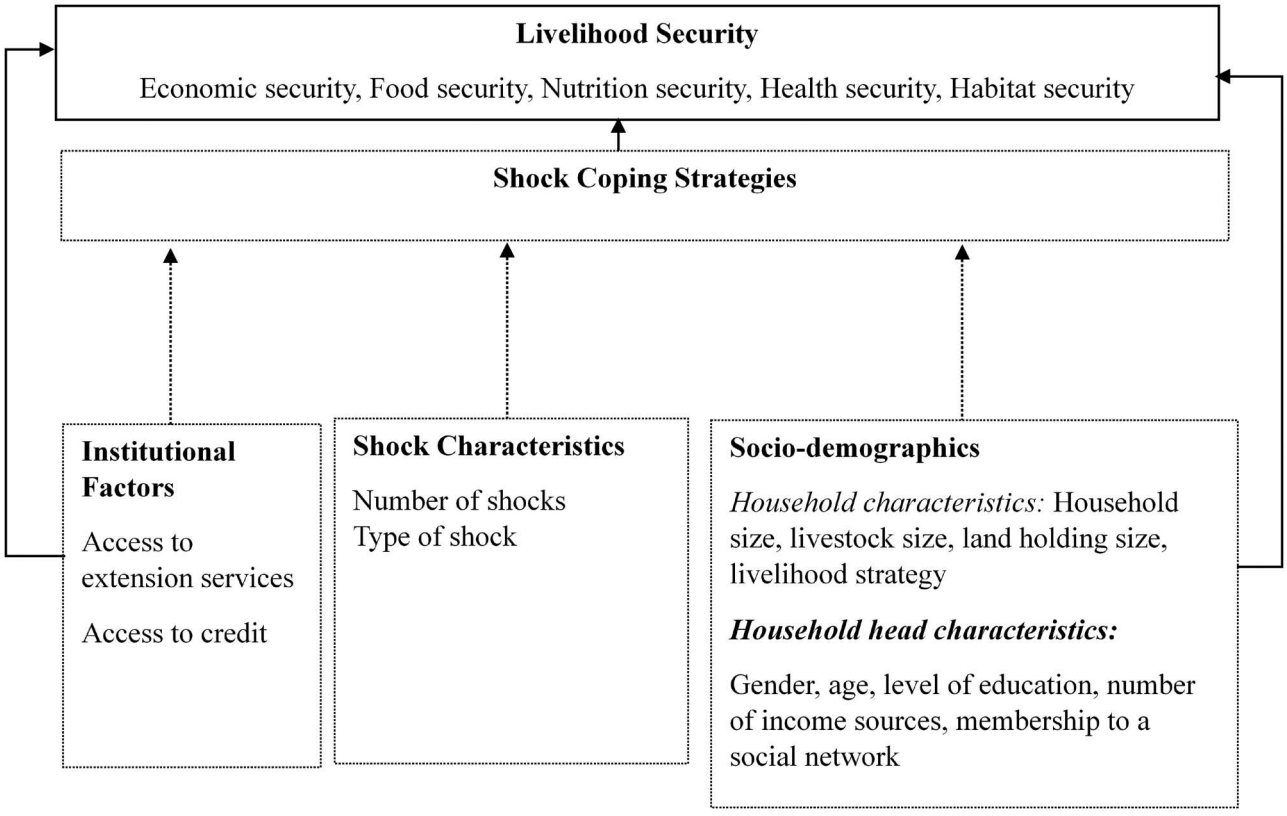


Figure 1. Determinants of household coping mechanism to shocks (Adapted from Dercon 2002; Modena and Gilbert 2012; and Musyoka 2021).

and northwestern Kenya. Four study sites were selected to represent variations in livelihood strategies, land management, and climate. These are Chepareria (West Pokot County) and Lokiriama-Lorengkipi (Turkana County) in Kenya, and Matany (Napak District) and Rupa (Moroto District) in Uganda. Agro-pastoralist communities are predominant in Chepareria and Matany, while Lokiriama-Lorengkipi and Rupa are primarily inhabited by pastoralists.

In Uganda's Karamoja sub-region, agricultural production depends on a unimodal climate with roughly six months of rain (April-October) and six months of dry season (World Food Programme 2013). Annual average rainfall ranges from 300 to 1200 mm, and temperatures average between 16°C and 24°C (USAID 2017). West Pokot County in Kenya, a semi-arid region, experiences bimodal rainfall, with long rains from April to August and short rains from October to February (Magal 2016). Lowlands receive about 600 mm of rainfall annually, while the highlands receive around 1600 mm (Magal 2016; Muricho 2018). Temperature variations are significant, with lowlands reaching up to 30°C and highlands maintaining moderate temperatures around 15°C (Domokwang 2022; Magal 2016; Muricho 2018). Neighbouring Turkana County is hot and dry year-round, characterized by seasonal and bimodal rainfall with high temporal and spatial variability (Opiyo, Wasonga, and Nyangito 2014). Long rains typically occur from March to May, and short rains from October to December (Mureithi 2012). Annual average rainfall ranges from 120 to 500 mm, with more rainfall in the highlands than the lowlands (Mureithi 2012). Temperatures in Turkana are consistently high, ranging from 23°C to 38°C, with an average of 30°C (Opiyo, Wasonga, and Nyangito 2014).

The Karamoja sub-region in northeastern Uganda is primarily agro-pastoralist and ranks the lowest in human development indicators in Uganda, with a poverty rate of 66% – more than three times the national average – making it one of the most food-insecure areas (Khakasa 2022; Muggaga et al. 2021; Olum et al. 2018). This sub-region is highly vulnerable to climate risks, particularly drought, which severely affects crop production and pasture availability (Muggaga et al. 2021). These conditions have disrupted the traditional lifestyle of cattle keepers, who have historically depended on livestock for subsistence. Ongoing shifts from nomadic to more sedentary lifestyles and farming has increased vulnerability to rainfall variability, dry spells, and natural resource conflicts, significantly affecting livelihood security (Tibaweswa 2022).

In Kenya's drylands, the pastoral economy accounts for 90% of employment opportunities and 95% of family income and livelihood security (Republic of Kenya, 2012). In Turkana County, pastoralism is the main livelihood for over 55% of the population, who engage in extensive nomadic livestock rearing on communal rangelands (Opiyo et al. 2015). However, changing climatic conditions have forced pastoralists to adopt supplementary activities like crop farming and fishing to meet economic and social needs (Opiyo, Wasonga, and Nyangito 2014). Turkana County remains deeply rooted in customs and traditions such as frequent migration, livestock borrowing, and cattle rustling, often leading to armed conflicts with neighboring communities. This hinders access to basic services like education and healthcare and limit the ability to pursue other livelihood options (Mutu 2017).

West Pokot County is marked by high levels of underdevelopment, with poverty, illiteracy, and other welfare indicators worse than the national average (Muricho 2018). Food poverty is nearly 70%, illiteracy is 60%, and infant mortality is almost 13%, compared to national averages of 50%, 40%, and 5%, respectively (Muricho 2018). Communities in West Pokot practice agro-pastoralism, combining mixed farming with nomadic pastoralism, with over 90% of households relying on livestock for food and income (Muricho 2018). However, drought-induced scarcity of grazing fields and watering points leads to conflicts over pasturelands and livestock raids, fueled by the need to replace lost animals (Osinde, Mulu, and Hamasi 2023)

3.2. Sample size determination, sampling procedure, and data collection

The study employed a quantitative design and utilized a two-stage cluster random sampling procedure. In the first stage, a list of all parishes and households was compiled. Number of villages required per parish was determined based on the probability proportional to the population size of each parish. Once the necessary villages were identified, the village chairperson provided a list of households in each selected village, from which 12–16 households were randomly chosen. Where village registers were either absent or inaccurate, households were selected through systematic random sampling. Within each village, households were randomly selected from all directions. This was done by first determining the total number of households in a specific village. Households were then selected using a systematic sampling interval.

The study collected household data through semi-structured questionnaires administered between June 2021 and January 2023. Both male and female adult household members participated as respondents. The questionnaire gathered information on socio-demographics, livelihoods, migration, assets, incomes and expenditures, livelihood shocks and crises, support, work, nutrition, health, and anthropometry. A specific module within the questionnaire documented various shocks experienced by households between June 2021 and January 2023. These shocks were categorized into three broad groups, described in the conceptual framework: Crop-related shocks, Livestock-related shocks, and General shocks.

Additionally, the questionnaire included questions on the various coping strategies adopted by households in response to these shocks and crises. These 12 strategies included reducing food consumption, selling livestock, selling assets (other than livestock), seeking assistance or loans from family and friends, children dropping out of school, marrying off girl children, relocating, relying on personal or family savings, seeking another job, using community or traditional conflict resolution mechanisms, keeping livestock in night-guarded kraals, and seeking intervention from police or the army.

In the baseline survey, the actual number of interviews was 944 households. Due to attrition, this number reduced in the follow up, and the actual number reached was 867 households. Due to missing observations in data collection, both the baseline and follow-up were used in analysis for this paper, providing data for 698 households. Details about the sample size determination can be found in Appendix 1, while details about attrition bias and missing data handling can be found in Appendix 2. The data were analysed using the STATA software package.[1]

3.3. Econometric approach

To analyse the choice of coping strategies adopted by households, the multivariate probit model (MVP) was employed. While scholars like Lokonon (2022) and Guloba (2014) have used the multinomial logit model (MNL) to analyse household coping strategies, the MNL assumes independence across outcomes and requires mutually exclusive choice variables (Greene 2017; Mihiretu, Okoyo, and Lemma 2019). Estimating an independent model for each coping strategy can result in a loss of information regarding interrelationships and simultaneous adoption decisions (Chukwuone and Amaechina 2021). Since households often adopt multiple strategies simultaneously, and the selection of one strategy was correlated with the choice of others (Nguyen, Nguyen, and Grote 2020), the MVP model was used.[2] This model allows for contemporaneous correlation in

the choice of coping strategies (Greene 2017; Mehar, Mittal, and Prasad 2016; Mihiretu, Okoyo, and Lemma 2019). The correlation between error terms can be due to positive correlation (complementarities) or negative correlation (substitutability) between different strategies (Ashraf, Routray, and Saeed 2014; Mehar, Mittal, and Prasad 2016).

The MVP model is based on the random utility model, which assumes that individuals have a set of alternative strategies to choose from (McFadden 1978). Households will choose strategies that maximize their utility from these alternatives. Following Mutunga et al. (2020) and Feleke et al. (2016), the random utility model assumes U_j is the expected utility from choosing coping strategy j, and U_k is the expected utility from choosing strategy k instead. The linear random utility model for adopting strategy j can then be expressed as:

$$U_{ij} = X_i\beta_j + \mu_j \quad (1)$$

The corresponding linear random utility model for adopting coping strategy k is given by:

$$U_{ik} = X_i\beta_k + \mu_k \quad (2)$$

where X_i is a vector of explanatory variables, β_j and β_k are vectors of parameter estimates for choosing coping strategy j and k respectively, and μ_j and μ_k are the error terms for choosing the jth and kth strategy. A household will therefore choose coping strategy j over k if the expected utility from choosing strategy j is greater than the utility from choosing strategy k:

$$U_{ij} = X_i\beta_j + \mu_j > U_{ik} = X_i\beta_k + \mu_k \quad (3)$$

Following Mehar, Mittal, and Prasad (2016), and Chukwuone and Amaechina (2021), the general form of the multivariate probit model is:

$$Y_{ij} = X_i' \beta_j + \varepsilon_{ij} \quad (4)$$

where Y_{ij} (j = 1, … .,n), represents the coping strategies, X_i' is a vector of observed explanatory variables, β_j represents the vector of unknown parameters to be estimated, and ε_{ij} represents the unobserved error terms. Assuming the error terms across coping categories are multivariate normally distributed with a mean vector of zero, the unknown parameters in equation (4) can be estimated using simulated maximum likelihood (Mehar, Mittal, and Prasad 2016). This method uses the Geweke-Hajivassiliour-Keane (GHK) smooth recursive conditioning simulator procedure to evaluate the multivariate normal distribution (Mehar, Mittal, and Prasad 2016).

Diagnostic tests were conducted to identify and correct potential issues affecting the accuracy and precision of the study results. The variation inflation factor (VIF) test was used to check for multicollinearity, with VIF values ranging from 1.11 to 1.66 and a mean VIF of 1.26, indicating no multicollinearity among independent variables. Multicollinearity exists when the VIF value exceeds 10. Additionally, heteroscedasticity probit models were run to check for heteroscedasticity. Since the null hypothesis of homoscedasticity was rejected, robust standard errors were used to adjust the parameter estimates to account for heteroscedasticity.

The variables included in the empirical model (Table 1) were derived from various empirical studies on coping (Ashraf, Routray, and Saeed 2014; Berman, Quinn, and Paavola 2015; Guloba 2014; Lawson and Kasirye 2013; Lokonon 2022; Magal 2016; Mehar, Mittal, and Prasad 2016; Mihiretu, Okoyo, and Lemma 2019; Nkurunziza, Kabanda, and McSharry 2023). These studies suggest that household coping strategies are influenced by household characteristics, institutional factors, location factors, and shock characteristics. Therefore, we control for household characteristics such as age, education level, and gender of the household head, membership in social networks, household size, number of income sources, livestock size, and farmland size. Institutional factors include access to extension

Table 1. Definition of explanatory variables.

Explanatory Variable	Description
Household head characteristics	
Gender of the household head	Dummy 1 = male, 0 otherwise
Age of the household head	Continous (years)
Education level of the household head	Continuous (Years of schooling)
Membership to a social network	Dummy 1 = Yes, 0 otherwise
Household characteristics	
Household size	Number of individuals living in the household
Income sources	Continuous (Number of income sources)
Livestock size in TLU	Continuous (Number of livestock)
Farm land size	Continous (number of acres used for crops and livestock grazing)
Institutional Factors	
Access to extension services	Dummy, 1 if household has access to extension services, 0 otherwise
Access to credit	Dummy, 1 if household has access to financial services, 0 otherwise
Shock characteristics	
Proportion of crop shocks	Number of crop shocks experienced by a household
Proportion of livestock shocks	Number of livestock shocks experienced by a household
Proportion of general shocks	Number of general shocks experienced by a household
Location Factors	
Livelihood strategy	Dummy (1 if the household is agro-pastoralist, 0 otherwise)
Region	Dummy (1 if the household is located in Uganda, 0 otherwise)

services and credit. We also control for the number of shocks, livelihood strategy, and region.

The household head's gender is a significant predictor of coping strategy choices, as women tend to be more risk-averse than men (Nkurunziza, Kabanda, and McSharry 2023). Education is another crucial variable influencing households' ability to decide on different coping strategies (Berman, Quinn, and Paavola 2015), where educated households can diversify livelihoods and secure savings to cushion against shocks. Additionally, older household heads are more likely to understand early warning information and crop and animal management better (Magal 2016). Membership in social groups is included as a measure of social capital, which is critical for risk management in volatile and uncertain environments (Iyer 2021; Lawson and Kasirye 2013). Social capital can provide a buffer through gifts or loans in times of need, helping to recoup short-term losses such as food shortages. Larger households have higher labor endowments, enabling them to accomplish certain production tasks and adopt specific strategies (Magal 2016). However, larger household sizes can also lead to adoption of destructive coping strategies, like reducing food consumption, especially if the dependency ratio is high (Lokonon 2022). Furthermore, access to extension services significantly enhances the ability to make informed decisions and choose appropriate coping strategies (Mehar, Mittal, and Prasad 2016). Access to affordable credit can ease cash constraints, allowing farmers to invest in production inputs to mitigate or minimize the impact of shocks (Ashraf, Routray, and Saeed 2014; Lokonon 2022). Farm size serves as a proxy for a farmer's economic status, acting as a positive incentive for investments in crop and livestock management practices (Mehar, Mittal, and Prasad 2016), while income diversity enhances resilience to shocks (Nkurunziza, Kabanda, and McSharry 2023). Empirical studies show that farmers often cope with shocks by selling livestock (Lawson and Kasirye 2013; Mehar, Mittal, and Prasad 2016). Finally, location factors, such as the physical environment and land tenure arrangements can drive coping strategy choices (Berman, Quinn, and Paavola 2015; Guloba 2014).

4. Results

4.1. Demographic characteristics

According to the summary statistics (Table 2), a majority of respondents were from Uganda, representing 62.5% of the surveyed population. Respondents from Kenya accounted for 37.5%. The share of male respondents was 88.1%, with no significant difference between the countries. In terms of livelihood strategies, 53.3% of the surveyed households were agro-pastoralists, compared to 46.7% pure pastoralists, with a significantly higher share in Kenya. The distribution of respondents by study site showed that Moroto accounted for 35.67% of the sampled households, Napak 26.79%, West Pokot 26.50%, and Turkana 11.03%.

Summary statistics also show a mean age of household heads in both countries of 41 years, with no significant difference between countries. Average years of schooling in both regions is three years, though Kenyan household heads are slightly more educated, averaging five years of schooling. Average household size is six persons for both regions, with Kenyan households having more members compared to Ugandan. Ugandan households have

Table 2. Socio-economic and demographic characteristics of surveyed households.

	All Households (Obs = 698)		Kenya (Obs = 262)		Uganda (Obs = 436)		T-statistic, Difference = mean(Kenya)-mean(Uganda)
Variable	Mean	Std Dev.	Mean	Std Dev.	Mean	Std. Dev.	
Distribution (percent)	100		37.54		62.46		
Age of the household head (in years)	41.19	13.76	40.72	11.83	41.47	14.80	−0.70
Gender of household head (Female = 1; 0 otherwise)	0.11	0.32	0.09	0.29	0.13	0.33	−1.24
Education of the household head (Number of years in school)	2.67	4.50	4.75	5.30	1.42	3.39	10.11***
Household size (continuous)	5.84	2.10	6.57	2.21	5.40	1.90	7.37***
Share agropastoralist (Agropastoralist = 1; 0 = pastoralist)	0.53	0.49	0.70	0.45	0.42	0.49	7.36***
Farmland size (acres)	33.17	68.96	11.85	18.45	45.98	83.52	−6.51***
Livestock holding (TLU)	7.05	17.01	11.81	15.87	4.18	17.05	5.87***
Member of a social group	0.42	0.49	0.38	0.48	0.45	0.49	−1.71*
Number of income sources (continuous)	3.36	1.45	3.04	1.46	3.55	1.40	−4.53***
Access to extension (1 = yes, 0 otherwise)	0.31	0.46	0.32	0.47	0.30	0.45	0.70
Access to credit (1 = yes, 0 otherwise)	0.23	0.42	0.10	0.30	0.31	0.46	−6.35***
Study site (Percent)							
West Pokot	26.50						
Turkana	11.03						
Napak	26.79						
Moroto	35.67						

Note: *** = significance at 1%, ** = significance at 5%, * = significance at 10%
Source: Authors' fieldwork.

access to an average of 45.9 acres, compared to 11.8 acres for Kenyan households. Kenyan households also own more tropical livestock units, TLUs (11.8 TLUs) than Ugandan households (4.2 TLUs). Additionally, results show that on average, 42% of all surveyed households belong to a social group, 31% have access to extension services, and 23% have access to credit, with Ugandan households having more access to credit compared to Kenyan households. In terms of income diversity, the surveyed households have at least three income sources on average, with Ugandan households having more income sources compared to the Kenyan households.

4.2. Shocks and crises

Table 3 identifies the variation in the types of shocks experienced by households in the drylands of Uganda and Kenya along with respective means. Results indicate that differences in means between Kenya and Uganda are statistically significant, with Ugandan households experiencing a higher general incidence of shocks compared to those in Kenya. T-test results also reveal that certain specific shocks are significantly more common in Uganda, including livestock death, livestock illness, livestock raids, reduced crop harvest, crop pests including locust invasion, lack of food, wildfires, destroyed or damaged dwellings, land grabbing, and insecurity. However, results show that drops in livestock sale prices, livestock productivity loss, increases in livestock input prices, falls in crop sale prices, rises in agricultural input prices, water shortages, and land loss due to erosion are more prevalent in Kenya. Haile et al. (2019) support the high incidence of droughts in Kenya, noting that among East African countries, Somalia, Ethiopia, and Kenya have experienced the most severe drought events.

Table 4 illustrates the variation in shocks reported by households during wet and dry seasons. Differences in the means of shocks reported in the wet season compared to the dry season are statistically significant, indicating that households were more vulnerable to livelihood shocks in the wet season. T-test results also show that all livestock-related shocks (livestock death, livestock illness, drop in livestock sale price, livestock productivity loss, livestock raids, livestock input price rise), crop shocks (fall in crop sale prices, increase in agricultural input prices), and general shocks (lack of food, locust invasion, floods, and insecurity) are more common in the wet season.

While conditions are expected to be worse in the dry season due to high temperatures and reduced precipitation, which create a breeding ground for diseases as animals compete for scarce pastures and water, the

Table 3. Share of respondents who had experienced various shocks and crises.

Livestock shocks	Pooled (n = 956)	Kenya (n = 505)	Uganda (n = 451)	Difference
Livestock death	0.600 (0.015)	0.574 (0.022)	0.630 (0.022)	−0.056* (0.031)
Livestock illness	0.594 (0.015)	0.524 (0.022)	0.671 (0.022)	−0.147*** (0.031)
Drop in livestock sale price	0.302 (0.014)	0.352 (0.021)	0.246 (0.020)	0.106*** (0.029)
Livestock productivity loss	0.364 (0.015)	0.396 (0.021)	0.328 (0.022)	0.067** (0.031)
Livestock raids	0.333 (0.015)	0.079 (0.012)	0.618 (0.022)	−0.539*** (0.025)
Livestock input price rise	0.300 (0.014)	0.328 (0.020)	0.268 (0.020)	0.060** (0.029)
Crop shocks	**Pooled (n = 8 55)**	**Kenya (n = 226)**	**Uganda (n = 629)**	**Difference**
Reduced crop harvest	0.762 (0.014)	0.628 (0.032)	0.810 (0.015)	−0.182*** (0.032)
Crop pests	0.552 (0.017)	0.132 (0.022)	0.702 (0.018)	−0.569*** (0.033)
Fall of crop sale prices	0.044 (0.007)	0.097 (0.019)	0.025 (0.006)	0.071*** (0.015)
Increase in agricultural input prices	0.560 (0.016)	0.712 (0.030)	0.505 (0.019)	0.206*** (0.037)
General shocks	**Pooled (n = 1179)**	**Kenya (n = 414)**	**Uganda (n = 765)**	**Difference**
Salary loss in HH	0.007 (0.002)	0.004 (0.003)	0.009 (0.003)	−0.004 (0.005)
Lack of food	0.520 (0.014)	0.316 (0.022)	0.631 (0.017)	−0.314*** (0.029)
Locust invasion	0.063 (0.007)	0.009 (0.004)	0.092 (0.010)	−0.083*** (0.014)
Water lack (drought)	0.313 (0.013)	0.396 (0.024)	0.269 (0.016)	0.126*** (0.028)
Floods	0.006 (0.002)	0.004 (0.003)	0.007 (0.003)	−0.003 (0.005)
Wild fires	0.019 (0.004)	0.000 (0.000)	0.030 (0.006)	−0.030*** (0.008)
Land grabbing	0.012 (0.003)	0.002 (0.002)	0.018 (0.004)	−0.015** (0.006)
Land loss due to erosion	0.021 (0.004)	0.038 (0.009)	0.011 (0.003)	0.026*** (0.008)
Dwelling damaged/destroyed	0.113 (0.009)	0.004 (0.003)	0.172 (0.013)	−0.167*** (0.018)
Severe disease in the family	0.089 (0.008)	0.082 (0.013)	0.092 (0.010)	−0.010 (0.017)
Insecurity	0.327 (0.013)	0.004 (0.003)	0.501 (0.018)	−0.497*** (0.024)

Standard errors are in parentheses.
Difference = mean (Kenya)-mean (Uganda).
Note: *** = significance at 1% ** = significance at 5% * = significance at 10%.
Source: Authors' fieldwork.

Table 4. Variation in shocks by agricultural season, share of respondents in the two samples who experienced a certain shock.

Livestock shocks	Pooled (n = 956)	Wet season (1) (n = 507)	Dry Season (2) (n = 449)	Difference
Livestock death	0.600 (0.015)	0.696 (0.020)	0.492 (0.023)	0.204*** (0.031)
Livestock illness	0.594 (0.015)	0.692 (0.020)	0.483 (0.023)	0.209*** (0.031)
Drop in livestock sale price	0.302 (0.014)	0.392 (0.021)	0.200 (0.018)	0.192*** (0.029)
Livestock productivity loss	0.364 (0.015)	0.388 (0.021)	0.336 (0.022)	0.052* (0.031)
Livestock raids	0.333 (0.015)	0.380 (0.021)	0.280 (0.021)	0.100*** (0.030)
Livestock input price rise	0.300 (0.014)	0.396 (0.021)	0.191 (0.018)	0.204*** (0.028)
Crop shocks	**Pooled (n = 855)**	**Wet season (1) (n = 528)**	**Dry season (2) (n = 327)**	**Difference**
Reduced crop harvest	0.762 (0.014)	0.678 (0.020)	0.898 (0.016)	−0.200*** (0.029)
Crop pests	0.552 (0.017)	0.509 (0.021)	0.620 (0.026)	−0.111*** (0.034)
Fall of crop sale prices	0.044 (0.007)	0.060 (0.010)	0.018 (0.007)	0.042*** (0.014)
Increase in agricultural input prices	0.560(0.016)	0.715 (0.019)	0.308 (0.025)	0.407*** (0.032)
General shocks	**Pooled (n = 1179)**	**Wet season (1) (n = 528)**	**Dry season (2) (n = 651)**	**Difference**
Salary loss in HH	0.007 (0.002)	0.005 (0.003)	0.009 (0.003)	−0.003 (0.005)
Lack of food	0.520 (0.014)	0.581 (0.021)	0.471 (0.019)	0.109*** (0.029)
Locust invasion	0.063 (0.007)	0.130 (0.014)	0.009 (0.003)	0.121*** (0.013)
Water shortage (drought)	0.313 (0.013)	0.306 (0.020)	0.319 (0.018)	−0.012 (0.027)
Floods	0.006 (0.002)	0.013 (0.004)	0.001 (0.001)	0.011** (0.004)
Wild fires	0.019 (0.004)	0 .026 (0.006)	0.013 (0.004)	0.012 (0.008)
Land grabbing	0.012 (0.003)	0.009 (0.004)	0.015 (0.004)	−0.005 (0.006)
Land loss due to erosion	0.021 (0.004)	0.028 (0.007)	0.015 (0.004)	0.013 (0.008)
Dwelling damaged/destroyed	0.113 (0.009)	0.117 (0.014)	0.110 (0.012)	−0.006 (0.018)
Severe disease in the family	0.089 (0.008)	0.102 (0.013)	0.078 (0.010)	0.023 (0.016)
Insecurity	0.327 (0.013)	0.378 (0.021)	0.285 (0.017)	0.093*** (0.027)

Standard errors are in parentheses.
Difference = mean (Wet season)-mean (Dry season).
Note: *** = significance at 1% ** = significance at 5% * = significance at 10%.
Source: Authors' fieldwork.

high incidence of livestock-related shocks in the wet season can in fact be attributed to the lagged effects of the extended dry season. Data were collected during a transition from a very dry season. According to Muricho, David, and Willis (2018) and Domokwang (2022), heat stress compromises animals' mating, resulting in low milk and meat productivity, which are crucial components of pastoralists' diets. Climate change also negatively impacts livestock production through poor grass and fodder crop growth, drying water points, and changes in pasture quality (Domokwang 2022).

A review of East African rainfall data by Nicholson (2017) showed that over the past decades droughts have become longer and more frequent across the rainy seasons (March-May). It is not surprising that these shocks peaked from January to May 2022, with March, April, and May normally being the wet season in Karamoja. A lagged effect also explains why food shortages are higher in the wet season, where conditions are expected to be favorable for growing crops and grazing animals.

The increase in agricultural input prices during the wet season can be explained by market forces of demand and supply, as inputs are in high demand during the planting season. Additionally, the wet season creates ideal breeding conditions for locusts, explaining their high significance level during this period. Livestock raids and insecurity are also highly significant in the wet season, likely due to extended drought conditions that persist, increasing competition for scarce pastures and water. Huho (2012) and Musyoka (2021) found that the 1999–2001 drought, which killed entire livestock populations among the Turkana people, increased pressure on community resources, leading to pastoralists attacking each other to restock herds. Therefore, it is not surprising that insecurity and livestock raids are highly significant in the wet season (extended dry season). On the other hand, reduced crop harvests and crop pests were significantly higher in the dry season due to high temperatures providing favorable conditions for pest breeding, thus increasing their incidence and reducing crop harvests.

4.3. Coping strategies

Table 5 shows the variation in coping strategies adopted by households in response to shocks. Results show that in the event of livestock death, households are more likely to sell livestock, draw on savings or reduce food consumption. This also applies to livestock illness, drop in livestock sale prices and livestock productivity loss.

Table 5. Variation in coping strategies for various shocks.

Coping strategies	Livestock death	Livestock illness	Drop in livestock sale price	Livestock productivity loss
Reduce food consumption	0.293 (0.019)	0.216 (0.017)	0.408 (0.028)	0.652 (0.025)
Sold livestock	0.249 (0.018)	0.265 (0.018)	0.235 (0.024)	0.241 (0.022)
Sold assets	0.064 (0.010)	0.047 (0.008)	0.159 (0.021)	
Sought assistance/loans	0.244 (0.017)	0.209 (0.017)	0.211 (0.024)	0.258 (0.023)
Migrated to another location	0.097 (0.012)	0.070 (0.010)		0.074 (0.014)
Savings	0.291 (0.019)	0.308 (0.019)	0.304 (0.027)	0.353 (0.025)
Sought another job	0.102 (0.012)	0.110 (0.013)	0.128 (0.019)	0.126 (0.017)
N	573	568	289	348
	Livestock input price rise	Reduced crop harvest	Crop pests	Food shortage
Reduce food consumption	0.261 (0.025)	0.519 (0.019)	0.436 (0.022)	0.614 (0.019)
Sold livestock	0.432 (0.029)	0.152 (0.014)		0.151 (0.014)
Sold assets	0.135 (0.020)	0.056 (0.009)		0.048 (0.008)
Sought assistance/loans	0.296 (0.026)	0.296 (0.017)	0.258 (0.020)	0.343 (0.019)
Savings	0.351 (0.028)	0.304 (0.018)	0.307 (0.021)	0.288 (0.018)
Sought another job	0.076 (0.015)	0.262 (0.017)	0.298 (0.021)	0.185 (0.015)
N	287	651	472	614
	Water shortage	Insecurity	Livestock raids	
Reduce food consumption	0.227 (0.021)	0.303 (0.023)	0.250 (0.024)	
Traditional conflict resolution		0.349 (0.024)	0.347 (0.026)	
Kept livestock in kraals		0.103 (0.015)	0.225 (0.023)	
Sold livestock	0.110 (0.016)			
Sold assets				
Sought assistance/loans	0.143 (0.018)	0.290 (0.023)	0.197 (0.022)	
Migrated to another location	0.078 (0.013)		0.087 (0.015)	
Savings	0.202 (0.020)	0.347 (0.024)	0.238 (0.023)	
Sought another job			0.122 (0.018)	
N	370	386	319	

Standard errors are in parentheses.
Source: Authors' fieldwork.

For a rise in livestock input prices, households are more likely to cope by selling livestock and seeking assistance or loans. The need to purchase livestock inputs like vaccines may drive these actions. For reduced crop harvests, households are more likely to reduce food consumption, seek assistance or loans, and seek other jobs. Dry conditions increase the risk of crop failure, necessitating these coping strategies. In the event of crop pests, households are more likely to reduce food consumption and seek another job in the dry season due to the higher incidence of pests. For water shortages, reducing food consumption, seeking assistance or loans, and drawing on savings are common, similar to strategies to cope with reduced crop harvest. Finally, traditional conflict resolution mechanisms and keeping livestock in kraals are significant coping mechanisms in the event of insecurity.

Multivariate probit models were run for the three shock events that are most common in the pooled sample in Table 5: livestock deaths, livestock illness, and reduced crop harvest. The four most adopted coping strategies were selected as dependent variables for each shock event and regressed on a set of 13 explanatory variables hypothesized to influence the choice of coping strategies (cf. section 2 above). Results (Table 6) are mixed across the four coping strategy choices adopted in response to livestock deaths. The Wald chi-square value (358.23) is significant at 1% significance level, indicating the relevance of the model for explaining the role of the selected explanatory variables in a household's decision to cope with shocks. Furthermore, the likelihood ratio test indicates that at least one covariance of the error term is statistically significant, implying that the equations in the model are connected.

The gender of the head of household was found to positively influence the decision to reduce food consumption. The probability of reducing food consumption was higher by 11.36% when the household head was female, which aligns with Guloba (2014), and Mehar, Mittal, and Prasad (2016). Conversely, gender negatively influenced the decision to sell livestock or rely on savings; the probability of selling livestock and relying on savings was 17.55% and 12.24% lower for female-headed households, respectively, in the event of livestock deaths. Societal norms and practices can restrict women's access to and control over assets, including livestock (Paumgarten et al. 2020). This limited access, coupled with restricted decision-making power (Galiè et al. 2015), can hinder their ability to sell livestock even in times of need. Furthermore, women often bear the care burden and may not have sufficient time to engage in diverse income-generating

Table 6. Factors determining coping strategies adopted for livestock deaths (Marginal effects).

Variable	Reduced food consumption	Sold livestock	Sought assistance/loans	Relied on own/family savings
Gender of Head (Female = 1)	0.1136*	−0.1755**	0.0141	−0.1224*
	(0.0652)	(0.0809)	(0.0711)	(0.0734)
Age of Head	−0.0025	−0.0008	0.0011	−0.0058***
	(0.0016)	(0.0016)	(0.0017)	(0.0017)
School years Head	−0.0022	−0.0023	0.0107*	0.0024
	(0.0056)	(0.0054)	(0.0060)	(0.0060)
Household size	0.0289***	−0.0095	0.0098	0.0276**
	(0.0097)	(0.0101)	(0.0114)	(0.0113)
Farmland size (acres)	−0.0031***	−0.0022**	−0.0011*	−0.0010
	(0.0006)	(0.0008)	(0.0006)	(0.0006)
Total TLU	0.0003	−0.0018	−0.0001	−0.0010
	(0.0007)	(0.0006)	(0.0010)	(0.0010)
Group membership	−0.0098**	−0.0182	0.0661	0.0906*
	(0.0471)	(0.0493)	(0.0487)	(0.0502)
Number of income sources	0.0059	−0.0130	0.0307**	0.0838***
	(0.0138)	(0.0161)	(0.0149)	(0.0136)
Extension	0.0632	0.1472***	−0.0035	−0.1324***
	(0.0526)	(0.0485)	(0.0562)	(0.0497)
Access to credit	−0.1048	−0.0382	−0.3123***	−0.3456***
	(0.0700)	(0.0711)	(0.0875)	(0.0748)
Number of livestock shocks experienced	0.4014***	0.5203***	0.1256	0.2933**
	(0.1338)	(0.1372)	(0.1463)	(0.1484)
Agro-pastoralist	0.0237	0.0979	−0.2981***	−0.1164*
(1 = West Pokot & Napak, 0 otherwise)	(0.0583)	(0.0611)	(0.0745)	(0.0680)
Country	0.1623***	−0.2384***	−0.1345**	0.0926
(0 = Kenya, 1 = Uganda)	(0.0600)	(0.0582)	(0.0586)	(0.0605)
Correlation Coefficients Coefficient *P*-Value				
Rho_12 −0.3310 0.036**				
Rho_13 −0.1238 0.495				
Rho_14 0.3710 0.036**				
Rho_23 −0.0262 0.854				
Rho_24 0.1893 0.189				
Rho_34 0.2417 0.070*				
Number of observations = 353				
Log likelihood value = −631.4270; Wald chi2 (52) = 358.23***				
Likelihood Ratio Test H0: rho12 = rho13 = rho14 = rho23 = rho24 = rho34 = 0				
chi2(13) = 38.81 *p*-value = 0.0000				

Robust Standard errors are in parentheses.
Note: *** = significance at 1% ** = significance at 5% * = significance at 10%.
Source: Authors' fieldwork.

activities to build savings, which is consistent with Lokonon (2022) and Guloba (2014).

The age of the head of household was found to negatively influence the decision to rely on savings in the event of livestock death. Marginal effects show that an increase in the age of the household head by one year reduces the probability of relying on savings by 0.58%. One possible explanation is that experience gained over time in crop and livestock management may reduce the incidence of such losses. However, the reduced likelihood of relying on savings could also reflect diminished savings capacity among older households, potentially due to reduced income during their post-peak productive years (Mishra et al. 2023). This highlights a potential vulnerability for older households who may have fewer resources and limited capacity to adapt to shocks, emphasizing the need for targeted social protection programs.

School years of the household head positively influenced the decision to seek assistance or loans. This could be because educated household heads have greater access to stable, diversified income sources and are more likely to possess the collateral needed to secure assistance or loans (Olawuyi, Fola, and Mufutau Oyedapo 2011). Farmland size negatively influenced the decision to reduce food consumption, sell livestock, and seek assistance or loans. According to Mehar, Mittal, and Prasad (2016), land ownership acts as a positive incentive for farmer investments in their farms, which can potentially reduce the incidence of shocks.

Group membership was found to negatively influence a household's decision to reduce food consumption, which aligns with Carmen et al. (2022), who found that social capital enhances resilience after crises by improving access to resources and support. Conversely, group membership positively influences the decision to rely on savings at the 10% significance level. This finding suggests that social networks provide valuable support during shocks. Groups often encourage savings, enabling members to borrow during difficult times and repay loans later (Iyer 2021).

Number of income sources positively influences the decision to seek assistance or loans and rely on own or family savings. Diverse income sources provide the means to acquire assets that can be used as collateral for loans and secure savings to offset shocks (Nkurunziza, Kabanda, and McSharry 2023). Household size positively influences the decision to reduce food consumption and rely on savings. Larger households may have higher consumption demands but fewer income sources due to a smaller share of main laborers (Nguyen, Nguyen, and Grote 2020). Additionally, larger household sizes imply more responsibilities, limiting their ability to cope with shocks (Olawuyi, Fola, and Mufutau Oyedapo 2011). Such households may adopt destructive strategies like reducing food consumption, affecting their physical well-being. However, having more adult working family members can increase productive family size and savings, which can be relied on during adversity.

Access to extension services positively influences the sale of livestock and negatively influences seeking assistance or loans and relying on savings, increasing the probability of selling livestock by 14.7% and decreasing the probability of seeking assistance or loans and relying on savings by 13.2%. Although livestock can serve as assets and insurance against shocks (Mehar, Mittal, and Prasad 2016), poor extension education may explain the sale of livestock, while effective extension delivery helps bridge shocks by providing information on disease control, mitigating livestock deaths, and reducing the need for loans or savings. Access to credit negatively influences the probability of seeking assistance or loans and relying on savings by 31.2% and 34.6%, respectively. Credit helps bridge shocks by providing funds to purchase livestock inputs like vaccines, and helps farmers diversify and increase incomes that mitigate the impact of shocks (Alemayehu and Bewket 2017).

Number of livestock shocks experienced by a household positively influences the decision to adopt multiple strategies. A small increase in the number of livestock shocks increases the probability of reducing food consumption, selling livestock, and relying on savings by 40.1%, 52.0%, and 29.3%, respectively. This finding suggests that households facing multiple, simultaneous shocks are compelled to employ a wider range of coping mechanisms to mitigate their cumulative impact. This aligns with Akampumuza and Matsuda (2017) and Mehar, Mittal, and Prasad (2016), who observed that households often resort to multiple strategies when confronted with severe and widespread shocks. Our findings further support the importance of savings as a key coping mechanism, as highlighted by Yilma et al. (2014).

Agro-pastoral households are less likely to seek assistance or loans and rely on savings, decreasing the chances of seeking assistance or loans by 29.8% and relying on savings by 11.6%. A mixed livelihood strategy combining crop and livestock farming can diversify income sources and reduce vulnerability to shocks (Stavi et al. 2021). Finally, households in Uganda are more likely to reduce food consumption than their Kenyan counterparts by 16.2% in the event of livestock deaths. Conversely, they are less likely to sell livestock and seek assistance or loans. These differences in coping strategies between Kenya and Uganda may be influenced by variations in land tenure systems, social protection programs, and governance structures. Berman, Quinn, and Paavola (2015) emphasize the role of location-specific factors, including land tenure and the physical environment, in shaping coping strategies, particularly concerning livestock sales.

To identify the factors influencing households' choice of coping strategies in response to livestock illness, the four most commonly reported strategies (reducing food consumption, selling livestock, seeking assistance or loans, and relying on personal or family savings) were analyzed using the same set of explanatory variables as those used in the analysis of coping strategies in the event of livestock deaths (Table 7). Results show that school years of the household head, number of income sources, access to extension, and livelihood strategies positively influence the choice of coping strategies. Conversely, farmland size, tropical livestock units (TLU), group membership, access to credit, and extension negatively influence these choices.

Similar to livestock deaths, the number of school years of the household head positively influences the decision to seek assistance or loans. Educated household heads likely have better access to diverse and stable income sources, which facilitates access to credit and other forms of financial assistance (Olawuyi, Fola, and Mufutau Oyedapo 2011). This finding underscores the importance of investing in human capital development, particularly education, to improve access to financial resources to enhance households' capacity to manage livestock and mitigate the impact of shocks.

Farmland size again negatively influences the decision to seek assistance or loans. This implies that having access to more land may help households better cope with shocks. Increased landholdings can incentivize farmers to adopt improved production techniques, including pest and disease management, potentially minimizing losses and maximizing productivity (Mehar, Mittal, and Prasad 2016). Livestock ownership negatively influences the decision to rely on savings. Households with more livestock may prefer to sell some to obtain money for

Table 7. Factors determining coping strategies adopted for livestock illness (Marginal effects).

Variable	Reduced food consumption	Sold livestock	Sought assistance/loans	Relied on own/family savings
Gender of Head	0.0600	0.0491	−0.0874	−0.0917
(0 = Male, 1 = Female)	(0.0637)	(0.0626)	(0.0634)	(0.0869)
Age of Head	−0.0015	−0.0002	0.0019	0.0005
	(0.0014)	(0.0015)	(0.0016)	(0.0018)
School years Head	−0.0008	0.0040	0.0164***	0.0038
	(0.0051)	(0.0052)	(0.0063)	(0.0068)
Household size	0 .0102	−0.0136	−0.0011	0.0060
	(0.0097)	(0.0097)	(0.0114)	(0.0119)
Farmland size	−0.0024***	−0.0011	−0.0003	−0.0005
	(0.0006)	(0.0009)	(0.0006)	(0.0005)
Total TLU	−0.0001	−0.0001	−0.0001	−0.0027**
	(0.0006)	(0.0007)	(0.0009)	(0.0013)
Group membership	−0.1188***	0.0559	−0.0847*	0.0468
	(0.0400)	(0.0506)	(0.0459)	(0.0564)
Number of income sources	0.0111	0.0346**	0.0515***	0.0836***
	(0.0129)	(0.0143)	(0.0139)	(0.0162)
Extension	−0.0847*	0.0930**	−0.0039	−0.1834***
	(0.0487)	(0.0469)	(0.0511)	(0.0569)
Access to credit	0.0096	−0.0418	−0.4169***	−0.2339***
	(0.0638)	(0.0684)	(0.0892)	(0.0786)
Number of livestock shocks experienced	0.4855***	0.3630***	−0.0351	0.2760**
	(0.1235)	(0.1391)	(0.1264)	(0.1405)
Agro-pastoralist	0.1169**	0.1346**	−0.0162	−0.0786
(1 = West Pokot & Napak, 0 otherwise)	(0.0504)	(0.0587)	(0.0587)	(0.0704)
Country: Uganda	0.1308*	−0.2827***	0.0433	0.0758
(0 = Kenya, 1 = Uganda)	(0.0580)	(0.0523)	(0.0600)	(0.0669)
Correlation Coefficients Coefficient *P*-Value				
Rho_12 0.0477 0.823				
Rho_13 −0.0342 0.835				
Rho_14 0.5295 0.003***				
Rho_23 0.1246 0.496				
Rho_24 0.2112 0.123				
Rho_34 0.5668 0.000***				
Number of observations = 351				
Log likelihood value = −607.4861; Wald chi2 (52) = 293.14***				
Likelihood Ratio Test H0: rho12 = rho13 = rho14 = rho23 = rho24 = rho34 = 0				
chi2(12) = 57.48 *p*-value = 0.0000				

Robust Standard errors are in parentheses.
Note: *** = significance at 1% ** = significance at 5% * = significance at 10%.
Source: Authors' fieldwork.

veterinary services rather than drawing on savings, and empirical studies show that farmers often cope with shocks by selling livestock (Lawson and Kasirye 2013; Mehar, Mittal, and Prasad 2016). As in the case of livestock death, group membership negatively influences the decision to reduce food consumption. According to Iyer (2021), groups facilitate resource sharing (livestock, money, food), mitigating the need for drastic measures like reducing food consumption.

Number of income sources positively influences the decision to sell livestock and to seek assistance or loans and rely on savings. The increased likelihood of seeking loans may indicate that these households, despite having multiple income streams, are engaged in low-return activities that do not generate sufficient surplus for shock absorption. Alternatively, income diversification may facilitate access to credit. Having diverse income sources could enable households to acquire assets (for example, land, and livestock) that can be used as collateral, making loans a more accessible and attractive option (Alemayehu and Bewket 2017). Nkurunziza, Kabanda, and McSharry (2023) support the idea that diverse livelihoods can enhance savings, explaining the increased reliance on this coping mechanism. Nikoloski, Christiaensen, and Hill (2017) also highlight the common use of savings and borrowing as primary coping strategies.

Access to extension services increases the probability of selling livestock by 9.3% and decreases the probability of reducing food consumption and relying on savings by 8.5% and 18.3%, respectively. This seemingly counterintuitive finding may indicate that extension services, while potentially promoting better livestock management in the long term, might also inadvertently facilitate livestock sales during crises. For example, extension services might advise farmers on optimal timing for livestock sales to maximize returns during drought or disease outbreaks, effectively turning livestock into a readily liquid asset, a form of insurance, as noted by Mehar, Mittal, and Prasad (2016). This does not necessarily imply poor extension quality; rather, it suggests that farmers may strategically utilize livestock sales as

a coping mechanism with the advice of extension services. On the other hand, effective extension services can indeed help mitigate the negative impacts of shocks. By providing information on disease and pest control, and promoting improved farming practices, extension services can reduce losses and lessen the need for distress coping strategies like borrowing, depleting savings, or reducing food intake.

Having access to credit decreases the probability of seeking assistance or loans by 41.7% and relying on savings by 23.4%. Credit can provide necessary funds to purchase essential inputs like vaccines, pesticides, and improved seed varieties, as well as invest in better farming technologies. These investments enhance productivity and resilience, mitigating the negative impacts of shocks and reducing the need for potentially disruptive coping mechanisms. This aligns with Alemayehu and Bewket (2017), who argue that access to credit empowers farmers to diversify income, increase earnings, and implement long-term solutions for shock mitigation.

A small increase in the number of livestock shocks experienced by a household increases the probability of reducing food consumption by 48.5%, selling livestock by 36.3%, and relying on savings by 27.6%. This aligns with Akampumuza and Matsuda (2017) and Mehar, Mittal, and Prasad (2016), who observed that households often resort to multiple strategies when confronted with severe and widespread shocks. The number of shocks had no significant effect on the decision to seek assistance or loans. The reduced likelihood of seeking loans may be due to limited access to credit, potentially driven by a lack of collateral (Alemayehu and Bewket 2017). Credit institutions often require collateral, such as land or housing, which may be unavailable to households experiencing repeated crop losses.

Agro-pastoral households are more likely to reduce food consumption and sell livestock when faced with livestock illness. This could be because the harvest from crop production is insufficient to sustain households at the same level of consumption. The sale of livestock may also be driven by the need to acquire income to pay for veterinary services. This finding contrasts with Stavi et al. (2021), who found that a mixed livelihood strategy combining crop and livestock farming can diversify income sources and reduce vulnerability to shocks, leading to improved livelihood security. Results further show that households in Uganda are more likely to reduce food consumption, compared with Kenya. Furthermore, living in the drylands of Uganda decreases the probability of selling livestock by 28.3%, compared with Kenya.

Finally, to determine factors influencing the choice of coping strategies adopted by households in the event of reduced crop harvest, the four most frequently reported coping strategies (reduced food consumption, sold livestock, sought assistance or loans, and sought another job) were analysed, again using the same set of explanatory variables (Table 8). The Wald chi-square value (328) is significant at the 1% level, indicating the model's relevance in explaining the role of the selected explanatory variables in a household's decisions to cope with shocks. The likelihood ratio test indicates that at least one covariance of the error term is statistically significant, implying that the equations in the model are interconnected.

Being in a female-headed household reduces the probability of relying on savings by 19.2% in the event of a reduced crop harvest. This may be because women often bear the care burden and do not have sufficient time to engage in diverse income-generating activities to build savings to cushion shocks, which is consistent with Lokonon (2022). Conversely, female-headed households were more likely to seek another job to cope with reduced crop harvest, likely due to the same care burden that leaves them no alternative but to seek additional employment to support their families.

Age of the household head was found to negatively influence the decision to rely on savings and to seek another job. The lower propensity to seek additional jobs is consistent with Olawuyi, Fola, and Mufutau Oyedapo (2011) and Mishra et al. (2023), who observed declining income diversification and reduced productivity with increasing age, suggesting limitations on older individuals' ability to engage in additional paid labor activities.

Farmland size was found to negatively influence the decision to reduce food consumption and rely on savings. According to Mehar, Mittal, and Prasad (2016), land ownership acts as a positive incentive for farmer investments in adaptation and good crop and management practices, potentially reducing the intensity of shocks. Group membership negatively influences the decision to seek another job, which aligns with Iyer (2021), who noted that informal insurance through social networks is a dominant form of social protection among pastoralists, with frequent exchanges of livestock, money, food, and other items to cope with drought.

Number of income sources positively influences the decision to seek assistance or loans and rely on own or family savings. Greater livelihood diversity enables households to secure savings to offset shocks and facilitates the purchase of assets that can be used as collateral for loans (Nkurunziza, Kabanda, and McSharry 2023). Credit institutions often require farmers to own properties such as corrugated iron-roofed houses and farmland

Table 8. Factors determining coping strategies adopted for reduced crop harvest (Marginal effects).

Variable	Reduced food consumption	Sought assistance/loans	Relied on own/family savings	Sought another job
Gender of Head	−0.0453	−0.0863	−0.1918*	0.1655***
(0 = Male, 1 = Female)	(0.1002)	(0.1117)	(0.1130)	(0.0626)
Age of Head	−0.0012	0.0024	−0.0029*	−0.0034**
	(0.0021)	(0.0018)	(0.0016)	(0.0014)
School years Head	−0.0043	0.0093	0.0001	0.0070
	(0.0064)	(0.0057)	(0.0054)	(0.0056)
Household size	−0.0188	−0.0092	0.0163	−0.0054
	(0.0199)	(0.0106)	(0.0105)	(0.0089)
Farmland size	−0.0024***	−0.0001	−0.0039***	0.0029***
	(0.0006)	(0.0005)	(0.0005)	(0.0004)
Total TLU	−0.0001	0.0016	0.0001	−0.0008
	(0.0012)	(0.0011)	(0.0009)	(0.0012)
Group membership	−0.0022	−0.0250	0.0571	−0.0837*
	(0.0588)	(0.0500)	(0.0501)	(0.0428)
Number of income sources	0.0061	0.0309*	0.0342**	−0.0054
	(0.0200)	(0.0179)	(0.0160)	(0.0127)
Extension	0.0840	0.0661	−0.1152**	−0.0157
	(0.0628)	(0.0543)	(0.0584)	(0.0440)
Access to credit	−0.0744	−0.2123***	−0.1199**	−0.0092
	(0.0715)	(0.0613)	(0.0564)	(0.0489)
Number of crop shocks	0.2573	−0.3168**	0.3544**	−0.3755***
	(0.1769)	(0.1571)	(0.1587)	(0.1235)
Agro-pastoralist	−0.0575	−0.2090***	−0.2640***	−0.0409
(1 = West Pokot & Napak, 0 otherwise)	(0.0788)	(0.0698)	(0.0648)	(0.0513)
Country: Uganda	0.2139**	−0.1454*	−0.1537**	0.1396**
(0 = Kenya, 1 = Uganda)	(0.0877)	(0.0799)	(0.0741)	(0.0652)
Correlation Coefficients Coefficient *P*-Value				
Rho_12 −0.345 0.015**				
Rho_13 0.2524 0.045**				
Rho_14 −0.3578 0.013**				
Rho_23 0.1354 0.333				
Rho_24 −0.0821 0.585				
Rho_34 −0.6098 0.006***				
Number of observations = 358				
Log likelihood value = −666.3970; Wald chi2 (52) = 328.00***				
Likelihood Ratio Test H0: rho12 = rho13 = rho14 = rho23 = rho24 = rho34 = 0				
chi2(13) = 80.42 *p*-value = 0.0000				

Robust Standard errors are in parentheses.
Note: *** = significance at 1% ** = significance at 5% * = significance at 10%.
Source: Authors' fieldwork.

as collateral (Alemayehu and Bewket 2017). Access to extension services negatively influences the decision to rely on savings when faced with reduced crop harvest. Extension services help bridge shocks by providing information on crop management, pest control, and soil conservation practices, mitigating crop productivity loss (Mehar, Mittal, and Prasad 2016), reducing the need for coping strategies like seeking loans or drawing on savings.

Having access to credit decreases the probability of seeking assistance or loans by 21.2% and relying on savings by 11.9%. Credit helps bridge shocks by providing funds to purchase crop inputs like pesticides and fertilizers, preventing crop loss and reducing the need for these coping strategies, which is supported by Alemayehu and Bewket (2017), who found that accessing credit helps farmers diversify and increase incomes, providing long-term solutions that mitigate the impact of shocks.

A marginal increase in the number of crop shocks experienced by a household increases the probability of relying on savings by 35.4%. In the event of multiple livelihood shocks, households may have no alternative but to draw on savings to cope, which aligns with Yilma et al. (2014), who found that households rely heavily on savings to cope with natural and economic shocks. Conversely, number of crop shocks experienced negatively influences the decision to seek assistance or loans and seek another job. The lower likelihood of seeking another job contrasts with findings by Alemayehu and Bewket (2017) and Assan et al. (2018), who noted that seasonal migration in search of alternative livelihoods, is an important income source in drought-affected communities.

Results further show that being an agro-pastoral household decreases the chances of seeking assistance or loans by 20.9% and relying on savings by 26.4% in case of reduced crop harvest, again consistent with Stavi et al. (2021). Living in the drylands of Uganda increases the probability of reducing food consumption by 21.4%, compared with Kenya, and seeking another job by 13.9% to cope with reduced crop harvest.

Conversely, households in Uganda are less likely than those in Kenya, to seek assistance or loans and rely on savings.

5. Discussion

The results of this study highlight the diverse coping strategies employed by households in response to shocks, with reducing food consumption, relying on savings, seeking assistance or loans, and selling livestock being commonly adopted strategies across all shock types. However, factors influencing the adoption of these strategies vary across shock types. Among factors that enhance the resilience to shocks is membership in social groups, which often encourages saving, allowing members to borrow from group savings to smooth consumption and repay once the shock has subsided (Berman, Quinn, and Paavola 2015). Notably, Nikoloski, Christiaensen, and Hill (2017) found that informal assistance from social networks is a prevalent coping mechanism among female-headed households. Furthermore, households use multiple strategies to minimize the impact of shocks (Akampumuza and Matsuda 2017; Mehar, Mittal, and Prasad 2016), like reducing food intake, depleting savings, and selling livestock, which can have major implications for human and physical capital accumulation, thereby trapping households in vicious cycles of livelihood insecurity. Results also reveal that some coping strategies like selling livestock are less likely among female-headed households. This could be explained by gender-related barriers to asset accumulation and sales (Paumgarten et al. 2020). According to Galiè et al. (2015), laws and customs negatively affect women's access to and control over resources, including water, land, livestock, and crops, which impede women's economic advancement. Assan et al. (2018) found that husbands must permit female heads to sell livestock to meet household needs, as women in these communities are not considered owners of household livestock. These findings underscore the need for targeted interventions that consider specific vulnerabilities in the drylands of Uganda and Kenya when designing and implementing strategies to mitigate the impacts of shocks.

The differences in shock prevalence between Uganda and Kenya highlight the critical role of land tenure. In Uganda, insecure land tenure discourages long-term investments in climate-resilient practices (cf. FAO 2021), making households more vulnerable to shocks like reduced crop harvests. In contrast, more secure tenure in Kenya facilitates better access to credit and sustainable land management (Mbudzya, Gido, and Owuor 2022), reducing shock incidence. Efforts to formalize land tenure in Kenya have increased tenure security, positively influencing credit access and agricultural productivity. Secure land tenure also shapes coping strategies, such as selling livestock (Berman, Quinn, and Paavola 2015), which is more common in Kenya's drylands. Furthermore, financial market limitations significantly affect shock coping capacity (Grandolini 2015). Limited financial inclusion, especially for women and marginalized groups, restricts access to credit and insurance, hindering resilience. This is particularly problematic in dryland regions with unpredictable incomes and high climate risks. While digital financial services like mobile money can expand access (Demirgüç-Kunt et al. 2018), disparities remain for smallholder farmers and pastoralists lacking collateral. Limited penetration of robust insurance mechanisms, such as index-based livestock insurance (cf. Janzen and Carter 2019), further exposes households to catastrophic losses, eroding their resilience. However, Kenya's more advanced financial sector, characterized by deeper markets and greater inclusion, offers better access to credit and insurance, thereby facilitating more resilient coping strategies (Demirgüç-Kunt et al. 2022). In contrast, Uganda's less developed markets limit access to these resources, forcing reliance on less sustainable mechanisms like reducing food consumption. Addressing financial market limitations is crucial for enhancing resilience in dryland ecosystems.

Governance constraints undermine the resilience of dryland households in Uganda and Kenya, though differently. Corruption and lack of transparency impede climate adaptation and disaster management, as emphasized by the United Nations Development Programme (UNDP 2024). Both countries struggle with corruption, diverting resources from essential services. Kenya's decentralization faces implementation and accountability challenges (Josse-Durand 2021), while Uganda's efforts are hindered by central government influence, limiting local autonomy (Titeca 2018). As highlighted by Ribot (2016), these issues affect local shock responses and adaptation strategies, with decentralized governance and local participation being crucial for building climate resilience.

Agricultural markets in dryland regions face challenges with inherent market failures like information asymmetry, high transaction costs, poor infrastructure, weak contractual enforcement, and limited market information, hindering fair transactions and market participation for smallholder farmers (cf. Lutta et al. 2021). Addressing these issues through improved information systems, infrastructure development, and stronger market institutions is crucial for building household resilience. Policy gaps in social protection systems also

exacerbate vulnerability to shocks. Inadequate safety nets force households to deplete assets and adopt unsustainable coping mechanisms (Bowen et al. 2020). Integrated policy approaches that align social protection with climate adaptation, agricultural development, and natural resource management are essential. Effective climate adaptation requires context-specific strategies tailored to diverse livelihood systems, addressing the real needs and vulnerabilities of dryland households.

6. Concluding remarks

This study utilized panel data collected between 2022 and 2023 across four study sites in West Pokot and Turkana counties in Kenya, and Napak and Moroto districts in Uganda. The aim of the study was to examine variation in shocks and coping strategies by country and agricultural season and analyse determinants of coping strategies employed by households in response to livelihood shocks. Descriptive statistics indicate that livelihood shocks were significantly higher in the drylands of Uganda compared to Kenya. Similarly, shock incidence was significantly higher in the wet season compared to the dry season, likely due to lagged effects of the extended dry season. The results also show that reducing food consumption, relying on savings, and seeking assistance or loans are common coping strategies for all shock types. Although the degree of shock experiences, direction of influence on choice of coping strategies, and significance vary by country and study site (agro-pastoral and pastoral), the results indicate that in the event of livestock deaths, livestock illness, and reduced crop harvest, key factors determining households' coping strategies include the gender of the household head, group membership, available farmland size for crop and livestock farming, number of income sources, access to extension services and credit, and the number of shocks experienced.

The results however reveal several similarities in the factors that influence the choice of coping strategies across the three shock types. In the event of livestock death, livestock illness, and reduced crop harvest, households experiencing more shocks were more likely to adopt multiple coping strategies. In addition, households that belonged to social groups were less likely to reduce food consumption for all shock types. Female-headed and larger-sized households, and those in the drylands of Uganda were more likely to reduce food consumption.

Results demonstrate that households that were older, female-headed, experienced several shocks, those that did not belong to a social group, and those that lived in Uganda are on average more vulnerable, and more likely to resort to problematic coping strategies, such as reducing food consumption. Although the study confirms findings from some other studies, for many of the results, especially the cross-country comparisons between Kenya and Uganda, there are no close predecessors to this paper. By enabling comparisons across different dimensions, including contrasting the influence of land tenure, financial structures, and governance systems on shock prevalence and adoption of coping strategy choices, this study contributes to novel development literature on shocks and coping in the drylands of Uganda and Kenya. In conclusion, this study highlights the need for a holistic approach to development policy in drylands, addressing structural drivers of vulnerability and ineffective coping strategies. Policies should prioritize social inequalities, economic marginalization, and strengthening social protection systems. Cross-border collaboration between Uganda and Kenya is essential for shared challenges like livestock raiding and water scarcity. Policymakers should focus on enhancing land tenure security, improving financial inclusion, strengthening governance, promoting climate-smart agriculture, and developing robust social protection mechanisms. Addressing these issues can enhance resilience and improve long-term livelihood security in dryland communities.

Quantitative data were used to analyze the determinants of household coping strategy choices. However, household coping strategy choices could be further explored through qualitative insights into the drivers and motivations for adopting certain coping strategy choices. Employing a mixed methods approach would enable the drawing of meaningful inferences and the formulation of more informed recommendations, guiding households to adopt effective coping mechanisms and better manage shocks.

7. Policy implications

To promote community and household level resilience to shocks and prevent households from resorting to counterproductive coping strategies in the drylands of Uganda and Kenya, we make the following recommendations based on the findings of this study:

Strengthen social protection programs. These provide safety nets for households facing multiple livelihood shocks. Particularly, these safety nets should be inclusive of female-headed households. Provision of reliable emergency relief services and loss compensation arrangements as well as insurance schemes are possible safety nets for the study areas, to help households maintain their livelihoods during crises. Food and cash transfer arrangements have been put in place for marginalized communities in arid and semi-arid regions of Ethiopia,

that are facing food insecurity. Such arrangements provide predictable support to foster resilience.

Promote livestock development. Livestock are a main source of livelihood for households in the Karamoja border region, and developing mechanisms to improve production and productivity would directly improve resilience to shocks for many households. Promoting livestock development involves breed improvement, and addressing infrastructural deficits, such as inadequate veterinary services, poor market access for livestock and livestock products, as well as inputs for production. This calls for substantial investment, which can be a significant hurdle given the limited budgetary resources for agriculture in both Uganda and Kenya. In both countries, livestock breeding and improvement programs are in place, but may need to be strengthened with targeted efforts for vulnerable areas. Mongolia has a livestock insurance scheme that protects herders in Mongolia's dryland regions against livestock losses due to extreme weather events. Under the program, financial compensation for lost animals is provided, thus providing economic stability for affected households.

Enhance financial inclusion. There is a need to expand access and depth of the services of banks and microfinance institutions to underserved rural areas. Easy-to-use, innovative financial products for smallholder farmers such as digital financial services can help facilitate transactions and reduce costs. Both Kenya and Uganda have efficiently functioning mobile money services with wide reach, which have improved access to financial services greatly. However, access to credit is still limited in rural areas such as Karamoja, with low density of financial service providers. Therefore, there is a need to support the financial sector to develop innovative financial products for smallholder farmers. This entails understanding their unique needs and creating tailored solutions that offer affordable credit, with favorable borrowing and payment terms.

Encourage agro-pastoral systems. Reducing reliance on a single source of income can mitigate the impact of shocks and contribute to greater economic stability. For the study area, diversifying agricultural enterprises reduces risk and impact from shocks to households. A profitable agro-pastoral system is achievable for some of the communities in the drylands of Uganda and Kenya, especially those located in agro-pastoral areas. This, however, must be coupled with promotion of climate-smart agricultural practices to address water scarcity in the drylands, and expanding and improving agricultural extension services. Although both Kenya and Uganda have fully fledged extension services in place, these are plagued by insufficient numbers of trained personnel with very high farmer to extension agent ratio.

Support group membership and cooperatives. Membership in groups and cooperatives directly strengthens social protection. These groups are an avenue for provision of training services such as adult education, agricultural extension, and financial literacy. In addition, they facilitate saving, and access to credit and other services. They are also powerful sources of bargaining power for members. Supporting group membership and cooperatives necessitates significant investment in training and capacity building in management, marketing, and negotiation skills. Ensuring that cooperatives are inclusive and representative of all community members adds another layer of complexity. This requires robust administrative frameworks and efficient delivery mechanisms.

Strengthening governance and institutions. This involves not only creating robust policies and frameworks but also ensuring their effective implementation and monitoring. Effective implementation necessitates strong political will and collaboration between various stakeholders, including government agencies, NGOs, and local communities. This also includes enhancing disaster preparedness in the form of early warning systems, contingency planning, and rapid response units to mitigate the impact of shocks. Given shared challenges in Uganda and Kenya drylands, cross-border collaboration is vital. Policies should focus on establishing joint initiatives to address livestock raiding and enhance security in border regions, collaborating on water management projects to mitigate scarcity, promote sustainable use of water resources, and sharing best practices and coordinating efforts to tackle climate change and its impact on dryland communities.

Investing in human capital development. For the Karamoja border regions, this involves improving literacy rates and complementing these efforts with awareness of key areas of concern such as health and nutrition to enhance overall household livelihood security. This comprehensive approach requires substantial and sustained investment, coordination between different sectors, and overcoming cultural barriers that may hinder participation.

Improving agricultural markets. Successful improvement of both crop and livestock productivity requires that markets are developed to cater for the distribution of surplus production but also supply of inputs. To address market failures, both Uganda and Kenya need to develop robust information systems to reduce information asymmetry and improve market transparency. Enhanced information dissemination to farmers through modern technologies such as mobile applications can improve market participation.

Secure land tenure. To mitigate vulnerabilities from insecure land tenure, there is a need to prioritize the

formalization of land tenure. For both countries, communal land is the most common type of land ownership in the drylands in the Karamoja border region. Ways to safeguard ownership include establishment of land registration systems to ensure secure property rights; enactment of legal reforms that protect land rights and promote long-term investments in climate-resilient practices; and engagement of local communities in the adjudication process to ensure protection of customary land rights. There is need to be widespread coverage and enforcement of the policies to secure tenure to ensure equitable access to farmland and support land tenure security for all smallholder farmers. In addition, the policy environment should provide legal recognition of land rights for all community members, especially women and marginalized groups.

Notes

1. Regarding missing data, we employed listwise deletion, resulting in the exclusion of households with incomplete records. While this approach can introduce bias if attrition is not completely random (Allison 2003), we believe it was appropriate given the relatively small proportion of missing data (approximately 19.3% from the 867 final households).
2. To justify the MVP model choice, its results were compared with univariate probit models (available on request). Although both models yield similar results, the MVP model has theoretical advantages by modelling simultaneous adoption of coping strategies and their correlations. Significant correlations between coping strategies for livelihood shocks (livestock deaths, illness, reduced crop harvest) confirm the MVP model's adequacy, with significant correlation coefficients for 3, 2, and 4 out of 6 combinations (cf. tables 7–9 below).

Acknowledgements

The study was conducted within the project 'Achieving the SDGs in East African drylands: Pathways and challenges towards a socio-ecological transformation of landscapes, livestock and livelihoods' (Drylands Transform). We are forever grateful to our great enumerators who gathered the data in the field, all the respondents who took their time to answer the survey, and the two anonymous reviewers for their comments.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Svenska Forskningsrådet Formas: [Grant Number 2020-00478].

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Appendices

Appendix 1: Sample size determination

For the Drylands Transform Project, under which the survey data was collected, nutrition was a key component, mostly focusing on maternal and child nutrition. Therefore, to have a sampling procedure that was feasible and valid for both this study and the nutrition aspects, the Emergency Nutrition Assessment for SMART software (https://smartcorp.com/) was used to estimate the sample size for each of the four study sites as follows:

$$n = t^2 * \frac{p(1-p)}{d^2} * DEFF \quad (A1)$$

Equation 1 considers the sample size for children (n), the desired precision (d), the t-value associated with the 95% confidence interval for cluster sampling (t^2), the estimated

proportion of a nutritional indicator under study (*p*), and the design effect (*DEFF*). Precision is a measure of the consistency of the survey results. A precision of 5% indicates that the true population value is within a range of 5% higher or 5% lower than the estimated value. The small range of +/− 5% represents a higher precision and lower margin of error. In this case, the nutritional indicator was the prevalence of global acute malnutrition (GAM). The design effect (*DEFF*) is a correction factor used to adjust for the variability in acute malnutrition rates between villages. If a few villages have disproportionately higher malnutrition rates, the overall prevalence estimate may be inflated. To account for this variation, the sample size was increased by using a correction factor called the design effect, which is set at 1.2 in this study.

The 2021 Integrated Food Security Phase Classification (IPC) report for Karamoja (IPC 2021) provided estimates for household size, number of children under five, and Global Acute Malnutrition (GAM) rates for Matany and Rupa. The Smart Nutrition Surveys 2019 for Turkana County (Turkana County Government 2019) and West Pokot County (West Pokot County Government 2019) provided estimates for Lokiriama and Chepareria, respectively. The formula in Equation (A1) was used to estimate the number of children for each study site. To estimate the total number of households required to meet the target number of children, given the average household size and proportion of children under 5 years, Equation A2 was used.

$$\text{Number of households to be visited} = \frac{\text{Sample size for children (one per household)}}{\text{Average household size x percentage of children} > 5 \text{ x } 0.9} \quad (A2)$$

Based on these estimates, the total required household sample size was 920.

Appendix 2: Attrition bias and missing data handling

Attrition bias

To assess potential attrition bias between the baseline sample and the follow-up sample, we used t-tests (Fitzgerald, Gottschalk, and Moffitt 1998) to compare baseline characteristics of households that were lost to attrition (n = 77) with those that were successfully followed up (n = 867). Results of these comparisons are presented in Appendix 2a below:

Appendix 2a. Socio-demographic characteristics of the attritors and follow-up sample.

Variable	All Households (N = 944) Mean.	Attritors (Obs = 77) Mean	Follow up (Obs = 867) Mean	T-statistic,
Age of the household head (in years)	41.09	40.10	41.21	−1.02
Education of the household head (Number of years in school)	2.64	2.36	2.67	−0.85
Household size (continuous)	5.85	5.99	5.83	0.96

(*Continued*)

Appendix 2a. Continued.

Variable	All Households (N = 944) Mean.	Attritors (Obs = 77) Mean	Follow up (Obs = 867) Mean	T-statistic,
Farmland size (acres)	31.40	15.86	33.32	−3.30***
Livestock holding (TLU)	7.88	14.71	7.04	5.50***
Member of a social group	0.41	0.29	0.43	−3.51***
Number of income sources (continuous)	3.34	3.18	3.36	−1.54
Access to credit (1=yes, 0 otherwise)	0.23	0.17	0.24	−2.01**
Access to extension (1 = yes, 0 otherwise)	0.33	0.45	0.31	3.44***

Source: Authors' fieldwork.

As shown above, the t-tests revealed statistically significant differences between the attritors and the follow-up sample for five baseline household characteristics, namely farmland size, livestock holding (in Tropical Livestock Units), membership in a social group, access to credit, and access to extension services. Specifically, households that were lost to attrition had, on average, smaller farmland sizes, larger livestock holdings, were less likely to be members of a social group, had lower access to credit, and were more likely to have had access to extension services compared to the households that remained in the study at the follow-up.

In contrast, the age and education level of the household head, household size, and the number of income sources were not statistically significantly different between the attritors and the follow-up sample. This suggests that attrition was not systematically related to these particular demographic and economic characteristics. The statistically significant differences in farmland size, livestock holding, group membership, access to credit, and access to extension indicate the potential for attrition bias in our subsequent analyses. However, the lack of significant differences in key demographic variables such as age and education of the household head and household size provides some reassurance that the attrition may not have introduced bias across all dimensions.

Missing data handling

The reduction in our analysis sample from 867 households at the follow-up to 698 households in the final analysis was primarily due to incomplete records for key variables of interest. Specifically, a notable portion of the baseline and follow-up survey responses contained missing or unusable data for crucial household characteristics such as age of household members and years of schooling. Given that these variables are central to our research questions and the intended analyses, including households with such incomplete or erroneous data would have introduced significant measurement error and potentially biased our findings. Therefore, we opted for listwise deletion, removing households with any missing or unusable data on these critical variables to ensure the integrity and reliability of our results. Second, we deliberately decided to exclude households identified as child-headed from our final analysis (ages 0–11). This is because the dynamics and

decision-making processes in child-headed households are fundamentally different and require a separate analytical framework beyond the scope of this particular study. By focusing on adult-headed households with complete data on our key variables, we aimed to achieve a more homogenous sample relevant to our specific research objectives. While we acknowledge that listwise deletion can reduce statistical power and potentially introduce bias if the missing data is not completely random (Allison 2003), we deemed it the most appropriate strategy in this specific context to maintain the accuracy of our key measures and the validity of our conclusions.