

Pastoralism in the Changing Climate of the Horn of Africa

Livelihoods, Vulnerability and the Economics of Anticipatory Action





ICPALD

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ISBN: 978-9914-9342-5-0

Cover Photo Credit: ICPALD

Published by: IGAD Centre for Pastoral Areas and Livestock Development.

The book is accessible at: <https://icpald.org/publications>

FOREWORD

Pastoralism underpins the livelihoods of millions of people across the Horn of Africa. It remains a vital contributor to food security, social stability, and economic development in the IGAD region. For generations, pastoral and agropastoral communities have successfully adapted to highly variable dryland environments through mobility, livestock diversification, and indigenous knowledge systems. These adaptive strategies have enabled pastoral societies to thrive in some of the world's most challenging landscapes.

Today, however, pastoral systems face unprecedented pressures. Climate change is increasing the frequency and severity of droughts, while rising temperatures and uncertain rainfall patterns are intensifying risks to livestock, rangelands, and rural livelihoods. At the same time, limited mobility, rangeland fragmentation, market constraints, and longstanding socioeconomic inequalities have weakened the resilience of many pastoral communities. As a result, droughts increasingly translate into humanitarian crises, threatening lives, livelihoods, and development gains.

Recognising these challenges, IGAD and its Member States have long promoted a shift from emergency response toward resilience building. Initiatives such as the IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI) have strengthened investments in rangeland management, livestock development, cross-border cooperation, and sustainable natural resource governance. More recently, Anticipatory Action has emerged as a promising approach that enables governments and partners to act before drought impacts escalate, using early warning information to protect livelihoods, reduce losses, and strengthen resilience.

This book makes a timely and significant contribution to this agenda. Drawing on evidence from pastoral and agropastoral communities in selected IGAD clusters, it examines livestock economies, drought risk, household vulnerability, and the economics of anticipatory action. The analysis demonstrates the value of integrating climate information with socioeconomic indicators such as livestock ownership, market participation, inequality, and adaptive capacity to improve risk analysis, targeting, and decision-making.

The findings presented in this volume reinforce the case for proactive investment in resilience and risk management. They demonstrate that well-designed anticipatory interventions can protect productive assets, reduce humanitarian needs, and generate significant economic returns. Equally important, the study highlights the diversity of pastoral systems across the region and the need for context-specific approaches tailored to local realities.

As climate risks continue to intensify, the future of pastoralism will depend on our collective ability to anticipate shocks, strengthen adaptive capacity, and invest in

sustainable livelihood systems. This publication provides evidence and practical insights to help policymakers, development practitioners, humanitarian actors, and researchers advance that goal.

On behalf of IGAD, I commend the authors, researchers, and partners whose efforts made this work possible. I believe this publication will support more informed policies, stronger early warning systems, and more effective anticipatory actions that enhance the resilience and prosperity of pastoral and agropastoral communities across the IGAD region.

H.E. Dr. Workneh Gebeyehu
Executive Secretary
Intergovernmental Authority on Development (IGAD)

ACKNOWLEDGEMENTS

The Intergovernmental Authority on Development (IGAD) sincerely appreciates all individuals and institutions that contributed to this study on drought risk, vulnerability, and anticipatory action in drought-prone pastoral and agro-pastoral areas of the IGAD region. We are particularly grateful to the national and sub-national authorities across the Karamoja, Mandera, and Moyale clusters for their support during the planning and implementation of the fieldwork. Their cooperation facilitated access to study sites and enriched the study with valuable contextual insights.

We extend our deepest appreciation to the pastoral and agro-pastoral households who generously shared their time, experiences, and knowledge. Their willingness to participate in the survey provided the evidence base for this analysis and contributed significantly to a better understanding of drought vulnerability, resilience, and livelihood dynamics in the region.

We acknowledge the dedication and professionalism of the enumerators, supervisors, and data management teams who conducted the household surveys under challenging field conditions across multiple countries. Their commitment ensured the collection of high-quality and reliable data.

We further extend our sincere appreciation to Dr. Asfaw Muleta, the lead researcher of this work, and to Dr. Guyo Roba, Dr. Dereje Wakjira and Christine Jeptoo, whose methodological guidance, analytical support, and constructive feedback were invaluable throughout the research and writing process. We also acknowledge Ahmed Mohamoud for his effective coordination and support in facilitating the study. Their collective contributions significantly enhanced the quality, rigour, and relevance of this work. We also thank Samuel Derbyshire for his thorough technical review and insightful comments, which strengthened the analysis and further improved the overall quality of this book.

This work was carried out with financial support from the UK Government's Foreign, Commonwealth & Development Office and the International Development Research Centre, Ottawa, Canada as part of the Climate Adaptation and Resilience Program (CLARE).

Finally, IGAD expresses its gratitude to all development partners and stakeholders supporting efforts to strengthen drought resilience, climate adaptation, and anticipatory action in the Horn of Africa. The evidence and insights presented in this book are intended to inform evidence-based policies, programmes, and investments that strengthen preparedness, protect livelihoods, and build resilience among pastoral and agro-pastoral communities across the region.

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ACRONYMS AND ABBREVIATIONS

AA	Anticipatory Action
BCR	Benefit–Cost Ratio
ENB	Expected Net Benefit
EWS	Early Warning Systems
FAO	Food and Agriculture Organization of the United Nations
FEWS NET	Famine Early Warning Systems Network
FSNWG	Food Security and Nutrition Working Group
GHACOF	Greater Horn of Africa Climate Outlook Forum
HDDS	Household Dietary Diversity Score
I\$	International Dollar
ICPAC	IGAD Climate Prediction and Application Centre
ICPALD	IGAD Centre for Pastoral Areas and Livestock Development
IGAD	International Authority on Development
IPCC	Intergovernmental Panel on Climate Change
MAM	March–May
OECD	Organisation for Economic Co-operation and Development
OND	October–December
PCA	Principal Component Analysis
PPP	Purchasing Power Parity
TLU	Tropical Livestock Units
UNDRR	United Nations Office for Disaster Risk Reduction
USD	United States Dollar
VaR	Value at Risk
WFP	World Food Programme

BACKGROUND



I.0 BACKGROUND

Livestock production is crucial to the livelihoods of over 200 million pastoralists and agro-pastoralists in arid and semi-arid regions worldwide (Rass, 2006). Pastoralism, a livelihood system practised across approximately 25 per cent of the global land area, contributes about 10 per cent of global meat production (Gertel and Le Heron, 2011). In the Horn of Africa, nearly 70 per cent of the rural population depends on livestock as their primary livelihood, supported by an estimated 473 million ruminants (International Authority on Development [IGAD]).

More broadly, around 50 million people in Sub-Saharan Africa (Rass, 2006) and approximately 30 million pastoralists in the Horn of Africa (IGAD) rely on pastoral production for their livelihoods and well-being. Beyond its importance to household survival, pastoralism also makes a significant contribution to national economies. For instance, it accounts for between 10 per cent and 50 per cent of agricultural Gross Domestic Product among IGAD Member States (IGAD, 2025).

The dryland production system, also known as arid and semi-arid areas, is increasingly conceptualised as a complex social-ecological system in which human activities actively shape ecosystems to generate goods and services that meet societal demands (Janssen et al., 2007; Kaufmann, 2007). Although rangelands in dryland areas are often characterised as natural ecosystems and described primarily in ecological terms, their current conditions result from long-term interactions among humans, livestock, and the environment.

In this context, human users should be understood not as external disturbances, but as integral drivers of rangeland dynamics. The complexity of dryland production systems arises from their inherently dynamic nature, characterised by both linear and non-linear interactions among multiple components (Folke et al., 2002). Consequently, understanding the development and sustainability of these social-ecological systems requires engagement with key concepts such as resilience, adaptive capacity, and transformation.

Production in dryland, primarily pastoral and agro-pastoral systems, is inherently adapted to rainfall variability, enabling it to absorb disturbances such as precipitation fluctuations while maintaining core functions. A fundamental principle of pastoral production systems is the use of strategies that address temporal and spatial variability by exploiting resource heterogeneity.

Mobility is central to this approach, allowing pastoralists to track and utilise dispersed and seasonally variable resources. Consequently, heterogeneity and mobility constitute two defining characteristics of pastoral systems. In addition to mobility, diversification

is a key strategy, including maintaining different livestock species and pursuing complementary livelihood activities, which together enhance the efficient use of heterogeneous and variable resources.

While resilience is typically applied to describe the capacity of the system to absorb shocks and maintain function, vulnerability focuses on the condition of individual actors, particularly households. Vulnerability encompasses dimensions such as exposure, sensitivity or susceptibility, and adaptive capacity, providing a framework for understanding how different groups within the system experience and respond to environmental and socioeconomic stresses.

Climate change, as a major global environmental process, poses significant challenges to pastoral livestock production, particularly in dryland regions where livelihoods are closely tied to climate-sensitive resources. Its impacts are expected to directly affect fodder and water availability, which are critical for sustaining pastoral systems.

Projections for the Horn of Africa indicate a likely increase in average temperatures, along with greater variability and uncertainty in rainfall patterns (IPCC, 2022). These changes are expected to intensify the frequency and severity of drought events, with profound implications for pastoral livelihoods.

Frequent and severe droughts can significantly undermine the resilience of pastoral households, especially those whose herd sizes fall below the threshold required for viability. Such households are less able to recover from shocks, as livestock losses reduce both their productive assets and their coping capacity. For example, the recurrent droughts experienced in the Horn of Africa over the past decade have substantially hindered herd recovery, trapping many households in cycles of asset depletion and heightened vulnerability.

To reduce pastoral vulnerability to drought, several countries in the Horn of Africa have made several investments and taken diverse actions since 2012. One example is the IGAD Drought Disaster Resilience and Sustainability Initiative, developed in the wake of the devastating 2010-2011 drought in the Horn of Africa. It aims to end drought emergencies in the region through investments in strategic pillars of resilience—rangeland management and pasture development, securing regional and cross-border trade, and transboundary disease control. The programme implemented a variety of humanitarian and responses and long-term resilience building programmes, among others.

However, the vulnerability of pastoral and agro-pastoral communities in the Greater Horn of Africa cannot be understood solely through the lens of climate hazards. Contemporary drought impacts are deeply rooted in historical political and economic processes that have progressively constrained the traditional adaptive strategies of pastoral societies.

For centuries, mobility served as the cornerstone of pastoral resilience, enabling herders to respond to highly variable rainfall patterns through seasonal movements across extensive landscapes. However, colonial and post-independence policies often viewed mobility as backward, inefficient, or environmentally destructive, leading governments to promote sedentarisation, fixed settlements, and administrative boundaries that restricted access to traditional grazing areas and migration routes (Sandford, 1983; Fratkin, 1997; Homewood, 2008). Fragmentation of rangelands through state borders, conservation areas, large-scale agricultural schemes, and privatisation further reduced the flexibility that pastoralists historically relied upon to manage climatic uncertainty.

Development interventions have also often prioritised sedentary models of production and service delivery, often overlooking the ecological logic of mobile livestock systems in dryland environments. Investments in infrastructure, education, health services, and agricultural development have tended to favour settled populations, while pastoral areas received comparatively limited public investment and institutional support (Behnke & Scoones, 1993; Nori & Davies, 2007). As a result, many pastoral communities have faced chronic marginalisation, weak market integration, insecure land tenure, and limited access to essential services.

These structural inequalities have not only undermined adaptive capacity but have also increased sensitivity to drought and other shocks. Consequently, many of the crises observed today are not simply the product of climatic extremes; rather, they reflect the interaction between environmental stress and long-standing political, economic, and institutional constraints that have progressively weakened pastoral resilience (Devereux, 2006).

Disaster responses among pastoral and agro-pastoral communities in East Africa have traditionally been reactive, with resources mobilised mostly after shocks occur. While necessary during emergencies, this approach is often costly and can lead to greater livestock losses, asset depletion, and weakening of household resilience.

As a result, there is a growing shift toward Anticipatory Action (AA), which uses early warning information to trigger pre-planned and pre-financed interventions before hazards materialise. Anticipatory actions, including cash transfers, livestock feed support, water management, veterinary services, and private-sector-led livestock market interventions, help reduce losses, protect livelihoods, and strengthen community resilience. Despite increasing adoption, evidence on the economic efficiency and long-term benefits of anticipatory action, particularly in East African pastoral systems remains limited.

This book, compiled by ICPALD, helps address this gap by presenting socioeconomic analyses of anticipatory action, including economic valuation and cost-effectiveness assessments to inform policy, investment, and resilience-building efforts across pastoral regions.

The following chapters build progressively from an understanding of pastoral household asset bases to an assessment of climate-related risks and the economic rationale for resilience interventions.

Chapter 2 examines the livestock economy of pastoral and agro-pastoral households across the IGAD region, focusing on patterns of livestock ownership, herd composition, diversity, and off-take, and their implications for household wellbeing and livelihood security.

Chapter 3 profiles the climatic risks and vulnerabilities households face, developing drought hazard, exposure, sensitivity, adaptive capacity, and vulnerability indices to generate differentiated risk profiles across countries, livelihood systems, and gender groups.

Building on these findings, Chapter 4 evaluates the economic impacts of drought and assesses the potential benefits of anticipatory action using both deterministic and probabilistic ex-ante economic models.

The book concludes by synthesising the key findings and drawing out policy implications for strengthening drought resilience, supporting pastoral livelihoods, and promoting evidence-based investments in risk-informed development across the IGAD region.

1.1 The purpose and scope of the study

The study was conducted in selected drought-prone pastoral and agro-pastoral clusters within the IGAD region: the **Karamoja Cluster**, which spans parts of Uganda, Kenya, and South Sudan; the **Mandera Cluster**, covering border areas of Kenya, Ethiopia, and Somalia; and the **Moyale Cluster**, situated along the Kenya–Ethiopia border (see Figure 1).

The study areas were purposively selected on a combination of ecological, socioeconomic and operational considerations. These included a high dependence on pastoral and agro-pastoral livelihoods; recurrent exposure to drought and other climate-related shocks; low and highly variable rainfall; and the significant effects of climate variability on food security and household welfare.

The selected clusters also provide diverse ecological and socioeconomic conditions across the Horn of Africa. These are strategically important to regional early warning and anticipatory action initiatives.

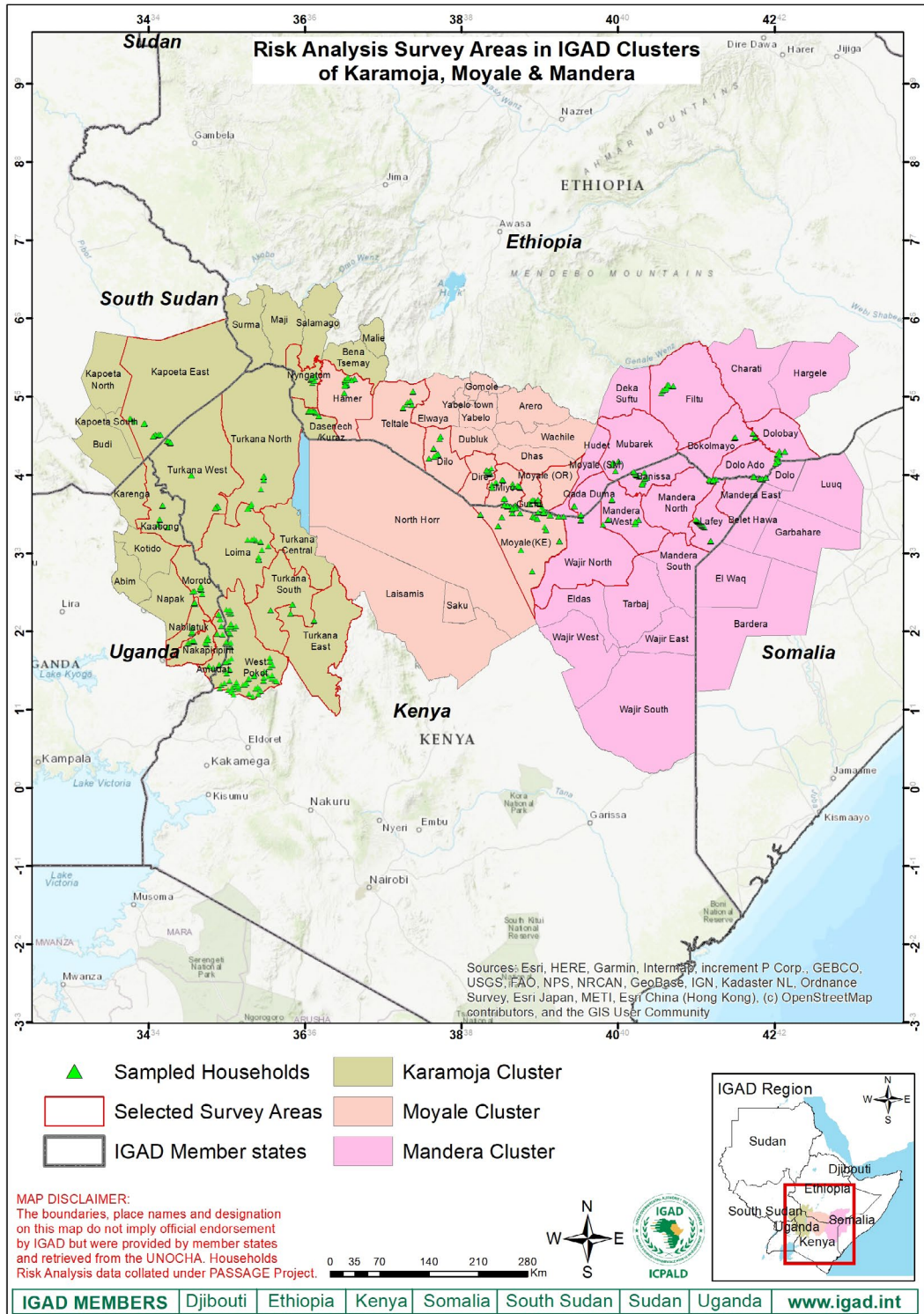


Figure 1: Study Area within Selected IGAD Cross-Border Clusters

1.2 Sampling and household survey

The study primarily relied primarily on household-level survey data collected across the three clusters to assess drought experiences, livelihood dynamics, and the impacts of climate variability on household welfare. The study, conducted between July and September 2025, employed a multi-stage cluster sampling approach designed to adequately represent pastoral and agro-pastoral communities across the selected study areas.

In the first stage, administrative units, including districts, counties, or sub-counties, with significant pastoral populations were purposively selected. Selection was guided by three main considerations: historical exposure to drought, concentration of pastoral households, and accessibility and logistical feasibility for field teams.

In the second stage, villages and settlements within each selected administrative units were identified as secondary sampling units. At the household level, respondents were selected using systematic sampling and/or stratified random sampling techniques. These approaches were applied to minimise selection bias while effectively capturing spatial and socioeconomic variations across the study areas.

A total of 1,155 households were surveyed, with the sample distributed across the three clusters. Sample allocation considered the population of the selected areas, the intensity of pastoral and agro-pastoral activities, and operational feasibility.

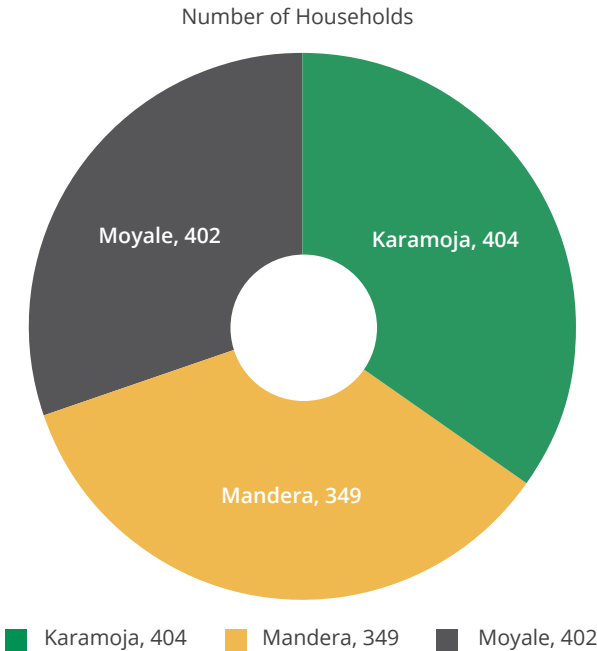


Figure 2: Sample allocation across the three clusters

1.3 Data collection

Primary data were collected using a structured household questionnaire administered digitally through the KoboToolbox platform. Digital data collection supported efficient, consistent fieldwork and incorporated built-in features to improve data accuracy and completeness.

The structured surveys collected information on household exposure to drought hazards, sensitivity to climate-related shocks, adaptive capacity, asset ownership, livestock and income losses, and coping and adaptation strategies. These data provided the basis for assessing household vulnerability and estimating the economic effects of drought on pastoral and agro-pastoral livelihoods.

1.4 Secondary data and analytical inputs

Secondary data were obtained from a range of sources to complement the household survey. These included published academic literature, programme evaluation and project reports, climate monitoring and drought forecasting systems, economic studies of drought impacts, and databases relating to early warning and anticipatory action.

These secondary data informed the analytical models and helped estimate key parameters, including, drought forecast probabilities, the Value at Risk (VaR) associated with drought impacts, the cost of implementing anticipatory actions, and the effectiveness of different anticipatory action interventions.

1.5 Methodological limitations

A key methodological limitation of this study is its reliance on households and individual livestock ownership as the primary units of analysis. While these units are widely used in humanitarian, development and economic research to facilitate data collection, analysis and targeting, they partially capture the social and institutional complexity of pastoral systems.

Pastoral livelihoods are embedded in broader kinship networks, reciprocal exchange arrangements and collective resource-management institutions that often extend beyond household boundaries. Livestock ownership is frequently shared, distributed or negotiated among extended family members, with herds managed across multiple locations and generations.

Similarly, access to grazing land, water, labour, and risk-sharing mechanisms is often organised through communal institutions rather than individual ownership structures. Consequently, a household-based analytical framework may underrepresent important dimensions of social protection, resource pooling, redistribution, and collective resilience that are central to pastoral adaptation. Furthermore, the concept of a household itself

can be difficult to define in pastoral contexts, where large and geographically dispersed family units may maintain complex social and economic relationships.

The overall findings should therefore be interpreted as an analytical approximation designed to facilitate comparison across countries, locations and livelihoods, while recognising that important aspects of pastoral organisation and resilience may not be fully reflected in household-level indicators alone. Data from Somalia were not available due to logistical and security constraints encountered during data collection.

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ECONOMIC DYNAMICS OF PASTORAL HOUSEHOLDS IN THE HORN OF AFRICA



Photo Credit: ICPALD

2.0 ECONOMIC DYNAMICS OF PASTORAL HOUSEHOLDS IN THE HORN OF AFRICA

2.1 Introduction

Pastoralism in the IGAD region operates amid significant uncertainty, driven by recurrent climate-induced droughts and volatile livestock markets that threaten the stability of pastoral livelihoods. The pastoral livestock economy is highly heterogeneous, characterised by unequal livestock ownership, widespread livestock poverty, varying herd compositions, and differing levels of market participation. Understanding these structural features is essential because they reveal patterns of vulnerability and resilience, helping to explain how households cope with shocks and how risks are distributed across pastoral populations.

As climate change intensifies, livestock-related indicators such as herd size, mortality rates, milk production, market prices, body condition scores, and livestock off-take have become increasingly important components of early warning systems. However, relying solely on environmental and production indicators can overlook underlying socioeconomic disparities. Information on livestock ownership distribution and inequality provides critical context for interpreting household sensitivity to shocks and anticipating the unequal impacts of drought and market disruptions. The chapter argues that integrating structural livestock economy indicators with conventional early warning information, including climate forecasts, vegetation conditions, rainfall anomalies, and conflict trends, can improve the accuracy and timeliness of risk analysis. Such integration is particularly important for anticipatory action mechanisms, which aim to protect livelihoods before crises escalate.

Households with small herds, limited species diversification, and weak market engagement are especially vulnerable to drought-related losses and are often forced into distress sales when resources become scarce. The analysis further shows that high levels of livestock ownership inequality can conceal growing vulnerability among poorer households, even when aggregate livestock numbers appear stable. Consequently, effective early warning and anticipatory action systems should incorporate both environmental and socioeconomic indicators to ensure that interventions are timely, targeted, and capable of protecting productive assets.

Overall, the chapter highlights that livestock ownership patterns, herd structures, and market participation strongly influence household welfare and resilience. Structural weaknesses such as livestock poverty, limited asset recovery capacity, and unequal asset distribution amplify the effects of climatic shocks and contribute to the transformation of droughts into humanitarian crises. By strengthening the integration of livestock economy data into risk analysis and early warning systems, the results advocate a shift from reactive emergency responses to proactive risk management that enhances resilience and safeguards pastoral and agro-pastoral livelihoods across the IGAD region.

2.2 Livestock ownership across the IGAD region

Livestock ownership is central to pastoral and agro-pastoral livelihoods across the IGAD region, serving as the primary source of income, food security, and social stability (FAO, 2018; Little et al., 2001). Frequency analysis of livestock ownership provides critical insights into the prevalence and distribution of different livestock species across countries, livelihood clusters, and gender groups (Homewood et al., 2009; McPeak & Little, 2017). Understanding who owns livestock and which types of livestock is essential for assessing household resilience, exposure to climatic and market shocks, and capacity to respond to crises (Ellis & Allison, 2004; Swift, 2008).

This section presents the results of a frequency analysis of livestock ownership among pastoral households in the IGAD cross-border areas. It highlights key variations across countries, clusters, and gender, and discusses implications for risk analysis, early warning systems, and anticipatory action planning (FAO & IGAD, 2016; Levine et al., 2011).

2.2.1 Overall livestock ownership patterns

Across the full sample of 1,155 households (Ethiopia: 453; Kenya: 552; South Sudan: 50; Uganda: 100), livestock ownership remains widespread but uneven.

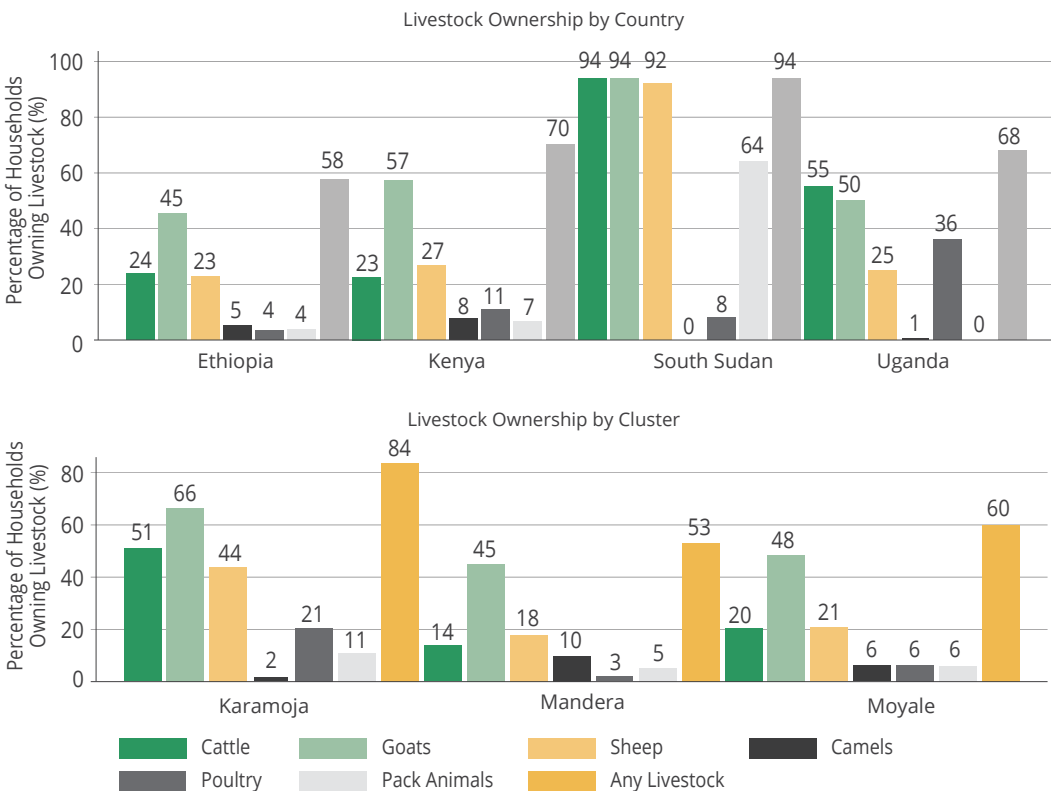


Figure 3: Livestock ownership among pastoral households in the IGAD cross-border areas

Overall, 66 per cent of households own at least one livestock species. Goats are the most commonly owned species (54 per cent of households), followed by cattle (29 per cent) and sheep (28 per cent). Camel ownership remains limited (6 per cent, as do pack animals (7 per cent) and poultry (10 per cent).

Cattle ownership in South Sudan is characterised by a high prevalence of absentee ownership, in which individuals, including urban elites, politicians, military officers, and businessmen, own livestock that are managed by others in rural areas. This pattern, widely documented in the literature, is recognised as an important feature of the country's livestock economy (Catley, A. (2018); Humphrey, et al 2023).

Country-level variation

Country-level patterns reveal stark differences:

- South Sudan shows near-universal ownership, with 94 per cent of households owning livestock. Ownership of cattle, goats, and sheep is similarly high, reflecting highly livestock-dependent livelihoods.
- Uganda reports 68 per cent overall ownership, with notably higher poultry ownership (36 per cent, indicating stronger crop–livestock integration and livelihood diversification.
- Kenya shows relatively high ownership (70 per cent), with goats (57 per cent) more prevalent than cattle (23 per cent).
- Ethiopia has lower overall ownership (58 per cent, with goats (45 per cent) again dominating cattle (24 per cent).

Cluster-level variation

The cluster-level analysis aligns with ecological gradients and livelihood systems:

- Karamoja: High livestock ownership (84 per cent), with strong presence of both goats (66 per cent and cattle (51 per cent), reflecting mixed pastoralism.
- Mandera: Moderate ownership (53 per cent), with higher camel ownership (10 per cent), consistent with adaptation to arid conditions.
- Moyale: Moderate ownership (60 per cent), dominated by goats (48 per cent) and lower cattle ownership (20 per cent), characteristic of semi-arid agro-pastoralism.

Herd variation

These ownership patterns reflect interaction among ecology, culture, market access, and livelihood strategies across the IGAD cross-border region. The dominance of goats across the sample underscores the strategic importance of small ruminants for risk

management in semi-arid and arid environments. Goats tolerate feed scarcity, reproduce quickly, and are easily sold in local markets, making them a critical buffer asset for households facing shocks.

The very high prevalence of cattle ownership in South Sudan highlights the social and economic centrality of large ruminants within pastoral systems. However, high ownership rates should not be automatically interpreted as resilience, as they do not capture herd size, composition in Tropical Livestock Units (TLU), or distributional inequality within communities. Uganda's comparatively high poultry ownership reflects more diversified, mixed crop–livestock systems, where small, fast-reproducing animals provide quick returns for consumption and petty trade.

The cluster-level differences align closely with ecological conditions and cross-border dynamics. Karamoja's high incidence of both goats and cattle indicates persistent mixed pastoralism.

Mandera's higher camel ownership reflects adaptation to hyper-arid conditions and mobility-based livelihoods. Moyale, with moderate cattle and high goat ownership, typifies semi-arid agro-pastoral systems shaped by cross-border exchange between Ethiopia and Kenya.

The livestock ownership composition directly shapes household risk profiles. While goat ownership enhances drought resilience and recovery capacity, the heavy reliance on cattle increases drought vulnerability because of higher feed and water needs. Similarly, low ownership of poultry and pack animals limits diversification and coping options.

2.2.2 Livestock ownership pattern implications

Overall, these findings have substantial and practical implications for risk analysis and anticipatory programming.

First, livestock ownership incidence by species emerges as a readily measurable, low-cost indicator that can be integrated into early warning systems to improve vulnerability targeting. Routine monitoring of the proportion of households owning key species (cattle, goats, sheep, camels, and poultry) establishes a baseline against which asset depletion, distress sales, or restocking trends can be detected.

A sharp decline in the proportion of households owning livestock or specific species should be interpreted as an early signal of asset erosion and used to trigger scaled anticipatory responses.

Second, species-specific ownership patterns should guide the design of response packages. In areas with high goat ownership, interventions that sustain small ruminant productivity should be prioritised. These include targeted veterinary services, strategic feed and water provision for breeding stock, and improved market access. Goats are

particularly valuable because of their relatively rapid recovery rates and contribution to quick livelihood stabilisation.

Conversely, in cattle-dominated systems, especially where ownership prevalence is high, such as in South Sudan, anticipatory actions must focus on protecting high-value assets and maintaining market functionality. Measures such as pre-emptive vaccination, large-scale fodder reserves, negotiated mobility corridors, and market stabilisation strategies are critical to prevent distress sales that permanently erode household wealth.

Third, gender-sensitive targeting is essential. Female-headed households typically exhibit lower ownership incidence and smaller asset bases, making them particularly vulnerable. These households should be prioritised in early assistance triggers and supported through interventions tailored to their asset profiles.

Such interventions may include providing small ruminants or poultry, women-friendly veterinary outreach, access to microcredit or cash-for-work programmes, and enhanced support for women's market participation. These measures strengthen resilience efficiently, as small stock and poultry can quickly rebuild productive capacity.

Fourth, cluster- and country-level variations necessitate differentiated anticipatory thresholds and trigger mechanisms. A uniform trigger applied across the IGAD cross-border region would be ineffective. Instead, triggers should be calibrated to local ownership baselines and species vulnerabilities. For example, a 20 per cent reduction in goat ownership in a goat-dominant cluster may be as significant as a 5 per cent decline in cattle ownership in a cattle-dominant system.

Fifth, ownership incidence should be combined with complementary indicators to form multi-signal early-warning triggers. These include TLU per household, measures of asset distribution and inequality, livestock body condition scores, market prices, and mobility constraints.

While ownership incidence identifies asset access, TLU and distribution metrics reveal sufficiency and concentration, and market and body-condition indicators reflect asset viability. Together, these signals support anticipatory actions that are timely, proportionate, and efficient.

Finally, the findings underscore the importance of cross-border coordination. Livestock ownership and mobility frequently transcend administrative boundaries in pastoral systems. As such, early warning and anticipatory mechanisms must operate across borders, incorporating shared data systems, harmonised veterinary campaigns, and coordinated interventions in livestock corridors and dry-season grazing areas. This approach is essential for safeguarding herds and protecting pastoral livelihoods.

Overall, the frequency analysis of livestock ownership provides actionable and contextually rich intelligence for risk analysis and management by governments and humanitarian actors. When institutionalised within early warning systems and linked

to tailored, anticipatory interventions that are species-specific, gender-sensitive, and calibrated to local contexts, these indicators can help prevent irreversible asset loss, reduce humanitarian needs, and strengthen the resilience of pastoral communities across the IGAD cross-borderlands.

2.2.3 Herd size

The size and composition of livestock holdings are widely recognised as direct indicators of household resilience, adaptive capacity, and vulnerability (Ellis & Allison, 2004; McPeak & Little, 2017). Measuring livestock assets in TLU provides a standardised metric that enables comparison across species, production systems, and countries (Jahnke, 1982; FAO, 2011).

This section presents the results of analyses of household-level livestock holdings, disaggregated by country, sampled IGAD clusters, and gender, for targeted pastoral communities in Ethiopia, Kenya, South Sudan, and Uganda. Additional insights are drawn from cross-border clusters, including Karamoja, Mandera, and Moyale.

The findings offer empirical evidence on patterns of livestock asset distribution, highlighting structural inequalities and vulnerabilities, and providing a basis for the design of early warning systems and anticipatory actions that are responsive to local contexts and livelihood systems (Catley et al., 2013; Levine et al., 2011; FAO & IGAD, 2016).

The findings reveal that livestock holdings vary markedly across countries. South Sudan stands out with exceptionally large herds, averaging 233.12 TLU per household and 32.47 TLU per capita, reflecting a strong cattle-based pastoral system where livestock serve both economic and socio-cultural functions (see Table 1).

By contrast, Ethiopia (18.16 TLU per household) and Kenya (12.34 TLU per household) exhibit substantially smaller herd sizes, while Uganda (23.07 TLU per household) falls in between. Lower per capita holdings in Ethiopia (3.33 TLU) and Kenya (2.42 TLU) point to greater lower livestock assets which heightens household vulnerability to asset depletion during shocks.

Table 1: Average livestock holdings (in TLUs) of pastoral households by country, cluster, gender, and overall

Species	Country					Cluster			Gender	
	All	Ethiopia	Kenya	South Sudan	Uganda	Karamoja	Mandera	Moyale	Female	Male
Oxen bulls	1.83	2.12	0.11	13.15	2.68	3.57	0.69	0.25	1.34	1.98
Local cow	12.02	1.98	2.72	143.16	12.97	24.82	1.66	2.01	2.62	14.87
Crossbred cow	0.79	0.00	0.08	12.19	0.00	1.78	0.00	0.01	0.00	1.03
Local heifers	0.87	0.22	0.12	9.66	1.53	1.77	0.24	0.08	0.41	1.00
Crossbred heifers	0.02	0.03	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.02
Calves	0.19	0.08	0.04	1.05	0.93	0.41	0.03	0.02	0.06	0.24
Cattle, all	15.71	4.43	3.08	179.21	18.11	32.39	2.62	2.37	19.14	4.44
Sheep	2.21	0.87	0.72	24.06	0.83	4.17	0.93	0.47	0.74	2.66
Goats	8.00	9.62	5.81	23.21	3.80	6.18	8.81	9.95	5.50	8.76
Camels	2.41	3.15	2.59	0.00	0.21	0.20	7.91	1.28	3.31	2.13
Donkeys	0.50	0.08	0.12	6.61	0.00	0.97	0.14	0.11	0.13	0.61
Horses	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry	0.03	0.01	0.03	0.04	0.12	0.06	0.01	0.01	0.02	0.04
TLU per Household	28.87	18.16	12.34	233.12	23.07	43.97	20.40	14.19	14.14	33.34
TLU per Capita	4.64	3.33	2.42	32.47	3.07	6.50	3.89	2.60	2.60	5.26
N	764	261	388	47	68	338	185	241	178	586

Note: TLU is computed for households at least with one livestock.

TLU Conversion Factor: Oxen/Bull 1, Cow/local 0.7, Cow/cross 0.8, Heifers/local 0.5, Heifers/cross 0.6, Calves 0.25, Sheep 0.1, Goats 0.1, Camels 1.25, Donkey 0.5, Horses 0.8, Poultry 0.01.

The per capita figures are particularly important when assessing whether livestock holdings are sufficient to sustain pastoral livelihoods. Household- and per capita-based TLU are widely used as asset-based indicators of livelihood security and poverty in

pastoral systems. Evidence suggests that there are minimum herd-size thresholds below which pastoral households cannot sustain viable livelihoods. For example, studies in East Africa estimate that approximately 3–3.5 TLU per capita is required to maintain a predominantly pastoral or agro-pastoral livelihood.

Similarly, broader drylands analyses note that around 3.5 TLU per capita is needed to meet basic consumption needs, while actual averages are often far lower (for example, approximately 1.3 TLU per capita), indicating widespread structural vulnerability (Catley and Ayele 2021; de Haan 2016).

Households falling below the estimated livestock viability thresholds are considered as livestock-poor and are unlikely to meet minimum food and income requirements from livestock production alone. As a result, they face elevated risks of distress sales, asset depletion, and livelihood collapse during climatic or market shocks. Identifying such households and locations is therefore important for prioritising early warning and anticipatory response systems.

Significant heterogeneity also emerges at the cluster level. Karamoja records the highest average herd size (43.97 TLU per household), consistent with the persistence of pastoral livelihoods despite recurrent shocks and insecurity. Mandera follows with 20.40 TLU, while Moyale has smaller average holdings (14.19 TLU). These differences reflect both ecological conditions and the influence of cross-border livestock trade networks on accumulation and off-take patterns.

Overall, the livestock composition is heavily skewed toward cattle, particularly in South Sudan, where households hold an average of 179.21 cattle TLU, driving the country's exceptionally high total livestock holdings. In contrast, households in Ethiopia and Kenya maintain smaller cattle herds (4.43 and 3.08 TLU, respectively) and rely more on small ruminants—especially goats (9.62 TLU in Ethiopia and 5.81 TLU in Kenya)—which are better adapted to arid conditions.

Camels are concentrated in Mandera (7.91 TLU) and, to a lesser extent, Ethiopia (3.15 TLU), but are largely absent in South Sudan and Uganda, highlighting ecological and cultural specialisation. Sheep serve as an important secondary species, particularly in South Sudan (24.06 TLU) and Karamoja (4.17 TLU), contributing to dietary and income diversification. Although donkeys and poultry constitute only a small share of total TLUs, they respectively play critical roles in transport and household nutrition, especially among low-asset households.

The TLU patterns reveal important structural and ecological determinants of pastoral resilience across the IGAD region. The dominance of cattle in South Sudan and the prevalence of goats and camels in Ethiopia, Kenya, and Mandera reflect a clear ecological gradient from relatively humid to increasingly arid zones, alongside adaptive livelihood strategies. Larger herd sizes in South Sudan and Karamoja suggest greater potential wealth; however, they also mask significant inequality and risk exposure. In

such contexts, a small number of households with very large herds can inflate average TLUs, while poorer households remain highly vulnerable with sub-viable herd sizes.

Livestock composition plays a critical role in shaping risk exposure. Cattle-based systems are highly sensitive to drought and water scarcity but can generate higher returns under favorable conditions. In contrast, systems dominated by camels and goats tend to be more drought-resilient. However, they often yield lower economic returns and remain vulnerable to disease outbreaks and market price volatility.

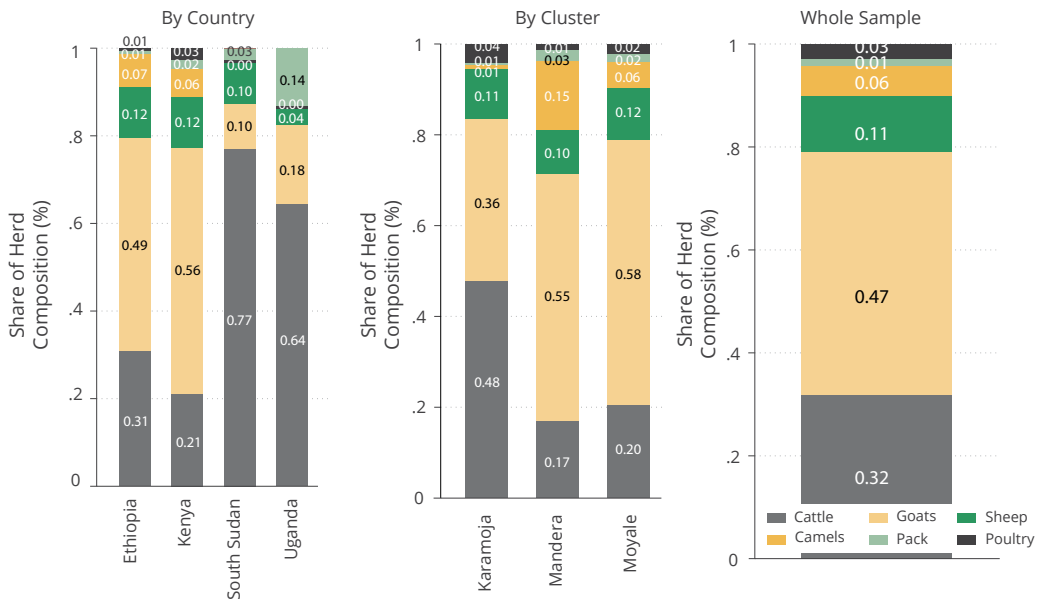
Although the study showed limited diversification in several clusters, the data represents a snapshot in time and should not be interpreted as a static picture of livestock-keeping practices. Pastoralists are well-aware that changing weather patterns and ecological dynamics require different approaches. This adaptability is a defining feature of pastoralism, which evolves in response to changing environmental, economic, and social conditions.

Gender disparities in TLU holdings have major implications for vulnerability. Female-headed households typically possess significantly fewer livestock assets, limiting their ability to absorb and recover from shocks. They also face constrained access to grazing resources, labour for herd mobility, extension services, and market information. These structural disadvantages amplify their exposure during droughts, market disruptions, and disease outbreaks, underscoring the need for gender-sensitive early warning indicators and anticipatory interventions.

2.2.4 Herd composition

Livestock herd composition is a fundamental determinant of income generation, food security, risk management, and resilience to climatic and economic shocks for pastoral and agro-pastoral households in the IGAD cross-borderlands (FAO, 2018; McPeak & Little, 2017). The types and diversity of livestock species households maintain reflect both ecological conditions and culturally embedded production preferences, with different species conferring distinct advantages and resilience under variable environmental and market conditions (Homewood, Kristjanson, & Trench, 2009; Scoones, 1995). Consequently, herd composition offers a critical lens for assessing household exposure, coping capacity, and adaptive strategies amid recurrent droughts, disease outbreaks, and price fluctuations (Ellis & Allison, 2004; Swift, 2008; Little et al., 2001).

As such, examining household herd composition across countries, livelihood clusters, and gender groups can reveal how livestock assets are distributed, how pastoral households actively manage risk, and where structural vulnerabilities are concentrated. Moreover, shifts in herd structure such as reductions in cattle holdings or increased reliance on small ruminants often serve as early indicators of stress or adaptation. These dynamics can inform timely and targeted interventions to protect livelihoods and sustain pastoral production systems. Such evidence is central to effective risk analysis, early warning, and anticipatory action planning.



Source: Household Survey Data.

Figure 4: Household herd composition by country, cluster, and whole sample

The analysis of household herd composition across the IGAD cross-border regions reveals marked heterogeneity in livestock-species distribution, reflecting both ecological adaptations and cultural preferences. Overall, goats constitute the largest share of household herds at 47 per cent, followed by cattle (32 per cent), sheep (11 per cent), camels (6 per cent), poultry (3 per cent), and pack animals (1 per cent) (Figure 4). This distribution highlights the prominence of small ruminants—particularly goats—in pastoral and agro-pastoral livelihood systems. Their dominance is especially evident in arid and semi-arid environments, where goats show greater resilience to drought and limited forage availability than larger livestock species.

Country-level results reveal notable differences in herd composition across the study areas. In South Sudan, cattle dominate (77 per cent), underscoring their strong cultural and economic importance, while goats make up only 10 per cent. In contrast, Kenya and Ethiopia exhibit a more balanced distribution. Goats account for 56 per cent and 49 per cent of total livestock holdings, respectively, while cattle make up a smaller share. Uganda presents a distinct profile: although poultry constitutes a relatively significant portion (14 per cent) compared to other countries, cattle remain present but are less dominant than in South Sudan. Camels are largely confined to specific locations in northern Kenya, Mandera (15 per cent) and Moyale (6 per cent), reflecting their suitability to drier environments.

Cluster-level analysis further highlights localised patterns. Moyale records the highest proportion of goats (58 per cent), with cattle accounting for a smaller share (20 per cent), consistent with its ecological conditions and grazing practices. Karamoja displays

more diversified herd structures, with relatively higher proportions of cattle (48 per cent) and goats (36 per cent). Mandera, by contrast, shows a strong presence of camels (15 per cent) alongside goats (55 per cent), emphasising adaptation to arid conditions and reliance on drought-resilient species.

Gender-disaggregated findings indicate clear differences in livestock ownership patterns. Female-headed households tend to maintain higher proportions of goats (52 per cent) and poultry (5 per cent), while male-headed households hold larger shares of cattle (35 per cent) and camels (5 per cent). This suggests that female-headed households prioritise smaller, more manageable livestock that require fewer resources and reproduce more quickly. In contrast, male-headed households are more likely to invest in larger livestock species that demand greater capital, grazing space, and management capacity.

Herd composition plays a critical role in shaping livestock inequality and market participation across IGAD cross-borderlands. Regions dominated by cattle often exhibit higher levels of wealth inequality because large ruminants are high-value and concentrated in ownership. In contrast, goat-dominated systems tend to provide more equitable access to livestock assets, as goats are relatively affordable and widely owned. These disparities are further shaped by gendered patterns in species ownership, highlighting the importance of including female-headed households in risk analysis and programme design. Women's reliance on small livestock species necessitates targeted interventions to sustain herd viability, particularly during periods of crisis.

Across IGAD cross-borderlands, household herd composition reflects a dynamic interplay of environmental, cultural, and economic factors. Goats are the most ubiquitous species, valued for their drought resilience and capacity for rapid reproduction and herd recovery. Cattle remain central in areas with adequate grazing resources and strong cultural attachment, while camels are concentrated in more arid zones due to their superior drought tolerance. Poultry also plays an important role, particularly among female-headed households, contributing to household nutrition and income diversification. These patterns illustrate how households strategically balance their livestock portfolio, market engagement, and reproductive potential through a diversified livestock mix.

Herd composition directly affects livelihood resilience. Households maintaining diversified herds, that combine small and large ruminants tend to exhibit greater adaptive capacity to shocks. Conversely, reliance on a single species increases vulnerability to species-specific risks, such as disease outbreaks or prolonged drought. Gender-differentiated ownership patterns further influence resilience, as they shape access to income streams and coping strategies during stress periods.

Understanding herd composition is therefore essential for effective risk assessment and early warning systems. Shifts in species proportions, such as declining cattle populations or increased dependence on goats, can signal emerging ecological stress, drought impacts, or distress-driven asset depletion. Identifying these trends enables

timely and targeted interventions. For instance, areas with high concentrations of drought-sensitive species require anticipatory measures such as feed supplementation, water provision, and veterinary support to prevent large-scale herd losses.

Furthermore, herd composition informs broader livelihood diversification and development strategies. Cattle- and camel-dominated systems often benefit from investments in market infrastructure, veterinary services, and rangeland management. In contrast, goat-dominated systems require support mechanisms that enhance reproductive performance, disease control, and rapid market integration to maximise returns.

2.2.5 Livestock diversity indices

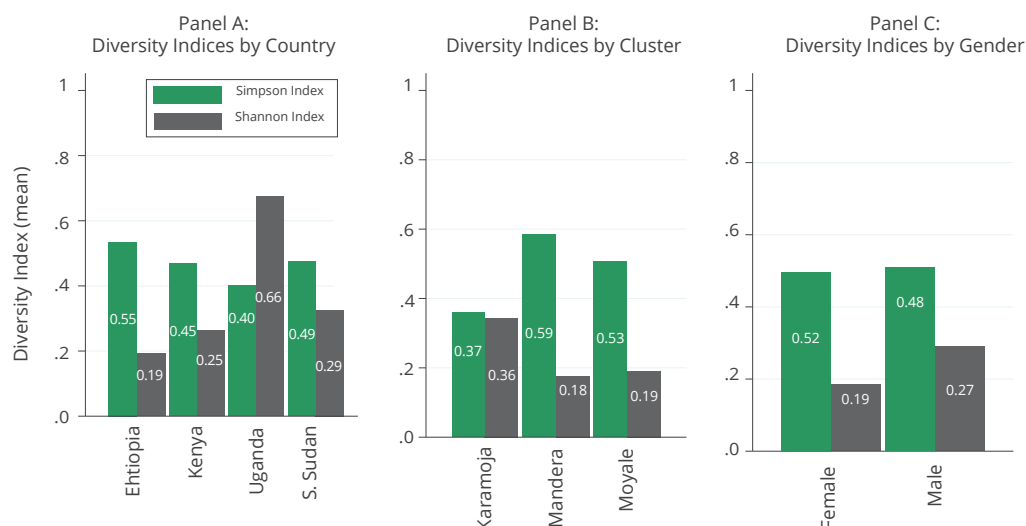
Variations across countries and livelihood clusters further illuminate how ecological conditions and production systems shape herd composition. In arid and semi-arid areas where rainfall is highly variable, households tend to maintain more diversified herds, combining drought-tolerant species such as camels and goats with cattle and sheep. This is reflected in relatively higher Shannon Index values, which are more sensitive to the presence of multiple species even when their proportions differ (see Figure 5).

In contrast, areas with relatively better pasture or more secure water access often exhibit lower diversity, as households specialise in cattle or small ruminants depending on market preferences and cultural norms. While such specialisation may enhance short-term productivity or income, it reduces the capacity of households to adapt to shocks, particularly during prolonged droughts when dominant species are more likely to experience significant mortality.

However, measuring adaptation is not straightforward, as adaptation is inherently a longer-term process that is not necessarily triggered by a single shock. Furthermore, pastoral production systems are highly dynamic, with herders continuously adjusting their strategies in response to evolving circumstances. Livestock portfolios can change rapidly, with households shifting toward small ruminants or other preferred species as part of their adaptive responses to environmental, economic, or social pressures.

Differences also emerge across livelihood clusters, highlighting the role of economic orientation and mobility patterns. Fully pastoral clusters, characterised by mobility and reliance on extensive grazing systems, generally show higher livestock diversity. This reflects a deliberate risk-spreading strategy, where households manage a mix of species with complementary grazing behaviours and resilience traits.

Agro-pastoral and peri-urban clusters, however, tend to exhibit lower diversity, often focusing on one or two species that align with crop integration or market demand. These systems may benefit from greater market access or supplementary income sources. However, their reduced herd diversity can increase vulnerability to livestock-specific shocks, such as disease outbreaks affecting a dominant species.



Indices measure livestock diversity, higher values imply greater diversity.

Figure 5: Distribution of livestock diversity indices across groups

Across countries, Ethiopia exhibits the highest Simpson Index (0.55), indicating relatively diversified livestock herds. This likely reflects the country's wide ecological and cultural diversity, which supports multiple species such as cattle, goats, sheep, and camels. Kenya follows with a Simpson Index of 0.45, suggesting moderate diversification, while South Sudan records the lowest value (0.40), indicating a stronger concentration of livestock ownership in a few species—primarily cattle. Uganda, with a value of 0.49, shows a relatively balanced level of diversification, close to the overall average.

The Shannon Index offers a complementary perspective by emphasising the evenness of species distribution rather than just diversity. The overall average Shannon Index across households is 0.25, pointing to generally uneven herd compositions. However, country-level variation is notable. South Sudan records the highest Shannon value (0.66), suggesting a more even distribution of livestock species despite lower overall diversification. This indicates that, although households in South Sudan may own fewer species, those species are more evenly represented within herds. In contrast, Ethiopia (0.19) and Kenya (0.25) exhibit lower Shannon values, reflecting herd structures dominated by a few key species, particularly cattle and goats. Uganda (0.29) demonstrates moderate evenness.

At the cluster level, Mandera stands out with the highest Simpson Index (0.59), indicating substantial livestock diversification. This pattern likely reflects adaptation to variable ecological and market conditions, where maintaining multiple species helps spread risk. Moyale follows with a Simpson value of 0.53, while Karamoja has the lowest (0.37), suggesting a narrower species composition dominated mainly by cattle and goats.

In contrast, the Shannon Index shows Karamoja as having the highest evenness (0.36), followed by Moyale (0.19) and Mandera (0.18). This suggests that although Mandera and Moyale have more diverse herds, they are numerically dominated by one or two species. Karamoja, despite its lower overall diversification, maintains a more balanced distribution among the species it does have.

Gender-disaggregated analysis adds another critical dimension to the findings. Female-headed households typically display lower livestock diversity compared to male-headed households. This pattern reflects structural constraints such as limited access to capital, grazing resources, and livestock markets, which limit women's ability to invest in and manage multiple species.

In many pastoral societies, cultural norms also shape livestock ownership and decision-making, often assigning priority species such as cattle or camels to men. At the same time, women may own smaller and less diversified herds. As a result, female-headed households are often more exposed to risk, as their herds lack the buffering capacity provided by species diversity. However, in some contexts, women's preference for small ruminants—due to their faster reproduction and easier management—can provide some resilience, particularly in rapidly changing environments.

Gender differences in livestock diversity appear relatively modest, though subtle variations exist in both species composition and distribution. The Simpson Index is slightly higher for male-headed households (0.52) than for female-headed households (0.48), indicating that men tend to manage more diversified herds overall. This pattern may reflect men's relatively greater access to grazing areas, higher mobility, and ownership of larger herds.

In contrast, the Shannon Index is marginally higher among female-headed households (0.27) compared to male-headed households (0.19). This suggests that, despite owning fewer livestock species, women maintain a more even distribution across the species they manage. Female-headed households may therefore prioritise a balanced livestock portfolio—particularly small stock such as goats, sheep, and poultry—which are often better suited to generating regular income and enhancing household food security under resource-constrained conditions.

The observed country-level differences reflect distinct ecological, cultural, and livelihood contexts. Ethiopia's relatively high diversification suggests adaptive herd management strategies that incorporate a wide range of livestock species suited to varied altitudinal zones and production systems. Kenya's moderate diversification is consistent with a semi-arid pastoral economy where goats and camels play a critical role in enhancing resilience to recurrent droughts.

In contrast, South Sudan's lower Simpson Index, despite a higher Shannon value, indicates a relative concentration in cattle-based livelihoods. This pattern points to a potential vulnerability, as cattle are less drought-tolerant and depend heavily on

extensive pasture and reliable water resources. Uganda's comparatively balanced indices, meanwhile, reflect its mixed crop–livestock systems, supported by relatively better access to water and grazing resources.

At the sub-national level, cluster-based variations further underscore how geography and livelihood specialisation shape diversification patterns. Mandera's high Simpson Index suggests herders actively diversify across multiple species, likely in response to repeated exposure to drought and conflict, thereby spreading risk more effectively.

In contrast, Karamoja's low Simpson but high Shannon values indicate herds concentrated in fewer species, yet with relatively even distribution among them. This pattern reflects more homogeneous production systems, where limited diversification may constrain adaptive capacity despite some degree of balance within existing livestock types.

Together, these findings underscore the importance of livestock diversity as both an indicator and a determinant of resilience in pastoral systems. Moderate overall diversity (Simpson Index of 0.49) suggests that while diversification strategies are present, they are not sufficiently robust to fully mitigate climatic and economic risks.

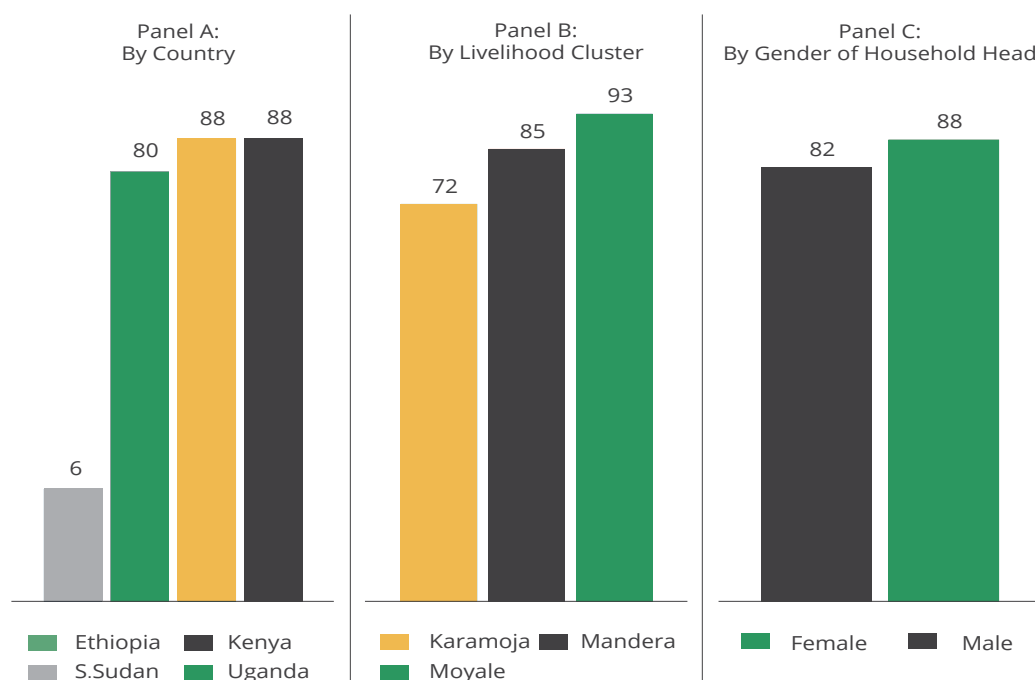
This has important implications for policy and programming. Interventions aimed at strengthening pastoral resilience should not only support herd recovery after shocks but also promote strategic diversification, including access to a wider range of species, veterinary services tailored to multi-species systems, and markets that accommodate diverse livestock products.

2.3 Herd ownership discrepancies

Decades of recurrent droughts, environmental degradation, conflict, and restricted mobility have progressively eroded household livestock assets, pushing many pastoralists below the viability threshold required to sustain traditional pastoral production systems (Homewood et al., 2009; McPeak & Little, 2017; Swift, 2008).

The concept of livestock poverty, defined as the condition in which households own livestock below the minimum level necessary to meet subsistence needs or recover from shocks, provides a critical lens for assessing vulnerability and resilience in dryland economies (Barrett, Carter, & Ikegami, 2013; Catley et al., 2013).

Measuring the proportion of livestock-poor households therefore offers a valuable quantitative indicator of livelihood fragility and enables a deeper understanding of patterns of inequality, risk exposure, and adaptive capacity across diverse socio-ecological contexts (Ellis & Allison, 2004; Scoones, 1995). In risk analysis and early warning, livestock asset holdings are both a determinant and a predictor of resilience.



Source: Author's computation based on pastoral household survey data.

Figure 6: Distribution of livestock-poor households by country, cluster, and gender

The analysis of livestock poverty across IGAD cross-border areas reveals a critical level of asset deprivation among pastoral and agro-pastoral households. On average, 83 per cent of households are classified as livestock-poor, indicating that the vast majority possess herd sizes below the minimum threshold required to sustain viable pastoral livelihoods or generate adequate income from livestock production. This highlights a systemic vulnerability in livestock-dependent economies, where insufficient asset ownership undermines resilience to shocks, particularly drought.

Disaggregation by country reveals significant regional disparities. Ethiopia and Kenya exhibit the highest proportions of livestock-poor households, both at 88 per cent, indicating widespread and deeply entrenched livestock asset poverty. In these contexts, most households operate at or below subsistence levels, with herd sizes too small to provide reliable income or buffer climatic shocks. This suggests chronic difficulties in herd accumulation and recovery, likely compounded by recurrent droughts, rangeland degradation, and limited access to services and markets.

Uganda also shows a high level of livestock poverty at 80 per cent, reflecting similar structural constraints. The relatively lower figure than in Ethiopia and Kenya may indicate variation in livelihood systems; however, most households still face substantial challenges in rebuilding or maintaining productive herds.

In contrast, South Sudan stands out with only 6 per cent of households classified as livestock-poor, presenting a stark divergence from the regional trend. This outcome may reflect the persistence of large herd ownership among pastoral communities, where livestock retain strong economic, social, and cultural significance. Households that remain within pastoral systems often maintain substantial livestock assets despite prolonged instability.

However, this finding should be interpreted with caution. The low incidence of livestock poverty in South Sudan may mask underlying inequalities and data limitations. This analysis likely captures primarily settled or stable pastoral households, while excluding displaced or conflict-affected populations who may have lost their herds entirely. Furthermore, significant disparities between wealthy and poorer pastoral households may persist but remain obscured in aggregate statistics.

Cluster-level differences provide critical insights into the spatial patterns of livestock asset inequality. The Moyale cluster has the highest proportion of livestock-poor households (93 per cent), highlighting extreme vulnerability among pastoral communities in this region. This situation reflects the cumulative effects of recurrent droughts, land degradation, and shrinking grazing areas, all of which have significantly eroded livestock assets.

Similarly, the Mandera cluster records a high level of livestock poverty at 85 per cent, suggesting comparable livelihood stress driven by repeated climate shocks and insecurity. Although still heavily affected, the Karamoja cluster shows a relatively lower share of livestock-poor households (72 per cent) compared to the other clusters. This may indicate partial recovery in herd sizes, possibly associated with recent improvements in security conditions and increased livelihood diversification.

Gender-disaggregated results reveal a persistent gap in livestock asset ownership. Male-headed households are slightly more likely to be livestock-poor (88 per cent) than female-headed households (82 per cent), although both rates remain alarmingly high (Figure 7). The relatively lower incidence among female-headed households may reflect differences in herd composition, with these households often maintaining smaller but more resilient livestock such as goats and poultry.

These species are generally easier to manage and reproduce more rapidly. However, this does not necessarily imply greater overall welfare among female-headed households; rather, it underscores distinct livelihood strategies and adaptive responses to resource constraints.

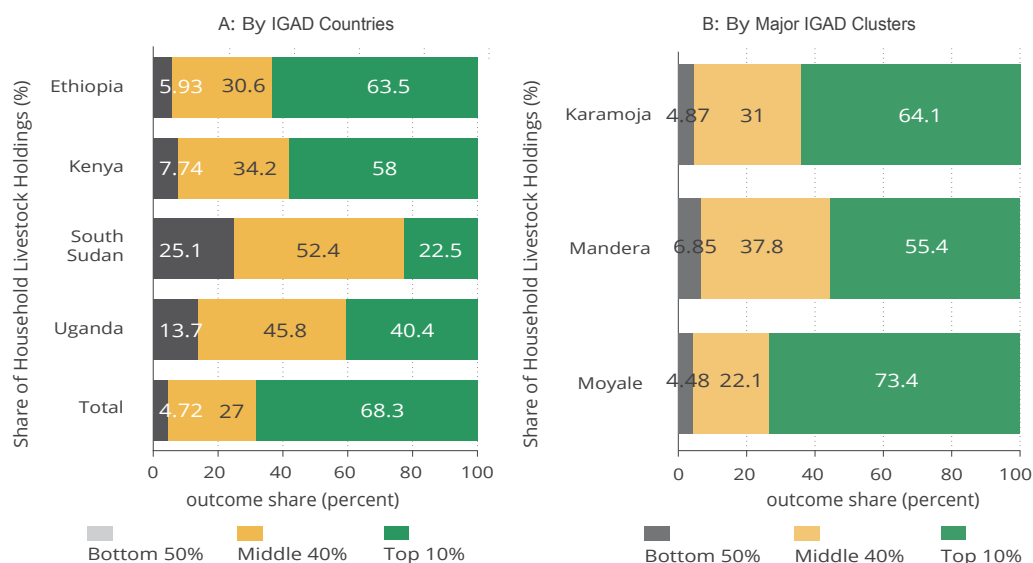


Figure 7: Inequality in household livestock holdings across percentile shares in IGAD countries and by clusters

Note: Under perfect equality, each household percentile (or quantile group) would own a share of total livestock equal to its share of the population. For instance, the bottom 50 per cent would own 50 per cent of total livestock holdings, the middle 40 per cent would own 40 per cent, and the top 10 per cent would own 10 per cent. Any deviation from this proportional pattern reflects inequality in livestock ownership.

Country-level disparities reflect differences in ecological conditions, conflict exposure, and levels of livelihood diversification. The high rates of livestock poverty in Ethiopia and Kenya likely stem from prolonged drought cycles, rangeland degradation, and reduced mobility from land fragmentation and tightening border restrictions.

In Uganda, elevated livestock poverty may be linked to policy-driven population pressures and a gradual shift toward mixed farming systems, where livestock play a supplementary rather than central role. By contrast, South Sudan's lower proportion of livestock-poor households appears to reflect a concentration of livestock assets within a smaller pastoral elite, pointing to inequality rather than broad-based resilience.

Cluster-level findings further highlight the spatial concentration of vulnerability. Moyale and Mandera—arid cross-border zones between Kenya and Ethiopia—emerge as critical hotspots of livestock poverty. These areas are characterised by recurrent drought, persistent insecurity, and disruptions to cross-border trade, all of which limit households' ability to rebuild and sustain herds. Karamoja, although still facing significant poverty, shows indications of gradual recovery, possibly due to sustained government and development interventions focused on restocking, livelihood diversification, and peacebuilding.

Gender dynamics add another layer of complexity. While both male- and female-headed households experience severe asset poverty, their vulnerability profiles differ. Higher livestock poverty among male-headed households may reflect the collapse of larger herds due to repeated drought and conflict shocks. In contrast, female-headed households often rely on smaller, more resilient species, which may be more manageable under constrained conditions. These differences underscore the importance of considering gendered herd composition and mobility patterns in designing targeted resilience interventions.

Overall, the analysis points to widespread and deep livestock asset poverty across IGAD cross-border areas, posing a serious threat to the sustainability of pastoral livelihoods. The finding that 83 per cent of households are livestock-poor signals a fundamental erosion of the traditional pastoral risk management system, which historically relied on herd accumulation and mobility. This asset depletion undermines not only household food security and income stability but also the capacity of communities to withstand and recover from climatic and market shocks.

The pronounced geographical disparities further reveal localised zones of acute vulnerability, particularly in Moyale and Mandera, where pastoralism faces existential pressures. Meanwhile, South Sudan's relatively lower livestock poverty rate highlights the importance of context-specific dynamics, especially in settings where pastoralism remains culturally embedded and livestock ownership continues to serve as a key marker of wealth, security, and social status.

2.4 Livestock off-take

Livestock commercial off-take is a key indicator of market integration and economic resilience within pastoral systems (Little, McPeak, Barrett, & Kristjanson, 2008). High off-take rates generally reflect well-functioning livestock markets and the capacity of households to convert animals into cash or other resources without compromising herd sustainability (Barrett, Bellemare, & Osterloh, 2006; McPeak & Little, 2017). In contrast, low off-take levels may signal weak market participation, subsistence-oriented herd management, or distress-driven behaviour during crises (Fratkin & Roth, 2005;).

A critical distinction in off-take analysis lies between gross and net measures. Gross commercial off-take refers to the total number of animals sold, while net commercial off-take accounts for sales minus purchases, providing a more accurate representation of herd dynamics and commercialisation levels (Jahnke, 1982; FAO, 2011).

Understanding livestock off-take patterns across countries, livelihood clusters, and gender groups in the IGAD cross-borderlands is essential for strengthening early warning and anticipatory action systems (Levine, Ludi, & Jones, 2011; FAO & IGAD, 2016). Variations in off-take rates can signal early stress or recovery in pastoral economies (Little et al., 2001; McPeak & Barrett, 2001). For example, a sharp decline

in off-take may indicate constrained market access or declining livestock conditions, whereas unusually high off-take levels may reflect distress sales triggered by shocks such as drought or insecurity (Barrett et al., 2006; Catley et al., 2013).

The results indicate that the average gross commercial off-take rate across IGAD cross-border households is 15 per cent, while the net off-take rate is only 8 per cent. This gap implies that nearly half of livestock sales are offset by purchases, suggesting that although pastoral households engage in livestock markets, their participation remains limited and largely geared toward short-term consumption and coping needs rather than sustained, market-oriented production.

At the country level, Ethiopia records the highest gross off-take rate (16 per cent) and a net off-take rate of 9 per cent, closely followed by Kenya (15 per cent gross and 9 per cent net). These relatively high rates point to more dynamic livestock trade and stronger market integration in both countries, supported by comparatively developed market infrastructure, established livestock corridors, and active cross-border trade networks (Figure 8).



Gross and Net Offtake in Percentage of Tropical Livestock Units (TLU) owned per household

Figure 8: Gross vs net livestock commercial off-take by country, cluster, and gender

Uganda presents a contrasting pattern, with the highest gross off-take rate (18 per cent) but a very low net off-take rate (2 per cent). This disparity suggests that while many animals are sold, purchases remain minimal, resulting in limited net gains from market engagement. This pattern may reflect distress-driven sales, where households are compelled to sell livestock in response to drought or economic stress, with limited capacity to reinvest in herd rebuilding. Alternatively, it could indicate a shift toward production systems in which livestock are less central, reducing incentives to reinvest in herd accumulation.

In contrast, South Sudan exhibits both low gross (4 per cent) and net (3 per cent) off-take rates, indicating very limited market participation. This pattern likely reflects the combined effects of prolonged conflict, weak infrastructure, and restricted access to functional livestock markets, all of which constrain regular sales and exchanges. Livestock holdings are therefore often maintained primarily for cultural, social, and security purposes rather than for commercial gain, reducing economic liquidity and limiting households' ability to respond to shocks through market-based strategies.

At the cluster level, off-take rates appear relatively uniform across study areas. Karamoja, Mandera, and Moyale all report gross off-take rates of approximately 15 per cent, with net off-take ranging from 7 to 9 per cent. This consistency suggests broadly similar market engagement across clusters, although the underlying dynamics differ. For example, Mandera's relatively higher net off-take rate (8 per cent) may reflect stronger market stability and better herd regeneration capacity. In contrast, Karamoja's slightly lower rate (7 per cent) may point to lingering constraints in market access and herd recovery following past episodes of drought and insecurity.

Gender-disaggregated results reveal modest but meaningful differences. Female-headed households report higher gross off-take rates (16 per cent) compared to male-headed households (13 per cent), possibly indicating greater reliance on livestock sales to meet immediate household needs such as food, healthcare, and education expenses. Despite this difference, both groups exhibit identical net off-take rates (8 per cent), suggesting similar overall levels of market engagement. This convergence masks important differences in motivation and constraints, with women potentially engaging in more frequent but smaller transactions, reflecting distinct livelihood strategies and access limitations.

2.5 Policy Implications

The findings show that pastoral vulnerability is shaped by drought exposure, but also by differences in livestock assets, herd composition, livestock poverty, market access and household characteristics. This has important implications for designing early warning systems, anticipatory action, and livestock development programmes.

1. Integrate structural livestock vulnerability into early warning and anticipatory systems

Early warning systems should move beyond monitoring climatic hazards alone and incorporate structural livestock indicators such as herd size, herd composition, livestock poverty, asset inequality, gender-disaggregated ownership and market access. Developing livestock vulnerability profiles would help identify households and areas most at risk and enable anticipatory interventions to be triggered before crises escalate. This represents a shift from monitoring hazards alone to monitoring their potential impacts on livelihoods and productive assets.

2. Target anticipatory interventions through context-specific and gender-responsive approaches

Anticipatory action mechanisms should be calibrated to local livestock production systems, asset distributions, and levels of inequality rather than relying on uniform regional thresholds. Particular attention should be given to livestock-poor household to help protect and, where necessary, rebuild their productive assets before and during drought. Interventions should also recognise differences in herd composition and support appropriate livestock diversification where it is economically and ecologically viable. Gender-responsive approaches should address differences in livestock ownership and ensure the participation of women in decision-making.

3. Strengthen livestock market systems and regional coordination to protect livestock assets

Resilience investments should focus on maintaining livestock productivity and market functionality before crises occur through measures such as feed support, veterinary services, strategic off-take, improved market access, mobility support and appropriate financing. Given the transboundary nature of pastoral systems, regional coordination on livestock monitoring, trade, mobility, disease control, and grazing management is also essential. These measures can help protect productive assets and enable countries move from reactive crisis response towards coordinated, asset-protection approaches to pastoral resilience.

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PROFILING CLIMATIC RISKS AND HOUSEHOLD VULNERABILITY IN PASTORAL AND AGRO-PASTORAL AREAS OF THE IGAD REGION



Photo Credit: ICPALD

3.0 PROFILING CLIMATIC RISKS AND HOUSEHOLD VULNERABILITY IN PASTORAL AND AGRO-PASTORAL AREAS OF THE IGAD REGION

3.1 Introduction

This chapter examines drought risk among pastoral and agro-pastoral households in the IGAD region, where livelihoods depend heavily on climate-sensitive livestock production systems. While pastoralism has traditionally served as an effective adaptation strategy to environmental uncertainty, increasing climate variability and the growing frequency of severe droughts are placing unprecedented pressure on the livelihoods, food security, and economic stability of households. The chapter emphasises that drought impacts cannot be understood solely through the lens of climatic hazards; rather, risk emerges from the interaction of drought exposure, household sensitivity, and adaptive capacity.

Drawing on the Intergovernmental Panel on Climate Change (IPCC) vulnerability framework, the chapter highlights that households highly dependent on livestock, with limited livelihood diversification, weak market access, and inadequate services, are generally more vulnerable to drought shocks. In contrast, adaptive capacity is strengthened through access to education, financial services, social networks, and institutional support systems that enable households to anticipate, withstand, and recover from climatic shocks. Although previous studies across East Africa have documented substantial drought-related livestock losses, declining incomes, food insecurity, and displacement, they have often focused on single indicators and failed to capture the multidimensional nature of drought risk.

To address these shortcomings, the chapter develops a comprehensive household-level drought risk assessment framework based on four dimensions: hazard, exposure, sensitivity, and adaptive capacity. Using PCA, it constructs composite indices that provide statistically robust and data-driven measures of each component. These indices are subsequently integrated into a composite drought risk index that captures both environmental and socioeconomic drivers of vulnerability. This approach offers a more holistic and policy-relevant understanding of drought risk and provides a stronger basis for ex-ante economic valuation, early warning systems, anticipatory action, and resilience programming. A key contribution of the chapter is its focus on household-level analysis, which reveals important variations in risk that are often obscured by national or regional averages. The study further enhances drought risk assessment through risk quadrant profiling, classifying households into resilient, adaptive, latent vulnerable, and high-risk categories. This typology provides practical guidance for policymakers and development actors seeking to target interventions more effectively and monitor changes in vulnerability over time.

Overall, the chapter advances drought risk analysis in the IGAD region by integrating environmental hazards with socioeconomic vulnerability, applying rigorous composite index methodologies, and emphasising household-level heterogeneity. Its findings support a shift from reactive disaster response to proactive risk management, enabling more informed planning, targeted investments, and effective anticipatory actions to strengthen resilience among pastoral and agro-pastoral communities.

3.2 Data analysis and construction of indices

3.2.1 Identification of hazards

Identifying hazard events is a foundational step in the risk assessment framework used in this study. In pastoral and agro-pastoral production systems, livelihoods are highly exposed to a wide array of climatic, ecological, biological, and socioeconomic shocks that can disrupt livestock production, reduce household incomes, and undermine food security. A comprehensive identification of these hazards is therefore essential for understanding the risk environment faced by pastoral communities and for informing effective resilience-building and risk management strategies. In climate risk research, hazards are commonly defined as potentially damaging physical events, trends, or human-induced processes that may result in loss of life, injury, livelihood disruption, or environmental degradation (IPCC, 2014).

The hazard identification process in this study followed a triangulated approach that combined empirical evidence, regional data systems, and expert knowledge. First, the study conducted an extensive literature review on pastoral risk systems and climate vulnerability in dryland regions to identify the most prevalent shocks affecting pastoral livelihoods. Second, the study drew on regional early warning systems and food security monitoring platforms, which routinely track climatic variability, livestock conditions, market dynamics, and conflict patterns across the Greater Horn of Africa.

Third, the study consulted subject matter experts, development practitioners, and regional stakeholders to validate the relevance and contextual appropriateness of the identified hazards within the Intergovernmental Authority on Development (IGAD) region. Such triangulated approaches are widely recommended in disaster risk assessment to ensure that hazard identification reflects both empirical evidence and locally grounded knowledge systems (United Nations Office for Disaster Risk Reduction [UNDRR], 2022).

Drawing on this process, eleven major shocks were identified as the most significant hazards affecting pastoral and agro-pastoral production systems in the IGAD region. These hazards span multiple risk domains, reflecting the inherently complex and interconnected nature of livelihood systems in dryland environments. For analytical clarity, the identified shocks are grouped into six broad categories: climatic shocks, animal health shocks, human health shocks, market shocks, conflict and insecurity

shocks, and environmental shocks (Table 1). Collectively, these categories capture the principal drivers of livelihood instability and vulnerability in pastoral economies.

Table 2: Hazard events considered in the risk analysis of pastoral and agro-pastoral systems in the IGAD region

Category	Specific Shock Variable
Climatic	Drought, flood
Animal health	Livestock disease, feed/pasture and water shortages
Human health	Human disease/epidemics
Market	Collapse in livestock/crop prices, input price shocks
Conflict/insecurity	Local/clan conflict, resource raids
Environmental	Crop rangelands degradation

Source: Authors' elaboration based on literature review

Climatic shocks represent the most pervasive and widely documented risks affecting pastoral production systems in the IGAD region. Among these, drought stands out as the dominant hazard, frequently leading to severe pasture shortages, livestock mortality, declining milk production, and reduced household incomes. Recurrent droughts define the dryland ecosystems of the Horn of Africa and have been widely identified as the primary driver of humanitarian crises and food insecurity in pastoral areas (Funk et al., 2019; Morton, 2007).

Although less frequent, floods also pose significant risks, particularly in low-lying areas and along river basins, where intense rainfall events can destroy infrastructure, displace households, and damage cropland in agropastoral systems. Increasing rainfall variability and the growing incidence of extreme weather events associated with climate change are expected to further intensify these hazards across the region (Nicholson, 2017; Thornton et al., 2009).

Animal health shocks constitute another critical dimension of risk in pastoral economies, where livestock serve as the primary productive asset and main source of income. Disease outbreaks can spread rapidly across herds, resulting in high mortality rates, reduced productivity, and substantial economic losses. Diseases such as contagious bovine pleuropneumonia and peste des petits ruminants, alongside other endemic conditions, are recurrent challenges affecting pastoral herds across the region.

Beyond disease, ecological stressors such as pasture scarcity and water shortages represent significant shocks that directly affect livestock nutrition and survival. During prolonged dry periods, depleted grazing resources and water points often compel pastoral households to undertake long-distance migration, increasing herd stress and heightening the risk of conflict over scarce resources (Catley et al., 2013; Reid, Fernández-Giménez, & Galvin, 2014).

Human health shocks also shape household vulnerability. Illnesses and epidemics affecting household members can reduce labour availability and increase medical expenditures, thereby weakening the overall economic resilience of households. In pastoral systems—where livelihoods depend heavily on family labour for herding, livestock management, and mobility—health shocks can substantially undermine productive capacity and exacerbate exposure to other risks (Dercon, 2004).

Market shocks represent a major source of economic instability in pastoral and agropastoral systems. Livestock markets are highly sensitive to climatic conditions, seasonal cycles, and trade disruptions. During drought periods, distress sales often cause sharp declines in livestock prices as many households simultaneously attempt to liquidate assets. At the same time, rising prices of key inputs—such as animal feed, veterinary services, and agricultural inputs—raise production costs and erode household incomes.

In agropastoral areas, declining crop prices or disruptions in market access further compound livelihood stress by reducing returns from crop production. Empirical studies indicate that price volatility and weak market integration significantly amplify the impacts of climatic shocks on pastoral households (McPeak & Little, 2006; Little, McPeak, & Barrett, 2008).

Conflict and insecurity shocks are also prevalent in many pastoral areas of the IGAD region. These include inter-ethnic and clan-based conflicts, resource-related raids, and broader forms of violence that threaten household safety, disrupt mobility patterns, and restrict access to grazing lands and water resources. Mobility is a central adaptive strategy in pastoral systems, enabling households to track resources that vary spatially and temporally. However, insecurity can constrain this mobility, intensify competition over scarce resources, and undermine traditional coping mechanisms, thereby increasing household vulnerability (Hesse & MacGregor, 2006).

Finally, environmental shocks add another dimension of risk, particularly in agropastoral systems where crop production complements livestock rearing. Processes such as land degradation—including soil erosion, declining soil fertility, and loss of vegetation cover reduce both agricultural productivity and the ecological sustainability of pastoral landscapes. Cropland degradation limits the capacity of agropastoral households to rely on crop production as a buffer against livestock losses during drought periods. Such environmental changes not only weaken immediate livelihood outcomes but also contribute to longer-term declines in the resilience of dryland systems (Turner et al., 2003; Thornton et al., 2009).

3.2.2 Attributes of shocks

3.2.2.1 Measurement of shock incidence

Shock incidence represents the simplest indicator of hazard occurrence. It captures whether a household experienced a particular shock at least once during the reference

period. In the survey instrument, households were asked whether each of the eleven shocks had occurred during the previous ten years.

The incidence variable is a binary indicator of whether a household encountered a given shock during the recall period. A value of 0 indicates that the household did not experience the shock, while a value of 1 indicates that the household experienced the shock at least once. Despite its simplicity, this variable is important because it determines whether subsequent dimensions of the shock such as frequency and severity—are relevant for analysis.

3.2.2.2 Measurement of shock frequency

While incidence captures whether a shock occurred, it does not reflect how often it occurred. Shock frequency therefore measures shock recurrence over the ten-year recall period. The raw frequency ranges from 0 to 10, representing the number of years in which the shock occurred. To ensure comparability across households, the variable is normalised to a scale between 0 and 1. A value of 0 indicates that the shock never occurred, whereas a value of 1 indicates that the shock occurred every year during the recall period.

3.2.2.3 Measurement of shock severity

Shock severity reflects the magnitude of impacts on household livelihoods. In pastoral systems, shocks often affect multiple dimensions of welfare, including livestock assets, income, food consumption, and access to grazing resources. To capture this multidimensional nature, severity is measured across four dimensions:

1. Geographic extent - the proportion of grazing land or farmland affected.
2. Asset losses - the magnitude of livestock or other asset losses.
3. Income reduction - the decline in household income.
4. Consumption impact - the reduction in food consumption or access.

Each dimension is assessed using a five-point scale (0–5), where 0 denotes no impact, and 5 indicates a very severe impact. The raw scores are first normalised using a min–max procedure. PCA is then applied to the normalised scores to construct a composite severity index for each shock. Higher index values indicate greater overall impact on assets, income, and consumption.

3.2.2.4 Measurement of recovery capacity

Recovery capacity reflects the ability of households to restore their livelihoods after a shock. It is a key indicator of resilience, as households that recover more quickly are less vulnerable to persistent welfare losses. Households were asked to evaluate

their recovery status following each shock using a five-point scale, where 0 represents no recovery, and 5 represents full recovery. Higher values indicate stronger recovery capacity and greater resilience.

3.2.3 Data transformation and composite index construction

Before applying PCA, the indicators are standardised because they are measured on different scales. Without standardisation, variables with larger variance would dominate the covariance structure and disproportionately influence the resulting components. The min–max normalisation method is used in the composite index construction.

The min–max normalisation method is used in the composite index construction. Min–max normalisation rescales each variable to the interval between zero and one using the transformation:

$$X_i^* = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

where X_i is the original value of the indicator, $X_{\min}$ is the minimum value, and $X_{\max}$ is the maximum value of the variable in the sample.

PCA is a multivariate statistical technique widely used to reduce the dimensionality of datasets containing correlated variables. The method transforms the original set of correlated variables into a new set of uncorrelated variables known as principal components. Each principal component is a linear combination of the original standardised variables.

Mathematically, the first principal component for the i th household can be expressed as:

$$PC_{1,i} = w_1 Z_{1i} + w_2 Z_{2i} + \dots + w_k Z_{ki}$$

where Z_{ki} denotes the normalised value of variable k for the i -th household, and w_k represents the corresponding weight derived from the eigenvector associated with that variable.

The first principal component captures the maximum possible variance in the dataset. Because it reflects the largest share of the overall variability among the indicators, it is often interpreted as the most informative summary measure. Consequently, the first principal component is commonly used as a composite index in empirical analysis, particularly for constructing socioeconomic or welfare indices.

3.2.3.1 Construction of the drought hazard index

The drought hazard index captures the physical intensity of drought conditions experienced by pastoral households. Two key indicators are used to represent this dimension:

- Frequency of drought occurrences reported by the household, which reflects the recurrence of drought shocks within the reference period.
- Average duration of drought episodes, measured in months, which captures the persistence of drought conditions. In pastoral production systems, drought duration is particularly critical, as prolonged dry periods lead to cumulative pasture degradation, water-resource depletion, and gradual declines in livestock productivity.

Prior to index construction, the drought duration variable is adjusted to reduce the influence of extreme values. Household survey data may occasionally report unusually long drought durations due to measurement errors or rare extreme climatic events. Such outliers can distort statistical distributions and disproportionately influence composite indices.

To address this issue, the drought duration variable is winsorized at the 95th percentile. Winsorization replaces observations above this threshold with the 95th percentile value, limiting the effect of extreme values while preserving the overall distribution of the data. This approach is widely recommended in applied statistical analysis when working with survey-based variables (Wilcox, 2012).

Following the treatment of outliers, both drought frequency and drought duration are transformed using the min–max normalisation method described earlier. Because the indicators are measured in different units, direct aggregation would otherwise assign disproportionate weight to variables with larger numerical ranges.

Normalisation is applied to households that reported experiencing drought-related shocks or stressors. For households without reported shocks, the normalised hazard indicators are assigned a value of zero. This ensures that the index reflects the intensity of experienced drought conditions rather than merely their occurrence.

After normalisation, PCA is applied to the two indicators. The first principal component is extracted and interpreted as the raw drought hazard score. The associated factor loadings determine the implicit weights assigned to each indicator. This data-driven weighting approach is preferred over arbitrary weighting schemes, as it allows the underlying statistical structure determine the relative importance of each variable (Organisation for Economic Co-operation and Development [OECD], 2018).

Since PCA scores are unbounded, a final normalisation step is required to facilitate interpretation and comparability. The raw hazard scores are therefore rescaled using the same min–max normalization procedure. This produces the final drought hazard index, which ranges from 0 to 1. Higher index values indicate households experiencing more frequent and longer drought events and therefore facing greater climatic hazard intensity.

3.2.3.2 Construction of the drought exposure index

While the hazard index captures the physical characteristics of drought events, it does not directly reflect the extent to which these events translate into economic losses and livelihood disruptions at the household level. To address this limitation, a separate drought exposure index is constructed to measure the magnitude of drought-induced impacts on pastoral households.

Five indicators are used to represent household exposure to drought impacts, capturing the primary pathways through which drought affects pastoral livelihoods:

- Reductions in grazing area or pasture availability resulting from drought conditions.
- Livestock asset losses due to mortality or distress sales.
- Income losses attributable to drought-induced declines in livestock productivity or market activity.
- Reductions in household consumption, often arising from coping strategies such as reduced food intake.
- The time households need to recover from drought impacts and return to normal livelihood conditions.

As with the hazard indicators, all exposure variables are first transformed using min–max normalisation to ensure comparability across indicators measured in different units. However, the recovery time variable requires special treatment due to its inverse relationship with exposure. Households that recover quickly from drought face less long-term exposures, whereas those with prolonged recovery periods face greater exposure. To ensure a consistent directional interpretation across all indicators, the normalised recovery variable is reverse-transformed using the following expression:

$$X_{\text{rev}} = 1 - X_{\text{norm}}$$

where X_{rev} denotes the reverse – normalised value, and X_{norm} represents the original normalised variable. This transformation ensures that higher values uniformly indicate greater exposure across all indicators.

Following normalisation and directional adjustment, PCA is applied to the five exposure indicators. The first principal component captures the dominant pattern of variation among the indicators and summarises the combined effects of pasture loss, livestock losses, income reduction, consumption decline, and recovery time. The resulting component scores are interpreted as the raw exposure index for each household. Because PCA scores are unbounded and can be positive or negative, a final normalisation step rescales the index between zero and one using the min–max

transformation described earlier. This yields the final drought exposure index, where higher values indicate households experiencing greater economic losses and livelihood disruptions due to drought.

Taken together, the drought hazard and drought exposure indices provide a multidimensional representation of drought risk in pastoral systems. The hazard index reflects the climatic intensity and recurrence of drought events, while the exposure index captures the extent of their socioeconomic impacts on households. By distinguishing between these two dimensions, the methodology enables a more nuanced analysis of drought risk, separating areas where climatic conditions are inherently severe from those where structural vulnerabilities amplify impacts.

This distinction has important implications for policy design. Regions characterised by high hazard intensity may require investments in climate monitoring systems, rangeland management, and early warning mechanisms. In contrast, areas with high exposure may benefit more from interventions that strengthen household resilience, such as livestock insurance schemes, livelihood diversification, and improved market access.

The composite indices developed through this approach therefore provide a robust empirical basis for identifying spatial patterns of drought risk and prioritising targeted policy interventions.

3.2.3.3 Constructing the household drought sensitivity index

In climate risk analysis, sensitivity refers to the degree to which a system or household is affected by climatic shocks. Within the widely used framework advanced by the IPCC, sensitivity reflects the underlying structural characteristics that determine how strongly a household responds to climate-related hazards.

In pastoral and agro-pastoral systems, demographic structure, dependence on climate-sensitive livelihoods, food security conditions, and asset composition shape sensitivity. These factors influence the extent to which drought shocks translate into welfare losses, livestock mortality, and food insecurity. Consequently, measuring sensitivity requires a multidimensional approach that integrates demographic, economic, and livelihood indicators into a single analytical metric.

This study constructs a Household Drought Sensitivity Index using household survey data through a sequence of statistical procedures, including indicator transformation, outlier treatment, normalisation, and PCA. PCA is widely used in vulnerability and development studies because it allows multiple correlated indicators to be combined into a single composite index without relying on arbitrary weighting schemes (Pearson, 1901; Hotelling, 1933; OECD, 2008).

The final index is normalised to range between zero and one, where higher values indicate greater sensitivity to drought shocks.

Conceptual dimension of sensitivity

The index is constructed based on four key dimensions that capture the principal determinants of household vulnerability in pastoral systems:

1. Demographic dependence and social characteristics
2. Food security conditions
3. Livestock asset composition
4. Livelihood structure and diversification

These dimensions collectively reflect the extent of reliance on climate-sensitive resources and the degree to which household characteristics amplify drought effects. Similar multidimensional approaches are widely applied in vulnerability analysis in developing country contexts (Dercon, 2004; Füssel, 2007; Vincent, 2007).

Demographic dependence and social characteristics

The first dimension captures demographic structure and social characteristics, which strongly influence adaptive capacity. Households with limited labour availability or high dependency burdens often face constraints in responding to environmental stress.

A **female-headed household indicator** is constructed by reversing the household head gender variable so that a value of one represents a female-headed household. This reflects structural disadvantages often associated with female-headed households in pastoral contexts.

Educational attainment is captured through a binary variable indicating absence of formal education. This variable is also reverse-coded so that a value of 1 represents no education, reflecting lower human capital and higher sensitivity.

Additional variables include:

- Age of household head
- Household size
- Adult-equivalent household size
- Dependency ratio

The **dependency ratio** is particularly important, as a higher ratio implies greater pressure on productive household members. To reduce the influence of extreme values arising from unusual household compositions, the dependency ratio is **winsorized at the 95th percentile**.

All demographic indicators are subsequently **normalised using min–max transformation** to ensure comparability across variables measured in different units.

Food security conditions

The second-dimension captures food security, a key pathway through which drought affects household welfare. Food-insecure households are more vulnerable to consumption shocks during drought events.

Three indicators are used:

- Household Dietary Diversity Score (HDDS)
- Food Insecurity Experience Scale-based score
- Share of household income spent on food

Because higher dietary diversity typically reflects better food security, the **HDDS is reverse-coded** so that higher values correspond to greater sensitivity. Similarly, food security indicators are transformed to ensure a consistent interpretation direction across the index.

The **share of income spent on food** is also normalised using min–max scaling, as households that allocate a larger proportion of income to food are less able to absorb shocks.

Livestock asset composition

The third-dimension captures livestock asset composition, a central component of pastoral livelihoods. While livestock ownership is a key asset, heavy reliance on certain species can increase vulnerability.

The **share of cattle in total livestock holdings** is used as an indicator of sensitivity. Cattle are more drought-sensitive compared to small ruminants due to their higher water and feed requirements. Thus, a higher share of cattle indicates greater vulnerability to drought-induced pasture and water shortages.

Livelihood structure and diversification

The fourth dimension reflects livelihood dependence and diversification.

Households relying heavily on climate-sensitive agricultural activities are more vulnerable. At the same time, diversification into non-agricultural income sources—such as wage employment, self-employment, property income, and social protection—reduces sensitivity.

A composite index of non-agricultural livelihood activities is constructed using sub-indices for:

- Non-agricultural employment
- Self-employment

- Property income
- Social safety nets

Because these variables represent resilience, they are reverse-coded so that higher values indicate greater sensitivity. PCA is then applied to these reversed variables to generate a diversification index reflecting limited access to alternative livelihoods.

Construction of the composite sensitivity index

The final sensitivity index is constructed by applying PCA to the full set of normalised indicators, including:

- Demographic characteristics (female-headed household, no education, age, household size, dependency ratio)
- Food security indicators
- Livestock composition (share of cattle)
- Livelihood dependence on agriculture
- Non-agricultural diversification index

PCA extracts the first principal component, which captures the dominant variation across these variables and is interpreted as the latent dimension of household sensitivity to drought.

The resulting PCA scores are unbounded and may take negative values. Therefore, a final min–max normalisation transforms the scores into a standardised index ranging from 0 to 1.

3.2.4 Constructing the household drought adaptive capacity index

Adaptive capacity refers to the ability of households or livelihood systems to anticipate, respond to, and recover from climatic shocks such as drought. Within the climate risk framework developed by the IPCC, adaptive capacity encompasses the resources, institutions, and capabilities that enable individuals or communities to adjust to potential damage, capitalise on emerging opportunities, and cope with the consequences of climate variability. This concept is particularly critical in pastoral and agro-pastoral production systems, where livelihoods depend heavily on natural resources that are highly sensitive to climatic fluctuations.

Households with stronger asset bases, diversified income sources, improved access to information and services, and more robust institutional support systems are generally better positioned to withstand drought shocks and recover from their impacts. As a result, assessing adaptive capacity requires a comprehensive analytical framework that integrates multiple dimensions of household resources, livelihood strategies, and institutional support mechanisms.

To capture these multidimensional characteristics, this study constructs a Household Adaptive Capacity Index using household survey data through a composite indicator approach. The index integrates a diverse set of variables representing key dimensions of adaptive capacity, including human capital, financial capital, natural capital, physical capital, institutional capacity, livelihood diversification, coping strategies, and access to information systems.

Composite indices of adaptive capacity are widely employed in climate vulnerability research, as they enable the aggregation of multiple indicators into a single, coherent metric that reflects households' overall ability to anticipate, respond to, and recover from climatic shocks (Füssel, 2007; Vincent, 2007). The methodological framework adopted in this study follows established best practices for composite indicator construction as outlined by the OECD. It incorporates rigorous procedures for indicator normalisation, treatment of outliers, and multivariate statistical aggregation using PCA to ensure robustness and comparability of results.

The construction of the adaptive capacity index follows a systematic sequence of data preparation and statistical procedures. These include data cleaning and transformation, treatment of extreme values through winsorization, normalisation of variables using the min–max transformation, and dimensionality reduction through PCA. Together, these steps ensure that the resulting index is statistically robust, comparable across households, and capable of capturing the relative importance of underlying indicators based on the data structure.

The first stage of index construction involves data cleaning and preparation. Several variables used in the adaptive capacity index are composite indicators derived from survey responses and may contain missing or negative values arising from data entry errors or intermediate calculation procedures. Since negative values have no meaningful interpretation in the context of adaptive capacity, such observations are recoded to zero. This transformation ensures that all variables represent non-negative measures of capacity and prevents distortions in subsequent statistical analyses.

Following data cleaning, the analysis addresses the influence of extreme observations in asset-related variables. Livestock assets constitute a key component of wealth among pastoral households and are typically measured in TLU. However, livestock ownership distributions are often highly skewed, with a small proportion of households owning disproportionately large herds. These extreme values can unduly influence statistical estimates and composite index construction. To mitigate this effect, the livestock asset variable is winsorized at specified lower and upper percentile thresholds, thereby limiting the impact of outliers while preserving the overall distributional structure of the data.

After addressing extreme values, the livestock asset variable is normalised using the min–max transformation. Given that the indicators included in the adaptive capacity index are measured in different units and scales, normalisation is essential to ensure

comparability across variables. The min–max method rescales each indicator to a bounded range between 0 and 1, where higher values correspond to greater adaptive capacity. This approach is widely used in the construction of composite indicators, including the Human Development Index and other vulnerability indices, because it preserves the relative variation in the data while ensuring proportional contribution of each variable to the overall index (OECD, 2018).

Dimensions of adaptive capacity

The adaptive capacity index integrates a comprehensive set of indicators representing various forms of capital and institutional support that shape households' ability to respond to drought shocks.

Human capital is captured through variables such as the educational attainment of the household head and adult-equivalent labour availability. Education enhances households' capacity to access and process information, adopt improved technologies, and diversify livelihood strategies, thereby strengthening adaptive capacity. Similarly, labour availability is critical for implementing coping strategies and maintaining livestock and agricultural activities during drought.

Social capital is represented by participation in collective organisations and self-help groups. Engagement in such groups facilitates access to informal support networks, enhances information exchange, and promotes collective resource management, all of which are vital for managing climate-related risks in pastoral systems.

Financial capital is measured through livestock ownership, expressed in TLUs, and access to financial services such as savings, credit, and insurance. Livestock assets serve as a critical buffer, enabling households to smooth consumption and manage risks through strategic sales or herd adjustments during drought periods. Access to financial services further strengthens resilience by allowing households to mobilise resources in times of economic stress.

Physical capital encompasses access to productive assets and infrastructure that support livelihood activities. This includes composite asset indices and access to essential services such as extension and veterinary care, which are critical for sustaining livestock production.

Natural capital is captured through indicators of feed availability and rangeland condition, both of which are fundamental for maintaining livestock productivity under drought conditions.

Institutional capacity is reflected in access to government support programmes and social protection mechanisms. Interventions such as safety nets, drought relief initiatives, and extension services play a crucial role in enhancing resilience by providing external assistance during climatic shocks.

Livelihood diversification constitutes another key dimension of adaptive capacity. Households with diversified income portfolios are generally less vulnerable to drought, as they can rely on alternative income sources when primary activities decline. Diversification is measured using indices such as the Livelihood Diversification Index and the Simpson Diversity Index, which capture the distribution and balance of income across different economic activities.

Finally, the index incorporates indicators related to **household coping strategies** and **access to climate information**. Coping strategies include behavioural responses such as livestock mobility, herd diversification, and temporary migration. Access to early warning systems is particularly important for pastoral households, as timely information on rainfall variability and drought forecasts enables proactive decision-making regarding herd management, grazing patterns, and market engagement.

Once all variables are standardised to a common scale, PCA is applied to the full set of adaptive capacity indicators. These include variables related to human capital, asset ownership, livelihood diversification, coping strategies, institutional support, and access to climate information systems.

The first principal component derived from this analysis is interpreted as the raw adaptive capacity score for each household. The corresponding factor loadings indicate the relative contribution of each variable, thereby providing a data-driven weighting scheme for constructing the composite index.

Because PCA scores are unbounded and can be positive or negative, they are transformed to facilitate interpretation and comparability. This is achieved through min-max normalisation, which rescales the scores to a range between 0 and 1. The resulting values represent the final Adaptive Capacity Index, where higher scores indicate greater adaptive capacity and an enhanced ability to cope with drought-related shocks.

This index offers a comprehensive measure of the resources, capabilities, and institutional support available to pastoral households in managing climatic risks. By integrating multiple forms of capital alongside institutional factors into a single metric, it allows for the identification of households or regions with limited adaptive capacity that may require targeted policy interventions. Such multidimensional indices are increasingly adopted in climate risk research, as they provide a more holistic and nuanced understanding of resilience and vulnerability within complex livelihood systems.

3.2.5 Constructing household drought vulnerability and risk indices

Assessing climate-related vulnerability requires an analytical framework that integrates multiple dimensions of risk, including the intensity of climatic hazards, the degree of household exposure to those hazards, the structural sensitivity of livelihood systems, and the capacity of households to adapt and recover.

Within the widely used IPCC framework, vulnerability is conceptualised as the propensity or predisposition of a system to be adversely affected by climate variability and extreme events. This concept captures the interaction between exposure to hazards, the sensitivity of socioeconomic systems, and the adaptive capacity available to mitigate potential impacts.

In pastoral and agro-pastoral production systems, these components jointly determine how drought events translate into livelihood disruptions, food insecurity, and asset depletion. Households that are highly exposed to climatic stressors and structurally sensitive to those stresses are more likely to experience severe impacts, particularly when their adaptive capacity is limited.

Building on this conceptual foundation, the present study constructs a Household Drought Vulnerability Index using household survey data alongside previously derived composite indices of exposure, sensitivity, and adaptive capacity. The methodology follows a structured sequence of statistical procedures designed to ensure conceptual consistency, robustness to extreme observations, and comparability across households. These procedures include:

- Formulation of a theoretical vulnerability index.
- Treatment of extreme values using winsorization.
- Normalisation of the index using a min–max transformation.

The first step integrates the three underlying components—exposure, sensitivity, and adaptive capacity—into a single composite measure. In climate risk analysis, vulnerability is typically expressed as a function of the interaction among these dimensions. While higher exposure and sensitivity increase vulnerability, greater adaptive capacity reduces it by enhancing the ability of households to cope with and recover from climatic shocks.

Accordingly, the vulnerability index is specified using a multiplicative–divisive functional form commonly applied in climate risk literature:

$$V_i = \frac{E_i - S_i}{AC_i}$$

where:

- V_i denotes the vulnerability index for household i ,
- E_i represents the exposure index,
- S_i represents the sensitivity index, and
- AC_i denotes the adaptive capacity index.

The drought vulnerability index is subjected to winsorization at the 5th and 95th percentiles to mitigate the influence of extreme observations. The winsorized values

are subsequently normalised using a min–max transformation, yielding a standardised index ranging from 0 to 1. This procedure enhances comparability across households and ensures consistent interpretation alongside other risk indicators used in the study.

To further extend the analytical framework, a Drought Risk Index is constructed by integrating the vulnerability index with the previously estimated drought hazard index. In climate risk literature, risk is commonly conceptualised as the interaction between hazard intensity and vulnerability. Thus, households with similar vulnerability levels may experience different degrees of risk depending on the magnitude, frequency, and duration of drought events in their respective locations.

To capture this interaction, the drought risk index is defined as:

$$\text{Risk}_i = \text{DV}_{\text{norm},i} \times H_i$$

where Risk_i denotes the drought risk index for household i , $\text{DV}_{\text{norm},i}$ represents the normalised drought vulnerability index, and H_i corresponds to the drought hazard index derived from indicators such as drought frequency and duration. This multiplicative formulation aligns with the widely accepted conceptualisation of climate risk, wherein risk emerges from the interaction between hazard exposure and vulnerability (Füssel, 2007).

The resulting index provides a comprehensive measure of household-level drought risk by jointly accounting for environmental and socioeconomic dimensions. Higher index values identify households that are both exposed to severe drought hazards and characterised by structural vulnerabilities, such as limited adaptive capacity or constrained livelihood options. In contrast, households with stronger adaptive capacities and more diversified income sources may exhibit lower levels of risk, even within drought-prone environments.

By integrating hazard, exposure, sensitivity, and adaptive capacity into a unified framework, this methodology offers a robust empirical basis for identifying populations most at risk. Multidimensional indices of this nature are increasingly applied in climate risk assessment, early warning systems, and ex-ante economic evaluations of anticipatory interventions. They provide policymakers with actionable insights into the underlying drivers of vulnerability and help identify strategic entry points for resilience-building measures.

3.2.5.1 Household drought risk profiling

In addition to constructing composite indices of drought vulnerability and overall risk, the study employs a quadrant risk profiling approach to classify households based on their levels of drought exposure and vulnerability.

This method offers a simple and analytically robust framework for identifying distinct household risk profiles and understanding how drought risk emerges from the inter-

action between environmental hazards and household susceptibility. Quadrant-based classification techniques are widely used in climate vulnerability and disaster risk research because they enable clear visualization of the joint distribution of key risk determinants and facilitate the identification of priority groups for targeted policy interventions (Adger, 2006; Cutter, Boruff, & Shirley, 2003).

The theoretical foundation of the quadrant approach is grounded in the broader climate risk framework advanced by the IPCC, which conceptualises climate-related risk as the outcome of interactions among hazard, exposure, and vulnerability. E

xposure refers to the presence of populations, livelihoods, and assets in areas subject to climatic hazards such as drought. Vulnerability, in contrast, reflects the extent to which these households are susceptible to harm due to socioeconomic conditions, livelihood characteristics, and constrained coping capacity (IPCC, 2014; Füssel, 2007).

In pastoral and agro-pastoral systems, drought exposure is typically associated with climatic variability, recurrent rainfall deficits, and environmental degradation. Vulnerability, however, is shaped by structural factors such as limited asset ownership, low levels of livelihood diversification, weak institutional support, and restricted access to markets, financial services, and early warning systems.

The quadrant risk profiling method operationalises this conceptual framework by classifying households according to whether their levels of drought exposure and vulnerability fall above or below their respective median values. Using the median as a threshold provides a robust and distribution-sensitive measure of central tendency, minimising the influence of extreme values and skewed distributions.

This approach ensures a balanced categorisation of households along each dimension, thereby enabling meaningful comparisons across the resulting risk profiles and enhancing the interpretability of the analysis (Wilcox, 2017).

Let MDE and MVD denote the median values of the drought exposure index and the drought vulnerability index across all households, respectively. Each household is classified based on its relative position with respect to these thresholds. Specifically, households with DE_i

$\geq MDE$ are categorised as having high drought exposure, while those with DE_i

$< MDE$ are classified as having low drought exposure. Similarly, households with DV_i

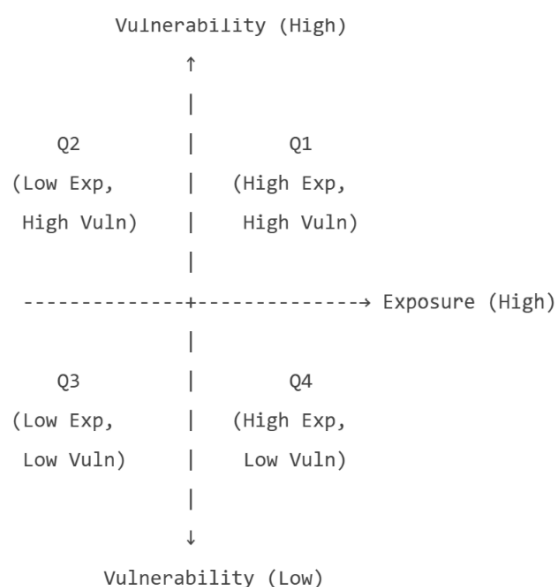
$\geq MVD$ are identified as highly vulnerable, whereas those with DV_i

$< MVD$ are considered to have relatively low vulnerability.

By combining these two binary classifications, households are grouped into four distinct risk quadrants. These quadrants represent different combinations of climatic exposure

and socioeconomic vulnerability, thereby enabling the identification of heterogeneous risk profiles. This classification framework allows the analysis to distinguish between households that are structurally at risk and those that are relatively resilient.

Graphically, the quadrant approach can be represented in a two-dimensional space, where drought exposure is plotted along the horizontal axis and vulnerability along the vertical axis. The median values of both variables define intersecting threshold lines that partition the space into four quadrants. Each quadrant corresponds to a specific drought risk regime, reflecting the interaction between environmental exposure and household vulnerability, and providing an intuitive basis for interpreting differential risk patterns across households.



Q1: Highest risk (high exposure + high vulnerability)

Q2: Socially vulnerable but less exposed

Q3: Lowest risk

Q4: Environmentally exposed but relatively resilient

Quadrant I: High exposure-high vulnerability

The first quadrant represents households facing both high drought exposure and high vulnerability. These households are frequently subjected to severe drought conditions while lacking the necessary resources and coping capacity to manage such shocks. Consequently, they experience the highest levels of drought risk, often leading to significant livelihood disruptions, asset depletion, and food insecurity during prolonged drought periods.

In pastoral systems, such households typically have small herd sizes, limited access to grazing resources, weak market integration, and poor access to financial services or institutional support. The interaction of environmental stress and socioeconomic constraints amplifies their risk, as drought shocks quickly translate into severe welfare losses. This group constitutes the most critical target for drought risk reduction interventions, including anticipatory action, adaptive social protection, and resilience-building programmes (Dercon, 2004; Fussler, 2007).

Quadrant 2: High exposure – low vulnerability

The second quadrant includes households that operate in drought-prone environments but maintain relatively low vulnerability. Their stronger livelihood systems reduce their susceptibility to drought impacts. This resilience may be attributed to larger livestock holdings, diversified income sources, better market integration, and stronger institutional support networks.

Although frequently exposed to drought, these households are better equipped to absorb shocks and recover more rapidly. As a result, they can be considered relatively resilient despite high environmental exposure. Policy interventions for this group should emphasise climate risk management, improved market access, and promoting climate-smart pastoral production systems to sustain their adaptive capacity (Adger, 2006).

Quadrant 3: Low exposure – high vulnerability

The third quadrant represents households with low drought exposure but high socioeconomic vulnerability. These households reside in relatively less drought-prone areas but remain structurally disadvantaged. Their vulnerability often stems from limited assets, poor access to services, low educational attainment, and weak livelihood diversification.

Despite lower exposure, their limited coping capacity means that even moderate shocks can have severe welfare impacts. Many of these households remain chronically vulnerable due to insufficient economic buffers. Policy responses should therefore focus on strengthening assets, enhancing livelihood diversification, and improving access to financial services and institutional support.

Quadrant 4: Low exposure – low vulnerability

The fourth quadrant comprises households with both low drought exposure and low vulnerability. These households benefit from relatively favourable environmental conditions and possess strong socioeconomic resources. They typically have diversified livelihoods, robust asset bases, and reliable access to markets, services, and institutions.

As a result, they face minimal risk and demonstrate greater capacity to maintain stable livelihoods and recover quickly from occasional shocks. This group represents the most secure segment of the population.

The quadrant risk profiling approach offers several important advantages for drought risk assessment and policy design. First, it provides a clear analytical framework for distinguishing between households whose drought risk is primarily driven by environmental exposure and those whose risk stems from socioeconomic vulnerability.

While composite indices offer useful summaries of overall vulnerability, they often obscure critical differences in underlying risk drivers. By explicitly separating exposure and vulnerability into two dimensions, the quadrant approach reveals the distinct mechanisms through which drought risk emerges and affects different households.

Second, the framework enables more targeted and context-specific policy interventions. By identifying groups with different combinations of exposure and vulnerability, it becomes possible to tailor interventions more effectively. For example, households in the high-exposure or high-vulnerability quadrant require integrated support that combines drought risk reduction, livelihood strengthening, social protection, and resilience-building measures.

In contrast, households with high exposure but low vulnerability may benefit more from investments in climate-smart infrastructure, improved rangeland management, and enhanced market access to sustain their adaptive capacity in drought-prone environments.

Finally, the quadrant framework provides an intuitive and visually accessible tool for decision-making, particularly in early warning and anticipatory action systems. By clearly categorising households by risk profile, policymakers and practitioners can more easily prioritise resources and interventions toward the most at-risk populations. This approach not only improves targeting efficiency but also supports the design of interventions that directly address the specific drivers of drought vulnerability, thereby enhancing overall effectiveness and impact.

3.3 Results and discussion

3.3.1 Prevalence, frequency and drought risk profile

3.3.1.1 Prevalence of shocks and stresses

The analysis of shocks and stressors affecting pastoral and agro-pastoral households over the past decade across Ethiopia, Kenya, South Sudan, and Uganda is based on survey data from 1,155 households. The findings, disaggregated by country, cluster, household head gender, and overall sample, provide important insights into nature, frequency, and distribution of climate, health, economic, and conflict-related risks. These findings form a critical empirical basis for understanding vulnerability patterns and supporting drought risk profiling in the IGAD region.

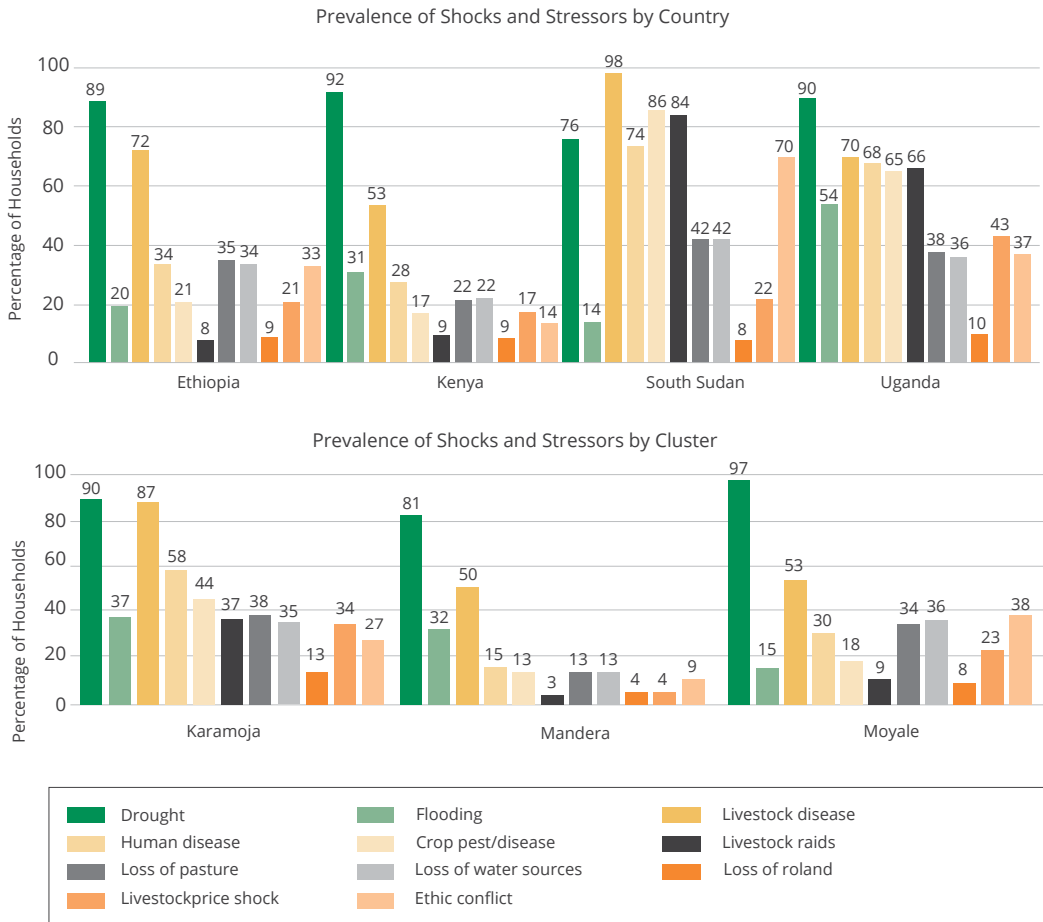


Figure 9: Prevalence of shocks and stressors among pastoral and agro-pastoral households by Country and cluster in the IGAD regions over the last 10 years since 2015 (Percent reporting the shock/stress)

Drought is the most prevalent shock across the sample, affecting approximately 90 per cent of households surveyed. This underscores its significance as the primary climatic hazard in pastoral systems within the Horn of Africa. Drought prevalence is consistently high across all four countries Kenya (92 per cent), Uganda (90 per cent), Ethiopia (89 per cent) and South Sudan (76 per cent). At the cluster level, drought prevalence is even more pronounced in Moyale (97 per cent), Karamoja (90 per cent) and Mandera (81 per cent). These findings confirm that drought is a widespread experience among pastoral households in the region.

Climate risks are multidimensional, extending beyond drought to include flooding and other extremes. Flooding is reported by 28 per cent of households overall, highlighting substantial climate variability across the region. Notable cross-country differences exist with Uganda reporting the highest prevalence (54 per cent), followed by Kenya

(31 per cent), while Ethiopia and South Sudan show lower levels. The coexistence of both drought and flooding within the same regions illustrates the increasingly erratic nature of climate patterns in Eastern Africa. Pastoral communities may face alternating extreme events, such as prolonged dry spells followed by intense rainfall and flooding within relatively short periods. This pattern complicates traditional adaptation strategies and can increase livelihood vulnerability.

Following drought, livestock disease is the second most significant shock, affecting 64 per cent of households overall. Given the centrality of livestock in pastoral livelihoods, this represents a major threat to household income, food security and livestock assets. Livestock disease prevalence varies significantly across countries, with the highest reported in South Sudan (98 per cent), followed by Ethiopia (72 per cent), Uganda (70 per cent) and Kenya (53 per cent). At the cluster level Karamoja records the highest prevalence (87 per cent).

The extremely high prevalence in South Sudan highlights severe animal health challenges. This may be associated with limited veterinary services and weak animal health systems, although the available data do not establish these factors as direct causes.

The findings further highlight the significance of crop disease and broader agricultural shocks, affecting 26 per cent of households overall. However, the distribution varies considerably across countries, reflecting differences in livelihood systems and reliance on crop production.

Country-level prevalence is highest in South Sudan (86 per cent), Uganda (65 per cent), Ethiopia (21 per cent) and Kenya (17 per cent). The high incidence in South Sudan and Uganda is consistent with greater integration of crop production within agro-pastoral systems. In contrast, the relatively low prevalence in Ethiopia and Kenya is consistent with dependence on livestock-based livelihoods in the surveyed areas.

Conflict-related shocks are another major driver of vulnerability in pastoral areas. Livestock raids affect 17 per cent of households overall but are significantly more prevalent in South Sudan (84 per cent) and Uganda (66 per cent). Ethnic conflict affects 26 per cent of households overall, with the highest levels reported in South Sudan (70 per cent), followed by Uganda (37 per cent), Ethiopia (33 per cent), and Kenya (14 per cent). These patterns highlight how insecurity and conflict shape livelihood risks.

Economic shocks also impact pastoral livelihoods, particularly through livestock price volatility, which 21 per cent of households report. The problem is most acute in Uganda (43 per cent) and South Sudan (22 per cent), while Kenya (17 per cent) and Ethiopia (21 per cent) report relatively lower levels. Given that livestock markets are central to income generation and food access, price fluctuations can significantly weaken household purchasing power and affect the households' ability to maintain their livelihoods.

Gender-disaggregated results reveal modest but meaningful differences in reported shock exposure. Male-headed households consistently report slightly higher prevalence across most shock types. For instance, drought affects 91 per cent of male-headed households compared to 88 per cent of female-headed households, while livestock disease affects 67 per cent versus 54 per cent, respectively.

Similarly, livestock raids affect 20 per cent of male-headed households, compared with 10 per cent of female-headed households. These differences may reflect variations in livelihood strategies and asset ownership, as male-headed households tend to manage larger herds and engage more in mobile pastoralism, increasing their exposure to conflict and other risks.

Overall, the findings highlight that pastoral and agro-pastoral households in the IGAD region operate in a complex and multidimensional risk environment. Households face overlapping climatic, biological, economic, and conflict-related shocks, with drought emerging as the most widespread. However, other shocks, including livestock disease, crop disease, flooding, human illness, conflict and economic shocks also play important roles in shaping vulnerability. The frequent co-occurrence of multiple shocks indicates that households face not only isolated events but also compound and cascading risks, which significantly constrain their ability to recover and build resilience.

3.3.1.2 Frequency of shocks and stresses

The results show that drought is the most frequent and recurring shock affecting pastoral and agro-pastoral households across the IGAD region. On average, households experienced drought 3.9 times over a ten-year period, indicating that drought occurs approximately once every two to three years.

At the country level, Ethiopia reports the highest drought frequency (4.1 times), followed closely by Uganda (4.0 times) and Kenya (3.9 times). In contrast, South Sudan reports a lower frequency (2.8 times), although this still represents substantial recurrence. At the cluster level, Mandera records the highest drought frequency (4.6 times), followed by Moyale (3.7 times) and Karamoja (3.6 times).

Crop disease occurs at a relatively high frequency with households reporting an average of 3.2 occurrences over the ten-year period. The frequency is particularly high in Uganda (5.3 occurrences) and South Sudan (4.6 occurrences), followed by Ethiopia (3.4 occurrences) and Kenya (2.5 occurrences).

At the cluster level, crop disease is most prevalent in Karamoja (4.4 occurrences), followed by Mandera (2.8 occurrences) and Moyale (2.2 occurrences). These patterns indicate that climate variability not only affects livestock systems but also exacerbates the spread of agricultural pests and diseases, thereby compounding livelihood risks for agro-pastoral households.

Another important category of shocks is livestock disease, which occurs, on average, 1.1 times over the ten years across the sample. Although less frequent than drought and crop disease, it remains a critical threat due to its direct impact on livestock assets, income, and food security. The frequency is particularly high in South Sudan (3.1 occurrences) and Uganda (2.3 occurrences), compared with Ethiopia (1.3 occurrences) and Kenya (0.5 occurrences).

Livestock raiding occurs on average 1.7 times over the ten years, although the frequency varies considerably across countries. Households in Uganda report livestock raids 4.8 times on average, followed by South Sudan at 4.1 times, Ethiopia at 1.4 times, and Kenya at 1.1 times.

At the cluster level, livestock raiding is particularly prevalent in Karamoja (3.1 occurrences), underscoring the region's long-standing inter-community conflicts over livestock and grazing resources.

Environmental resource shocks also occur repeatedly across the study area. Households report pasture loss 1.2 times on average, while loss of water sources occurs 0.7 times over the ten-year period. These shocks are particularly high in South Sudan, where households report 4.2 pasture loss and 4.4 water losses. Uganda also exhibits relatively high frequencies, with pasture and water losses recorded at 3.9 and 2.6 occurrences, respectively. In contrast, Ethiopia and Kenya report significantly lower frequencies of these resource-related shocks.

At the cluster-level, Karamoja records the highest frequency of pasture loss (2.2 occurrences) and water loss (1.7 occurrences).

Economic shocks are also evident within pastoral economies. Livestock price shocks occur on average 1.6 times over the ten-year period, with the highest frequencies observed in South Sudan (3.68 occurrences) and Uganda (2.0 occurrences). Ethiopia records 1.7 occurrences, while Kenya reports 1.1 occurrences.

These shocks are particularly consequential, as pastoral households depend heavily on livestock markets for both income generation and food access. As such, price volatility can significantly undermine household purchasing power and overall food security.

Other shocks occur less frequently but remain important in specific contexts. Flooding occurs 1.0 times on average, although it is considerably more frequent in Uganda (2.9 occurrences) and Karamoja (1.7 occurrences). Loss of cropland occurs 1.4 times on average, with elevated frequencies in South Sudan (3.0 occurrences) and Uganda (2.3 occurrences).

On the other hand, ethnic conflict, while relatively infrequent overall at 0.26 occurrences, continues to represent a critical localised risk, particularly where competition over natural resources and grazing land remains intense.

Gender-disaggregated results indicate that male-headed households report slightly higher frequencies of most shocks compared to female-headed households. For instance, drought occurs 3.9 times among male-headed households compared to 3.8 times among female-headed households.

In contrast, livestock raiding occurs 1.7 times among male-headed households compared with 1.4 times among female-headed households. These differences may reflect the greater involvement of male-headed households in mobile pastoralism and livestock management, which increases their direct exposure to environmental and security-related risks.

Overall, the analysis demonstrates that pastoral and agro-pastoral households in the IGAD region experience recurrent and overlapping shocks rather than isolated events. Drought emerges as the most persistent climatic hazard, occurring nearly four times within a decade. Other shocks, including crop disease, livestock disease, livestock raiding, and natural resource degradation, also occur frequently.

The frequency patterns reveal significant spatial variation. South Sudan and Uganda experience particularly high frequencies of conflict-related and environmental shocks. In contrast, drought-related stresses more strongly characterise Ethiopia and Kenya.

Taken together, these findings highlight that vulnerability in pastoral systems is shaped not only by climate variability but also by the interaction of ecological, economic, and conflict-related factors, which collectively intensify livelihood insecurity.

3.3.1.3 Shock burdens

Many households experienced multiple shocks, highlighting the highly volatile and risk-prone environment in which pastoral livelihoods operate in the Horn of Africa.

Figure 10 and Annex 2 present the distribution of the number of shocks experienced by pastoral and agro-pastoral households over the past ten years across the IGAD region.

The results indicate that only 3.6 per cent of households reported no exposure to shocks during the period. At the aggregate level, 18 per cent experienced one shock, while approximately 19 per cent experienced two shocks. About 30 per cent experienced three to four shocks, while a further 29 per cent experienced five or more shocks. In total, nearly 60 per cent of households were exposed to at least three shocks during the period under review.

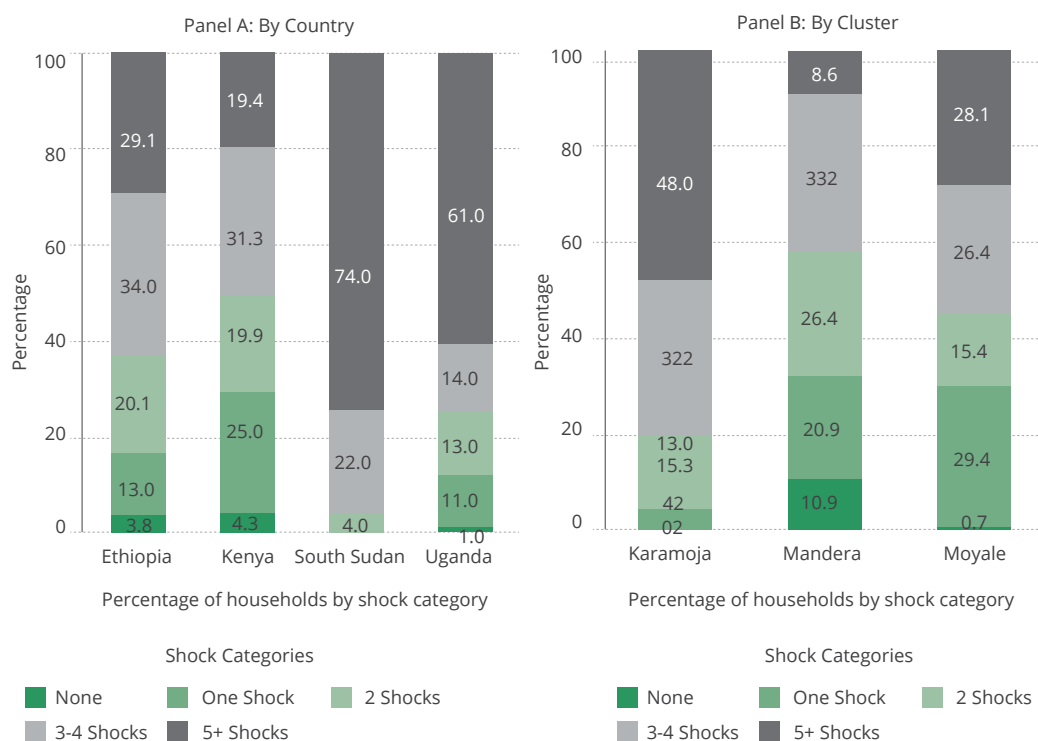


Figure 10: Household shock burden by country and cluster

There are also pronounced differences in the distribution of shock exposure across countries. In Ethiopia, only 4 per cent of households reported no shocks, while 13 per cent experienced one shock and 20 per cent experienced two. Most households experienced higher levels of shock multiplicity: 34 per cent encountered three to four shocks, while 29 per cent experienced five or more. This implies that nearly two-thirds of Ethiopian households faced at least three shocks, highlighting the high level of vulnerability in pastoral and agro-pastoral systems.

In Kenya, about 25 per cent of households experienced one shock, and 20 per cent experienced two shocks. A further 31 per cent faced three to four shocks, while 19 per cent experienced five or more. While the proportion of households experiencing very high shock burdens is lower than in Ethiopia, the results still indicate widespread exposure to multiple shocks.

The situation is most severe in South Sudan, where shock multiplicity is exceptionally high. None of the surveyed households reported experiencing zero or one shock, and only 4 per cent experienced two shocks. In contrast, 22 per cent experienced three to four shocks and 74 per cent experienced five or more shocks over the ten years. This reflects an extremely volatile operating environment, where climatic shocks such as drought and flooding intersect with conflict-related pressures including livestock raiding and ethnic violence.

Uganda shows a similarly concerning pattern. Only 1 per cent reported no shocks, 11 per cent experienced one shock, and 13 per cent experienced two shocks. However, 14 per cent faced three to four shocks, while 61 per cent experienced five or more. These findings indicate that pastoral households in Uganda—particularly in Karamoja—are subject to extremely high cumulative exposure to risk.

The cluster-level analysis reveals pronounced disparities in shock exposure across pastoral regions, underscoring the uneven distribution of livelihood vulnerability. In Karamoja, which spans parts of Uganda and neighbouring areas, households experience an exceptionally high shock burden. Only 0.2 per cent of households reported no shocks, and just 4 per cent experienced a single shock. In contrast, 15 per cent were exposed to two shocks, 32 per cent experienced three to four shocks, and 48 per cent experienced five or more shocks.

In Mandera, approximately 11 per cent of households reported no shocks—significantly higher than in other clusters—21 per cent experienced one shock, and 26 per cent experienced two shocks. A further 33 per cent faced three to four shocks, and only 9 per cent experienced five or more shocks. Although households in Mandera are clearly exposed to multiple risks, the cumulative intensity of shocks is lower than in Karamoja and Moyale.

Moyale presents an intermediate. Only 0.7 per cent reported no shocks, 29 per cent experienced one shock, and 15 per cent experienced two shocks. However, a substantial proportion of households faced higher shock multiplicity: Twenty-six per cent experienced three to four shocks, while 28 per cent experienced five or more shocks. These findings suggest that while Moyale's shock burden is less severe than Karamoja's, a considerable share of households still confront multiple, overlapping shocks.

Overall, the findings demonstrate that pastoral and agro-pastoral households face multiple and concurrent stressors. Most households experience at least three shocks within a decade, and a significant proportion experience five or more. This pattern reflects a system of chronic risk exposure in which climatic shocks (such as drought) interact with biological shocks (such as livestock diseases), economic disruptions (including price volatility), and conflict-related events (such as livestock raiding). The cumulative and overlapping nature of these shocks can exacerbate livelihood vulnerability and constrain household recovery.

The results further highlight strong geographical disparities in shock burden. Households in South Sudan and Uganda face the highest levels of cumulative shocks, while those in Kenya and Ethiopia experience somewhat lower, though still substantial, levels of exposure. At the cluster level, Karamoja clearly stands out as one of the most vulnerable regions, with nearly half of households experiencing five or more shocks. This spatial concentration of risk underscores the need for geographically targeted interventions that address the specific drivers of vulnerability in the most affected pastoral systems.

3.3.2 Drought exposure-vulnerability risk profiling

There are variation in drought hazards across countries. Figure 11 presents composite indices derived from household survey data, capturing the multidimensional components of drought risk among pastoral and agro-pastoral households across the IGAD region.

The findings indicate that the average drought hazard index for the full sample is 0.39, suggesting a moderate level of climatic hazard exposure across pastoral systems in the region. Ethiopia records the highest index value at 0.41, followed closely by Uganda at 0.40 and Kenya at 0.39. In contrast, South Sudan records a lower hazard value of 0.28, suggesting relatively lower reported frequency or duration of drought hazards during the survey period.

At the cluster level, Mandera exhibits the highest drought hazard index at 0.46, indicating particularly high climatic exposure within this cluster. Moyale follows with a value of 0.37, while Karamoja records a comparatively lower index of 0.35. These variations suggest that although drought hazards are widespread, their intensity and frequency differ significantly across localised contexts.

Overall, these results underscore the importance of considering both national and sub-regional heterogeneity in drought hazard exposure. While aggregate figures point to moderate regional exposure, cluster-level differences reveal pockets of heightened vulnerability, particularly in areas such as Mandera, where climatic stress is most pronounced.

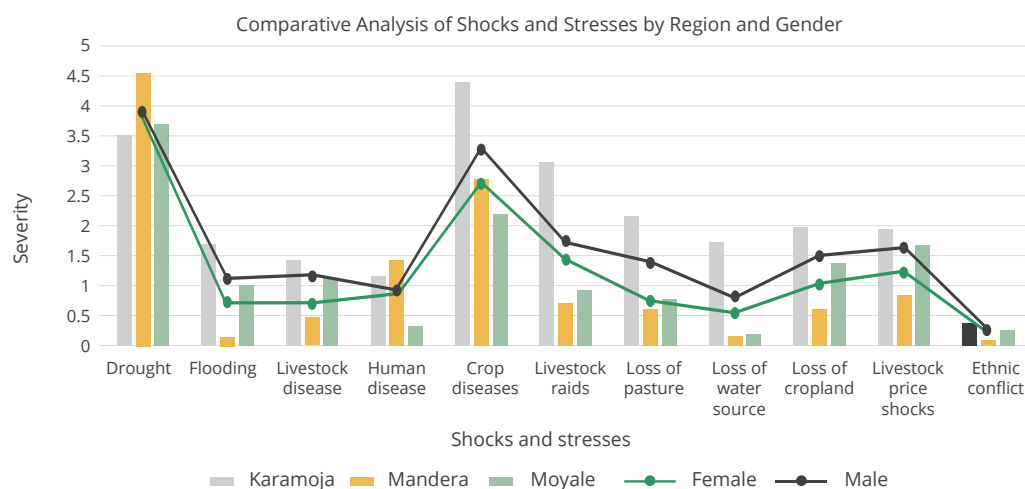


Figure 11: Comparative analysis of shocks and stresses by regions and gender

The Drought Exposure Index, which captures the extent to which households are physically and economically exposed to drought hazards, averages 0.62 for the overall sample, indicating a generally high level of exposure among pastoral households.

Exposure levels vary across countries and clusters. The highest exposure is observed in Moyale (0.69), reflecting the strong reliance of households on climate-sensitive livestock production systems. At the national level, Ethiopia and Uganda also exhibit high exposure levels, at 0.65 and 0.63 respectively, while Kenya records a similar value of 0.63. In contrast, South Sudan records significantly lower exposure at 0.38, possibly reflecting differences in livelihood structures, mobility patterns, or reporting dynamics. At the cluster level, Moyale, has the highest exposure, while Mandera records a comparatively lower exposure index of 0.56.

The sensitivity index, which reflects the degree to which households are affected by drought, averages 0.30 across the sample. South Sudan records the highest sensitivity at 0.47, followed by Uganda at 0.41. In contrast, Kenya records a lower sensitivity value of 0.27, while Ethiopia records 0.30. At the cluster level, Karamoja exhibits the highest sensitivity at 0.36, while Mandera and Moyale record relatively lower values of 0.26 and 0.27, respectively.

The higher sensitivity in some locations suggest greater susceptibility to drought impacts, although the specific drivers should be interpreted alongside the underlying sensitivity indicators presented in the methodology.

The adaptive capacity index, which measures the ability of households to anticipate, cope with, and recover from drought shocks, averages 0.30 across the sample. There are notable cross-country differences. South Sudan records the highest adaptive capacity value at 0.55, followed by Uganda at 0.46, suggesting relatively stronger coping mechanisms, social networks, or informal support systems.

In contrast, Ethiopia and Kenya exhibit lower adaptive capacity levels, at 0.28 and 0.27 respectively. At the cluster level, Karamoja records a moderate adaptive capacity index of 0.39, while Mandera shows the lowest value at 0.21, indicating limited resilience mechanisms and weaker capacity to manage drought-related shocks. Moyale records an intermediate adaptive capacity value of 0.29.

The vulnerability index, which combines exposure, sensitivity, and adaptive capacity to capture overall susceptibility to drought impacts, averages 0.45 across the sample. Ethiopia records the highest vulnerability at 0.47, closely followed by Kenya at 0.45. Uganda records 0.39, while South Sudan records the lowest vulnerability at 0.35. At the cluster level, Mandera records the highest vulnerability index at 0.48, indicating that households in this cluster face particularly high susceptibility to drought impacts despite somewhat lower exposure levels. Karamoja records a vulnerability value of 0.42, while Moyale records 0.45.

Finally, the overall drought risk index, which integrates hazard exposure with vulnerability, averages 0.20 for the full sample. Ethiopia records the highest risk value at 0.21, followed closely by South Sudan at 0.20, while Kenya and Uganda record slightly lower levels of 0.19. At the cluster level, Mandera records the highest risk index at 0.24,

indicating that households in this cluster face the greatest overall drought risk when both hazard intensity and vulnerability are considered together. Karamoja records a risk value of 0.18, while Moyale records 0.19.

Overall, these findings highlight substantial spatial variation in the different components of drought risk. While exposure levels are generally high, particularly in livestock-dependent systems, differences in sensitivity and adaptive capacity play a critical role in shaping vulnerability and overall risk outcomes. In particular, the high vulnerability and risk observed in clusters such as Mandera underscore the importance of strengthening household resilience capacities, even in areas where hazard exposure may not be the highest.

Gender-disaggregated results reveal notable differences in drought risk profiles. Male-headed households exhibit higher levels of exposure (0.63), sensitivity (0.33), vulnerability (0.47), and overall risk (0.21) compared to female-headed households, which record values of 0.60, 0.21, 0.37, and 0.17, respectively. At the same time, male-headed households demonstrate slightly higher adaptive capacity (0.32) relative to female-headed households (0.25).

These differences likely reflect variations in asset ownership, access to resources, and participation in pastoral mobility systems, where male-headed households are often more engaged in livestock-based livelihoods that are highly exposed to climatic shocks. Conversely, female-headed households, while exhibiting lower exposure and sensitivity, may also face structural constraints that limit their adaptive capacity, including reduced access to land, capital, and social networks.

The findings also highlight significant geographical variation in vulnerability profiles. Mandera emerges as one of the most vulnerable clusters, characterised by relatively high exposure and notably low adaptive capacity, which together amplify overall risk. In South Sudan, high sensitivity coupled with lower exposure suggests that households are particularly susceptible to the impacts of drought when it occurs, even if hazard levels are comparatively lower. Meanwhile, Ethiopia and Kenya exhibit relatively high vulnerability, driven by persistent drought exposure and limited adaptive capacity. These patterns point to the need for geographically differentiated resilience strategies that address the specific drivers of vulnerability in each context.

3.3.2.1 Livelihood vulnerabilities

Figure 12 presents a spider (radar) diagram illustrating the relative magnitude of key components of livelihood vulnerability among pastoral and agro-pastoral households across the IGAD region. This multidimensional visualisation captures different dimensions of vulnerability, namely climatic exposure, sensitivity, and adaptive capacity, by plotting them simultaneously on a radial scale. Such a representation facilitates direct comparison of the strengths and weaknesses of livelihood systems across countries and clusters, highlighting both shared and location-specific vulnerability patterns.

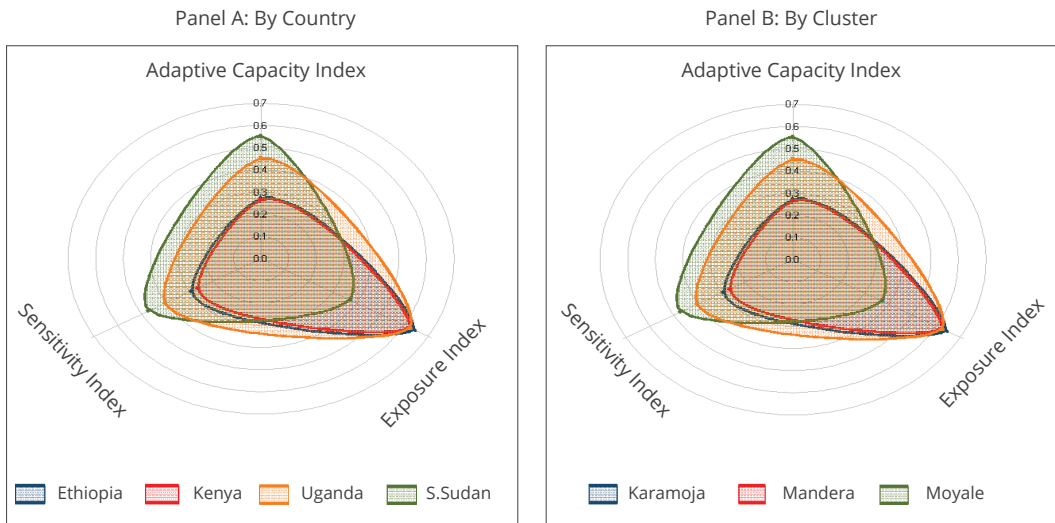


Figure 12: Components of livelihood vulnerabilities by country and cluster

The spider diagram shows that climatic exposure, particularly drought-related vulnerability, is a prominent component across all countries and clusters. The radial axis representing drought exposure consistently extends outward across the geographic units, underscoring its widespread and persistent impact. This aligns with earlier empirical findings, showing that drought is the most prevalent and recurrent hazard affecting pastoral and agro-pastoral communities in the IGAD region.

At the country level, Ethiopia, Kenya, and Uganda exhibit notably high levels of drought-related vulnerability, while South Sudan shows relatively lower but still significant levels. At the cluster level, drought vulnerability is especially pronounced in Moyale and Karamoja, reflecting the high climatic variability, recurrent dry spells, and arid conditions characteristic of these areas.

Overall, the diagram emphasises that while multiple factors contribute to livelihood vulnerability, exposure to drought remains the most critical driver, shaping the risk profiles of households across different ecological and socioeconomic contexts.

3.3.2.2 Exposure–vulnerability risk profiling

The exposure–vulnerability analysis is based on the conceptual foundations of the Climate Change Vulnerability Framework, which defines risk as the outcome of interactions among hazards, exposure, sensitivity, and adaptive capacity. The framework has been widely applied in climate risk research, including by the IPCC, to assess vulnerability in socio-ecological systems (Adger, 2006; Fussler, 2007).

The results of the exposure–vulnerability risk profiling analysis are presented in Figures 13, 14, 15 and Annex 3. The profiling framework categorises households into four

distinct groups based on the interaction between drought exposure and household vulnerability:

- Resilient households - low exposure and low vulnerability.
- High-exposure adaptive households - high exposure but relatively lower vulnerability, associated with stronger adaptive capacity
- Latent vulnerable households - low exposure but high vulnerability, often associated with structural livelihood constraints.
- High-risk households - high exposure combined with high vulnerability.

At the aggregate level across the IGAD region, the results reveal a heterogeneous distribution of household risk profiles among pastoral and agro-pastoral populations. Approximately one-third of households (33 per cent) fall into the resilient category, indicating that a substantial proportion experience relatively low levels of both exposure and vulnerability. These households are likely to exhibit stronger adaptive capacities, including livelihood diversification, access to social safety nets, and improved livestock management practices that reduce their sensitivity to climatic shocks.

However, the largest share of households (37 per cent) is classified as high-risk, underscoring the considerable vulnerability within pastoral systems in the region. These households are simultaneously exposed to frequent and severe drought conditions and possess limited adaptive capacity, making them particularly susceptible to livelihood disruptions and asset losses.

The remaining households are evenly split between the high-exposure adaptive group (15 per cent) and the latent vulnerable group (15 per cent). Households in the high-exposure adaptive category demonstrate the ability to cope with climatic stress despite living in highly exposed environments, suggesting effective adaptation mechanisms.

In contrast, latent vulnerable households, although currently less exposed to drought shocks, remain highly susceptible due to underlying structural constraints such as limited asset bases, poor market integration, and restricted access to services. The exposure-vulnerability profiling highlights the complex and uneven nature of vulnerability across the IGAD region, emphasising that both exposure and adaptive capacity must be addressed simultaneously to effectively reduce climate-related risk among pastoral and agro-pastoral communities.

The presence of households within the high-exposure adaptive category suggests that a segment of pastoral households is able to withstand high levels of climatic stress due to relatively strong resilience mechanisms. These mechanisms may include herd mobility, livestock diversification, access to remittances, and engagement in non-pastoral income-generating activities. Such strategies enhance adaptive capacity and enable households to mitigate the adverse effects of recurrent droughts despite operating in highly exposed environments.

Conversely, households classified as latent vulnerable represent a group that currently experiences relatively low levels of drought exposure but remains structurally vulnerable. This vulnerability is primarily driven by underlying socioeconomic constraints, including poverty, limited access to productive assets, and weak institutional support systems.

From a policy perspective, this group warrants particular attention, as even modest increases in climatic exposure could rapidly shift these households into the high-risk category. These findings reinforce the broader argument that vulnerability in pastoral systems is not determined solely by climatic hazards but is also shaped by structural socioeconomic conditions and institutional factors (Thornton et al., 2007; Reid et al., 2014).

3.3.2.3 Country-level risk profiles

When disaggregated at the country level, the results reveal notable variations across the four countries included in the study.

Ethiopia

In Ethiopia, the distribution of households across risk categories shows a relatively high concentration in the high-risk group. Approximately 44 per cent of households fall into this category, representing the largest proportion among the countries analysed. In contrast, only 27 per cent of households are classified as resilient.

The high prevalence of high-risk households reflects the recurrent and severe drought conditions affecting pastoral areas in Ethiopia, particularly within the Borana pastoral system. These regions are characterised by frequent rainfall variability, rangeland degradation, and livestock disease outbreaks, all of which contribute to elevated levels of both exposure and vulnerability.

At the same time, 15 per cent of households fall into the high-exposure adaptive category, indicating that some households have developed effective coping and adaptation mechanisms that enable them to manage drought-related risks. An additional 14 per cent are categorised as latent vulnerable, suggesting that structural vulnerabilities persist even in areas where drought exposure may be relatively moderate.

Overall, these patterns are consistent with earlier studies demonstrating that pastoral livelihoods in Ethiopia remain highly sensitive to climatic variability and environmental change (McPeak & Little, 2006; Little, 2014). The findings underscore the need for integrated policy interventions that simultaneously reduce climatic exposure while strengthening the adaptive capacity of vulnerable households.

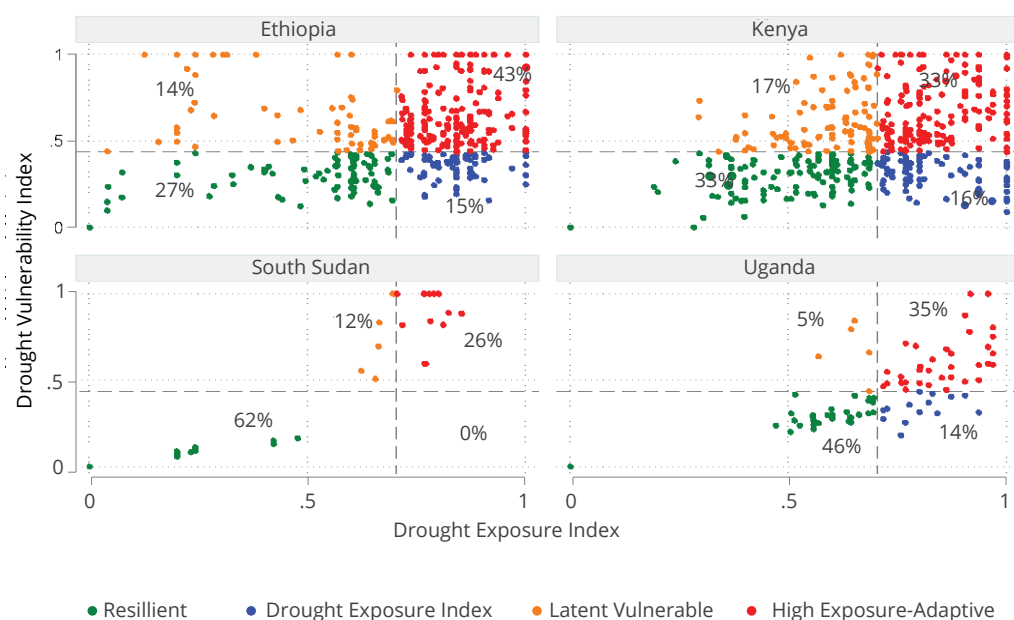


Figure 13: Exposure-vulnerability risk profile of pastoral and agro-pastoral households in the IGAD region by country

Kenya

In Kenya, the distribution of households across risk categories appears more balanced compared to Ethiopia. Approximately one-third of households (33 per cent) fall into the resilient category, while an equal share (33 per cent) is classified as high risk. The high-exposure adaptive group accounts for 16 per cent of households, and 17 per cent fall into the latent vulnerable category. This relatively even distribution indicates that Kenyan pastoral systems embody a complex mix of resilience and vulnerability.

Pastoral communities in northern Kenya have historically developed a range of adaptive strategies, including herd mobility, cross-border livestock trade, and diversification into non-pastoral activities such as petty trade and wage labor. These strategies strengthen adaptive capacity and enhance households' ability to cope with climatic stress. However, increasing climate variability, land pressures, and evolving socioeconomic challenges continue to constrain these adaptive systems (Thornton et al., 2007; Reid et al., 2014).

South Sudan

South Sudan exhibits a distinct risk profile compared to the other countries included in the analysis. A relatively large proportion of households (62 per cent) falls into the resilient category, while 26 per cent are classified as high risk. The latent vulnerable group accounts for 12 per cent of households, and notably, no households are categorised as high-exposure adaptive.

While the high share of resilient households may suggest comparatively lower overall vulnerability, this finding should be interpreted with caution. The result is influenced by the relatively small sample size and the country's complex socio-political context.

Conflict, displacement, and disruptions to pastoral mobility significantly shape exposure and vulnerability patterns, often in ways that diverge from purely climate-driven risks. These factors can mask or distort conventional vulnerability indicators, underscoring the importance of contextual interpretation (Hesse & MacGregor, 2006).

Uganda

In Uganda, the results indicate that 46 per cent of households fall into the resilient category, while 35 per cent are classified as high risk. The high-exposure adaptive group accounts for 14 per cent, and only 5 per cent fall into the latent vulnerable category.

These findings suggest that although drought exposure remains considerable—particularly in regions such as Karamoja—many households possess adaptive strategies that help maintain relatively lower levels of vulnerability compared to neighbouring countries.

Nevertheless, the substantial proportion of households in the high-risk category highlights that drought continues to pose a significant threat to pastoral livelihoods in Uganda. Persistent climatic stress, coupled with structural constraints such as limited infrastructure and market access, continues to undermine resilience among vulnerable groups.

3.3.2.4 Cluster-level risk profiles

Cluster-level analysis provides additional insight into the spatial distribution of risk.

Karamoja

In the Karamoja cluster, 42 per cent of households are classified as resilient, while 32 per cent fall into the high-risk category. Approximately 15 per cent are categorised as latent vulnerable, and 11 per cent as high-exposure adaptive.

The relatively high proportion of resilient households may reflect the strength of social networks, indigenous knowledge systems, and traditional coping mechanisms within Karamoja pastoral systems.

However, the significant share of high-risk households points to persistent structural vulnerabilities, including chronic poverty, environmental degradation, and limited access to basic services and infrastructure. These conditions constrain the effectiveness of local coping strategies and reinforce livelihood insecurity.

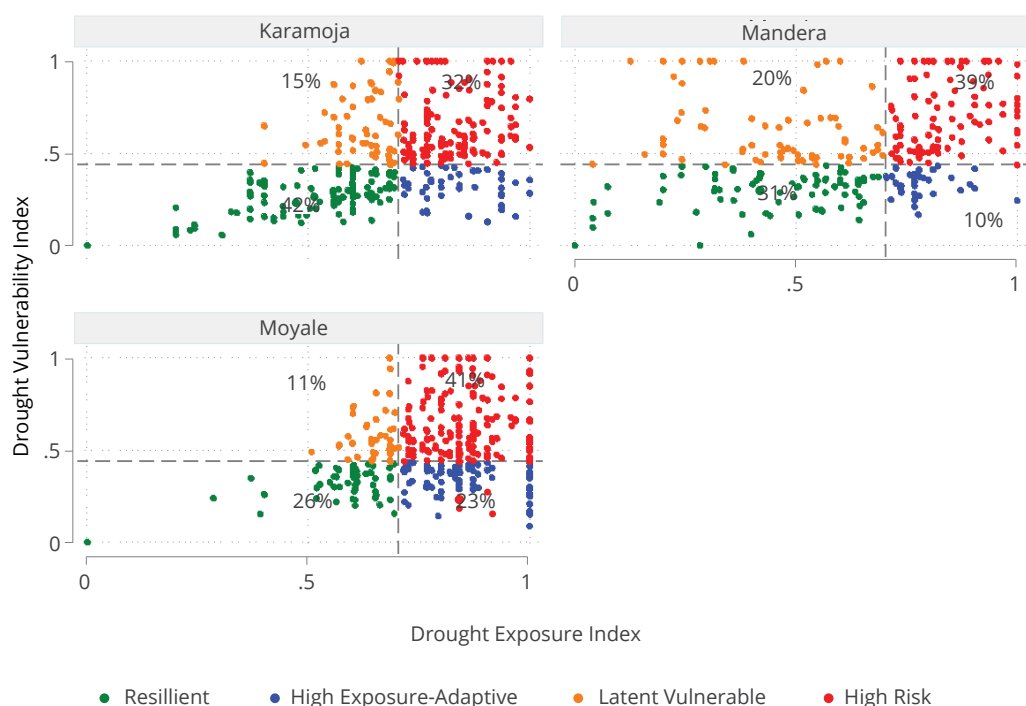


Figure 14: Exposure-Vulnerability risk profile of pastoral and agro-pastoral households in the IGAD region by cluster

Mandera

In the Mandera cluster, 39 per cent of households are classified as high risk, representing the largest share among the clusters included in the analysis. Approximately 31 per cent are categorised as resilient, while 20 per cent fall into the latent vulnerable group and 10 per cent into the high-exposure adaptive category. The relatively high proportion of high-risk households in Mandera reflects the compounded effects of recurrent droughts, cross-border insecurity, and limited opportunities for economic diversification. These interacting stressors constrain both adaptive capacity and livelihood stability, thereby amplifying overall vulnerability.

Moyale

The Moyale cluster presents another distinct risk profile. In this cluster, 40 per cent of households are categorised as high risk, while only 26 per cent are considered resilient. The high-exposure adaptive group accounts for 23 per cent of households, representing the largest share of this category across all clusters. This pattern suggests that although households in Moyale are exposed to substantial climatic stress, a notable proportion has developed coping strategies that partially offset vulnerability. However, the persistence of a large high-risk population indicates that these adaptive mechanisms remain insufficient to fully mitigate the impacts of recurrent drought.

3.3.2.5 Gender-differentiated risk profiles

Gender-disaggregated results provide additional insights into the distribution of vulnerability. Among female-headed households, 38 per cent are classified as resilient, while 27 per cent fall into the high-risk category. In contrast, among male-headed households, 32 per cent are categorised as resilient and 40 per cent as high risk. Male-headed households also show a smaller proportion in the high-exposure adaptive category compared to female-headed households.

These findings suggest that female-headed households may rely more heavily on diversified livelihood strategies, informal income sources, and social support networks that enhance their resilience to climatic stress.

At the same time, structural inequalities—particularly in access to productive assets, financial services, and institutional support—continue to shape gendered patterns of vulnerability in pastoral systems (Adger, 2006; Cutter et al., 2003). Thus, while female-headed households may demonstrate adaptive strengths, they often operate within more constrained resource environments.

3.3.2.6 Key findings from exposure-vulnerability risk profiling

Overall, several key findings emerge from the exposure–vulnerability risk profiling analysis.

First, drought-related risk among pastoral and agro-pastoral households in the IGAD region is highly heterogeneous across countries, clusters, and demographic groups, reflecting diverse socio-ecological and institutional contexts.

Second, a substantial proportion of households remains concentrated in the high-risk category, indicating that existing coping and adaptation mechanisms are insufficient to keep pace with the increasing frequency and intensity of climatic shocks.

Third, the presence of households in the latent vulnerable category underscores the importance of addressing underlying structural constraints, such as poverty, limited asset ownership, and weak service delivery systems, before these households transition into higher-risk categories as exposure intensifies.

Taken together, these findings highlight the need for integrated policy responses that not only reduce exposure to climatic hazards but also strengthen adaptive capacity and address the structural drivers of vulnerability. Such approaches are essential for building resilient pastoral and agro-pastoral livelihoods in the face of accelerating climate variability and environmental change.

These findings carry important implications for policy design and development interventions in pastoral systems. Effective drought risk management requires a shift from predominantly reactive, crisis-driven responses to more proactive and integrated

resilience-building strategies. This approach emphasises long-term investments to reduce both exposure and sensitivity to climatic shocks.

Key priority areas include investments in rangeland restoration to enhance ecosystem productivity, expansion of water infrastructure to improve access during dry periods, and strengthened livestock health services to reduce mortality and productivity losses during droughts. In addition, promoting climate-resilient livelihood diversification, such as engagement in off-farm income-generating activities, can reduce dependence on climate-sensitive pastoral systems and enhance household stability.

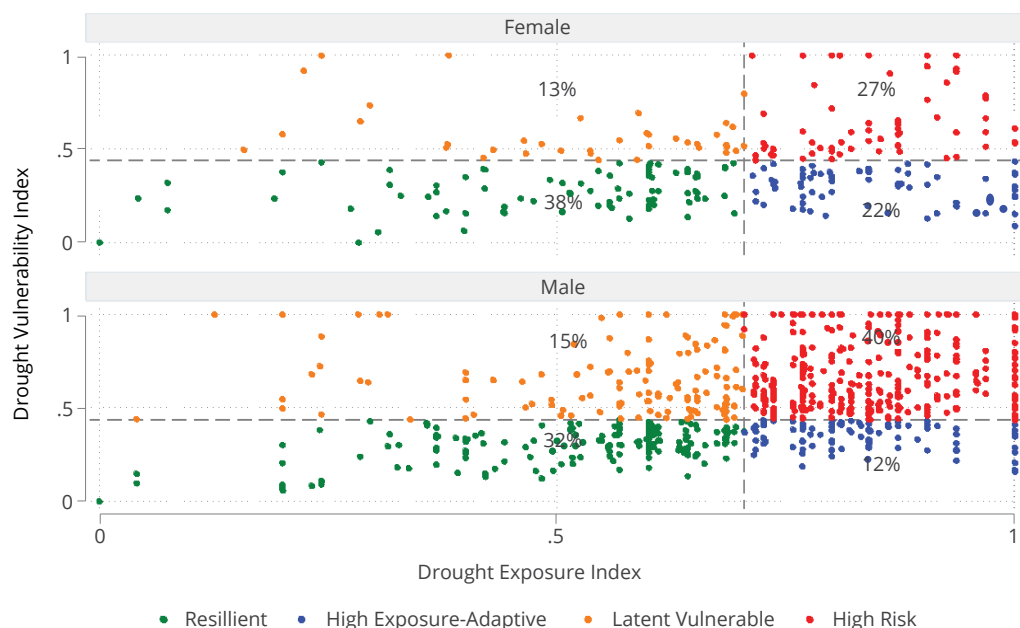


Figure 15: Exposure-vulnerability risk profile of pastoral and agro-pastoral households in the IGAD region by gender

Equally important is the need to strengthen adaptive capacity at the household and community levels. This can be achieved through improved access to functional markets, inclusive financial services, timely and reliable climate information, and effective early warning systems. These interventions enable households to anticipate, prepare for, and respond more effectively to climatic variability, thereby reducing overall vulnerability.

Finally, regional cooperation within the IGAD framework is critical for addressing the transboundary nature of pastoral systems. Facilitating cross-border livestock mobility, harmonising policies, and strengthening coordinated drought risk management strategies can significantly enhance resilience across the region. Such collaborative approaches are essential for sustaining pastoral livelihoods in the face of increasingly frequent and severe climate-related shocks.

3.4 Policy implications

This study provides a comprehensive assessment of drought-related risks affecting pastoral and agro-pastoral households across selected countries within the IGAD region. Drawing on household survey data from 1,155 households across Ethiopia, Kenya, South Sudan, and Uganda, the analysis developed a multidimensional risk framework integrating hazard, exposure, sensitivity, adaptive capacity, vulnerability, and overall drought risk. The indices were constructed using normalised indicators and principal component analysis, ensuring a systematic and empirically robust evaluation of the underlying drivers of risk in pastoral systems.

However, this study operationalises adaptive capacity without adequately considering several critical enabling factors, notably mobility, political agency, and social networks. In pastoral systems, mobility, or more broadly the ability to move without significant constraints, is arguably the central organising principle of adaptation and resilience. It enables households to respond to climatic variability, access dispersed resources, and manage risk across highly dynamic environments. As such, its limited treatment within the index risks overlooking one of the most important determinants of adaptive capacity. Consequently, the indices alone will provide a partial assessment of drought-related risk and adaptive capacity.

Nevertheless, the findings demonstrate that pastoral and agro-pastoral households in the IGAD region are highly exposed to multiple and recurrent shocks, with drought emerging as the most frequent and consequential hazard over the past decade. Frequency analysis indicates that drought events occur repeatedly across all countries and clusters, with an average occurrence of nearly four times within the ten-year recall period.

Other shocks, including crop diseases, livestock raiding, livestock disease outbreaks, and flooding, also affect households, although their prevalence varies spatially. These results confirm that pastoral systems operate within highly volatile environments characterised by compound risks, where climatic, environmental, and socioeconomic shocks interact to undermine livelihood stability.

Further analysis of the shock burden reveals the cumulative nature of risk exposure. Nearly 60 per cent of households reported experiencing three or more shocks within the ten-year recall period, while approximately 30 per cent reported exposure to five or more shocks. This pattern highlights that households are not only affected by isolated hazards but are instead subjected to overlapping and recurrent shocks that progressively erode resilience. The burden of multiple shocks is particularly severe in regions such as Karamoja and South Sudan, where most households reported exposure to five or more shocks.

The multidimensional drought risk index developed in this study identifies high exposure as the dominant driver of drought risk across pastoral systems. Exposure

levels remain consistently elevated due to the heavy dependence of pastoral livelihoods on climate-sensitive natural resources, including rangelands, water availability, and livestock production systems. In contrast, vulnerability levels vary significantly across countries and clusters, reflecting differences in sensitivity and adaptive capacity shaped by socioeconomic and institutional conditions.

Adaptive capacity remains relatively constrained in many pastoral areas. Limited access to markets, financial services, veterinary care, and climate information systems continue to hinder households' ability to anticipate, cope with, and recover from climatic shocks. As a result, vulnerability levels remain moderate to high across the study area, reinforcing persistent drought risk.

The quadrant-based exposure–vulnerability profiling further underscores the uneven distribution of risk. Approximately one-third of households fall into the very high-risk category, characterised by both high exposure and high vulnerability. When combined with other high-risk groups, nearly half of the surveyed households face significant drought-related threats. The analysis also reveals marked spatial variation in risk patterns.

South Sudan and Uganda exhibit the highest concentration of households in the very high-risk category, reflecting the compounded effects of climatic variability, conflict dynamics, weak institutional systems, and limited livelihood diversification. Ethiopia, by contrast, shows a relatively higher share of households in the resilient category, suggesting that stronger livelihood strategies and institutional support mechanisms may improve resilience in certain contexts.

Overall, the findings highlight that drought risk in pastoral and agro-pastoral systems of the IGAD region is structural, multidimensional, and spatially heterogeneous. While drought is an inherent feature of arid and semi-arid environments, its impacts are largely determined by underlying socioeconomic vulnerabilities and the capacity of institutions to support adaptation.

Addressing drought risk therefore requires a dual focus: reducing exposure to climatic hazards while simultaneously tackling structural drivers of vulnerability, including poverty, limited asset bases, and weak service delivery systems. Strengthening resilience in pastoral systems will depend on integrated, context-specific interventions that recognise the complex interplay between environmental, socio-economic, and institutional factors.

The results of this study carry important implications for drought risk management and resilience-building strategies across the IGAD region.

First, the findings demonstrate that vulnerability in pastoral systems is fundamentally shaped by structural constraints, including limited access to infrastructure, markets, financial services, and essential public services. Addressing these underlying barriers

is critical for strengthening adaptive capacity among pastoral households. Strategic investments in rural infrastructure particularly water supply systems, livestock markets, veterinary services, and transportation networks can significantly enhance the resilience and productivity of pastoral economies. Such investments not only reduce sensitivity to climatic shocks but also improve market integration and livelihood stability.

Second, the pronounced geographical variation in risk profiles underscores the need for spatially differentiated policy interventions. Regions such as South Sudan, Karamoja, and Mandera, where households face elevated levels of vulnerability, require targeted and integrated resilience-building programmes. These should combine livelihood diversification support, social protection mechanisms, and strengthened local institutions. Conversely, areas exhibiting relatively higher resilience should be supported through policies that sustain and scale up effective practices, including improved natural resource management, climate-smart livestock systems, and enhanced market access.

Third, the high incidence of multiple and overlapping shocks suggests that drought risk management should adopt a multi-hazard approach rather than focus exclusively on drought. Pastoral households frequently face a combination of risks, including livestock disease outbreaks, resource-based conflicts, and market disruptions. Integrating climate adaptation strategies within broader risk management frameworks can strengthen the capacity of households and institutions to address this compound and interacting risks in a more holistic and effective manner.

Finally, the transboundary nature of pastoral systems highlights the importance of strengthened regional cooperation among IGAD member states. Pastoral mobility, shared grazing resources, and cross-border livestock trade are central to the functioning and sustainability of these systems. Effective drought risk management therefore depends on coordinated regional efforts in rangeland governance, livestock health surveillance, conflict mitigation, and climate information sharing. Strengthening such cooperation can enhance the collective resilience of pastoral communities while supporting sustainable resource use across borders.

3.5 Recommendations

To enhance policy relevance and operational targeting, these recommendations are structured around four exposure–vulnerability profiles. These profiles reflect the interaction between drought exposure and household or system-level vulnerability across pastoral and agro-pastoral systems in the IGAD region. This framework recognises that resilience constraints are not uniform: some systems are primarily constrained by recurrent climatic shocks, while structural and institutional weaknesses limit others. Aligning interventions with these profiles enables more efficient resource allocation and improves the effectiveness of resilience-building strategies.

Profile 1: High exposure-high vulnerability (Hotspots of chronic risk)

This profile represents the most vulnerable pastoral systems, where frequent drought exposure coincides with high sensitivity and limited adaptive capacity. Households face recurrent livestock losses, degraded rangelands, weak market access, and chronic livelihood insecurity. Policy priorities should focus on anticipatory action, adaptive social protection, and critical pastoral infrastructure. Early warning systems linked to pre-arranged financing can trigger timely interventions such as livestock feed support, water provision, vaccination campaigns, and early cash transfers before drought impacts escalate. Expanding shock-responsive social protection, including scalable cash transfers and livestock insurance, can help households avoid distress asset sales. Investments in water infrastructure, veterinary services, and strategic grazing reserves are also essential to reduce vulnerability and stabilise livelihoods. The overarching goal is to prevent asset depletion, reduce humanitarian dependence, and build a foundation for long-term resilience.

Profile 2: High exposure-low vulnerability (Adaptive but climate-exposed systems)

These profile experience frequent droughts but maintain relatively strong adaptive capacity through better asset bases, market integration, mobility, and institutional support. Although highly exposed, they can generally absorb and recover from shocks. Policy priorities should focus on climate risk management and resilience enhancement rather than emergency protection. Key interventions include expanding climate information services, early warning systems, and index-based livestock insurance to support timely decision-making. Improving livestock markets, cross-border trade, and market information systems can strengthen adaptive responses and income stability. Investments in animal health, feed systems, water resources, and livestock productivity are also essential to sustain resilience under recurring climatic stress.

Profile 3: Low exposure-high vulnerability (Structurally constrained systems)

These households face relatively lower drought exposure but remain highly vulnerable due to poverty, limited assets, weak institutions, and poor access to services. Vulnerability is driven primarily by structural and socioeconomic constraints rather than climatic conditions. Policy priorities should focus on reducing structural vulnerability and strengthening adaptive capacity. This includes expanding social protection with graduation pathways, promoting livelihood diversification through non-farm enterprises and employment opportunities, and improving access to finance, education, and skills development. Investments in basic infrastructure, markets, extension services, and public services are also critical. The overall goal is to address underlying development deficits and build long-term resilience.

Profile 4: Low exposure-low vulnerability (Resilient and transition systems)

These systems face relatively low drought exposure and benefit from strong adaptive capacity, supported by better infrastructure, market access, and institutional support.

They provide a stable foundation for economic growth and livelihood transformation. Policy priorities should focus on consolidating resilience and promoting sustainable growth. Investments in livestock value chains, market access, processing, and quality improvement can increase incomes and competitiveness. Expanding financial inclusion, insurance, and private-sector investment can support productivity and innovation. At the same time, sustainable rangeland management and natural resource conservation are essential to maintain resilience and prevent future environmental degradation. The goal is to transition from resilience building to inclusive and sustainable economic development.

Overall, structuring policy responses around exposure–vulnerability profiles provides a coherent framework for targeted resilience building. High exposure–high vulnerability systems require immediate protection and anticipatory interventions to prevent asset collapse. High exposure–low vulnerability systems benefit from enhanced risk management and market-based adaptation strategies. Low exposure–high vulnerability systems require structural investments to address underlying development constraints, while low exposure–low vulnerability systems are best positioned for market-driven growth and sustainable transformation.

By aligning interventions with these distinct profiles, policymakers can move beyond one-size-fits-all approaches and design context-specific strategies that address both climatic risks and socioeconomic vulnerabilities, ultimately enhancing the efficiency, effectiveness, and sustainability of resilience-building efforts across pastoral and agro-pastoral systems in the IGAD region.

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Annex I

Prevalence of Shocks and Stresses Among Pastoral and Agro-pastoral Households over the Last 10 Years Since 2025 by Country, Cluster, Gender, and Overall

Shock/stress	Whole Sample	Ethiopia	Kenya	South Sudan	Uganda	Karamoja	Mandera	Moyale	Female	Male
Drought	89.96	89.18	91.85	76.00	90.00	90.10	81.38	97.26	87.63	90.77
Flooding	27.79	19.65	30.98	14.00	54.00	37.13	31.81	14.93	25.08	28.74
Livestock disease	64.07	71.96	53.44	98.00	70.00	86.88	50.14	53.23	54.18	67.52
Human disease	35.50	33.55	27.72	74.00	68.00	58.17	15.19	30.35	32.11	36.68
Crop disease	25.71	20.97	17.03	86.00	65.00	44.31	13.18	17.91	17.06	28.74
Livestock raids	17.06	8.17	9.42	84.00	66.00	36.88	2.87	9.45	9.70	19.63
Loss of pasture	29.09	34.88	21.56	42.00	38.00	38.12	12.61	34.33	22.07	31.54
Loss of water source	28.74	33.55	22.28	42.00	36.00	35.15	13.47	35.57	22.07	31.07
Loss of cropland	8.74	8.83	8.51	8.00	10.00	13.37	4.01	8.21	7.69	9.11
Livestock price shocks	21.13	20.97	17.21	22.00	43.00	34.41	4.01	22.64	15.05	23.25
Ethnic conflict	25.71	32.89	13.77	70.00	37.00	27.23	9.46	38.31	17.39	28.62
N	1155	453	552	50	100	404	349	402	299	856

Annex 2

Household Shock Burden by Country and Cluster

Item	None %	One shock %	Two shocks %	3-4 shocks %	5+ shocks %	Total %
Country name						
Ethiopia (n=453)	3.8	13	20.1	34	29.1	100
Kenya (n=552)	4.3	25	19.9	31.3	19.4	100
South Sudan (n=50)	0	0	4	22	74	100
Uganda (n=100)	1	11	13	14	61	100
Total (n=1,155)	3.6	18	18.7	30.5	29.2	100
Major Cluster						
Karamoja (n=404)	0.2	4.2	15.3	32.2	48	100
Mandera (n=349)	10.9	20.9	26.4	33.2	8.6	100
Moyale (n=402)	0.7	29.4	15.4	26.4	28.1	100
Total (n=1,155)	3.6	18	18.7	30.5	29.2	100

Annex 3

Risk Profile of Pastoral and Agro-pastoral Households by Exposure-Vulnerability in the IGAD Region by Country, Cluster and Gender

Risk Quadrant	All	Ethiopia	Kenya	South Sudan	Uganda	Kara moja	Mandera	Moyale	Female	Male
Resilient	33.33	27.37	33.33	62.00	46.00	42.33	31.23	26.12	38.13	31.66
High-Exposure-Adaptive	14.81	15.01	16.12	0.00	14.00	10.89	10.32	22.64	22.07	12.27
Latent Vulnerable	14.81	14.13	17.39	12.00	5.00	14.60	19.77	10.70	12.71	15.54
High Risk	37.06	43.49	33.15	26.00	35.00	32.18	38.68	40.55	27.09	40.54
N	1113	436	528	50	99	403	311	399	281	832

EX-ANTE ECONOMIC ANALYSIS OF THE IMPACTS OF ANTICIPATORY ACTIONS



Photo Credit: DITSL

4.0 EX-ANTE ECONOMIC ANALYSIS OF THE IMPACTS OF ANTICIPATORY ACTIONS

4.1 Introduction

This chapter examines the role of ex-ante economic analysis in strengthening Early Warning Systems (EWS) and Anticipatory Action (AA) for pastoral and agro-pastoral communities in the IGAD region. Drought remains one of the most significant threats to pastoral livelihoods, causing livestock mortality, declining productivity, loss of household income, distress sales of assets, and erosion of long-term livelihood resilience. These impacts are intensified by ecosystem degradation, competing land uses, uneven rainfall distribution, and the increasing frequency and severity of drought associated with climate change. Consequently, there is an urgent need for proactive approaches that reduce losses before crises reach humanitarian proportions.

The chapter highlights the growing importance of EWS and anticipatory action as key components of climate risk management. Early warning systems provide timely information on emerging hazards, while anticipatory actions enable pre-emptive interventions designed to protect livelihoods before severe impacts occur. In pastoral systems, measures such as commercial destocking, livestock feed supplementation, veterinary services, and flexible cash transfers can preserve livestock assets, sustain production, and enhance household resilience. These interventions are generally more cost-effective and dignified than post-disaster responses because they prevent losses rather than rebuilding assets after they have been destroyed.

Despite increasing adoption of anticipatory approaches, the chapter identifies a significant evidence gap regarding their economic efficiency and cost-effectiveness in pastoral and agro-pastoral systems within the IGAD region. Existing assessments are often conducted post-intervention and provide limited insight into expected returns under uncertain future drought conditions. To address this gap, the chapter applies an ex-ante economic analysis framework that estimates expected benefits before implementation by incorporating intervention costs, drought probabilities, and the value of losses avoided.

A key contribution of the chapter is its recognition of the considerable heterogeneity that characterises pastoral systems. Households differ in herd size, livestock composition, wealth status, market access, and risk exposure, resulting in substantial variation in vulnerability and potential intervention outcomes. Likewise, the effectiveness and costs of anticipatory interventions vary depending on local conditions, logistics, timing, and targeting mechanisms. Using household-level survey data, literature-based parameters, and probabilistic modelling, the framework captures both average expected benefits and the range of possible outcomes under uncertainty. The analysis further demonstrates how ex-ante assessment can identify households and contexts where interventions are consistently beneficial, conditionally viable, or unlikely to be cost-effective. Such

differentiation supports more efficient resource allocation, improves targeting, and promotes equity in humanitarian and development investments. The framework therefore provides a stronger evidence base for decision-making, risk financing, and accountability.

The chapter focuses on three drought-prone pastoral clusters in the IGAD region: Karamoja, Mander, and Moyale, spanning Ethiopia, Kenya, Somalia, South Sudan, and Uganda. These areas are characterised by low and erratic rainfall, fragile ecosystems, and recurrent climatic shocks, making anticipatory action an essential component of resilience-building strategies. The findings contribute to broader efforts to mainstream forecast-based financing, disaster risk reduction, and climate adaptation by providing robust quantitative evidence on the value of acting before drought impacts escalate. Ultimately, the chapter argues that ex-ante economic analysis can strengthen the effectiveness, efficiency, and scalability of anticipatory action, supporting a transition from reactive crisis response to proactive climate risk management across the IGAD region.

4.2 Methodology and model construction

4.2.1 Analytical framework

This study employs a comprehensive ex-ante economic analysis framework to evaluate the costs, benefits, and robustness of drought EWS and AA interventions in agro-pastoral and pastoral clusters of the selected IGAD region. The methodology integrates retrospective household-level drought impact data with literature-informed estimates of intervention costs and effectiveness, alongside probabilistic modelling techniques to assess expected net economic benefits under deep uncertainty.

Through systematically combining key components, including risk assessment, economic valuation, trigger probability estimation, and Monte Carlo simulation, the framework captures both the expected outcomes and the variability of potential impacts. This integrated approach enables a forward-looking, evidence-based evaluation of interventions, accounting for the inherent uncertainty and heterogeneity of pastoral systems. Ultimately, the framework is designed to generate actionable insights that support informed decision-making among policymakers, humanitarian agencies, and development partners, thereby strengthening the effectiveness and efficiency of proactive drought risk management strategies.

4.2.2 Household data and risk parameterisation

The empirical foundation of the risk assessment undertaken in this study is the household-level survey data. These data provide the critical link between observed drought impacts and the forward-looking economic evaluation of anticipatory action. Through this, the study develops a micro-level representation of drought risk that directly informs both deterministic and probabilistic ex-ante economic analyses. Thus,

the household survey data also forms the basis for constructing the key risk parameters that drive the economic assessment.

The survey captures household experiences of drought over a 10-year recall period, including the frequency and timing of drought events and associated losses in assets, income, and consumption. These data enable drought risk to be characterised in welfare-relevant terms that reflect actual livelihood disruptions, rather than relying solely on climatic indicators.

Furthermore, the survey identifies systematic differences in exposure, sensitivity, and coping capacity across household factors that help explain variations in drought impacts within agro-pastoral and pastoral systems.

To translate the survey evidence into a form suitable for ex-ante economic analysis, a composite household-level drought risk index, denoted $\mathcal{R}$, is constructed for each household. The index integrates multiple dimensions of drought risk emphasised in the disaster risk and climate vulnerability literature, including:

- the likelihood of exposure to drought conditions;
- the sensitivity of household livelihoods to drought-related shocks; and
- the capacity of households to cope with or adapt to adverse impacts.

The index is normalised to range between zero and one, with higher values indicating greater vulnerability to drought.

By construction, the index captures continuous variation in risk across households rather than imposing a binary classification of affected versus non-affected populations. This is particularly important in pastoral contexts, where heterogeneity in livelihood strategies, asset endowments, and mobility patterns leads to substantial variation in drought exposure and response, even within the same geographic area. The risk index therefore offers a parsimonious yet flexible representation of household-level vulnerability that can be applied consistently in economic modelling.

The household-level drought risk index plays a central role in both components of the ex-ante economic analysis. In the deterministic framework, the index is treated as a fixed, household-specific scaling factor that adjusts expected drought-related losses under mean conditions. In the probabilistic framework, the same index informs the parameterisation of loss distributions and contributes to the propagation of uncertainty through Monte Carlo simulation.

Through this, the household survey data provides a unified empirical foundation for evaluating anticipatory action under both certainty and uncertainty, ensuring analytical consistency across deterministic and stochastic assessments and enhancing the policy relevance of the resulting economic metrics (Catley & Cullis, 2012; FAO, 2021).

Additionally, the study draws on a range of secondary data sources to parameterise key components of the ex-ante economic analysis. These sources inform estimates of expected costs under both anticipatory action and no-action scenarios, drought forecast probabilities, per-household intervention costs, and assumptions regarding the effectiveness of anticipatory measures in reducing losses.

While the model specifications discuss the types of secondary data used, the document lacks detailed documentation, including data sources, variable construction, parameterisation choices, imputation procedures, and adjustments for inflation and purchasing power parity.

4.2.3 Deterministic ex-ante economic model

The deterministic ex-ante economic model quantifies, in a transparent and policy-relevant manner, the expected economic performance of anticipatory actions under clearly defined drought scenarios. The model compares outcomes with and without anticipatory action by integrating information on household exposure, vulnerability, drought probability, and the costs and effectiveness of predefined interventions. This enables the estimation of expected losses, avoided losses, and net economic benefits.

By relying on point estimates rather than stochastic distributions, the deterministic specification provides a clear and interpretable baseline assessment of cost-effectiveness. It is particularly useful for ex-ante planning and communication with decision-makers, as it isolates the core economic mechanisms through which anticipatory actions reduce drought-induced welfare losses. Additionally, it serves as a benchmark against which more advanced probabilistic analyses can be evaluated.

The following section presents the structure of the model, defines its key parameters, and outlines the assumptions underpinning the deterministic ex-ante framework.

4.2.3.1 Formulation of expected loss without anticipatory action

The expected economic loss in the absence of anticipatory action for a given household i in cluster c , denoted EL_i^{noAA} , is expressed as:

$$EL_i^{noAA} = p_c \cdot VE_i \cdot r_i, p_c \in [0,1], r_i \in [0,1] \quad (1)$$

where:

- p_c denotes the probability of drought occurrence in cluster c ;
- VE_i represents the total value exposed to drought-related losses for household i ; and
- r_i is the household-specific drought risk index.

In this formulation, the product $V_{E_i} r_i$ represents the household's **value at risk (VaR)**, capturing the proportion of exposed value expected to be lost conditional on the occurrence of a drought event. The probability term reflects the likelihood of a drought event within the relevant temporal and spatial context.

In the primary analysis, the probability is derived from retrospective household survey data, which documents the frequency, duration, and severity of drought events experienced over time. This empirical calibration ensures that drought probabilities reflect localised historical conditions and household-specific exposure contexts (Carter et al., 2007; Kunreuther et al., 2013).

The analytical framework is intentionally flexible regarding the specification of the probability term. The retrospective estimate of p_c can be replaced with forecast-based probabilities derived from seasonal climate prediction systems, such as those produced by the European Centre for Medium-Range Weather Forecasts or the North American Multi-Model Ensemble, without altering the structure of the model (Gneiting & Katzfuss, 2014; WMO, 2020).

This flexibility allows the model to support both retrospective risk assessment and forward-looking anticipatory decision-making, depending on data availability and operational requirements.

VAR is defined broadly as the total livelihood value of a household exposed to a drought shock, rather than being restricted solely to livestock assets. This comprehensive definition is essential for ensuring an equitable assessment of drought impacts across heterogeneous households. The measure comprises two principal components: (i) the value of livestock assets, and (ii) the value of non-livestock livelihood components, including expected income and consumption losses (Dercon et al., 2014; FAO et al., 2018).

Together, these components enable the economic model to capture the full spectrum of potential losses, including those experienced by vulnerable households with limited or no livestock holdings. In the deterministic analysis, VaR_c (Value at Risk at the cluster level) is assumed to be homogeneous at the cluster level to provide a simplified and policy-relevant benchmark.

In contrast, within the Monte Carlo simulation framework, VaR_i (Value at Risk at the individual household level) is treated as a stochastic parameter to reflect household-level heterogeneity and uncertainty.

The household-specific risk index r_i is constructed as a composite indicator derived from primary survey data to capture the multidimensional nature of household vulnerability. Consistent with established vulnerability frameworks, it integrates standardised measures of:

- exposure to drought hazards;
- sensitivity of livelihood systems to shocks; and
- adaptive capacity to cope with or adjust to adverse impacts.

Within the model, r_i functions as a scaling parameter that adjusts expected household-level losses to reflect heterogeneity in vulnerability profiles, thereby introducing realistic variation into the ex-ante economic analysis. In the Monte Carlo simulation, r_i is similarly treated as a stochastic parameter, enabling the model to account for both uncertainty and diversity in household vulnerability across the population.

4.2.3.2 Formulation of expected loss with anticipatory action

When anticipatory action (AA) is implemented, expected economic losses are reduced through timely interventions that mitigate the severity of drought impacts. Accordingly, the expected economic loss with anticipatory action for a given household in cluster is expressed as:

$$EL_i^{AA} = p_c \cdot VE_i \cdot r_i \cdot (1 - ER_c), p_c \in [0,1], r_i \in [0,1], ER_c \in [0,1] \quad (2)$$

where ER_c denotes the effectiveness of anticipatory action, defined as the proportion of drought-related losses that can be avoided for households in cluster c (Hill et al., 2019; Clarke & Hill, 2013). All other variables are as previously defined.

Here, anticipatory action operates as a **loss-reducing mechanism rather than a probability-altering variable**. Specifically, AA does not affect the likelihood of drought occurrence, captured by p_c , but instead reduces the realised severity of losses conditional on the occurrence of a drought event (Kunreuther et al., 2013; Hill & Porter, 2017).

When $ER_c = 0$, anticipatory action has no effect, and expected losses revert to the no-AA case. Conversely, when $ER_c = 1$, anticipatory action fully offsets drought-related losses, resulting in zero expected loss.

The parameter ER_c captures both:

1. The intrinsic effectiveness of the anticipatory interventions (such as, livestock protection, early destocking, feed provision, or improved water access); and
2. The extent to which these interventions are implemented with sufficient lead time to influence outcomes.

In the deterministic analysis, ER_c is calibrated using empirical evidence from the literature and programme evaluations. In the stochastic extension, ER_c is treated as a random variable to capture uncertainty arising from implementation quality, household behavioural responses, and contextual constraints.

4.2.3.3 Avoided loss of expected economic benefit

The avoided loss (AL_i) or expected economic benefit attributable to AA is defined as the difference between expected losses without anticipatory action and expected losses with anticipatory action. Formally, for household i in cluster c :

$$AL_i = EL_i^{noAA} - EL_i^{AA} \quad (3)$$

Substituting from the respective expected loss formulations and factoring out common terms yields:

$$AL_i = p_c * VE_i * r_i * ER_c \quad (4)$$

This expression shows that avoided loss increases linearly with AA effectiveness and is proportional to baseline risk exposure (Hallegatte et al., 2012; Basher, 2012). In other words, AA generates larger economic benefits when drought probability is high, household value at risk is large, household vulnerability is high, and AA is effective.

The avoided loss formulation highlights that AA converts probabilistic risk into expected economic savings before a shock materialises. Importantly, avoided loss is not an ex-post outcome but an ex-ante expected value, making it directly comparable with the cost of AA in benefit-cost and net benefit analyses.

In a geographic cluster, avoided loss can be aggregated across households or equivalently expressed in per-household or per-capita terms for policy comparison across clusters. This avoided loss term constitutes the core economic benefit of anticipatory action and feeds directly into the computation of expected net benefits and benefit-cost ratios under both deterministic and Monte Carlo simulation frameworks.

4.2.3.4 Expected net economic benefit of anticipatory action

The expected net benefit (ENB) of anticipatory action provides the central welfare criterion for ex-ante decision-making under drought risk. It captures, in monetary terms, whether early intervention improves expected household welfare relative to a counterfactual of no early action. Formally, for household i in cluster c , the expected net benefit is defined as:

$$ENB_i = EL_i^{noAA} - EL_i^{AA} - C_i^{AA} \quad (5)$$

Using the earlier formulations for expected loss (Equation 2) with and without anticipatory action, this expression simplifies to:

$$ENB_i = p_c \cdot VE_i \cdot r_i \cdot ER_c - C_i^{AA} \quad (6)$$

This formulation highlights four critical features of anticipatory action economics:

1. **Probabilistic benefits:** Expected benefits scale linearly with the probability of drought occurrence.
2. **State-contingent benefits:** Benefits increase with the magnitude of exposure and vulnerability, captured by the value at risk (VE_i) and the drought intensity index (r_i).
3. **Operational performance:** Benefits depend on implementation effectiveness, summarised by the anticipatory action effectiveness parameter (ER_c), which reflects the share of losses avoided through timely intervention.
4. **Cost of intervention:** The term C_i^{AA} represents the per-household cost of delivering anticipatory action.

At the geographic (cluster) level, expected net benefits aggregate across heterogeneous households as:

$$ENB_c = \sum_{i=1}^{N_c} (p_c \cdot VE_i \cdot r_i \cdot ER_c - C_i^{AA}) \quad (7)$$

This aggregation preserves household-level heterogeneity in exposure and vulnerability while enabling policy-relevant comparisons across clusters. A positive cluster-level ENB indicates that anticipatory action improves aggregate welfare, even if some households experience negative net benefits, an issue that can be addressed through improved targeting or differentiated transfer design.

Benefit–cost ratio as a measure of economic efficiency

While expected net benefits capture absolute welfare gains, policymakers often require a normalised efficiency metric to compare interventions across contexts and scales. The benefit–cost ratio (BCR) fulfils this role and is defined as:

$$BCR_i = \frac{p_c \cdot VE_i \cdot r_i \cdot ER_c}{C_i^{AA}} \quad (8)$$

A BCR greater than unity implies that each unit of currency invested in anticipatory action generates more than one unit of expected avoided loss. Conversely, a BCR less than one indicates that the intervention is not economically efficient under the assumed parameters.

The BCR is particularly useful under budget constraints or when prioritising among multiple clusters or programmes, as it enables decision-makers to rank interventions according to their economic efficiency rather than absolute benefit size (Boardman et al., 2018).

Break-even cost of anticipatory action interventions

The break-even cost defines the upper bound on anticipatory action expenditure that remains economically justified. It is derived by setting expected net benefits equal to zero and solving for the intervention cost:

$$0 = p_c \cdot VE_i \cdot r_i \cdot ER_c - C_i^{AA} \quad (9)$$

$$C_i^{BE} = p_c \cdot VE_i \cdot r_i \cdot ER_c \quad (10)$$

where C_i^{BE} represents the break – even cost per household for intervention i .

This expression has a direct policy interpretation: it defines the maximum cost that can be incurred per household for anticipatory action without reducing expected welfare. If implementation costs exceed this threshold, the intervention is no longer economically efficient, implying that resources could yield greater benefits if allocated elsewhere.

In practice, break-even costs serve as a powerful diagnostic tool for decision-making under uncertainty. When observed programme costs are substantially below the break-even level, the intervention is not only justified but also robust to variations in key parameters such as forecast accuracy, effectiveness, or response rates. Conversely, when costs approach or exceed the break-even threshold, this signals the need for corrective measures such as improving targeting, reducing delivery costs, or enhancing intervention effectiveness to restore economic viability.

Break-even probability and trigger design

From an operational perspective, anticipatory action is typically triggered based on forecast probabilities. Rearranging the net benefit condition to solve the drought probability yields the **break-even probability**:

$$P_t^{BE} = \frac{C_t^{AA}}{VE_i \cdot r_i \cdot ER_c} \quad (11)$$

This value defines a **decision threshold**: anticipatory action should be triggered whenever the forecasted probability of drought exceeds P_t^{BE} .

Lower break-even probabilities indicate interventions that remain economically viable even under relatively low-risk conditions. This reflects contexts characterised by high vulnerability, large expected losses, or highly effective interventions. Conversely, higher break-even probabilities imply that action is justified only when the likelihood of drought is more certain.

4.2.3.5 Share of households with positive expected net benefits

In the deterministic ex-ante economic framework, a household is considered to benefit from anticipatory action if its expected net benefit is strictly greater than zero. Aggregating this binary outcome across all sampled households yields the **share of households for which anticipatory action is economically justified** under the assumed scenario.

Unlike probabilistic measures, this metric does not incorporate uncertainty in model inputs or stochastic variation across potential futures. Instead, it provides a **structural assessment** of how costs and benefits are distributed across heterogeneous households, given the model's baseline assumptions.

This indicator has important implications for policy design and targeting. A high share of households with positive expected net benefits suggests that anticipatory action is broadly welfare-enhancing across the population, even when average net benefits obscure underlying heterogeneity. Conversely, a lower share indicates that benefits are concentrated among specific household groups, pointing to the need for more targeted interventions or differentiated programme design.

From a policy perspective, this measure is particularly valuable for assessing **coverage and equity considerations**, as it focuses on how many households are expected to gain rather than the magnitude of average gains. It also offers a transparent basis for comparing alternative intervention designs by examining how variations in costs, targeting mechanisms, or assumed effectiveness influence the proportion of beneficiaries.

While this deterministic metric does not capture downside risk or uncertainty, it provides a clear, intuitive, and policy-relevant indicator of the **breadth of economic justification** for anticipatory action within the specified analytical framework.

4.3 Probabilistic ex-ante economic model and results

The deterministic ex-ante economic model provides a necessary first step in assessing the economic rationale for anticipatory action. By relying on point estimates of key parameters—such as drought probability, household-specific value at risk, vulnerability levels, and expected intervention effectiveness—it yields a clear and interpretable estimate of expected net economic benefits. Conceptually, this framework addresses whether anticipatory action is economically justified under average conditions, serving as a benchmark assessment of baseline economic viability.

However, the deterministic approach implicitly assumes that these parameters are known with certainty. In operational early warning and anticipatory action contexts, this assumption rarely holds. Forecast probabilities are inherently uncertain, value-at-risk estimates vary across households and seasons, vulnerability indicators are subject

to measurement and contextual variability, and both the effectiveness and cost of anticipatory action depend on timing, implementation quality, and available lead time. As a result, exclusive reliance on deterministic estimates may obscure critical sources of risk, including the probability of unfavourable outcomes and the scale of potential losses under adverse but plausible scenarios.

To address these limitations, the analysis extends the deterministic framework into a **probabilistic ex-ante economic model** using Monte Carlo simulation. Rather than replacing the deterministic approach, the probabilistic model builds directly upon it. Point estimates from the deterministic framework define central tendencies, ensuring internal consistency across analytical approaches. Uncertainty is then explicitly incorporated by assigning probability distributions to key parameters, calibrated to reflect empirically plausible ranges observed in the literature and operational settings. This preserves the underlying economic structure while allowing outcomes to vary across simulated states of the world.

Central to the stochastic formulation is the **household-specific drought risk index**, r_i , derived from survey data and capturing heterogeneity in vulnerability across households. Model components are treated as stochastic but vary across different levels of aggregation. Household exposure and vulnerability parameters vary at the household level, while forecast performance, intervention effectiveness, and implementation costs vary at the cluster level. This hierarchical structure reflects the operational realities of anticipatory action systems, where some factors are locally specific while others are shared across groups of households.

Within this framework, the ENB of anticipatory action for household i in cluster c , under simulation s , is defined as:

$$ENB_{i,c}^{(s)} = P_c^{(s)} \cdot r_i^{(s)} \cdot VE_i^{(s)} \cdot ER_c^{(s)} - C_{i,c}^{AA(s)}$$

where:

- $P_c^{(s)}$ is the simulated drought probability for cluster c ,
- $r_i^{(s)}$ is the stochastic household-specific risk index,
- $VE_i^{(s)}$ is the value exposed to drought risk for household i ,
- $ER_c^{(s)}$ is the effectiveness of the anticipatory action in reducing losses,
- $C_{i,c}^{AA(s)}$ represents the cost of implementing anticipatory action.

In this formulation, stochasticity is introduced at multiple levels. Household-level uncertainty is captured through variation in exposure values and vulnerability indices. In contrast, cluster-level uncertainty reflects differences in forecast performance, operational effectiveness, and implementation costs across space and time. The simulation index s therefore represents joint draws from both household – and cluster – level

distributions. Expected net benefits are computed by averaging ENB_{ics} across simulations, yielding estimates at the household, cluster, or sample level. This hierarchical structure ensures internal consistency while allowing the model to capture both within-cluster heterogeneity and between-cluster operational uncertainty in the economic performance of anticipatory action.

Parameters naturally bound between zero and one, such as forecast probabilities and effectiveness rates, are modelled using beta distributions. These distributions are flexible, respect natural bounds, and are parameterised via moment matching to preserve the deterministic mean while incorporating calibrated variance. In contrast, intervention costs and values at risk are strictly positive and typically right-skewed due to the possibility of rare but severe losses. These parameters are therefore modelled using lognormal distributions, which ensure positivity, accommodate heavy-tailed behaviour, and preserve expected values.

Monte Carlo simulations are conducted over 1,000 iterations. In each iteration, stochastic draws are generated for all uncertain parameters conditional on household characteristics. The dataset is expanded so that each household is represented across all simulated realisations, enabling the model to jointly capture household-level heterogeneity and parameter uncertainty. For each draw, a distinct realisation of expected net benefits is calculated.

Lead time plays a critical role in shaping anticipatory action outcomes and is explicitly incorporated into the simulation. Stochastic lead-time realisations are generated and normalised relative to an optimal reference lead time. The resulting adjustment factor scales intervention effectiveness, reflecting diminishing returns when actions are implemented either too early or too late. This approach ensures that simulated outcomes realistically account for operational constraints in early warning and response systems.

The resulting ENB distribution provides insights that deterministic analysis alone cannot capture. It enables assessment of dispersion around the mean, the probability of negative net benefits, and the influence of low-probability, high-impact events in the tails of the distribution. This stochastic perspective is especially important in drought-prone pastoral and agro-pastoral systems, where extreme events frequently dominate welfare outcomes.

From these simulations, several risk-informed metrics are derived. The probability that expected net benefits are positive is computed as the share of simulation draws in which $ENB > 0$, providing a measure of economic robustness under uncertainty. In addition, simulated break-even (or trigger) probabilities are generated, defined as the forecast probability threshold above which anticipatory action becomes economically justified. The empirical distribution of these thresholds supports risk-sensitive trigger design and informs operational decision-making under uncertainty.

Deterministic and probabilistic modelling approaches are therefore complementary. The deterministic model establishes whether anticipatory action is economically viable under average conditions and offers a transparent benchmark for policy dialogue. The probabilistic model, by contrast, evaluates the robustness of this conclusion when uncertainty, nonlinearity, and parameter interactions are explicitly incorporated.

Taken together, this integrated deterministic–probabilistic framework provides a comprehensive and policy-relevant assessment of anticipatory action. Deterministic analysis facilitates strategic planning and comparative evaluation, while Monte Carlo simulation allows decision-makers to explicitly account for uncertainty, downside risk, and heterogeneity in vulnerability and outcomes.

By combining central estimates with distributional insights, the approach closely reflects the realities of forecast-based financing and early warning systems, where decisions must be made prior to shock realisation and effective risk management is as critical as maximising expected returns.

4.3.1 Ex-ante deterministic economic analysis

A critical component of ex-ante economic analysis of early warning systems and anticipatory action is the specification of parameters used in the mathematical formulation of expected losses, expected benefits, and expected net benefits. These parameters integrate inputs derived from empirical literature with endogenously determined model variables, ensuring that the results are both empirically grounded and responsive to simulated risk conditions.

Accordingly, before presenting the main findings, it is important to clearly outline the derivation of the key variables that underpin the analysis. These constructed measures provide the analytical foundation for evaluating the economic performance of anticipatory action interventions. The subsequent sections then present the results of both deterministic and probabilistic ex-ante economic analyses, offering complementary perspectives on expected outcomes, variability, and risk across alternative intervention scenarios.

4.3.2 Drought forecast probabilities

The drought forecast probabilities (pc) used in this analysis are derived from the literature and reflect empirically observed forecast skill. They provide a useful benchmark for assessing drought risk across clusters. For Karamoja, the assumed forecast probability is 0.525, indicating moderate but operationally meaningful drought risk. Mandera exhibits a higher forecast probability of 0.60, suggesting more frequent drought occurrences, while Moyale has a forecast probability of 0.575. Together, these values capture the probabilistic nature of drought risk under historical conditions and serve as the baseline inputs for model decision-making.

These probabilities are illustrative benchmarks drawn from literature. In practical applications, they should be replaced with locally available, timely, and cluster-specific seasonal forecasts or other credible data sources that reflect current conditions. Incorporating real-time operational forecasts would enable endogenous trigger probabilities to adjust dynamically to evolving risk patterns, thereby improving the accuracy, relevance, and efficiency of anticipatory actions. This approach ensures interventions are targeted spatially and temporally to areas of greatest need. This, in turn, enhances both the economic efficiency and protective impact of early warning systems and anticipatory action frameworks.

The VaR quantifies the magnitude of potential losses from households' exposure to drought, based on estimates from literature. In the clusters analysed, Karamoja and Moyale are assumed to have a VaR of United States dollar (USD) 350 per household, while Mandera exhibits a higher VaR of USD 450 per household, reflecting the relatively more severe potential losses in this cluster.

These VaR values are critical for defining the upper bound of expected losses and for shaping the distribution of net benefits across households. However, VaR reflects losses under average drought conditions and does not capture the absolute worst-case scenario. In practice, actual household losses may exceed the estimated VaR under extreme or compounded shocks, such as prolonged droughts combined with other stressors.

In addition to cluster-level forecast probabilities and endogenous trigger mechanisms, the analysis incorporates a household-level drought risk index derived directly from survey data. This index captures micro-level vulnerability to drought by reflecting key dimensions such as exposure, sensitivity, and adaptive capacity. The overall average household drought risk index is estimated at 0.23. At the cluster level, average index values are 0.21 for Karamoja, 0.27 for Mandera, and 0.21 for Moyale. These figures suggest broadly comparable drought-risk levels across clusters, with Mandera exhibiting a slightly higher vulnerability relative to the others.

Figure 16 presents the kernel density distributions of the household drought risk index for each cluster. The distributions indicate that while most households cluster around their respective means, risk levels vary notably within each community. In Karamoja and Moyale, the distributions are slightly skewed to the right, indicating a subset of households facing significantly higher drought vulnerability than the cluster average. In contrast, Mandera's distribution appears more symmetric and concentrated around the mean, suggesting a more homogeneous risk profile among households.

These patterns highlight the importance of household-level targeting. Even within clusters with similar average risk levels, substantial heterogeneity exists, implying that certain households are far more vulnerable and may benefit disproportionately from anticipatory interventions.

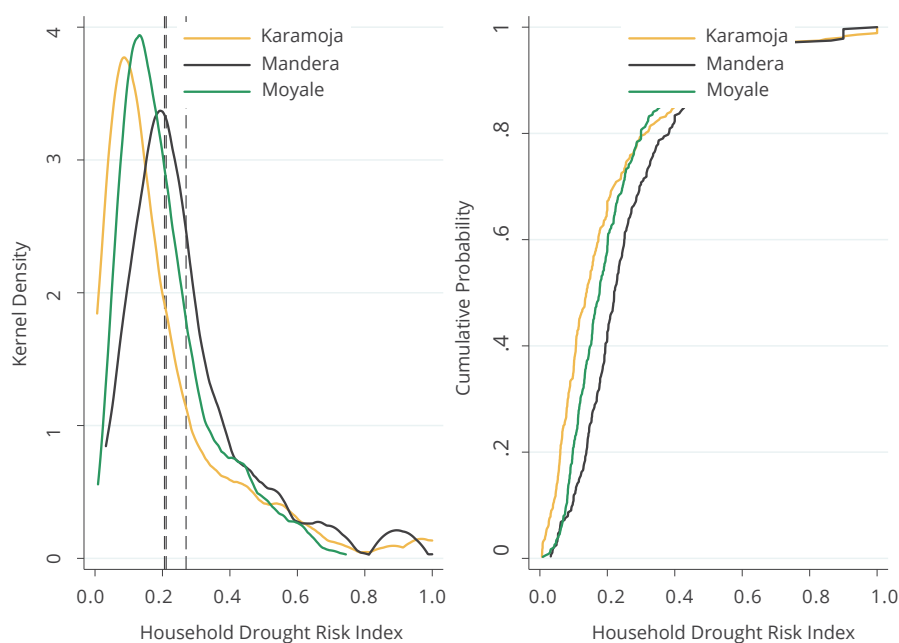


Figure 16: Kernel density and cumulative density of Household drought risk index by IGAD pastoral and agro-pastoral cluster

By integrating household-level risk indices with cluster-specific VaR and anticipatory action parameters, the analysis captures both the likelihood of adverse events at the household level and the magnitude of potential losses under severe conditions. This combined approach provides a critical link between micro-level, survey-based risk assessments and the broader economic evaluation framework for anticipatory action. As a result, the model is better positioned to estimate expected avoided losses, net benefits, and benefit–cost ratios with greater accuracy. This integration strengthens both the deterministic and Monte Carlo analyses by ensuring that heterogeneity in household vulnerability is explicitly accounted for while maintaining consistency with cluster-level loss dynamics.

4.3.3 Anticipatory action effectiveness rate

The assumed effectiveness of anticipatory actions represents the proportion of potential drought-induced losses that can be averted when interventions are implemented in a timely and well-targeted manner. Drawing on evidence from the literature, effectiveness rates are estimated at 0.675 for Karamoja, 0.575 for Mandera, and 0.625 for Moyale.

These relatively high effectiveness rates imply that, once triggered, anticipatory actions can substantially mitigate drought-related impacts at the household level. Consequently, higher effectiveness directly translates into increased expected avoided losses, improved net economic benefits, and stronger benefit–cost ratios.

Variations in effectiveness across clusters reflect differences in contextual factors such as implementation capacity, targeting efficiency, and underlying vulnerability profiles. Incorporating these differentiated effectiveness rates into the analysis enhances its realism and ensures that the modelled outcomes more accurately capture the potential performance and robustness of anticipatory action interventions across diverse settings.

4.3.4 Trigger probabilities

The endogenous trigger probabilities, which determine the activation of anticipatory actions in each cluster, are estimated at approximately 0.18 for Karamoja, 0.20 for Mandera, and 0.13 for Moyale (Figure 17). Anticipatory actions are activated when forecast probabilities exceed these threshold values.



Figure 17: Kernel density of trigger probability by IGAD pastoral and agro-pastoral cluster

The kernel density distributions of the trigger probabilities indicate that most values are tightly concentrated around their respective means, with limited occurrences at extremely low or high levels. This concentration suggests that the model consistently identifies a relatively narrow range of economic thresholds at which anticipatory actions become optimal. In other words, the activation rule exhibits stability and predictability across simulations.

A comparison with literature-based drought forecast probabilities—estimated at 0.525 for Karamoja, 0.60 for Mandera, and 0.575 for Moyale—reveals that the endogenous trigger thresholds are substantially lower. This difference reflects the selective and economically driven nature of the activation mechanism.

While forecast probabilities indicate moderate to high drought risk, anticipatory actions are only triggered when the expected benefits of intervention, in terms of avoided losses, outweigh the associated costs and reflect the assumed effectiveness of the measures.

Thus, not every forecasted drought event triggers anticipatory action. Instead, the model applies an economic decision rule that ensures interventions are deployed only when they are justified on cost-effectiveness grounds. This approach enhances resource efficiency and supports more targeted and impactful implementation of anticipatory action. The concentration of trigger probabilities within the 0.13–0.18 range—despite being lower than forecast probabilities—indicates a relatively high likelihood of activating anticipatory action under the simulated risk environment.

In practical terms, this suggests that in most simulated scenarios, households or clusters are expected to implement anticipatory action because the anticipated avoided losses exceed the associated intervention costs. This consistent triggering behaviour underpins robust economic outcomes, ensuring anticipatory measures are deployed in a timely and predictable manner, thereby reducing both average and extreme drought-induced losses.

From a policy perspective, these findings carry several important implications. First, the high probability of activation confirms that anticipatory actions are not only economically justified but also operationally feasible under realistic forecast conditions.

Second, the clustering trigger probabilities within a narrow range offers a clear basis for defining early warning thresholds, enabling policymakers and practitioners to identify forecast probability levels that reliably justify intervention.

Third, selective triggering enhances resource efficiency by minimising expenditures in low-risk scenarios while concentrating efforts where they yield the highest economic returns.

Overall, this study highlights the critical importance of integrating probabilistic forecast information with household- and cluster-level risk profiles to guide the efficient and effective deployment of interventions across the IGAD pastoral and agro-pastoral regions.

The ex-ante deterministic economic analysis, summarised in Table 3, provides a comprehensive assessment of the economic implications of implementing anticipatory actions to mitigate drought-related livelihood shocks across the Karamoja, Mandera, and Moyale clusters. The analysis combines primary household survey data collected in 2025 with complementary secondary data sources that enhance and contextualise the household-level observations. This integrated approach strengthens the robustness, accuracy, and location-specific relevance of the economic estimates.

Table 3: Synopsis of the ex-ante deterministic economic analysis

Cluster/Parameter	Mean	SD	Min	Lower 5%	Median	Upper 95%	Max
Karamoja							
Expected Loss with no AA	4031.76	3923.2	195.5	372.9	2719.8	11855.5	19553.6
Expected Loss with AA	1310.32	1275.0	63.5	121.2	883.9	3853.0	6354.9
Expected Avoided Loss	2721.44	2648.2	132.0	251.7	1835.9	8002.5	13198.7
Cost of AA Per HH	350.00	0.0	350.0	350.0	350.0	350.0	350.0
Net Economic Benefit of AA	2371.44	2648.2	-218.0	-98.3	1485.9	7652.5	12848.7
Benefit Cost Ratio of AA	7.78	7.6	0.4	0.7	5.2	22.9	37.7
Break-Even Cost for AA	2721.44	2648.2	132.0	251.7	1835.9	8002.5	13198.7
P(NB) >0	0.93	0.3	0.0	0.0	1.0	1.0	1.0
Mandera							
Expected Loss with no AA	3663.61	2492.0	436.3	795.1	2978.3	9311.6	13521.0
Expected Loss with AA	1557.03	1059.1	185.4	337.9	1265.8	3957.4	5746.4
Expected Avoided Loss	2106.57	1432.9	250.9	457.2	1712.6	5354.2	7774.6
Cost of AA Per HH	450.00	0.0	450.0	450.0	450.0	450.0	450.0
Net Economic Benefit of AA	1656.57	1432.9	-199.1	7.2	1262.6	4904.2	7324.6
Benefit Cost Ratio of AA	4.68	3.2	0.6	1.0	3.8	11.9	17.3
Break-Even Cost for AA	2106.57	1432.9	250.9	457.2	1712.6	5354.2	7774.6
P(NB) >0	0.95	0.2	0.0	1.0	1.0	1.0	1.0
Moyale							
Expected Loss with no AA	3275.77	2122.5	155.0	936.3	2745.7	7734.6	11527.8
Expected Loss with AA	1228.41	795.9	58.1	351.1	1029.6	2900.5	4322.9
Expected Avoided Loss	2047.36	1326.5	96.9	585.2	1716.0	4834.2	7204.9

Cluster/Parameter	Mean	SD	Min	Lower 5%	Median	Upper 95%	Max
Cost of AA Per HH	350.00	0.0	350.0	350.0	350.0	350.0	350.0
Net Economic Benefit of AA	1697.36	1326.5	-253.1	235.2	1366.0	4484.2	6854.9
Benefit Cost Ratio of AA	5.85	3.8	0.3	1.7	4.9	13.8	20.6
Break-Even Cost for AA	2047.36	1326.5	96.9	585.2	1716.0	4834.2	7204.9
P(NB) >0	0.98	0.1	0.0	1.0	1.0	1.0	1.0
Total							
Expected Loss with no AA	3658.45	3001.9	155.0	703.4	2816.3	9544.2	19553.6
Expected Loss with AA	1350.39	1070.3	58.1	249.1	1066.8	3486.8	6354.9
Expected Avoided Loss	2308.06	1958.2	96.9	420.2	1745.2	6291.7	13198.7
Cost of AA Per HH	378.09	45.0	350.0	350.0	350.0	450.0	450.0
Net Economic Benefit of AA	1929.96	1961.6	-253.1	25.7	1364.1	5941.7	12848.7
Benefit Cost Ratio of AA	6.22	5.5	0.3	1.1	4.5	16.6	37.7
Break-Even Cost for AA	2308.06	1958.2	96.9	420.2	1745.2	6291.7	13198.7
P(NB) >0	0.96	0.2	0.0	1.0	1.0	1.0	1.0
N	986						

Source: Based on IGAD Household Survey Data, 2025.

The assumptions used to estimate expected losses, avoided losses, AA costs, net economic benefits, benefit–cost ratios, break-even costs, and the probability of achieving positive net benefits are detailed in Annexes A–D. This comprehensive documentation ensures transparency and supports the reproducibility of the analysis.

4.3.5 Expected loss in the absence of anticipatory action

The expected loss without anticipatory action represents the potential economic damage that households would incur in the absence of preemptive interventions. As illustrated in Figure 18, the Karamoja cluster records the highest mean expected loss, estimated at USD 4,032 per household, alongside a substantial standard deviation of USD 3,923. This high variability indicates pronounced differences in household-level exposure to drought and livestock-related shocks.

The wide range of expected losses in Karamoja—spanning from a minimum of USD 196 to a maximum of USD 19,554—highlights extreme heterogeneity across households. This dispersion is driven primarily by difference in herd size, asset holdings, and localised environmental conditions. The Mandera and Moyale clusters exhibit slightly lower mean expected losses of USD 3,664 and USD 3,276, respectively. Nevertheless, both clusters also demonstrate considerable variability, with standard deviations of USD 2,492 (Mandera) and USD 2,122 (Moyale). These findings suggest that, despite lower averages, significant within-cluster inequality in exposure to economic risk persists.

Furthermore, the 95th percentile analysis indicates that, during severe drought events, households in all clusters face the possibility of catastrophic, livelihood-threatening losses. This underscores the presence of a heavy upper tail in the loss distribution, where a subset of households bears disproportionately high risk. Overall, the pronounced heterogeneity observed across and within clusters emphasises the need for finely targeted anticipatory interventions. Reliance on mean values alone risks obscuring the severe vulnerabilities faced by high-risk households. Figure 18 illustrates the distribution of expected losses across the three clusters.

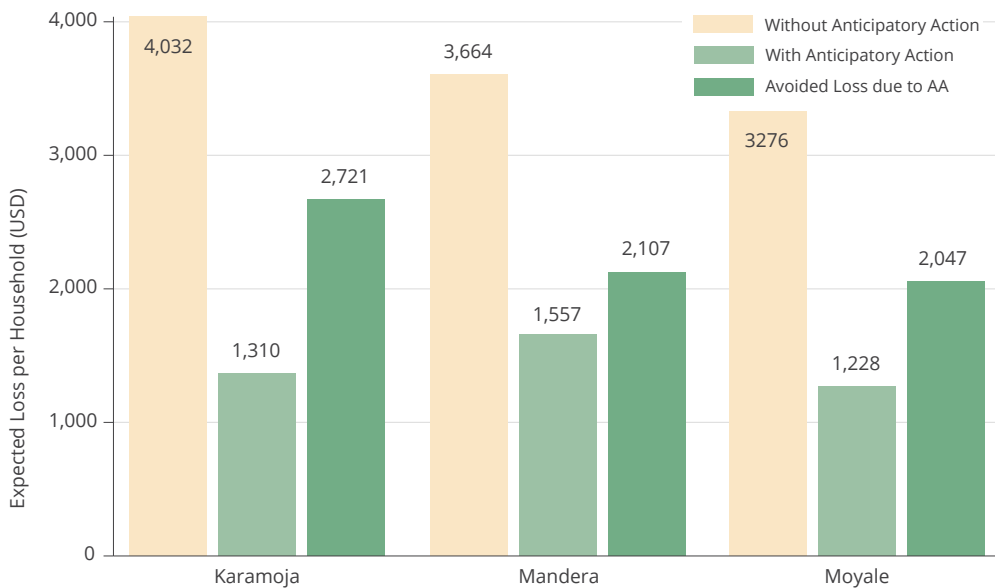


Figure 18: Expected drought losses and avoided losses from anticipatory action

Overall, the results demonstrate that households across all three clusters face substantial potential economic losses in the absence of anticipatory action, with Karamoja emerging as the highest-risk cluster. These findings suggest a dual policy approach. First, interventions should be geographically prioritised toward the most affected areas, particularly high-risk zones such as Karamoja. Second, household-level targeting should be strengthened by combining survey-based vulnerability indicators with secondary data sources, including historical drought loss patterns and livestock market dynamics.

Adopting such a targeted strategy would enable more efficient resource allocation and ensure support reaches the most vulnerable populations. Proactive measures to mitigate this high level of exposure can prevent large-scale economic shocks, protect livelihoods, and ultimately reduce long-term dependence on costly emergency humanitarian responses.

4.3.6 Expected loss with anticipatory action

The implementation of anticipatory actions substantially reduces projected economic losses across all clusters. Expected loss under anticipatory action is estimated using Equation (2) and presented in Table 3. In Karamoja, the mean expected loss per household decreases significantly from USD 4,032 to USD 1,310, a reduction of approximately two-thirds. Similar patterns are observed in Mandera and Moyale, where expected losses decline to USD 1,557 and USD 1,228, respectively.

Notably, the standard deviations of these losses also decline considerably. For example, in Karamoja, the standard deviation decreases from USD 3,923 to USD 1,275. This reduction in variability suggests that anticipatory action not only lowers the average level of economic damage but also stabilises household income streams by reducing the unpredictability of shock-related losses.

Importantly, this approach captures both household-level vulnerabilities and broader systemic shocks, including environmental and market-related risks. As such, the projected losses reflect a comprehensive assessment of risk under varying conditions. Overall, the findings provide strong evidence that anticipatory action interventions are effective in reducing both the magnitude and variability of economic losses, thereby enhancing household resilience and improving income predictability. The policy implication is clear: there is a compelling economic case for scaling up anticipatory action programmes across all clusters. Such efforts should prioritise households with the highest exposure to risk and continuously incorporate relevant secondary data sources to validate risk reduction estimates and improve the accuracy and effectiveness of interventions.

4.3.7 Expected avoided loss

The expected avoided loss—defined as the difference between projected losses without anticipatory action and those with anticipatory action—directly estimates of the economic value generated by these interventions. As shown in Table 3, mean avoided losses amount to USD 2,721 in Karamoja, USD 2,107 in Mandera, and USD 2,047 in Moyale.

Notably, the upper 95th percentile in Karamoja reaches USD 13,199, indicating that during high-severity drought events, anticipatory actions can yield exceptionally large economic benefits for the most vulnerable households. This highlights the non-linear

nature of climate impacts, where extreme events account for a disproportionate share of total losses. Consequently, preemptive interventions during such periods are especially critical.

To better communicate these findings, graphical representations—such as boxplots or overlaid density plots—would effectively illustrate both central tendencies and tail risks in the distribution of avoided losses across clusters. This would help policymakers and stakeholders clearly visualize not only the median benefits but also the potential for extreme gains.

4.3.8 Cost of anticipatory action per household

The analysis, based on secondary data sources, indicates that the costs of implementing anticipatory actions are relatively modest, particularly when compared to the potential losses they help avert. As presented in Table 3, the mean cost per household is estimated at USD 350 in both the Karamoja and Moyale clusters, and USD 450 in the Mandera cluster.

These cost estimates include direct implementation expenses, administrative overhead, and operational logistics. Further details on the secondary data sources used to derive these estimates are provided in Annex C. Overall, anticipatory action emerges as a highly cost-effective and financially feasible intervention, even within the resource-constrained contexts typical of IGAD pastoral and agro-pastoral regions. A key policy implication is that programme budgets can support substantial scale-up without exceeding realistic financial limits. Moreover, these results suggest that there is scope to incorporate additional complementary risk reduction measures, provided total programme costs remain comfortably below identified break-even thresholds.

4.3.9 Net economic benefit of anticipatory action

The ENB—defined as the difference between expected avoided losses and the cost of anticipatory action—is consistently positive across all clusters (Table 3 and Figure 19). The mean ENB is estimated at USD 2,371 in Karamoja, USD 1,657 in Mandera, and USD 1,697 in Moyale. Although the analysis identifies rare instances of negative minimum values (for example, –USD 218 in Karamoja), these outcomes are confined to households with unusually low baseline exposure to drought risk. Importantly, the probability of achieving a positive ENB remains very high across all clusters, ranging from 0.93 in Karamoja to 0.98 in Moyale.

These findings clearly demonstrate that anticipatory action is economically beneficial for many households. In practical terms, this implies that investments in anticipatory interventions not only reduce potential losses but also generate a reliable net financial gain, particularly under moderate- to high-risk scenarios.

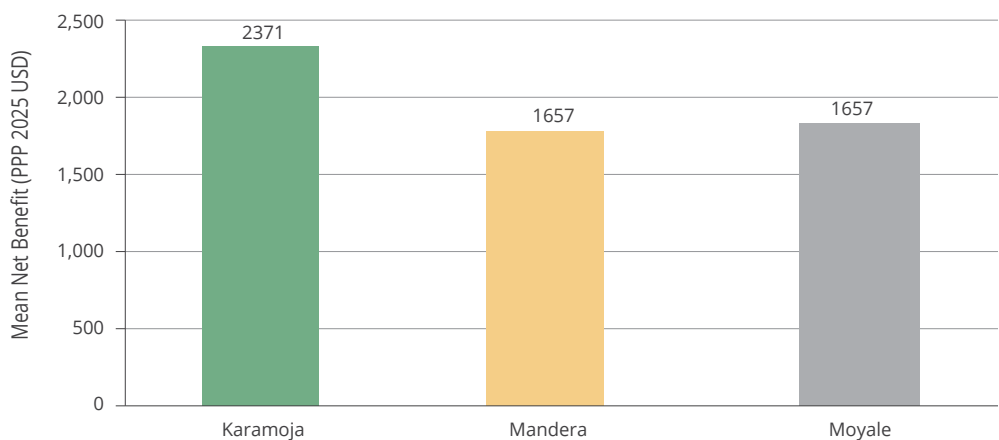


Figure 19: Expected net benefit of anticipatory action by cluster (PPP 2025 USD)

Anticipatory actions generate consistently strong positive economic returns and substantially reduce financial risk for most beneficiary households. The policy implications are threefold. First, targeting strategies should be refined to maximise aggregate net economic benefits, ensuring resources are directed to households most exposed to climate-related risks. Second, programme design should explicitly account for the small proportion of cases where net economic benefits may be negative, potentially through tiered targeting approaches or by integrating complementary social protection mechanisms. Third, the robustness and consistency of the net benefit results provide compelling evidence to support sustained, long-term investment in anticipatory action programmes by governments and development partners.

4.3.10 Benefit–cost ratio of anticipatory action

The BCR provides a standardised measure of economic efficiency and further confirms the strong value for money of anticipatory actions. As shown in Table I and Figure 20, the mean BCRs are 7.78 in Karamoja, 4.68 in Mandera, and 5.85 in Moyale. These results indicate that for every USD 1 invested in anticipatory action, households avoid approximately USD 4.7 to USD 7.8 in potential losses.

The upper-end values observed in the distributions—such as a BCR of 37.7 in Karamoja—underscore the exceptionally high returns that can be realised during severe drought events. This further reinforces the non-linear nature of climate risks, where extreme shocks generate disproportionately serious damage and, consequently, where anticipatory interventions yield the greatest economic returns.

Figure 20 illustrates the robustness of the results and demonstrates the strategic importance of anticipatory action as a high-return investment, particularly in crisis-prone environments.

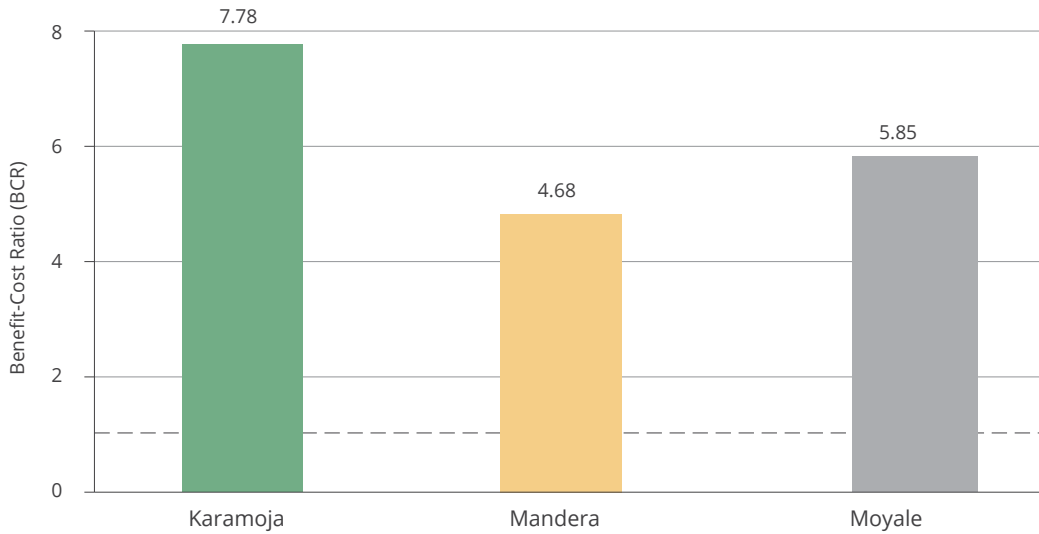


Figure 20: Cost-effectiveness of anticipatory action by IGAD agro-pastoral and pastoral cluster

In general, anticipatory action is highly cost-effective across all studied clusters. This finding has important policy implications for resource allocation: areas and sub-populations with higher estimated BCRs should be prioritised to ensure the most efficient use of limited financial resources. By directing investments toward contexts where returns are highest, policymakers can maximise overall economic impact.

Moreover, these strong efficiency metrics provide compelling evidence of the value for money offered by anticipatory action programmes. This is particularly important for engaging donors, government agencies, and development partners, as it strengthens the case for sustained and scaled-up investment. Ultimately, the consistently high BCRs reinforce anticipatory action as a financially sound and strategically critical approach within disaster risk management and resilience-building frameworks.

4.3.11 Break-even cost for anticipatory action

The break-even cost represents the maximum permissible expenditure on anticipatory action at which the net economic benefit remains non-negative. The analysis identifies mean break-even costs of 2,721 USD in Karamoja, 2,107 USD in Mandera, and 2,047 USD in Moyale (Figure 1.6). These values substantially exceed the actual implementation costs of 350–450 USD per household.

This positive differential indicates a significant buffer. It suggests that there is considerable scope to expand, enhance, or intensify interventions, whether by increasing the value of transfer packages, adding complementary activities, or extending coverage, without jeopardising the economic viability or positive net benefit of the programmes. It is also important to note that the current anticipatory action interventions are not only financially sustainable but also highly scalable within the identified cost parameters.

Policymakers and programme managers can utilise these break-even thresholds as critical benchmarks to guide budgeting, procurement, and strategic expansion decisions, ensuring that scale-up efforts continue to maximise net economic returns.

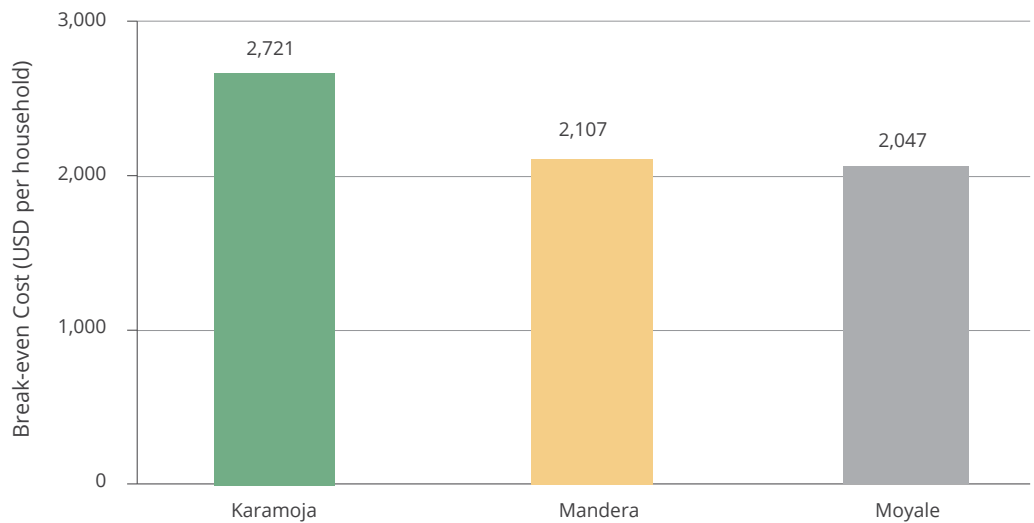


Figure 21: Break-even cost thresholds for anticipatory action by IGAD agro-pastoral and pastoral cluster

4.3.12 Probability that net benefit is positive

The high probabilities of achieving a positive net economic benefit—0.93 in Karamoja, 0.95 in Mandera, and 0.98 in Moyale—indicate that anticipatory action interventions are highly likely to generate favourable economic outcomes across a broad range of scenarios (Figure 22).

Importantly, these probabilities are not simple averages; rather, they are derived from full distributions that explicitly account for key sources of uncertainty. These include variation in household exposure to drought risks, fluctuations in market conditions, and inherent climate variability. As such, the estimates provide a more realistic and robust measure of expected performance under real-world conditions.

This robustness is further strengthened by the integrated analytical framework underpinning the analysis, which combines primary household survey data with relevant secondary data sources. By capturing both micro-level heterogeneity and broader systemic risks, the results offer a high degree of confidence in the reliability of the findings.

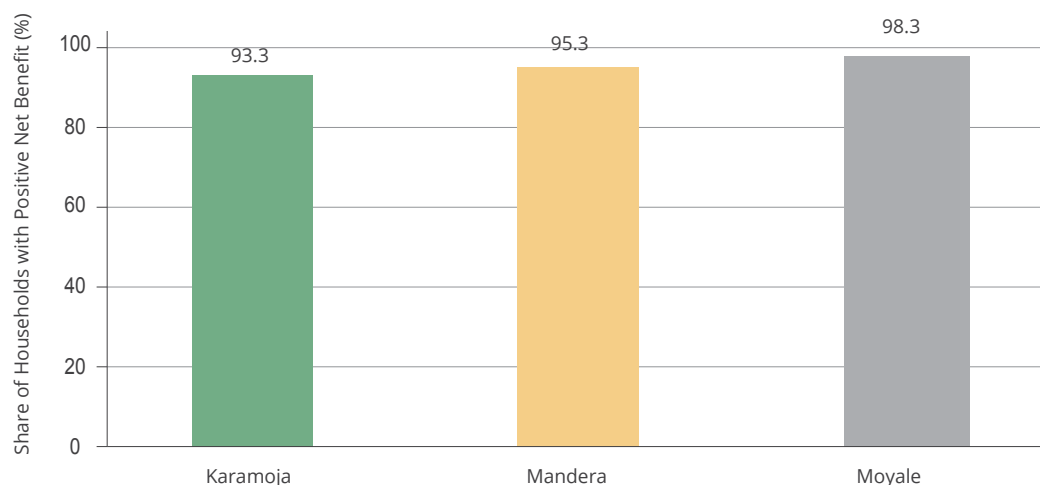


Figure 22: Percentage of households with positive expected net benefits IGAD agro-pastoral and pastoral cluster

It is observed that the anticipatory action interventions are a reliable and low-risk strategy for delivering economic benefits in drought-prone pastoral and agro-pastoral systems. This reliability provides decision-makers with greater confidence in allocating resources to anticipatory action ex-ante, rather than relying solely on ex-post emergency response. The policy implication is to institutionalise and sustain the integration of anticipatory action into regional and national drought management strategies, thereby reducing financial risk for both implementing agencies and beneficiary households.

In summary, the ex-ante deterministic economic analysis provides strong and conclusive evidence that anticipatory actions in the IGAD region's pastoral and agro-pastoral systems are highly effective. These interventions substantially reduce expected economic losses, generate significant positive net economic benefits, and demonstrate a high probability of success across diverse household contexts. While the Karamoja cluster exhibits the highest risk profile—and consequently the largest potential gains from intervention—all three clusters benefit from meaningful risk reduction and improved livelihood stability through anticipatory action. The integration of primary household survey data with secondary data sources strengthens the analysis, ensuring findings are both context-specific and reflective of the complex interaction between household-level vulnerability and broader systemic risk factors.

The policy implications arising from this evidence are both extensive and actionable. First, anticipatory actions should be systematically scaled up across high-risk areas within the IGAD region's pastoral and agro-pastoral systems. Second, targeting approaches should move beyond purely geographic criteria to incorporate household-level vulnerability indicators and expected net economic benefit metrics, thereby maximising both efficiency and equity. Third, anticipatory action programmes must be

closely linked with operational early warning systems and complemented by community capacity-building initiatives to ensure timely activation, local ownership, and sustained effectiveness.

Fourth, decision-making on resource allocation by governments, donors, and implementing agencies should be guided by key economic metrics—particularly break-even costs and benefit–cost ratios—to ensure financial sustainability and maximise returns on investment. Fifth, contingency planning frameworks must explicitly account for extreme drought scenarios, ensuring that households facing the highest levels of catastrophic risk receive adequate protection.

Together, this analysis provides a compelling evidence base demonstrating that anticipatory action is not only a critical humanitarian tool but also a sound economic investment. It justifies the need for predictable, long-term financing and stronger institutionalisation of anticipatory action within national and regional drought management systems.

Sustained commitment from governments, development partners, and humanitarian actors will be essential to fully realise the potential of anticipatory action in building resilient livelihoods across the IGAD region, particularly when anchored in robust drought early warning systems and proactive risk management strategies.

4.4 Probabilistic ex-ante economic analysis

While deterministic ex-ante economic analysis provides a foundational assessment of the expected economic impacts of anticipatory actions under fixed parameters, it does not capture the inherent variability and deep uncertainty that characterise real-world drought events, market fluctuations, and heterogeneous household vulnerability.

Pastoral and agro-pastoral households across the IGAD region face stochastic risks: drought severity varies year to year, livestock losses follow probabilistic patterns, and market prices exhibit both local and regional volatility. As such, deterministic estimates, while informative, may obscure the true economic value and risk profile of AA interventions by understating potential gains or failing to account for exposure to extreme losses.

The probabilistic ex-ante Monte Carlo analysis, summarised in Table 4, addresses these limitations by explicitly incorporating variability and uncertainty across multiple critical dimensions. By simulating thousands of plausible scenarios based on empirically derived distributions from household survey data, historical drought and livestock loss records, and regional climate and market datasets, the Monte Carlo framework produces a broad range of possible outcomes. This approach allows for the estimation not only of central expected values but also of the full distribution of key indicators, including avoided losses, net benefits, benefit–cost ratios, break-even costs, and extreme risk metrics such as VaR.

Therefore, transitioning from deterministic to probabilistic modelling significantly strengthens the evidence base for decision-making. It equips decision-makers with both central estimates of expected outcomes and a deeper understanding of variability and tail risks. Importantly, it enables the assessment of the probability that anticipatory action interventions yield positive net benefits under uncertainty, an essential consideration for planning, budgeting, and prioritising investments in resource-constrained, high-risk environments.

While deterministic analysis clarifies the average expected impact, probabilistic analysis reveals the robustness and reliability of anticipatory action interventions across a wide spectrum of plausible future scenarios, thereby reinforcing the economic rationale for proactive, anticipatory strategies.

Table 4: Summary statistics of key parameters for ex-ante Monte Carlo economic analysis by IGAD pastoral and agro-pastoral clusters

Cluster/ Parameter	Mean	SD	Min	Lower 5%	Median	Upper 95%	Max
Karamoja							
Simulated Expected Loss with no AA	4029.60	3981.2	117.2	377.3	2664.8	12313.4	30964.8
Simulated Expected Loss with AA	1309.53	1312.7	31.6	122.0	858.4	4061.5	12313.8
Simulated Expected Benefits with AA	2720.07	2696.4	75.3	254.7	1793.0	8345.3	21564.9
Simulated AA Cost	350.06	40.4	210.8	288.0	347.6	420.4	616.2
AA effectiveness Rate	0.67	0.0	0.5	0.6	0.7	0.7	0.8
Simulated Exposed Value	37235.64	4302.7	22132.8	30609.2	36995.5	44704.6	62881.9
Simulated Expected Net Benefit	2196.47	2563.1	-444.2	-116.3	1312.6	7548.6	21218.7
Simulated Benefit Cost Ratio	7.87	7.9	0.2	0.7	5.2	24.5	75.2
Simulated Break-even Cost	2720.07	2696.4	75.3	254.7	1793.0	8345.3	21564.9
Threshold Trigger Probability	0.20	0.3	0.0	0.0	0.1	0.8	24.0
Simulated Drought Forecast Probability	0.52	0.0	0.4	0.5	0.5	0.6	0.7
Probability ENB >0	0.92	0.3	0.0	0.0	1.0	1.0	1.0
Mandera							
Simulated Expected Loss with no AA	3664.07	2552.6	293.6	777.8	2984.8	9079.6	20204.8
Simulated Expected Loss with AA	1557.28	1095.1	105.5	331.3	1265.3	3873.1	8561.0
Simulated Expected Benefits with AA	2106.79	1475.2	161.5	447.7	1714.4	5234.7	12084.2

Cluster/ Parameter	Mean	SD	Min	Lower 5%	Median	Upper 95%	Max
Simulated AA Cost	450.20	51.9	255.6	370.2	447.3	540.5	736.0
AA effectiveness Rate	0.57	0.0	0.4	0.5	0.6	0.6	0.7
Simulated Value at Risk	22536.56	2601.8	12567.2	18531.6	22391.3	27051.2	37109.7
Simulated Expected Net Benefit	1447.61	1382.7	-556.9	-56.2	1087.4	4339.5	11398.5
Simulated Benefit Cost Ratio	4.74	3.4	0.3	1.0	3.8	11.9	33.0
Simulated Break-even Cost	2106.79	1475.2	161.5	447.7	1714.4	5234.7	12084.2
Threshold Trigger Probability	0.24	0.6	0.0	0.1	0.2	0.7	299.7
Simulated Drought Forecast Probability	0.60	0.0	0.4	0.5	0.6	0.7	0.8
Probability ENB >0	0.93	0.2	0.0	0.0	1.0	1.0	1.0
Moyale							
Simulated Expected Loss with no AA	3274.55	2177.4	96.6	907.0	2688.4	7855.8	17585.2
Simulated Expected Loss with AA	1228.15	828.5	32.7	332.9	1003.1	2966.7	7857.8
Simulated Expected Benefits with AA	2046.40	1368.5	61.5	563.5	1675.8	4919.3	10533.3
Simulated AA Cost	349.91	40.3	199.2	287.8	347.7	419.8	586.1
AA effectiveness Rate	0.62	0.0	0.5	0.6	0.6	0.7	0.8
Simulated Value at Risk	26945.28	3109.2	15872.3	22158.2	26761.8	32337.2	44384.6
Simulated Expected Net Benefit	1532.06	1300.0	-408.8	126.1	1178.1	4265.7	9883.4
Simulated Benefit Cost Ratio	5.93	4.1	0.1	1.6	4.8	14.4	35.3
Simulated Break-even Cost	2046.40	1368.5	61.5	563.5	1675.8	4919.3	10533.3
Threshold Trigger Probability	0.18	0.3	0.0	0.0	0.1	0.4	84.5
Simulated Drought Forecast Probability	0.57	0.0	0.4	0.5	0.6	0.6	0.7
Probability ENB >0	0.97	0.2	0.0	1.0	1.0	1.0	1.0
Total							
Simulated Expected Loss with no AA	3657.36	3060.1	96.6	672.7	2786.7	9776.0	30964.8
Simulated Expected Loss with AA	1350.08	1106.2	31.6	240.3	1044.0	3573.0	12313.8
Simulated Expected Benefits with AA	2307.28	2002.4	61.5	417.0	1719.1	6253.8	21564.9
Simulated AA Cost	378.14	62.9	199.2	293.4	366.7	497.9	736.0

Cluster/ Parameter	Mean	SD	Min	Lower 5%	Median	Upper 95%	Max
AA effectiveness Rate	0.63	0.1	0.4	0.5	0.6	0.7	0.8
Simulated Value at Risk	29432.54	7047.7	12567.2	20064.3	27813.4	41930.4	62881.9
Simulated Expected Net Benefit	1748.90	1906.3	-556.9	-22.4	1182.7	5494.6	21218.7
Simulated Benefit Cost Ratio	6.30	5.8	0.1	1.1	4.5	17.4	75.2
Simulated Break-even Cost	2307.28	2002.4	61.5	417.0	1719.1	6253.8	21564.9
Threshold Trigger Probability	0.20	0.4	0.0	0.0	0.1	0.6	299.7
Simulated Drought Forecast Probability	0.56	0.0	0.4	0.5	0.6	0.6	0.8
Probability ENB >0	0.95	0.2	0.0	0.0	1.0	1.0	1.0
N	986000						

4.4.1 Simulated expected loss in the absence of anticipatory action

The simulated expected loss without anticipatory action (EL_{noAA}) represents the distribution of potential economic damage that households would incur in the absence of pre-emptive interventions, explicitly accounting for probabilistic uncertainty. As reported in Table 4 above, the Karamoja cluster exhibits the highest mean simulated expected loss of USD 4,030 per household, with a notably large standard deviation of USD 3,981. This substantial dispersion reflects the wide range of potential exposures to drought and livestock-related shocks across households and simulated scenarios. The simulated loss ranges from a minimum of USD 117 to a maximum of USD 30,965, further underscoring the pronounced heterogeneity in household vulnerability and the potential for catastrophic outcomes under severe drought conditions.

The Mandera and Moyale clusters record lower mean simulated expected losses of USD 3,664 and USD 3,274, respectively. Nevertheless, both clusters demonstrate considerable variability, with standard deviations of USD 2,553 (Mandera) and USD 2,177 (Moyale). These findings reveal that, even when average losses appear comparatively lower, significant risk persists across all clusters. Moreover, the upper 95th percentile values reveal the latent potential for highly disruptive economic impacts during extreme drought years, risks that are not adequately captured by mean estimates alone.

Figure 23 presents the overlaid probability density functions of simulated expected losses without anticipatory action (EL_{noAA}) across clusters. The distributions exhibit pronounced skewness to the right, with a large concentration of probability mass around moderate loss levels but with extended right tails indicating a non-negligible probability of extreme losses. This asymmetry highlights a critical limitation of relying solely on average expected values. Mean estimates can substantially understate downside risk and fail to reflect exposure to low-probability, high-impact events.

The findings illustrated in Figure 23 therefore emphasises the importance of incorporating distributional analysis into economic risk assessments. The presence of right-skewed loss profiles provides strong empirical justification for proactive and robust risk management strategies, including anticipatory action. By explicitly targeting the reduction of tail risks, such interventions can play a crucial role in mitigating the potentially devastating consequences of rare but severe drought events, thereby enhancing household resilience and stabilising livelihoods in highly uncertain environments.

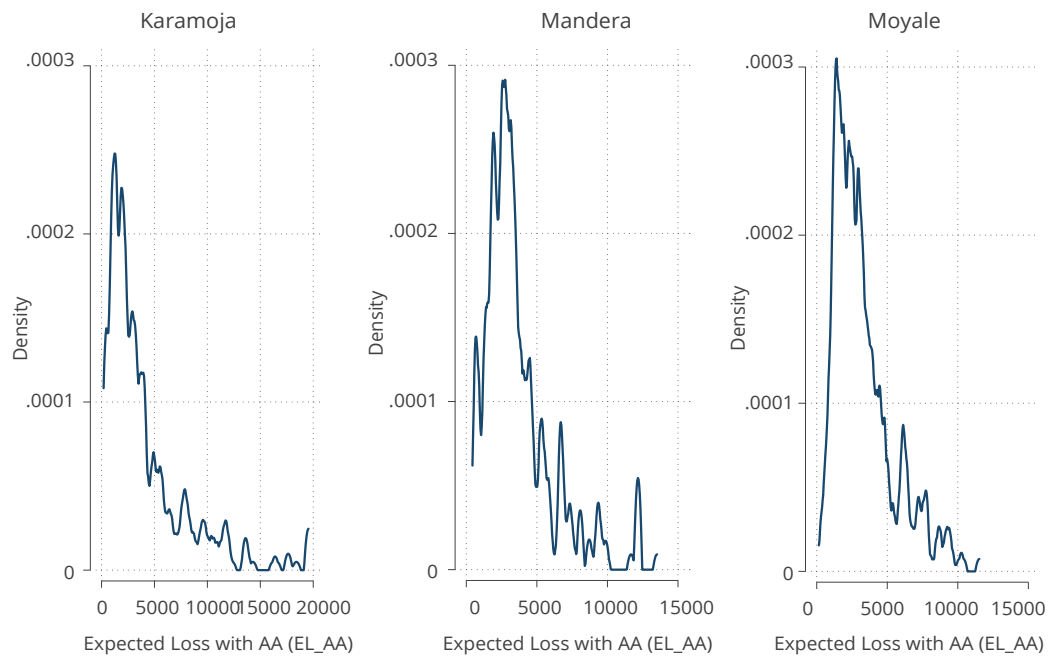


Figure 23: Kernel distribution of expected losses with no anticipatory action

4.4.2 Simulated expected loss with anticipatory action

The simulation results demonstrate that anticipatory action interventions are highly effective at reducing both the magnitude and variability of economic losses under deep uncertainty, thereby improving the predictability and stability of household income (Table 4). Across all clusters, implementing anticipatory action substantially reduces expected losses. In Karamoja, the mean simulated loss declines to USD 1,309 per household, a reduction of approximately two-thirds relative to the no-anticipatory action scenario. Similarly, mean losses decreased to USD 1,557 in Mandera and USD 1,228 in Moyale.

Essentially, the dispersion of losses also declines significantly under anticipatory action, with a marked reduction in standard deviations, indicating that anticipatory action not only lowers the central estimate of economic damage but also plays a critical role in stabilising household outcomes by reducing the volatility of potential losses. This

enhanced stability is particularly valuable for long-term planning, investment decisions and overall resilience in highly uncertain and risk-prone environments.

The distributions of simulated expected losses with and without anticipatory action across the three clusters are demonstrated in Figure 24. While introducing anticipatory action shifts the loss distributions downward, they remain right-skewed, indicating that extreme adverse outcomes are still possible.

This persistence of skewness reflects the structural and systemic nature of residual risk in pastoral and agro-pastoral systems, where exposure to severe climatic shocks cannot be fully eliminated. The anticipatory action substantially compresses the upper tail of the loss distribution and reduces the likelihood and severity of extreme outcomes. This shift demonstrates that the benefits of anticipatory action extend beyond reduces average losses to include meaningful attenuation of tail risk.

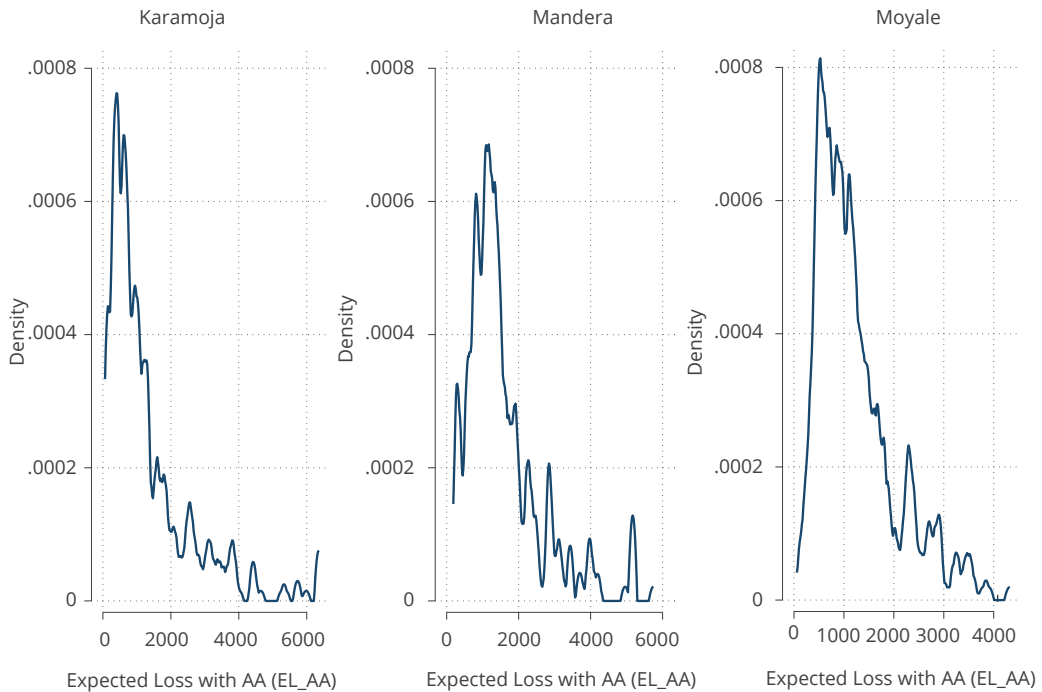


Figure 24: Kernel distribution of expected losses with anticipatory action

4.4.3 Simulated expected benefits of anticipatory action

The simulated expected benefits of anticipatory action, defined as the difference between losses without and losses with anticipatory action for each iteration, capture the full distribution of economic value generated by the interventions under uncertainty. As reported in Table 4 above, the mean simulated benefits amount to USD 2,720 per household in Karamoja, USD 2,107 in Mandera, and USD 2,046 in Moyale. These figures indicate substantial average gains attributable to AA across all clusters.

Beyond central tendencies, the distribution of benefits exhibits significant dispersion, reflecting heterogeneity in outcomes across different simulated scenarios. This is demonstrated by the pronounced upper tail of the benefit distribution. In Karamoja, for example, the 95th percentile of benefits reaches USD 21,565, highlighting the considerable upside potential of anticipatory action in extreme drought conditions. Although such high-impact scenarios occur with lower probability, they account for a disproportionate share of total avoided losses.

This pattern underscores the fundamentally non-linear nature of climate-related shocks, where the economic damages and, correspondingly, the benefits of mitigation escalate sharply under severe stress conditions. The ability of anticipatory action to generate exceptionally high benefits in these tail-risk scenarios provides strong empirical support for its role as a risk management and resilience-building instrument. These findings are consistent with the broader disaster risk reduction literature, which emphasises that interventions targeting low-probability, high-impact events often yield substantial economic returns by preventing catastrophic losses (Carter et al., 2018; UNDRR, 2020).

4.4.4 Simulated cost of anticipatory action

The analysis confirms that the costs of anticipatory action remain relatively modest, particularly relative to the scale of benefits generated. As presented in Table 4 above, the mean simulated costs amount to USD 350 per household in Karamoja, USD 450 in Mandera, and USD 350 in Moyale. These estimates encompass a comprehensive set of expenditures, including operational, logistical, and administrative components, derived from a synthesis of survey-based programme budgets and secondary market data.

To enhance realism, the simulation incorporates limited cost variability, reflecting practical uncertainties such as fluctuations in input prices, transportation costs, and implementation logistics. While this variability is relatively small compared with the variation observed in losses and benefits, its inclusion ensures a more robust and credible estimate of net benefits under real-world conditions. The comparatively low and stable cost structure of anticipatory action interventions, particularly when juxtaposed against the substantial and highly variable benefits generated, reinforces their strong economic efficiency. This cost–benefit dynamic further supports scaling up anticipatory action as a financially viable and risk-informed strategy for mitigating climate-induced shocks in vulnerable pastoral and agro-pastoral systems.

4.4.5 Simulated net economic benefit

The simulated ENB, defined as the difference between simulated benefits and anticipatory action costs in each iteration, provides a comprehensive measure of the overall economic performance of anticipatory action under uncertainty. The results show that anticipatory action generates strongly positive economic returns across

most simulated scenarios. As reported in Table 4 above and illustrated in Figure 25, mean ENBs amount to USD 2,196 per household in Karamoja, USD 1,448 in Mandera, and USD 1,532 in Moyale, confirming robust positive gains across all clusters.

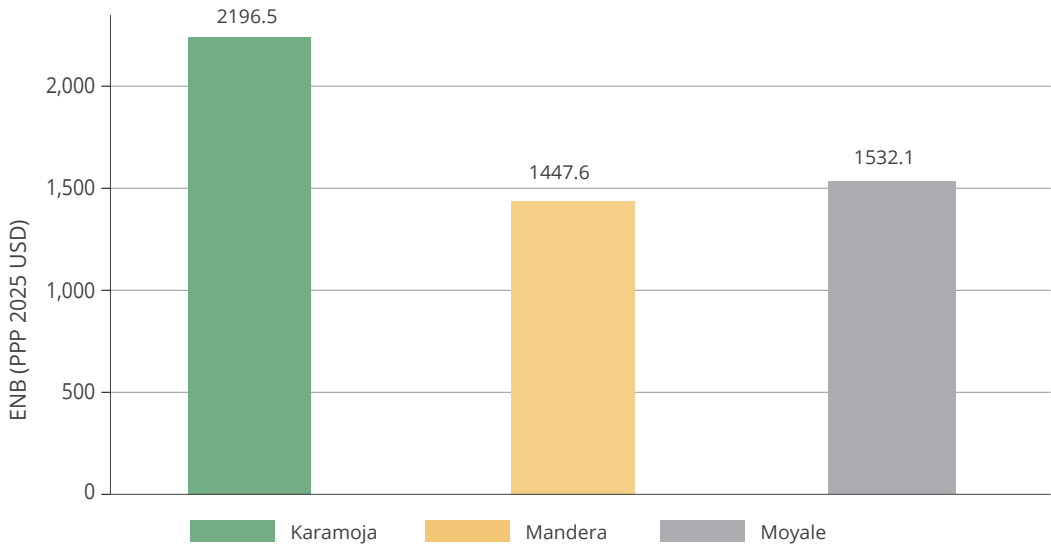


Figure 25: Expected net benefit per household from anticipatory action (Monte Carlo simulation)

While the distribution of ENB includes rare negative outcomes under extreme combinations of unfavourable parameters, such as a minimum ENB of -USD 444 in Karamoja, such cases are infrequent. The probability that ENB is positive remains consistently high, ranging from 0.92 to 0.97 across clusters (Figure 26). This high likelihood of positive returns underscores the resilience and reliability of AA investments, even amid considerable uncertainty.



Figure 26: Economic viability of anticipatory action

The ENB distribution is markedly right-skewed, with most outcomes clustered around moderate gains and a smaller subset of scenarios yielding substantially higher benefits (Figures 25, 26, and 27). This asymmetry reflects the state-contingent nature of anticipatory action, whereby avoided losses increase disproportionately during severe, though less frequent, drought events. As a result, a significant share of total economic value is concentrated in the upper tail of the distribution.

Including downside risk metrics, particularly the 5 per cent VaR, provides additional insight into the lower bound of performance. The VaR identifies the threshold below which only the worst 5 per cent of ENB outcomes fall. The finding that VaR remains close to zero or positive across clusters indicates that extreme unfavourable outcomes are limited in magnitude. This reinforces the protective role of anticipatory action in preventing catastrophic welfare losses, even under adverse conditions.

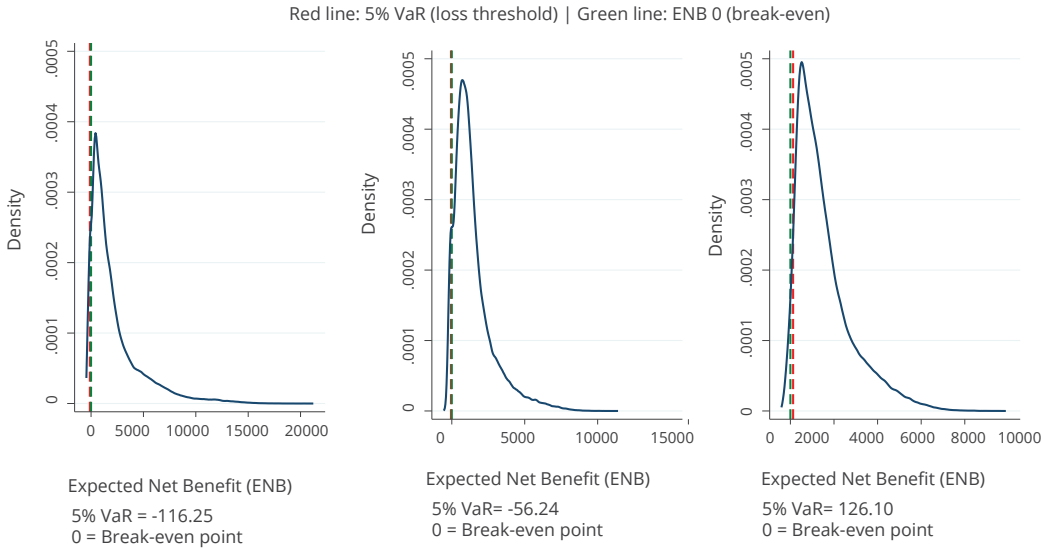


Figure 27: Kernel distribution of probabilistic expected net economic benefit by cluster

These findings highlight that reliance on mean ENB alone may understate the full economic value of anticipatory action. The combination of a right-skewed distribution and a favourable VaR profile demonstrates that anticipatory action functions as a highly effective risk management instrument, delivering disproportionate benefits in extreme realities while simultaneously constraining downside risk.

4.4.6 Simulated benefit-cost ratio

The simulated BCR in Table 4 and Figures 28, 29 and 30 below indicate highly favourable economic efficiency, with mean values of 7.9 in Karamoja, 4.7 in Mandera, and 5.93 in Moyale. These results indicate that for every USD 1 invested in anticipatory action,

losses of between USD 4.7 and 7.9 are averted on average. The extreme values in the upper percentiles, particularly the 75.2 in Karamoja, are highly informative. They suggest that in the simulated iterations representing extreme drought years, anticipatory action can deliver exceptionally high returns on investment, reinforcing the strategic value of interventions during major crises.

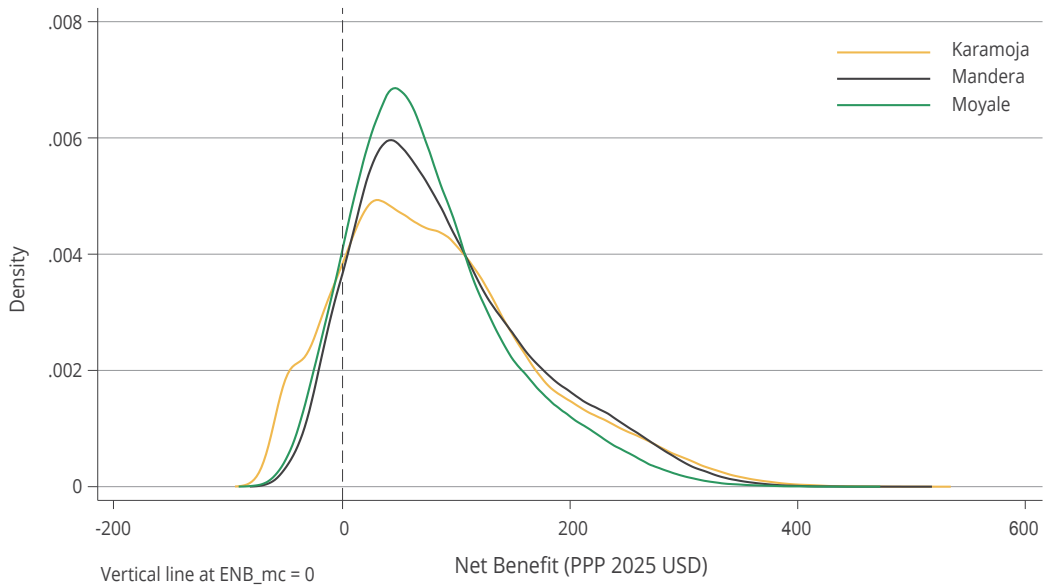


Figure 28: Distribution of expected net benefits of anticipatory action by cluster

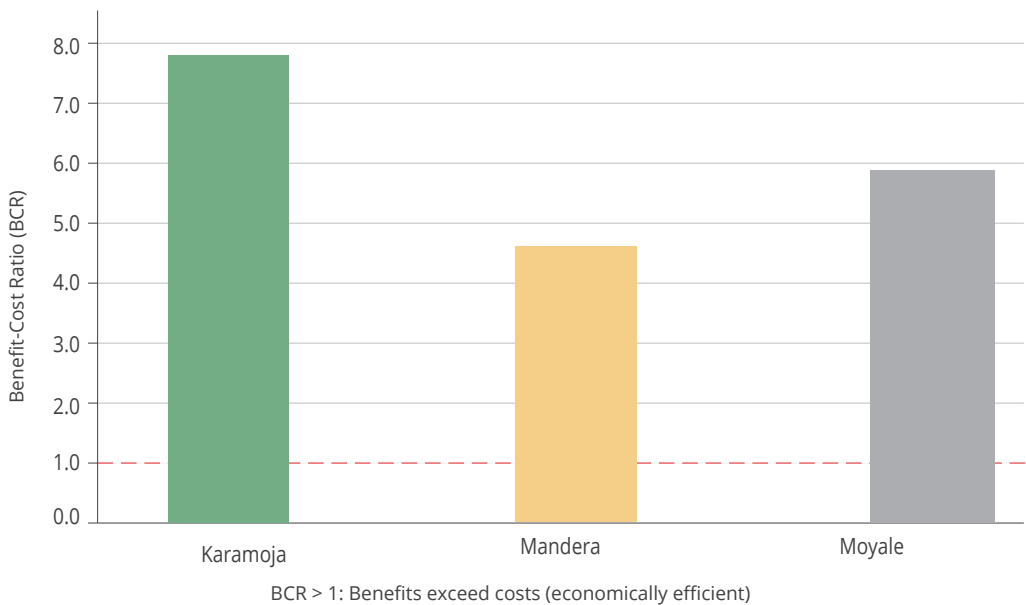


Figure 29: Economic efficiency of anticipatory action (mean benefit-cost ratio by cluster)

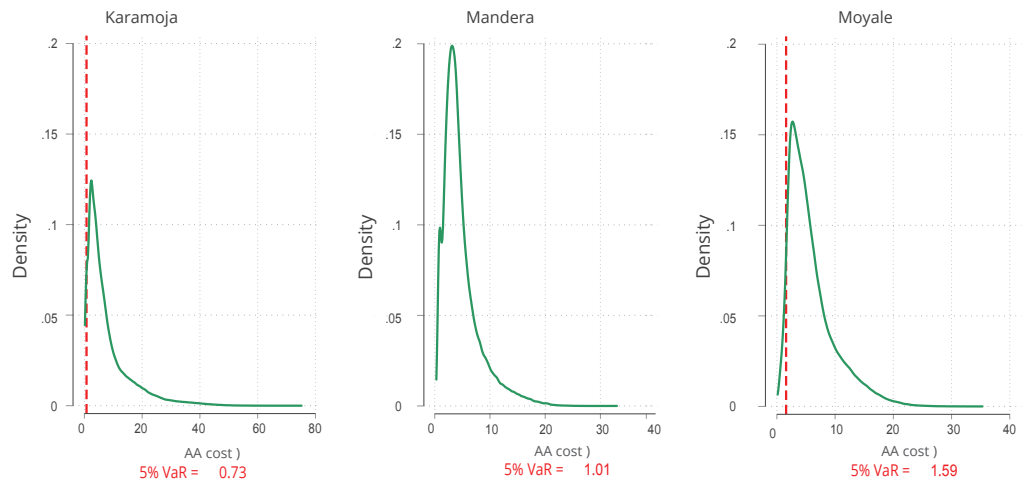


Figure 30: Kernel distribution of simulated benefit-cost ratio by cluster

4.4.7 Simulated break-even cost

The simulated break-even cost represents the maximum level of expenditure on anticipatory action at which the expected net economic benefit remains non-negative across the distribution of outcomes. As reported in Table 4 and illustrated in Figure 31, the estimated break-even thresholds are USD 2,720 per household in Karamoja, USD 2,107 in Mandera, and USD 2,046 in Moyale.

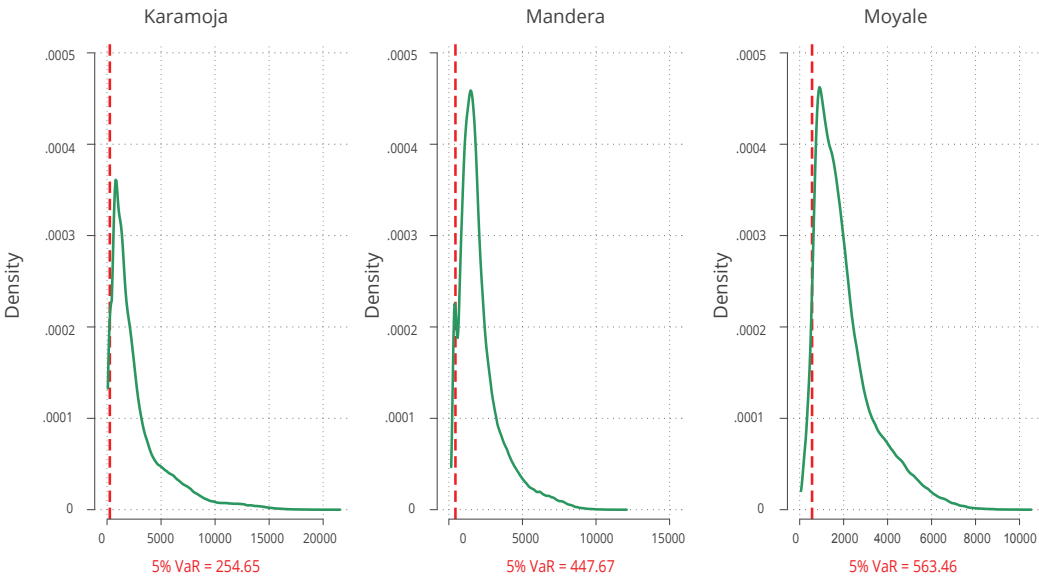


Figure 31: Distribution of break-even cost by livelihood cluster

These thresholds substantially exceed observed mean implementation costs, which range from approximately USD 350 to USD 450 per household. The large positive margin between actual costs and break-even levels indicates a considerable economic buffer, demonstrating that anticipatory action interventions remain highly cost-effective even under substantial increases in expenditure.

This margin has important policy implications. It suggests significant scope to scale up and strengthen anticipatory action interventions without compromising economic viability. Potential enhancements could include increasing transfer values, integrating complementary support such as livestock feed supplementation or veterinary services, improving targeting mechanisms, or expanding programme coverage to additional vulnerable households or regions.

From a risk management perspective, the break-even analysis further reinforces the robustness of anticipatory action investments under uncertainty. Even under adverse conditions or modest cost overruns, the probability that costs would exceed the benefits remains low. This highlights the resilience of anticipatory action as a policy instrument and underscores its suitability for deployment in highly uncertain, drought-prone environments.

Overall, the break-even cost analysis provides strong evidence that current anticipatory action programmes operate well within economically efficient bounds, offering policymakers both flexibility and confidence to invest in more ambitious and comprehensive anticipatory strategies.

4.4.8 Simulated exposed value

The simulated VaR for Karamoja, Mandera, and Moyale is estimated at USD 3,833, USD 4,467, and USD 4,150, respectively. The VaR represents the potential economic losses in the lower tail of the distribution and is derived from the exposed asset value and the household drought risk index. It therefore provides a concise measure of downside risk under extreme conditions.

Table 4 presents the underlying simulated exposed value, which captures the total asset base vulnerable to drought-related shocks. The results indicate mean exposed values of USD 37,236 in Karamoja, USD 22,537 in Mandera, and USD 26,945 in Moyale. These substantial asset levels highlight the scale of economic exposure facing pastoral and agro-pastoral households across the clusters.

While anticipatory action substantially reduces expected and moderately severe losses, the magnitude of exposed assets underscores that catastrophic impacts remain possible under extreme drought scenarios. This residual risk reflects structural vulnerability inherent in these systems. It emphasises the need for comprehensive risk management strategies that go beyond anticipatory action alone—potentially

including risk financing instruments, insurance mechanisms, and long-term resilience investments. Together, exposed value and VaR metrics provide critical insights into the scale of assets at risk and the importance of complementing anticipatory action with broader resilience planning.

4.4.9 Simulated anticipatory action effectiveness rate

The simulated anticipatory action effectiveness rate—defined as the proportion of potential losses averted through anticipatory interventions—directly measures programme performance under uncertainty. As reported in Table 4, the effectiveness rate ranges from 0.57 in Mandera to 0.67 in Karamoja, indicating that anticipatory action interventions avert well over half of the potential economic losses across all clusters.

This consistently high effectiveness demonstrates the strong capacity of anticipatory action to mitigate drought-related impacts across diverse contexts. The variation in effectiveness rates likely reflects differences in agro-ecological conditions, market integration, intervention timing, and the design and targeting efficiency of programmes in each location. From a policy perspective, these findings suggest that while anticipatory action is broadly effective, further gains may be achieved through context-specific optimisation of intervention design and delivery mechanisms.

4.4.10 Simulated drought forecast and trigger probabilities

The simulated drought forecast probabilities and trigger threshold probabilities provide important insights into the operational decision-making framework underpinning anticipatory action systems. Trigger threshold probabilities—the level of forecast confidence required to activate interventions—vary across clusters, with values of 0.20 for Karamoja, 0.24 for Mandera, and 0.18 for Moyale. These differences likely reflect variation in institutional risk tolerance, early warning systems calibration, and implementation protocols across regions or agencies.

The simulated drought forecast probabilities, which capture the likelihood of drought occurrence as indicated by early warning systems, range from 0.52 in Karamoja to 0.60 in Mandera. These values suggest moderate confidence in seasonal forecasts while acknowledging the inherent uncertainty in climate prediction. From a policy standpoint, the interplay between forecast probabilities and trigger thresholds is critical. Setting thresholds too high may delay action and reduce effectiveness, while overly low thresholds may lead to premature or unnecessary intervention costs. Therefore, the results highlight the importance of carefully balancing forecast reliability and risk tolerance in designing anticipatory action trigger mechanisms, ensuring timely and cost-effective responses to impending drought conditions.

4.5 Policy Implications

This evaluation applies both deterministic and probabilistic analytical approaches, which together provide complementary and mutually reinforcing insights into the economic performance of anticipatory action. The deterministic analysis establishes that anticipatory action interventions reduce expected losses and generate positive net benefits across all livelihood clusters. It offers clear, policy-relevant metrics—such as benefit–cost ratios and break-even costs—that support initial decision-making on resource allocation and programme justification. However, by relying on fixed parameter values, the deterministic framework is inherently limited in capturing the deep uncertainty and variability associated with drought risk, cost structures, and intervention effectiveness.

The probabilistic Monte Carlo analysis addresses this limitation by explicitly integrating uncertainty across key parameters and simulating a wide range of plausible future scenarios. Rather than producing single-point estimates, it generates full probability distributions of economic outcomes, thereby providing a more comprehensive and risk-informed assessment of anticipatory action performance. Critically, the probabilistic findings strongly validate and reinforce the deterministic results: net benefits and benefit–cost ratios remain consistently positive and economically significant across both approaches. This convergence strengthens the credibility and robustness of the findings, demonstrating that the economic case for AA is resilient even under substantial uncertainty and variability.

Taken together, the deterministic and probabilistic ex-ante analyses provide compelling evidence that anticipatory action in the IGAD region's pastoral and agro-pastoral systems is economically efficient, financially viable, and highly effective under both average and adverse conditions. Across all study clusters, anticipatory action substantially reduces not only the expected magnitude of losses but also their variability, thereby stabilising household outcomes and enhancing resilience. The interventions consistently generate large positive net benefits, exhibit high probabilities of success, and deliver exceptional value for money.

Moreover, the probabilistic results highlight that the economic value of anticipatory action is particularly pronounced in extreme drought scenarios, where avoided losses—and thus returns on investment—are greatest. At the same time, downside risks remain limited, reinforcing AA's role as a robust risk management instrument that protects households from catastrophic welfare losses.

Finally, the integrated analytical framework—combining detailed household-level survey data with complementary secondary datasets on climate, markets, and livestock systems—ensures that the findings are both empirically grounded and systemically relevant. This strengthens the policy relevance of the results and provides a solid evidence base for scaling up anticipatory action as a core strategy for managing climate-related risks in the region.

The findings of this study generate a set of clear, evidence-based implications for policy and operational planning in the IGAD region. These implications span strategic financing, targeting, system integration, and comprehensive risk management.

○ **Scale up anticipatory action as a cost-effective drought risk management strategy**

The consistently positive net economic benefits, high benefit-cost ratios (4.7-7.9), and high probabilities of positive returns (92-98 per cent) demonstrate that anticipatory action is a sound economic investment across all study clusters. Governments, donors, and humanitarian agencies should therefore institutionalise and expand anticipatory action programmes as a core component of drought risk management rather than relying primarily on costly post-disaster responses.

○ **Strengthen risk-based targeting using household and cluster-level vulnerability indicators**

The analysis reveals substantial heterogeneity in drought risk and expected losses both within and across clusters. Policymakers should move beyond geographic targeting alone and incorporate household-level drought risk indices, exposure levels, and expected net benefit metrics when allocating resources. This approach would improve efficiency, equity, and overall effectiveness of interventions by prioritising the most vulnerable households.

○ **Integrate anticipatory action with operational early warning and forecast systems**

The results show that forecast probabilities consistently exceed the economically optimal trigger thresholds, indicating strong potential for timely activation of interventions. Investments should therefore focus on strengthening drought forecasting systems, improving forecast accuracy, and establishing clear trigger mechanisms that link early warning information directly to pre-agreed financing and response actions. This would enhance both the timeliness and effectiveness of anticipatory interventions.

○ **Increase long-term financing and support programme expansion**

The estimated break-even costs are substantially higher than current implementation costs, indicating considerable scope for scaling up interventions while maintaining economic viability. Policymakers and development partners should establish predictable financing mechanisms that support more extensive coverage, higher transfer values, and complementary resilience-building measures such as livestock health services, fodder support, and climate adaptation initiatives, particularly in high-risk areas such as Karamoja.

Together, these findings suggest that anticipatory action should be mainstreamed within national and regional drought management frameworks as a financially viable, evidence-based, and resilient approach to reducing climate-related livelihood losses in the IGAD pastoral and agro-pastoral systems.

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Annex A

Seasonal Drought Forecast Probabilities and Assumptions for Ex-Ante Economic Analysis

A.1 Purpose and scope

This annex documents the forecast evidence and modelling assumptions used to represent seasonal drought risk in the ex-ante economic analysis for three IGAD cross-border areas: Karamoja, Moyale, and Mandera. These clusters join places where pastoral livelihoods, livestock movement, water access, and trade extend across national borders (IGAD & ICPAC, 2020).

The evidence window runs from 2019 through 2023, but it was not one continuous dry period. The March–May (MAM) 2019 forecast favoured above-normal rainfall at representative locations in all three clusters, while much of Eastern Africa was dry. October–December (OND) 2019 then brought exceptional rainfall, and MAM 2020 was wetter than usual in most of the target cluster area (ICPAC, 2019a; Ogallo, 2019; IGAD & IGAD Climate Prediction and Applications Centre (ICPAC), 2020). The regional multi-season drought most relevant to this analysis began with poor rains in late 2020. It intensified through five consecutive poor seasons in the eastern Horn before conditions improved in parts of the region during MAM 2023 (FAO, 2023).

A.2 Evidence sources and reconstruction method

The primary forecast records are the seasonal products of the Greater Horn of Africa Climate Outlook Forum (GHACOF), coordinated by the ICPAC. The products assign probabilities to three rainfall categories: above normal, near normal, and below normal. The 2021–2023 statements also explain how ICPAC recalibrated global seasonal prediction systems for the region and defined the categories against a 30-year climatology (ICPAC, 2021, 2022, 2023). This probability format follows established practice seasonal-forecasting practice (Gneiting & Katzfuss, 2014; Wilks, 2019; WMO, 2020).

This annex traces every number in Table A2 to an official dataset, regional probability map, or cluster-level downscaling report. Representative places within each cluster were located on the published probability zones. Where a cluster crosses a boundary, the table reports the adjacent zone values as a range. No spatially weighted cluster average was calculated. The range therefore shows geographic or seasonal variation; it is not a new probability estimate.

Forecast interpretation was checked against the Food Security and Nutrition Working Group (FSNWG) alert and the Famine Early Warning Systems Network (FEWS NET) seasonal and country monitoring products. These sources describe observed rainfall, pasture, water, crops, and food security after forecasts were issued (FSNWG, 2020; FEWS NET, 2021, 2022a, 2022b). They support impact pathways but do not replace the original GHACOF probability triplets (below, near and above normal rainfall probabilities).

Regional GHACOF maps cover broad zones. ICPAC explicitly advises users to consult national meteorological services for national and subnational detail (ICPAC, 2022, 2023). It is important to note that the figures below are appropriate for scenario analysis. They are not sufficiently precise to operate a local financing trigger without downscaling and local validation.

A.3 Why the analysis uses ranges

A single average across 2019–2023 would combine wet, near-normal, and dry outlooks and would hide the information available in each season. It would also imply more precision than the regional maps support. The ex-ante analysis should instead preserve the issued category probabilities and test results across the documented range (Gneiting & Katzfuss, 2014; Wilks, 2019; WMO, 2020, 2023).

The range is an input to sensitivity analysis, not an automatic trigger. Forecast-based action requires a threshold tied to the cost of acting, the losses avoided, forecast skill, implementation time, and the consequences of a false alarm or missed event. Coughlan de Perez et al. (2015) provide that decision framework but do not establish a universal 45 per cent or 50% per cent threshold for these clusters.

A.4 Cluster-specific characterisation

The three clusters do not respond as uniform climate units. They cross national boundaries and, in the case of Karamoja, several GHACOF probability zones. The published record supports the distinctions in Table A1. Karamoja spans southwestern Ethiopia, northwestern Kenya, southeastern South Sudan, and northeastern Uganda. Its eastern and western parts often carried different signals. FEWS NET reported poor eastern-Horn rangeland conditions in late 2021, while northeastern Uganda was wetter than average (FEWS NET, 2021).

In 2022, pastoral areas in Turkana faced severe drought impacts, but a single cluster-wide probability would still have concealed the spatial variation (FEWS NET, 2022b; ICPAC, 2022). Moyale covers Marsabit and the Borana borderlands. The 2020 cluster downscaling expected drier conditions and a late start in the eastern part of Marsabit and southern Ethiopia. By late 2022, FEWS NET documented erratic rainfall and deficits of 40 per cent or more in parts of southern Oromia, alongside severe pastoral stress (IGAD & ICPAC, 2020; FEWS NET, 2022a).

Mandera lies in the eastern Horn drought corridor. The below-normal probability was about 50 per cent in the OND 2021 regional zone and rose to 65 per cent across much of the area in OND 2022. The drought signal remained elevated in the MAM 2023 outlook, although the map still contained transition areas and local variation (ICPAC, 2021, 2022, 2023).

Table A1 Evidence-based seasonal drought characterisation by cluster

Cluster	Seasonal and spatial basis	Documented pattern	Decision relevance	Main limitation
Karamoja	MAM and OND; South Omo, Turkana, southeast South Sudan, northeast Uganda	Wet or mixed signals in 2019–2020; sharp east–west variation in 2021; much drier eastern subareas in 2022	Model eastern pastoral and western agro-pastoral subareas separately; track pasture and water with rainfall	Crosses several GHACOF zones; no defensible single cluster probability
Moyale	MAM/Belg/Gu and OND; Marsabit–Moyale–Borana	Drier eastern subareas in OND 2020; 45–50% below normal in OND 2021; 55–65% in OND 2022	Use rainfall onset and pasture/water monitoring together; retain a transition-zone scenario	Regional zone readings are approximate and do not replace local forecasts
Mandera	Gu/MAM and Deyr/OND; Mandera–Dolo–Gedo triangle	Drier signal in OND 2020; about 50% below normal in OND 2021; up to 65% in OND 2022	High priority for livestock, water, and market protection after consecutive poor seasons	Eastern border locations can sit near probability-zone boundaries

Source: Author synthesis from IGAD & ICPAC (2020), FEWS NET (2021, 2022a, 2022b), and ICPAC (2021, 2022, 2023).

A.5 Traceable probability evidence

Table A2 reports only probabilities or qualitative signals that can be traced to an official record.

Table A2 Season-specific below-normal rainfall evidence used to bound the analysis

Out-look	Karamoja	Moyale	Mandera	Evidence status and interpretation
MAM 2019	25%	25%	25%	Machine-readable GHACOF 51 dataset: above normal was favored at 40%. This was not a drought forecast.
OND 2019	No drought range used	No drought range used	No drought range used	ICPAC reported a normal-to-above-normal forecast and exceptional observed rainfall across much of Eastern Africa.
MAM 2020	Wetter than usual	Wetter than usual	Wetter than usual	Observed performance reported for most SECCCI cluster areas; not a below-normal probability.
OND 2020	Mostly average west; drier east	About 40–50% in drier eastern zones	About 40–50% in drier eastern zones	Cluster downscaling and GHACOF 56 map; eastern cluster II and III carried the drier signal.

Out-look	Karamoja	Moyale	Mandera	Evidence status and interpretation
OND 2021	33–45%	45–50%	About 50%	Map-derived readings from GHACOF 59; values near boundaries are reported as ranges.
OND 2022	35–65%	55–65%	About 65%	Map-derived readings from GHACOF 62; the widest spread occurs in the four-country Karamoja cluster.
MAM 2023	33–50%	40–50%	40–50%	Map-derived readings from GHACOF 63; equal-probability transition zones are retained.

Source: ICPAC (2019a, 2021, 2022, 2023), Ogallo (2019), and IGAD & ICPAC (2020).

Notes: Percentages refer to the below-normal category. Values are direct dataset readings or approximate readings of official probability zones at representative cluster locations. They are not spatial averages. Qualitative cells are intentionally not converted into numbers.

Taken together, the records show a wet or mixed opening to the period, clear deterioration after late 2020, and the strongest regional drought probabilities in OND 2022. Severity and timing differed across and within the clusters.

A.6 Seasons and timing for anticipatory action

The model should link action to the rainy season that precedes the expected livelihood loss, but the operational lead time depends on the action. Feed procurement, water-point repair, animal health campaigns, cash delivery, and commercial destocking have different preparation times. The cluster report recommends immediate dissemination, feed conservation, vaccination, water support, contingency planning, and timely destocking when adverse seasonal information is issued (IGAD & ICPAC, 2020). FEWS NET monitoring shows that pasture, livestock, nutrition, and market effects can persist well beyond the end of a failed season (FEWS NET, 2022a, 2022b).

Table A3 Action-relevant seasons and model timing assumptions

Cluster	Key season	Evidence-backed decision signal	Model action window	Expected stress window
Karamoja	MAM; OND as secondary	Below-normal category favored in affected subareas, confirmed by deteriorating pasture/water monitoring	Feb–Apr for MAM actions	Jun–Sep, with a second risk period after poor OND
Moyale	MAM/Belg/Gu	Adverse rainfall or onset signal plus poor pasture and water indicators	Feb–Apr	Jun–Oct; timing varies by subarea and herd mobility

Cluster	Key season	Evidence-backed decision signal	Model action window	Expected stress window
Mandera	Gu/MAM; Deyr/OND as secondary	Below-normal rainfall, delayed onset, early cessation, or dry-spell risk, corroborated by rangeland monitoring	Mar–May for Gu actions	Jul–Sep; prolonged after consecutive failed seasons

Source: IGAD & ICPAC (2020), FSNWG (2020), FEWSNET (2022a, 2022b), and Coughlan de Perez et al. (2015). The action windows are economic-model timing assumptions. They are not official agency trigger thresholds and require validation against the implementing agency's readiness, costs, and standard operating procedures.

A fixed probability by itself is not enough. The decision rule should state the forecast product and issue date, the geographic unit, the corroborating indicator, the action, the budget released, and the latest date on which the action still has value.

Annex B

Cluster-Specific Drought Anticipatory Action Protocols, Budgets, and Cost Assumptions

B.1 Purpose and status of the cost parameters

This annex documents the anticipatory action packages and per-household costs used in the ex-ante economic analysis for Karamoja, Mandera, and Moyale. The totals of 300–400 international dollars (I\$) for Karamoja, 400–500 I\$ for Mandera, and 300–400 I\$ for Moyale are model calibration ranges. No reviewed source publishes those complete cluster packages or the component shares shown in Tables B1–B3.

The ranges are retained so the existing economic model remains reproducible, but they should not be presented as FAO, WFP, IGAD, or government budgets. These values are estimated in 2025 international dollars.

B.2 What the published evidence supports

Evidence from the Horn of Africa supports early livestock health services, supplementary feed, water access, cash assistance, drought-tolerant seed, market support, and timely destocking. FAO's 2017 evaluation found substantial livelihood benefits from early pastoral interventions in Ethiopia, Kenya, and Somalia, while later WFP and FAO programs combined cash with early-warning information, fodder, rangeland management, water, and animal health activities (FAO, 2018, 2021, 2022; WFP, 2024a, 2024b).

The cluster record points in the same direction. The IGAD reports identify mobility, rangeland management, animal health, water, feed conservation, trade, conflict sensitivity, and contingency planning as recurring priorities in South Omo-Turkana/Karamoja,

Marsabit-Moyale, and Mandera (IGAD & ICPAC, 2020; Mohammed & Farah, 2020). Kenya’s livestock insurance experience also treats early payouts as asset-protection finance for feed, water, veterinary care, mobility planning, and timely sales rather than as compensation after animals die (Fava et al., 2021).

These sources justify the package components, not the percentage allocated to each component. Reviews of anticipatory action warn that costs and outcomes depend on hazard, lead time, delivery channel, local capacity, and conflict conditions (Weingärtner et al., 2020).

B.3 Costing method

A defensible budget begins with an activity-based bill of quantities. For each action, the analyst records the number of units per household, the local unit price, the expected coverage rate, transport and storage, payment fees, staffing, monitoring, safeguarding, security, and contingency. Shared costs are allocated across expected beneficiary households using a documented rule.

$$\text{Cost per household} = \text{sum (activity quantity} \times \text{local unit price)} + \text{delivery} + \text{monitoring} + \text{access/security} + \text{contingency}$$

Cash should be budgeted from the locally agreed transfer value and number of payment rounds. WFP’s technical guidance treats transfer value, timing, targeting, payment systems, protection, and monitoring as linked design choices rather than a fixed global amount (WFP, 2025).

B.4 Cluster packages used in the model

The tables B1 to B3 below show the current model midpoints and allocations.

Table B1 Karamoja model budget allocation at the 350 I\$ midpoint

Component	Model share	Model amount (2025 I\$)
Climate and crop support	40%	140
Livestock protection	30%	105
Cash assistance	20%	70
Conflict-sensitive access and delivery	10%	35
Total	100%	350

Source: Model calibration informed by IGAD & ICPAC (2020), Mohammed and Farah (2020), FAO (2018), and Weingärtner et al. (2020).

Karamoja combines crop and livestock exposure, so the model gives more weight to agricultural and livestock support than to cash alone. The operational package should

still be recalculated by subarea because pastoral Turkana and South Omo, agro-pastoral parts of Karamoja, and conflict-affected border locations do not have the same needs or delivery costs (IGAD & ICPAC, 2020; Mohammed & Farah, 2020).

Table B2 Mandera model budget allocation at the 450 I\$ midpoint

Component	Model share	Model amount (2025 I\$)
Emergency water access	35%	158
Cash assistance	30%	135
Livestock survival	25%	112
Security and access	10%	45
Total	100%	450

Source: Model calibration informed by FAO (2018, 2021, 2022), IGAD & ICPAC (2020), and Mohammed and Farah (2020). No reviewed source reports a 450 I\$ Mandera package or the component shares above.

Mandera receives the highest model midpoint because water delivery, dispersed settlements, cross-border coordination, and insecure access can raise operating costs. That ordering is plausible, but it must be tested against current borehole functionality, transport distances, local transfer values, and partner security plans before an activation.

Table B3 Moyale model budget allocation at the 350 I\$ midpoint

Component	Model share	Model amount (2025 I\$)
Market and livestock support	40%	140
Cash assistance	35%	123
Asset protection and mobility	15%	52
Conflict-sensitive delivery	10%	35
Total	100%	350

Source: Model calibration informed by WFP (2024a, 2024b), Fava et al. (2021), IGAD & ICPAC (2020), and Mohammed and Farah (2020).

B.5 Traceable external cost and transfer anchors

Published programme figures help reviewers judge scale, but they are not interchangeable with a complete cluster budget. The currency year, target population, package content, and whether the figure covers direct transfers or full delivery costs must remain attached to every benchmark.

Table B4 Programme figures that can be traced to an exact source

Program record	Place and year	Published figure	What the figure covers	Use in this annex
FAO drought project	Kenya, 2022	USD 100 per household	Two USD 50 unconditional cash rounds; wider project also included water and livestock activities	Cash benchmark only; not a full package
WFP AA activation	Somali Region, Ethiopia, 2024	USD 228.27 per household	Three months of anticipatory multipurpose cash	Cash benchmark only; not a full package
FAO drought project	Ethiopia, 2021-2022	USD 2,647,980 total budget	Cash plus livestock feed and animal health for 175,000 beneficiaries	Activity and scale reference; no household package can be inferred

Source: FAO (2021, 2022) and WFP (2024b). Figures are reported in their original nominal US dollars.

B.6 Comparative model parameters

Table B5 Cost ranges used for deterministic and Monte Carlo analysis

Cluster	Low	Central	High	Primary cost pressure	Parameter status
Karamoja	300	350	400	Mixed crop/livestock package and conflict-sensitive reach	Model assumption
Mandera	400	450	500	Water, dispersed delivery, access, and livestock survival	Model assumption
Moyale	300	350	400	Cash, livestock markets, mobility, and cross-border delivery	Model assumption

Source: Existing model calibration, retained for reproducibility. The qualitative cost pressures are supported by IGAD & ICPAC (2020), Mohammed and Farah (2020), and WFP (2024a); the numerical ranges are not reported by those sources.

The deterministic analysis should report the central value and both bounds. The Monte Carlo analysis may use a triangular distribution with the low, central, and high values above.

B.7 Trigger design and integration with the economic model

A package should not be released because one generic rainfall probability crosses a fixed threshold. The decision rule must identify the forecast product, geography, issue date, lead time, corroborating indicators, action cost, expected avoided loss, and tolerance for false alarms. Forecast-based financing frameworks and regional forecast-value research both treat thresholds as action- and user-specific (Coughlan de Perez et al., 2015).

Annex C

Methodological Framework and Assumptions for Anticipatory Action Effectiveness Rates

C.1 Definition and unit of measurement

In this model, effectiveness is the share of a specified drought loss that an anticipatory action package averts relative to a defined counterfactual. It is not the share of all household wealth protected, and it is not the same as forecast accuracy, coverage, transfer receipt, or beneficiary satisfaction.

$$\text{Effectiveness (e)} = (\text{loss without early action} - \text{loss with early action}) / \text{loss without early action}$$

The numerator and denominator must refer to the same outcome, population, geography, shock window, and valuation method. For example, an effect on distress livestock sales cannot be applied automatically to crop loss, malnutrition, or total household value. Forecast-based financing literature also separates the quality of the forecast from the effect of the action taken after a trigger (Coughlan de Perez et al., 2015; WMO, 2020).

C.2 Cluster effectiveness rates

The cluster ranges used are shown below (Table C1).

Table C1 Effectiveness calibration used in the existing economic model

Cluster	Livelihood system	Model range	Central value	Evidence status
Moyale	Cross-border pastoral and market system	55%-70%	62.5%	Model assumption; not externally validated
Mandera Triangle	Arid pastoral system with access constraints	50%-65%	57.5%	Model assumption; not externally validated
Karamoja	Pastoral and agro-pastoral system	60%-75%	67.5%	Model assumption; not externally validated

Source: Existing model calibration. FAO (2018, 2025), and Weingärtner et al. (2020) support the plausibility of positive and context-dependent effects but do not publish the cluster percentages shown here.

C.3 Cluster interpretation

Moyale may benefit from livestock-market access, mobility, veterinary support, feed, and anticipatory cash. Those mechanisms can protect productive assets when markets remain functional, but cross-border coordination and liquidity can fail during a severe shock. The 55 per cent to 70 per cent range should therefore be read as an optimistic model scenario rather than an evaluation result. The central value is 62.5 per cent.

Mandera faces longer distances to water, insecurity, and constrained humanitarian access. These conditions can reduce delivery and limit what cash or livestock support can achieve during an extreme drought. The model assigns Mandera the lowest central rate, but no verified Mandera study directly supports 57.5 per cent.

Karamoja offers several intervention pathways because crop and livestock activities coexist, yet conflict, unequal livestock ownership, and uneven service reach can lower realised effects. The model’s central value is 67.5 per cent. Forecast value also changes by season, location, lead time, and action. Research using Horn of Africa rainfall forecasts finds that optimal triggers are user-specific and that potential economic value declines as lead time and decision conditions change (Busker et al., 2023).

C.4 Timing, coverage, and delivery adjustments

The model should distinguish the effectiveness of a well-designed package from the share realised in an activation. A transparent structure applies separate factors for timing, coverage, delivery quality, and access. Each factor ranges from zero to one and must be documented.

$$\text{Realised effectiveness} = \text{base effectiveness} \times \text{timing factor} \times \text{coverage factor} \times \text{delivery factor} \times \text{access factor}$$

Table C2 Illustrative implementation factors for sensitivity analysis

Factor	High-performance case	Central case	Stress case	Status
Timing	1.00	0.85	0.65	Illustrative model factor
Coverage of intended package	1.00	0.85	0.70	Illustrative model factor
Delivery quality	1.00	0.90	0.70	Illustrative model factor
Access and security	1.00	0.90	0.60	Illustrative model factor

Source: Author-defined sensitivity structure informed by Coughlan de Perez et al. (2015), Busker et al. (2023), and WMO (2020). The numerical factors are illustrative assumptions and must be replaced with activation records when available.

Multiplying factors can produce very low realised rates, which is intentional when several constraints occur together. Analysts should check that the same failure is not counted twice; for example, households excluded by insecurity should not also be removed again under coverage unless the denominators differ.

Annex D

Monetary Valuation and Purchasing Power Parity (PPP) Adjustment

To ensure temporal consistency and contemporary policy relevance, all monetary values drawn from historical literature are updated to 2025 price levels. This study utilises a Purchasing Power Parity (PPP) adjustment, preferred over nominal exchange rate conversions for ex-ante welfare analysis. The PPP approach preserves the real domestic purchasing power of income, assets, and losses, avoiding distortions caused by exchange rate volatility in low-income economies (World Bank, 2023). The formal conversion for a historical monetary value X_t , expressed in nominal USD of year t , is:

$$X_{2025}^{PPP} = X_t * \frac{PPP_{2025}}{PPP_t}$$

where PPP_t and PPP_{2025} are the PPP conversion factors for the relevant country or regional average in the respective years. These 2025 PPP-adjusted figures serve as the central parameters in the analysis. In practice, because country-specific PPP series for 2025 are not yet finalised, this study applies the most recent available PPP benchmarks (e.g., 2017 or 2021 International Comparison Programme values) and extrapolates them to 2025 using observed domestic inflation differentials, consistent with World Bank methodological guidance (World Bank, 2023).

5.0 CONCLUSION

In the arid and semi-arid lands (ASALs) of the IGAD region, pastoral and agro-pastoral systems' vulnerability to periodic climate-induced shocks results from structural, economic, and socioecological realities. The analyses from the chapters demonstrate that livestock assets, drought risk, and anticipatory action are fundamentally interconnected dimensions of resilience in pastoral and agro-pastoral systems across the IGAD region.

Livestock remain the cornerstone of livelihoods, yet widespread livestock poverty, unequal asset distribution, and limited adaptive capacity continue to expose many households to recurrent drought-related losses and livelihood crises. The analyses show that drought risk is not solely a consequence of climatic hazards. It is also shaped by interactions among exposure, vulnerability, asset ownership, institutional capacity, and access to essential services and markets.

Across the study areas, livestock-based indicators such as herd size, livestock poverty, species diversity, market participation, and livestock ownership inequality emerge as important determinants of resilience and valuable predictors of drought vulnerability. At the same time, the multidimensional risk assessment highlights that structural constraints, including poverty, weak service delivery systems, limited financial inclusion, and inadequate access to climate and market information, significantly reduce households' ability to cope with and recover from shocks. Strengthening resilience therefore requires integrated approaches that protect and rebuild livestock assets. It also means addressing the underlying socioeconomic and institutional drivers of vulnerability.

The study further provides strong empirical evidence that anticipatory action offers a practical, economically viable, and highly effective means of reducing drought impacts. Both deterministic and probabilistic analyses consistently demonstrate that early action generates substantial net benefits, lowers expected losses, and remains cost-effective under a wide range of future scenarios. Beyond delivering positive economic returns, anticipatory action helps safeguard livelihoods, prevent irreversible asset depletion, and enhance the capacity of households to withstand and recover from severe drought events.

Taken together, the findings support a strategic shift from reactive crisis response toward proactive drought risk management. This transition should be anchored in strengthened early warning systems that integrate livestock and livelihood indicators, investments in adaptive capacity and service delivery, and the systematic scaling up of anticipatory action mechanisms. By combining risk-informed planning with timely interventions and sustained support for livestock-based economies, governments, regional institutions, and development partners can significantly reduce drought-related losses, enhance livelihood security, and build more resilient pastoral and agro-pastoral communities across the Horn of Africa.



Published by IGAD Centre for Pastoral Areas and Livestock Development

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ISBN 978-9914-9342-5-0



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