Climate change impacts, adaptation options and opportunities for investment in agro-pastoral value chains in arid and semi-arid regions of Kenya

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Summary

The nature-based value chains in the arid and semi-arid regions of Kenya have been adversely impacted by rising severity and frequency of droughts and floods, unprecedented emergence of pests and diseases, increased land degradation, and variations in temperature and rainfall. The stability of food systems, as well as the availability, accessibility and utilization of food, have all been significantly affected as a result. This has led to poor quality of life and increased vulnerability of communities to shocks and stress. The understanding of the climate change risks in nature-based value chains remains low especially among the rural population, who also happen to be the most susceptible to the significant changes in climatic conditions observed in arid and semi-arid areas of Kenya. This report examines the risk of climate-related impacts along the various nature-based value chains in four arid and semi-arid counties: Narok, Elgeyo Marakwet, West Pokot and Turkana. The risks result from the interaction of climate-related hazards with the exposure and vulnerability of pastoral communities and natural systems. The mapping of climate risks along value chains and identification of adaptation options was based on the value chain analysis for resilience in drylands, commonly referred to as the VC-ARID method, using a five-step approach for climate change risk assessment in rangeland value chains.

Based on their viability under the current climatic conditions and their contribution to the livelihoods and general well-being of the community, eight value chains were studied: pasture and fodder, livestock, bee, gum and resin, aloe, poultry, mango, and beadwork. Our findings indicated that all the counties had typically limited access to financial services, market information and climatic information, despite these being the most crucial services that support the development of sustainable value chains in rangeland counties. The mean surface maximum and minimum temperature is projected to increase coupled with decrease in annual precipitation over the four counties. This is expected to exacerbate water and heat stress which cause the proliferation of weeds, pests, and pathogens, shorten the length of growing season, and render some areas unsuitable for agricultural production, with adverse impacts on plant growth, animal productivity and yields. It is therefore necessary to manage climate risks by identifying, characterizing and reducing the susceptibility of natural and human systems to climate change, with a focus on enhancing adaptive capacity along pastoral value chains. To address climate risks and vulnerabilities, it is necessary to move from resilience to adaptation to transformational adaptation, which entails a reduction in the long-term root causes of vulnerability to climate change by shifting systems from unfavorable or unsustainable trajectories through the promotion of climate-resilient value chains.

Key words: rangelands; nature-based; value chain; climate change; resilience ; transformative adaptation

Abbreviations

ASAL	Arid and Semi-arid Lands
CBO	Community Based Organizations
CHIRPS	Climate Hazard Group Infrared Precipitation with Stations
CORDEX	Coordinated Regional Downscaling Experiment
FAO	Food and Agriculture Organization
FDG	Focus Group Discussions
HH	Household
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agricultural and Livestock Research Organization
KEFRI	Kenya Forest Research Institute
KII	Key Informant Interviews
KWS	Kenya Wildlife Services
LMA	Livestock market Associations
NDMA	National Drought Management Authority
NGO	Non-Governmental Organization
PPP	Public Private Partnership
RCPs	Representative Concentration Pathways
UNCCD	United Nations Convention to Combat Desertification
VC-ARID	Value chain analysis for resilience in drylands
WRUA	Water Resource Users' Associations

1. Introduction

1.1 Background information

Rangelands in Kenya are increasingly facing devastating impacts of severe and recurrent droughts which are a manifestation of changes in climate (Mugo et al., 2020). This is anticipated to worsen in the coming decades, with climate models indicating negative trends such as consecutive poor rains, an increase in drought-related shocks, and more unexpected and sometimes intense rainfall events. The IPCC models show that increasing severity and frequency of droughts and floods in East Africa are likely to exceed tolerance thresholds of both plants and animals, resulting in mass mortalities that threaten the well-being of communities whose livelihoods rely heavily on natural resources (IPCC, 2023). This means that populations in rangelands that rely primarily on pastoralism, small-scale crop farming, and ecotourism will bear the brunt of the socioeconomic and ecological consequences of climate-related shocks and stresses like droughts and floods (Apraku et al., 2021).

Pastoralism, which includes extensive livestock production, is heavily reliant on access and availability of water and pasture which are sparsely distributed due to the seasonality of rains in the tropical rangelands (Lutta et al., 2021). Rainfall is extremely localized, unpredictable, seasonal and unreliable, resulting in spatial-temporal fluctuations in water and pasture distribution throughout vast rangeland areas (Machan et al., 2022). Crop production, on the other hand, is particularly vulnerable to weather and climate-related risks such as drought and flooding, which contribute to rising food insecurity (Emali, 2023). This indicates that people, biodiversity and climate change are highly interdependent. There is a need for quick action on nature-based solutions to adapt to climate change while also reducing greenhouse gas emissions in order to prevent the further loss of life and biodiversity caused by the changing climate. This calls for a move toward transformative adaptation, particularly given the unevenness of the current adaptation progress and the growing gaps between what has been done and what is required to address the rising risks of climate change in Kenya's arid and semi-arid regions, which are characterized by lower-income populations.

Because they have less resources to fall back on in the event of shocks, poor households in arid and semi-arid areas are more exposed and vulnerable (Kirui et al., 2022). The loss of natural resources and effects of climate change make pastoral communities less resilient, adding to long-standing risks such as insecurity and conflict, market volatility, food shortages, and weak governance (Kariuki et al., 2018). Communities are therefore extremely vulnerable to climate change due to their reliance on climate-sensitive natural resource-based value chains. (Lind et al., 2020).

Pastoral communities in arid and semi-arid regions have historically adapted to the impacts of climate change through a range of resilient practices. These include flexible livestock management strategies, nomadic or semi-nomadic lifestyles, and a deep understanding of local ecosystems. They've traditionally moved their herds in response to changing weather patterns and the availability of grazing land, which helps them cope with prolonged droughts and fluctuations in forage and water resources.

However, the effectiveness of these traditional adaptation strategies is diminishing due to the accelerating pace and unpredictability of climate change (Muema et al., 2018). Prolonged droughts and more frequent extreme weather events disrupt these age-old practices, leading to overgrazing and land degradation. Simultaneously, population growth and changing land use patterns further strain resources, making it increasingly challenging for pastoral communities to adapt effectively. This necessitates the development of more contemporary and sustainable adaptation strategies that integrate traditional knowledge with modern approaches to address the evolving challenges posed by climate change.

Droughts and floods are becoming more severe and frequent, and the unprecedented re-emergence of pests and diseases, increased land degradation, and temperature and rainfall changes have all had an impact on the important value chains in arid and semi-arid areas such as honey, fodder and fruit value chains. This has significantly impacted food availability, accessibility and use, as well as food system stability, resulting in low quality of life and greater sensitivity to shocks and stress (Ndiritu, 2021). The rural population, who are also the most exposed to the significant shifts in climatic conditions witnessed in Kenya's dry and semi-arid areas, currently has a low grasp of these climate change risks in nature-based value chains (Apgar et al., 2017).

The production end of the value chain has received a lot of attention for research and development. However, this narrow focus overlooks the significance of harvesting, storage, processing, and marketing. It is critical to remember that food security is a combination of production, distribution, access, and affordability (Fanzo et al., 2017). As a result, transformational adaptation necessitates considering how climate change will impact all elements of the value chain. Addressing the various phases of the value chain will aid in addressing current and projected climate issues. This report examines the climate risks along the various value chains, as well as the adaptation interventions needed to boost resilience, by focusing on current and future climate risks, analyzing the implications for value chain activities, and evaluating various options for mitigating negative impacts.

1.2 Value chain mapping in arid and semi-arid environments

A value chain can be defined as the full range of activities which are required to bring a product or service from conception through the different phases of production, involving a combination of physical transformation and the input of various producer services, delivery to final customers, and final disposal after use (Fanzo et al., 2017; Farmery et al., 2021). For rangeland value chains, this encompasses all rangeland actors who buy or sell a specific product as it moves through the value chain, including input, farmers, traders, processors, transporters, wholesalers, retailers, and final consumers (Emali, 2023). As a result, assessing climate risk for value chains is a critical stage in any climate change adaptation plan. For value chain actors, it involves understanding current and future climate risks, considering the consequences for value chain activities, and examining various alternatives for mitigating negative impacts (Thongoh et al., 2021; Machan et al., 2022). This information can help value chain actors engage in forward-thinking and flexible planning processes that maximize their business potential while accounting for climate concerns.

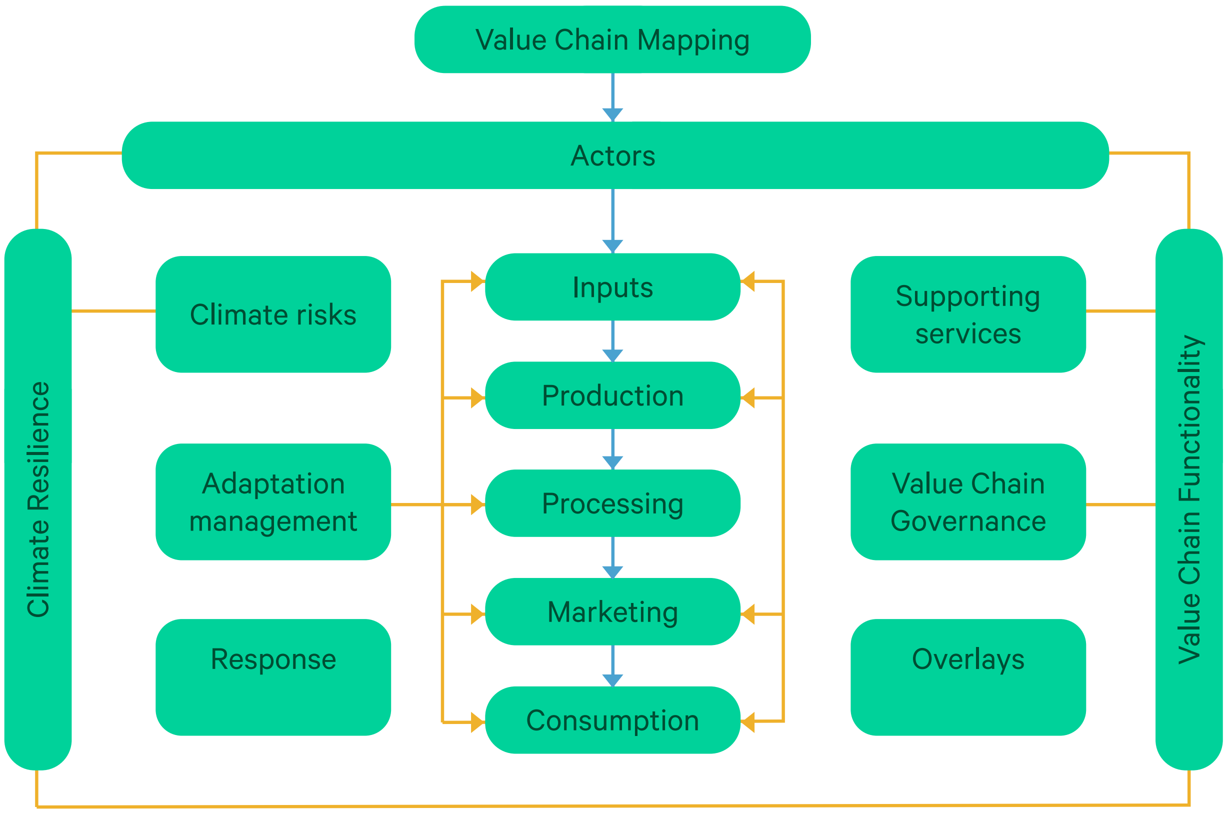
A comprehensive mapping that includes descriptions of interacting and competing channels, and the variety of final markets into which these connect, is required due to the complexity of some value chains in rangelands (Carabine & Simonet, 2017). This is especially needed in cases where input and output chains comprise more than one channel and the channels supply more than one final market. The mapping also includes an understanding of the value chain's functionality, which entails a thorough examination of crucial elements including supporting services, value chain governance and data overlays (Allen et al., 2019; Godde et al., 2021). Supporting services are firms or individuals that give value chain players essential services (e.g. inputs, capital, know-how, technical support), but who do not own or buy the product as it advances toward the end markets. Value chain governance analysis includes an understanding of the power dynamics used by various types of actors. Data overlays refer to quantitative information such as the number or percentage of actors at each functional level, labor, average land size (for agricultural production), volumes sold, input costs, sales revenue, unit price, and net profit.

These services are crucial in assisting nature-based value chains, particularly in rangelands, which face numerous difficulties (Carabine & Simonet, 2017). Building the capacity of value chain actors and ensuring that they have the information, knowledge and resources needed to carry out crucial value chain development activities requires investment in supporting services (Sala, 2019; EMALI, 2023). The ability of service providers to collaborate with value chain actors for the development of sustainable value chains that are gender-equitable and inclusive of the most vulnerable people is necessary for communities living in rangelands, and this requires investment in supporting services (Kinati & Mulema, 2019; Kalele et al., 2021).

Timely and efficient service delivery is therefore a crucial enabler for the growth of the value chain in rangelands. Climate information services (Ngigi & Muange, 2022), financial services (Njiru et al., 2021), and market information (Lutta et al., 2021) are some of the most crucial services that support the creation of sustainable value chains in rangelands. All decision-makers, from agro-pastoralists to banks and government agricultural investment programs, depend on climate information services. While early warnings for climate extremes might improve readiness for shocks, past and present climate patterns, future estimates and seasonal weather forecasts all support climate risk assessment (Thongoh et al., 2021). Commercial banks and microfinance organizations that provide financial services, such as credit, savings, and insurance, serve as a vital resource for many value chains (Lugusa, 2020; Kidali et al., 2023). Finance that is easily accessible helps with planning, diversifying sources of income and activities, and acting as a buffer during times of shock. Additionally, it promotes experimentation and creativity, two essential components of adaptive management.

Value chain actors can diversify their businesses and increase their earnings by using market information systems, which give data on pricing, supply, and demand of various commodities (Njiru et al., 2021). Market information may help risk analysis and guide decisions on value chain activities such as input purchases, which commodities to invest in, and when to hold a reserve of a certain product (Roba et al., 2019). This is especially true when combined with climate information that enables timely and efficient purchase and sale of products, including during periods of stress.

Figure 1: Value chain mapping



Source: Authors' own

Given that the productivity of tropical rangelands is inconsistent and primarily dictated by difficult-to-predict factors, climate resilience must be a priority outcome if investments in value chain development are to have a sustainable impact in reducing poverty and increasing food security. Therefore, all actors along the chain must be aware of climate risks and empowered to manage these risks on an ongoing basis. Given that climate hazards and changes are context-specific, strategies for improving value chains' sustainability must be customized to the unique ecological and socioeconomic setting in which the value chain operates. Therefore, all actors in the chain must carry out associated functions of climate risk assessment, adaptive management of value chain activities, and response as depicted in Figure 1 in order to develop climate resilient value chains.

1.3 Climate change vulnerability and adaptation in value chains

The rangeland ecology, biodiversity, socioeconomic and allied sectors, including water resources, livestock, crops, and food security, will all be significantly impacted by climate change in a variety of ways (Nyika, 2022). Flooding and/or severe water shortages are anticipated to result from changes in the rainfall pattern (Kalele et al., 2021). Changing crop growing seasons will negatively impact food security, and changes in the spread of pests and disease vectors will put more people at risk. Increases in temperature have the potential to significantly speed up the rate of extinction for many species of palatable plants and their environments, directly impacting most value chains and exacerbating the vulnerability of pastoralists.

Climate change adaptation will require adjustments and shifts at every level of the value chain. To cope with current and future climate stress, communities in arid and semi-arid areas must strengthen their resilience by adopting appropriate technologies and climate-proof value chains, leveraging traditional knowledge, and diversifying their livelihoods (Thongoh-muia, 2022). Local coping techniques and traditional knowledge must work in tandem with government and community actions. The selection of adaptation measures relies on how vulnerable the effects of climate change are (Omolo & Mafongoya, 2019); in the context of community-based action, national and sectoral planning, as well as disaster risk reduction, adaptation solutions must be matched to priority needs. To promote sustainable development and the effective use of resources for adaptation, adaptation plans must be incorporated into both top-down and bottom-up planning methodologies.

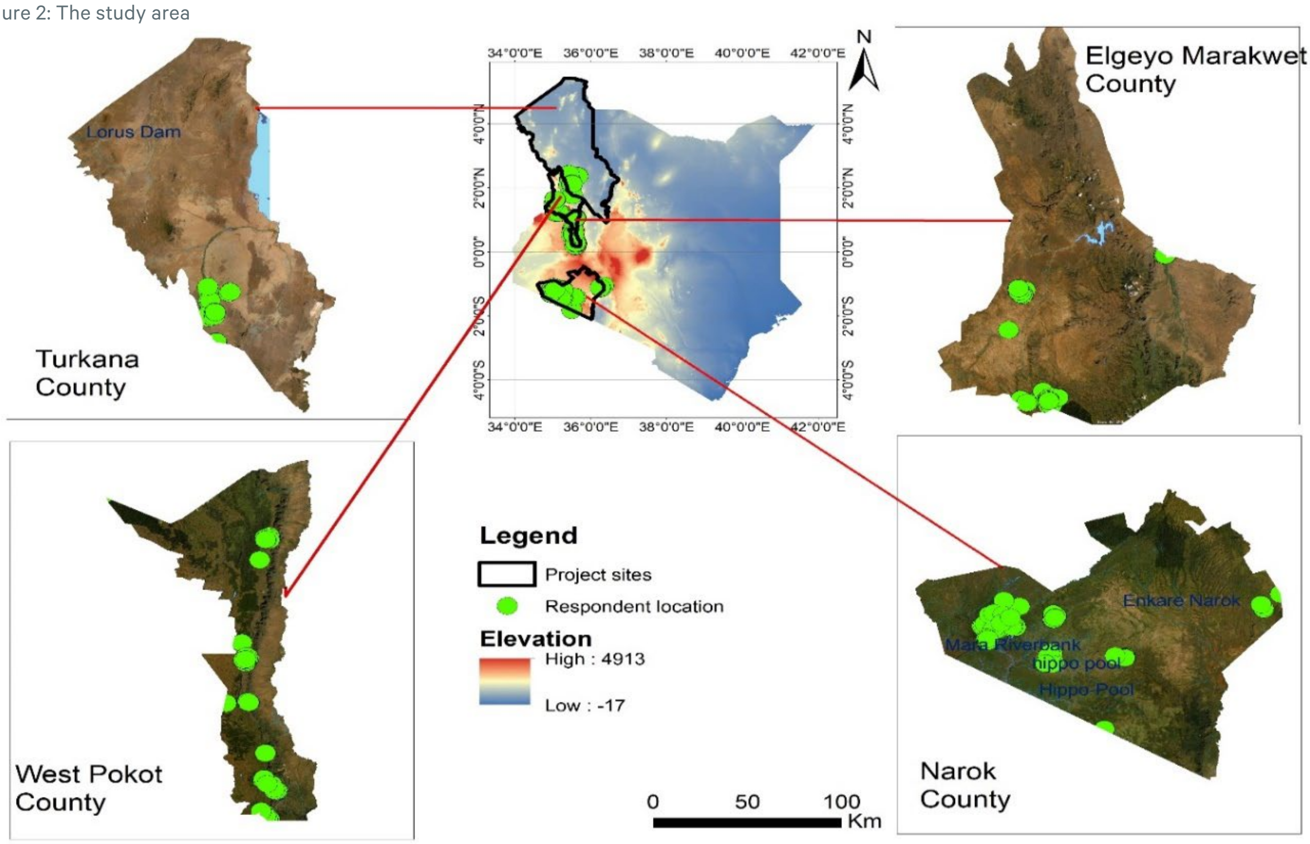
Mechanisms for validating adaptation alternatives should be introduced to avoid maladaptation. Adaptation for value chain players may entail monitoring both the climate hazard context and the performance of value chain operations, and then adapting or acting in response to what is observed as well as past experiences. Initiatives that could be executed might include diversification of activities, goods and income sources; protection of essential assets from climatic threats; and improved efficiency in resource management for value chain activities. The risk of climate-related impacts along the nature-based value chains was examined in four arid and semi-arid counties of Narok, Elgeyo Marakwet, West Pokot, and Turkana. These risks result from the interplay of climate-related hazards with the exposure and vulnerability of pastoral communities and environmental systems. This study examined the potential climate change risks that affected rangelands, as well as how value chains were exposed to the hazards and their vulnerability. In this case, hazards were defined as climate-related physical events or trends that impacted value chains (IPCC 2014). Exposure referred to the parts of the value chain that could be harmed, whereas vulnerability included agro-pastoralists' ability to cope with and adapt to changes.

2. Methodology

2.1 Study sites

This study involved assessment of climate risks and adaptation options along nature-based value chains in the arid and semi-arid counties of Narok, Turkana, West Pokot and Elgeyo Marakwet. The predominant economic activity the counties is extensive livestock production (pastoralism), and in some cases agro-pastoralism, which is characterized by livestock rearing and crop cultivation, particularly where there are dependable sources of water.

Figure 2: The study area



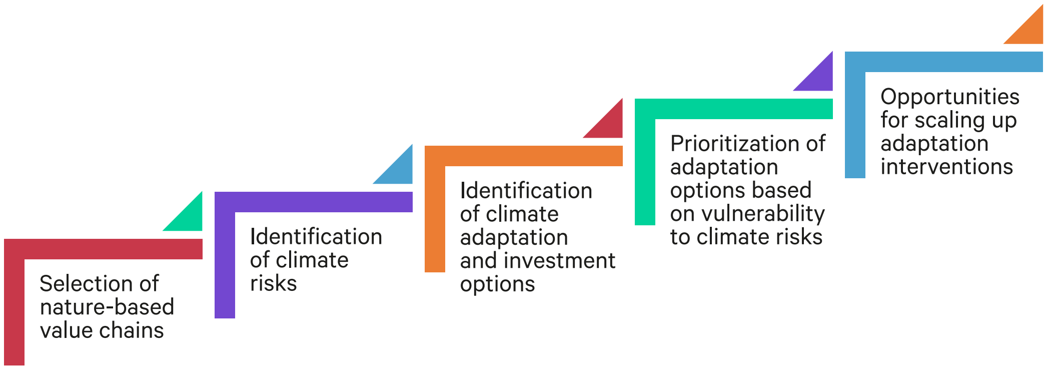
Source: Author's own

Other economic activities practiced by pastoralists in these counties include nature-based tourism and ecotourism, as well as crop production. Nature-based tourism encompasses all forms of tourism that involve experiencing natural environments, wildlife, and outdoor activities, while ecotourism is a subset of nature-based tourism with a more specific focus on responsible and sustainable travel to natural areas (Lawton and Weaver, 2021). In Narok County, for example, the neighboring settlements are home to most of the area's wildlife and thus the hub of tourism-related businesses, with most of the tourist hotels and lodges clustered around the Maasai Mara national reserve. Many pastoralists are combining cattle and crop production, particularly in Elgeyo Marakwet and parts of West Pokot, with crop production taking place on small plots of land near water sources. Irrigation farming is most common given the fluctuation of rainfall in most locations, and it employs water from diverse areas in the rangelands.

2.2 Value chain analysis

The mapping of climate risks along value chains and identification of adaptation options was based on the value chain analysis for resilience in drylands methodology, commonly referred to as VC-ARID, using the five-step approach for climate change risk assessment in value chains proposed by IFAD (2015). By combining more conventional sectoral analysis with an understanding of the unique traits and vulnerabilities of the various counties, VC-ARID offers a territorial approach to value chain analysis. The VC-ARID approach acknowledges that, as compared to other production systems, ecological and socioeconomic variability in semi-arid lands constitute major structural distinctions.

Figure 3: The value chain analysis approach used



Source: Adapted from IFAD (2015)

The initial step required selecting the value chains, which was done collaboratively with a wide range of community actors and the members of the ward development and planning committees. This included semi-structured interviews through focus group discussions (FGDs) with community members. The value chains were chosen based on their suitability for the local climate as well as their contribution to the livelihoods and general well-being of the community. This was further supported by a review of published and grey literature on the impacts of climate change and potential solutions in Kenya's arid and semi-arid regions. The primary value chain components mentioned included the value chain's essential activities, the key actors responsible for implementing them, how the product or service reached end markets, and the marketing channels available to do so.

The second stage involved the analysis of historical trends in rainfall and temperature in the counties between 1981 and 2021, as well as the probable rainfall and temperature based on the three Representative Concentration Pathways (RCPs) adopted by the IPCC Fifth Assessment Report (citation). Three RCPs that describe possible climate futures (scenarios) were adapted in this report. The three RCPs used were 2.6, 4.5 and 8.5. The climate RCP scenarios were used to project the possible effect of climate change on the value chains and the populations in the counties. The report used daily rainfall data from Climate Hazard Group Infrared Precipitation with Stations (CHIRPS) and the European Centre for Medium Range Weather Forecast Re-Analysis (ERA5) minimum and maximum temperature datasets from the Royal Netherlands Meteorological Institute Climate Explorer portal (https://climexp.knmi.nl/start.cgi). The datasets were at a horizontal resolution of 0.25^0 (25km x 25km) and for the period between 1981 and 2021. The daily datasets were then converted into a monthly timeseries for analysis. As an important pre-requisite, the datasets were validated using observed daily rainfall and temperature data.

The report also utilized daily rainfall along with maximum and minimum temperature outputs from the Coordinated Regional Downscaling Experiment (CORDEX) website (https://esgf-node.llnl.gov/search/esgf-llnl/). The Max-Plank Institute Earth System Model (MPI-ESM-LR) and the Irish

Centre for High-End Computing Model (ICHEC-EC-EARTH) were used to downscale rainfall and temperature data over Africa at a horizontal resolution of 0.44^{0} (50km x 50km) for the period 1981 to 2050, following three RCPs: RCP2.6, RCP4.5 and RCP8.5 emission scenarios. As a preliminary condition, the downscaled model outputs were bias corrected using a linear scaling method before any climate change analysis was done.

BOX 1. WHAT ARE RCPS?

Representative concentration pathways (RCP) are scenario pathways that provide time-dependent projections of atmospheric greenhouse gas concentrations. RCP2.6 refers to the emission pathway leading to very low greenhouse gas concentration levels. RCP4.5 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level. RCP6 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions. RCP8.5 is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels. Each Representative Concentration Pathway (RCP) defines a specific emissions trajectory and subsequent radiative forcing (a radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, measured in watts per square metre). In general, the lowest emissions are found for the scenario with the most stringent climate policy (RCP2.6) and the highest for the scenario without climate policy (RCP8.5).

Source: (Moss et al., 2010)

To understand climate risk at each stage of the value chain across the counties, a qualitative survey was conducted with 539 producer households, traders, processors and key specialists. Information on household characteristics, land ownership, service access, and perceptions of climate threats were all included in the survey. This was also supported with a qualitative analysis of perceived changes in climate in the last 10 years, how these changes had affected their production or business, and what measures had been put in place to cope with these changes with the full range of value chain actors identified in Step One, through a more comprehensive set of key informant interviews (KIIs) and FGDs. The climate risk analysis at each stage of the value chain was assessed, and the study also evaluated the interaction of climate risks with other shocks at the household level, such as conflict, diseases, and idiosyncratic shocks, allowing for the development of adaptation strategies for a more robust value chain. In addition to long-term climate change and variability, the assessment considered the seasonality of weather patterns that disrupt supply chains due to the ecological effects of intra-annual weather patterns.

The third stage entailed identifying climate investment options and adaptation measures based on the primary climate issues outlined in the second stage's forecasted climate scenarios. Identification of adaptation alternatives required knowledge of the local context, and therefore participatory methods such as focus group discussions (Figure 4), key informant interviews, and field visits were used to establish the suitable actions. We utilized participatory methodologies to determine social, economic and environmental implications of several adaption alternatives. Scenario analysis was used to allow participatory evaluation of the numerous alternatives, which offered information about prospective and desired futures, increased comprehension of complexity, and facilitated discussion of planning options for sustainable rangeland management. Local communities naturally use, value and influence the environment in which they live, and as such they were completely involved in scenario analysis. This is also important as they are the ones who will eventually implement ideas, work with conflict resolution, or make decisions for transformative adaptation options. Community participation ensured that existing values, experiences, and diverse types of knowledge in the study areas were more included and integrated. Local expert knowledge and experiences increased the quality of decision-making information, enhancing the credibility and legitimacy of adaptation options that address climate risk and have the potential to upgrade and alter value chains. Participants included representatives from national and county governments, the private sector, non-governmental organizations (NGOs), and civil society organizations. This knowledge was applied to the development of climate-resilient economic transformation and diversification alternatives in pastoral value chains.

The fourth phase involved determining the community's vulnerability, which helped to prioritize the adaptation activities required to increase the community's resilience to the effects of climate change. Prioritizing a top set of climate hazards based on the community's susceptibility was essential because it is impossible to integrate all solutions in a single project. Communities encounter a variety of difficulties; thus, it was necessary to rank the interventions together. The rating was done to make sure that there would be a coordinated effort to better the situation of pastoralists and their cattle, land and resource base. This is due to the inherent interconnectedness of pastoralism's challenges which call for comprehensive approaches to the state and condition of rangelands, rather than solitary efforts centered on the health of the rangeland, crops and cattle, or people independently. Therefore, measures that include rangeland, crop and livestock are more effective and efficient than those that focus solely on one area. The aim at this stage was to implement connected land-crop and livestock management measures based on efforts to improve rangeland condition and productivity to make sure that the alternatives for adaption in one area wouldn't make other sectors more vulnerable.

The last stage entailed identifying prospects for scaling up the interventions as well as potential avenues for private sector involvement in the beneficiation of rangeland products emerging from the various value chains identified in stage one. This also gave a chance to identify community capacity needs and how they could be met so that communities can act on local concerns and run their own activities to build their resilience. With escalating demands for quality and safety standards in high-value agriculture and livestock markets, increasingly sophisticated supply chains are required to manage the movement of goods and information among chain members. This may be out of reach for most pastoral communities, so public-private partnerships can thus play an important role in strengthening supply chain links, particularly where market failures limit poor access. As a result of this collaboration, pastoralists will be able to generate products for the market and associated revenue in a substantial amount, as well as increase upscaling.

Figure 4: A Focus group discussion session in West Pokot County

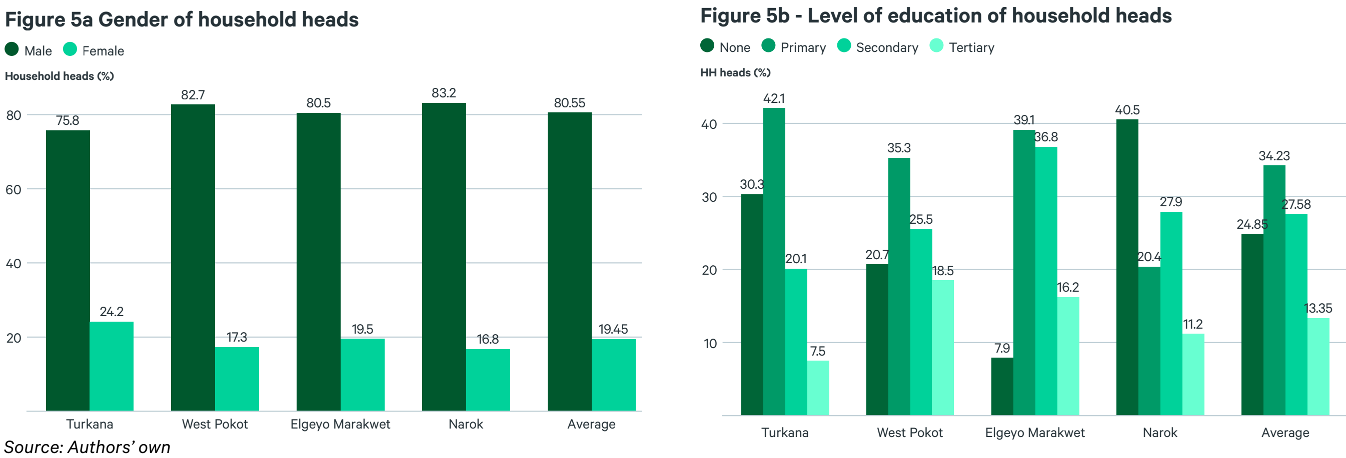
Source: Alphayo Lutta

3. Results

3.1 Household characteristics

Figure 5 shows the gender and education characteristics for households sampled in the four counties of Turkana, West Pokot, Elgeyo Marakwet and Narok.

Figure 5: Head of households' gender and education characteristics



Source: Authors' own

Gender

We found gender to be a salient factor in value chains throughout the counties. Most households (80.6%) were headed by men, with only a handful (19.4%) headed by women (see Figure 5). This does not, however, imply that fewer women are involved in the development of the value chain. On the contrary, women frequently play essential but invisible roles in value chains, making them crucial to upgrading efforts. It was revealed during the focus group discussions with women that their involvement spans every stage of these value chains, from the initial resource extraction or agricultural activities to the final marketing and distribution of products. Women are often key contributors to sustainable agricultural practices and biodiversity conservation in these arid and semi-arid areas, taking part in the protection of natural resources and being instrumental in the cultivation and processing of various products. Moreover, women frequently act as knowledge bearers, passing down traditional ecological knowledge and practices that promote harmony with nature. Their roles extend to marketing and selling natural products, thereby contributing significantly to the economic well-being of their households and communities. According to the women who participated in the FGDs, however, men are frequently regarded as the official decision-makers in their society, with power and control over how natural resources are managed. At 24.2%, Turkana County had the highest percentage of female household heads.

Education

As illustrated in Figure 5, the majority of household heads in the four counties had attained basic primary education. West Pokot County had the largest proportion of tertiary educated household heads (18.5%). Narok County had the fewest educated household heads, with nearly half (40.5%) without a basic education. Elgeyo Marakwet had the largest percentage of secondary-educated household heads (36.8%).

Basic education is significant because it improves managerial skills and the ability to use information that could be useful for the growth of the value chain (Ahmed et al., 2013). Education exposes one to technical skills and knowledge, which promotes value chain development. Through formal education, training programs and access to relevant resources, individuals gain insights into the latest industry trends, sustainable practices and emerging technologies. These technical skills enable them to add value to products, reduce waste, enhance product quality and adapt to evolving consumer demands. Moreover, education fosters an understanding of the economic, social and environmental dimensions of value chains, ensuring that development efforts are not only efficient but also socially and environmentally responsible.

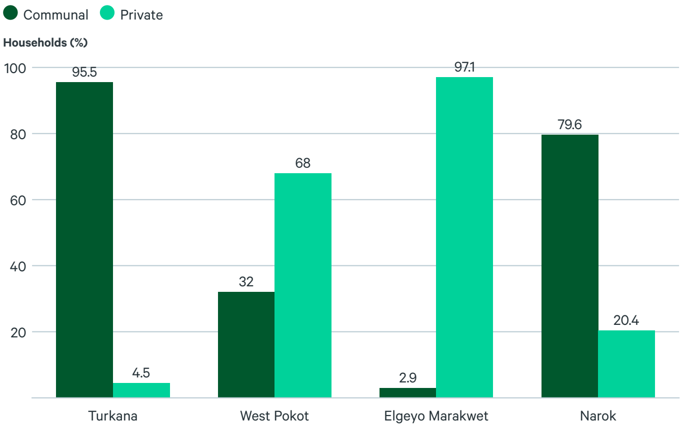
Land tenure

People are likely to be hesitant to invest in land that they do not technically own. According to Figure 6, the majority of land in Turkana (95.5%) and Narok (79.6%) is communally used, but 97.1% of land in Elgeyo Marakwet and 68% in West Pokot is privately held. Turkana (4.5%) and Elgeyo Marakwet (2.9%) have the fewest private land-owning households. It may be challenging to convince someone to enhance land that someone else may use in the future, such as communally owned land, where land ownership and rights of use are complex. However, due to the unpredictable nature of the weather in rangelands, collective usage of the rangeland helps communities manage the spatial and temporal unpredictability of resources.

Recognizing and addressing gender-specific land tenure challenges is also essential for unlocking the full potential of pastoral economies and empowering women as key actors in value chain development. According to the key informants, insecure land tenure restricts women's ability to make long-term investments in their livestock or engage effectively in value chain activities. This, in turn, hampers their opportunities for improving animal husbandry, diversifying income sources, and participating in markets. Moreover, as primary caregivers and contributors to pastoral livelihoods, women play a central role in livestock management and value addition processes. Therefore, securing women's land rights does not only enhance their socio-economic standing but also contributes to the resilience and productivity of the entire pastoral value chain.

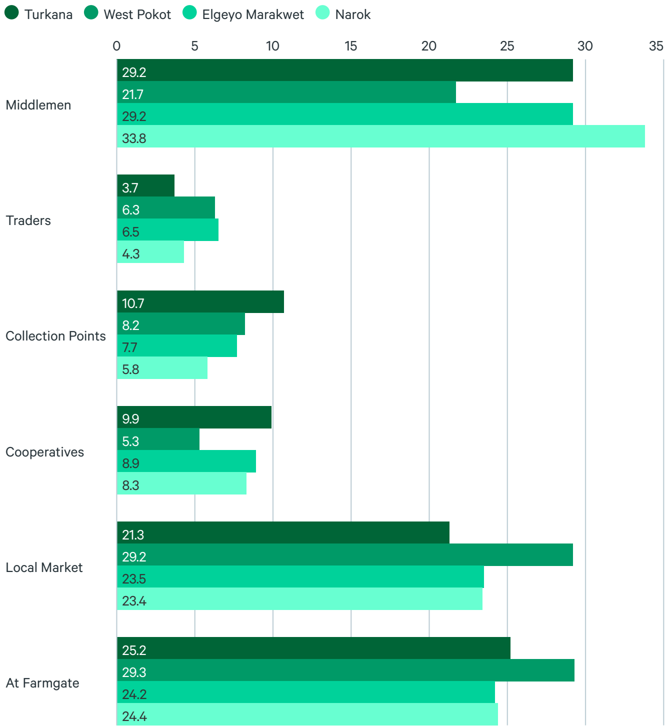
Figure 6: Characteristics of land tenure and market access

Figure 6a - Land tenure system



Source: Authors' own

Figure 6b - Market of farm produce



Market access

Results in Figure 6 show that most households market their farm produce mainly through middlemen (28.5%), at the farmgate (25.8%) and at the local market (24.4%). Narok County has the highest proportion of households marketing their produce through middlemen (33.8%), followed by Elgeyo Marakwet and Turkana both at 29.2%. Middlemen or intermediaries often play a pivotal role by connecting pastoralists to wider markets. They facilitate the trade of products, enabling producers to reach consumers in distant urban centers. However, according to key informants from the ministries of trade at the counties, these middlemen can sometimes exploit their position, leading to unequal returns for pastoralists.

Most of the households in West Pokot also market their produce at farmgate (29.3%). Local producers in the FGDs stated that farm gate sales offer the potential for higher returns as it eliminates intermediaries. The marketing of farm produce through cooperatives is relatively low within the four counties. Comparatively, Turkana has the highest percentage of households marketing their farm produce through cooperatives (9.9%) and at collection points (10.7%). These collective efforts allow producers to pool resources, access credit, and collectively market their products. It was reported by the honey cooperative group that cooperatives strengthen their bargaining power and increase their access to markets.

Most of the households in West Pokot also market their produce at the local market (29.2%). Local markets remain vital for day-to-day transactions and smaller-scale trading, often involving non-livestock commodities.

Climate change hazards and their impacts

The main climate-related challenges experienced in the four counties were drought, unpredictable rainfall, floods, spread of pest and diseases, and landslides. Drought (82.8%) and floods (67.6%) were the most common hazards reported by more than half of the respondents in all the counties as shown in Figure 7. The occurrence of pests and diseases was highest in West Pokot (67.5%). Elderly participants in focus groups reported that droughts now happen every one to two years, as opposed to every ten years in the 1980s, and that they are more severe and last longer than before. Floods are a threat as well because of the rangelands' poor soils, which have low aggregate stability and cause the majority of the rainwater they receive to wash away as surface runoff. Floods and droughts both cause significant population displacement and increase competition and conflict as communities migrate away from their homeland areas and into areas controlled by other pastoral groups. As production systems fail, severe droughts and floods have a negative impact on the mix of options and the livelihoods equation. It was reported in focus groups that farms cannot be cultivated, animal herding grounds are washed out, agri-business prospects are lost, and irrigation infrastructure is destroyed, disrupting markets and value chains.

Deforestation and unsustainable farming on fragile slopes and hanging valleys were blamed for the rampant landslides in Elgeyo Marakwet (66.5%) and West Pokot (50.1%) counties. Forests and trees play an important role in soil stabilization, storing water in catchments, and naturally managing the flow of water downstream. Unfortunately, widespread deforestation in West Pokot and Elgeyo Marakwet is contributing to an increase in landslides, mudslides and floods. The escarpment area, notably in Elgeyo Marakwet, is fragile due to geological instability, which makes it prone to landslides, posing a major risk to people and cattle downstream.

Figure 7: Climatic change hazards and their impacts

Figure 7a - Climate change hazards

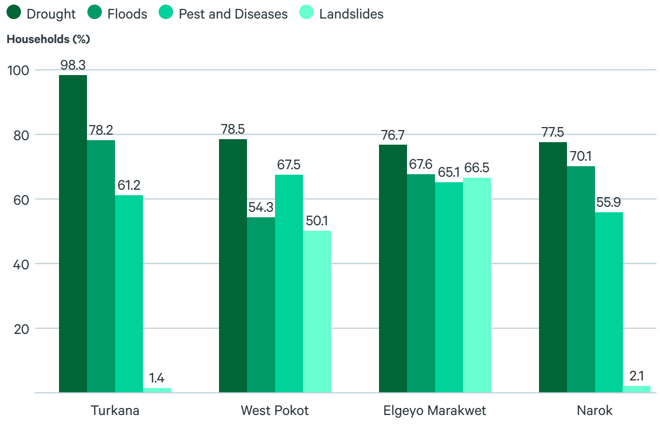
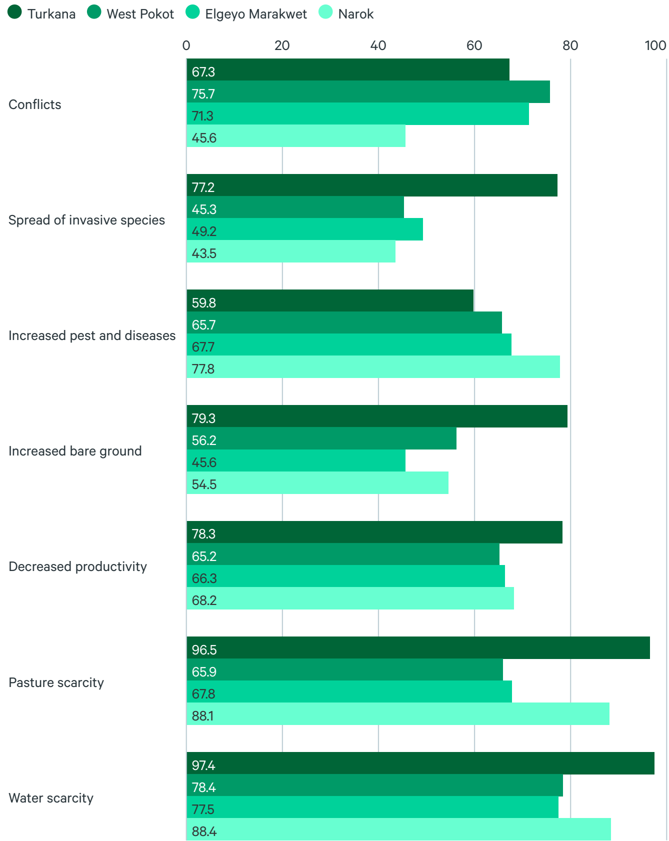


Figure 7b - Climate change impacts



Source: Authors' own

Water scarcity (85.4%), pasture scarcity (79.6%), invasive species spread (53.8%), pests and diseases (67.8%), decreased crop/livestock/tree productivity (69.5%), and intermittent conflicts (64.9%) were the main impacts of climate change on pastoral communities, as shown in Figure 7. Turkana had the highest incidences of water scarcity (97.4%), pasture scarcity (96.5%), decreased crop/livestock/tree productivity (78.3%), and the spread of invasive species (77.2%). West Pokot had the highest rate of climate-induced conflict (75.7%), while Narok County had the highest pest and disease incidence (77.8%). According to the focus group discussions, pastoral communities have honed their ability over generations to adapt to the inherent climate variability of their arid and semi-arid environments. These resilient traditions often include flexible mobility patterns, diversified livelihood strategies, and communal resource management. They've thrived in the face of sporadic droughts and irregular rainfall by migrating to access seasonal pasture and water sources.

Yet, the accelerated pace, unpredictability, and heightened intensity of contemporary climate change is challenging these time-tested practices. Rapid shifts in weather patterns, such as prolonged droughts or intense flash floods, disrupt the ecological balance and often exceed the coping capacity of pastoralists. The consistency, abundance and quality of forage, the need for water for agricultural production, as well as the broad patterns of vegetation in rangelands could all be impacted by climate change. The most obvious impact of climate change is on the grass, which also impacts animals and crops. In pastoral communities, a lack of pasture is causing more concern than ever. The lack of vegetation cover on the land has accelerated soil erosion, which has an adverse effect on the growth of both crops and livestock. Most respondents (69.5%) believed that livestock productivity, which is the main source of income in rangelands, had drastically decreased. Key informant interviews also highlighted that the extended droughts and rising temperatures have resulted in a drop in cattle feed intake, reproductive efficiency, and overall output; as such, innovative adaptation strategies are needed to bolster their resilience in the face of these new challenges.

Households' sources of income

As shown in Table 1, the main sources of income identified across the counties are the sale of live livestock (54.4%), livestock products (50.6%), subsistence crop farming (38.9%), and to some extent trading in urban and peri-urban centers (17.6%). Native pastoralists are increasingly getting involved in milk, meat, eggs, hides, skins, goats, camels, cattle, and poultry trade (50.6%). Narok has the highest proportion of households involved in sale of live animals (88.4%), sale of livestock products (88.3%), sale of honey (40.8%), pasture and fodder (14.3%), indigenous poultry (69.5%), casual jobs (29.7%), beadwork (34.5%) and business/trade (29.7%). Turkana is the leading producer of gum/resin (8.2%) and aloe (12.2%). Agro-pastoral populations mainly generate income from crop farming (maize, bean, tomato, green gram, cowpea, onion, and kale) across the counties, where rainfall can support crop growth, and under irrigation along various rivers.

The income sources can be divided into four groups based on the KIIs and FGDs: pastoralism, agro-pastoralism, crop farming, and non-agro-pastoral livelihoods (which include small businesses and the trade in firewood and charcoal, among other things). The results demonstrate that the categories are not mutually exclusive, as respondents claimed that households have diversified their income sources and that some households now engage in more than one form of livelihood, while others may engage in all four. In addition to agriculture, the main non-agro-pastoral activities listed were formal employment (17%) and casual labor (22.9%).

Table 1: Sources of income

Sources of income	Turkana (%)	West Pokot (%)	Elgeyo Marakwet (%)	Narok (%)	Average (%)
	N = 123	N = 122	N = 124	N = 170	N=539
Sale of crop produce	27.5	49.3	54.2	24.4	38.9
Sale of live animals	36.3	59.2	33.5	88.4	54.4
Sale of livestock products	29.9	45.3	38.9	88.3	50.6
Sale of honey	33.7	38.2	17.7	40.8	32.6
Pasture and fodder	2.7	7.3	8.5	14.3	8.2
Gums and resins	8.2	1.2	0.0	0.0	2.4
Aloe	12.2	6.3	0.9	0.7	5.0
Bead work	14.2	3.6	0.6	34.5	13.2
Indigenous poultry	18.4	32.7	33.7	69.5	38.6
Casual jobs	23.1	28.7	10.0	29.7	22.9
Salary (employment)	9.3	24.9	12.4	21.5	17.0
Business/trade	9.9	20.1	10.7	29.7	17.6

Households' livelihood risks

Poor market systems (65.3%), pests and diseases (56.5%), land use changes and land degradation (46.9%), intra-and inter-community conflicts (43.2%), and weak governance systems (37.5%) are the most common risks affecting the adaptive capacity of communities in the four counties, as shown in Table 2. Elgeyo Marakwet has the highest risk of land use changes/degradation (55.6%) and pests and diseases (61.3%). In Narok, severe livelihood threats include disease and pests (57.6%), drought and erratic rains (51.9%), human-wildlife conflict (35.7%), and weak market systems (71.1%). Turkana reported weak traditional governance systems (67.5%), drought and unpredictable rains (89.7%), poor market systems (68.4%) and intra- and inter-community conflicts (54.3%) as the main livelihood risks. Of the four counties, West Pokot has the highest intra- and inter-community conflict cases (57.2%).

Table 2: Livelihood risks

Livelihood risks	Turkana (%)	West Pokot (%)	Elgeyo Marakwet (%)	Narok (%)	Average (%)
	N = 123	N = 122	N = 124	N = 170	N=539
Land use changes/land degradation	42.4	45.3	55.6	44.3	46.9
Weak traditional governance systems	67.5	54.5	3.5	24.6	37.5
Pests and diseases	47.3	59.7	61.3	57.6	56.5
Drought and unpredictable rainfall	89.7	67.8	59.5	51.9	67.2
Spread of invasive species	45.6	21.3	12.7	9.5	22.3
Human wildlife conflicts	8.9	7.1	7.8	35.7	15.0
Poor markets systems	68.4	65.1	56.4	71.1	65.3
Intra-and inter-community conflicts	54.3	57.2	49.2	12.2	43.2
Floods	33.2	21.1	34.0	16.2	26.1
Spread of water- and vector-borne diseases	23.3	33.1	22.9	15.1	23.6

Source: Authors' own

With effects like decreased crop yield, low animal productivity and high livestock mortality, these risk factors have a detrimental impact on the pastoral economy and cause hunger, malnutrition, and loss of income for farmers. All focus group talks reached the same conclusion that the landscapes are undergoing enormous change as a result of population increase, urbanization, land privatization and fragmentation, which has a significant impact on how well communities can adapt to climate change. It was shown that there has been an increase in land subdivision, which has led to rangeland fragmentation, unsound land use, and a host of land-use management issues. It was further emphasized during the discussions that the extraction of charcoal for commercial use has also resulted in the unsustainable harvesting of shrubs and trees in conservation zones, which has caused rangeland degradation.

The livelihoods of these people were also mentioned as being threatened by weak traditional government systems. The management of rangelands heavily relies on customary institutions. But according to the Turkana and West Pokot focus group participants, most of the traditional institutions are dysfunctional and ineffective at managing rangelands. The encroachment of modern legal and administrative structures, which often have conflicting principles and goals, has eroded the authority and effectiveness of traditional institutions. According to the focus group discussion with the elders, fragmentation of pastoral lands, partly caused by the formalization of land ownership, has led to disputes over resources and grazing rights that traditional mechanisms struggle to address effectively. Climate change-induced shifts in weather patterns have disrupted traditional knowledge of ecological rhythms. These multifaceted challenges, coupled with limited capacity and sometimes a lack of adaptability within traditional systems, have led to their dysfunction. The breakdown of these organizations has resulted in inadequate management of natural resources, a loss of the sense of traditionalism, and a lack of motivation to uphold customary values.

The official institutions in place, such as county governments, are not adequately connected to the people on the ground and never collaborate with the traditional institutions and mechanisms that manage the rangelands at the local level, according to the respondents in focus group discussions. The management of the wards is largely under the county government's control, which assumes a different management style, and the county governments have established ward development committees to support the management of resources at the ward levels. A complicated governance system such as this requires intricate execution and diligent enforcement of the laws to sustainably benefit from land resources. Unsustainable resource extraction is partly due to a lack of coordination, as was demonstrated by the unsustainable charcoal burning in all counties, hence the need for innovative strategies that harmonize traditional and formal governance while addressing contemporary pastoral issues.

The market mechanisms for a variety of rangeland products are ineffective, as demonstrated in Table 2. Discussions with respondents from the community revealed that markets for value chain products from the pastoral economies such as fodder, honey and fruit products are uncompetitive and have significant inefficiencies as a result of a number of systemic constraints. These include erratic and inconsistent product supply, an unstructured market system with many intermediaries and high transaction costs, information asymmetry, and insufficient or absent key support such as financing, extension services, inputs and information. Additionally, they mentioned other inefficiencies such as the producers' weak organizational capability, underdeveloped interior market infrastructure, and governance systems.

3.2 Mapping of nature-based value chains

Six value chains were selected based on their feasibility under the prevailing climate conditions, as well as their contribution to the livelihoods and well-being of the wider community. As shown in Table 3, livestock (75.4%) and indigenous poultry (50.1%) value chains were the top two nature-based value chains in the four study counties. Narok had the highest proportion of respondents involved in fodder production (15.3%) and beadwork (35.5%). The aloe value chain (9.1%) and gum/resins (10.7%) were relatively high in Turkana County. Elgeyo Marakwet has the highest proportion of respondents (23.2%) involved in the mango value chain compared to Turkana (2.3%), West Pokot (3.1%), and Narok (5.2%). Generally, gum/resins (3.3%) and aloe (4.5%) are emerging nature-based value chains whose adoption is still low within the counties.

Three of the most important services that underpin development of sustainable value chains in these counties are climate information services, financial services and market information. Our results show that access to climate change information, financial services and market information was generally low in all the counties. Respectively, only 25%, 21% and 32.3% of the respondents were able to access and use climate information, financial services and market information. Comparatively, Elgeyo Marakwet had the highest proportion (26.5%) of respondents able to access and use climate information.

According to the key informants, communities access and use climate change information through a variety of channels and practices. Local radio stations and community gatherings play a crucial role in disseminating climate-related information. Radio broadcasts and programs often provide weather forecasts, climate change updates, and adaptation strategies, allowing people to stay informed and prepared. Additionally, community-based organizations and government agencies conduct workshops and training sessions to educate residents on climate change and its impacts.

Narok (26.2%) had relatively more respondents accessing financial services than in the other counties. Turkana (27.3%) had the least portion of respondents who receive timely market information such as market prices, costs, quality, and standards of products. The risks of climatic impacts vary greatly by value chain and are anticipated to be higher in nature-based value chains in arid and semi-arid regions with limited socio-economic and institutional resources for adaptation, necessitating the provision of suitable services. Large uncertainties remain regarding the future impacts of climate change on nature-based value chains. Additionally, there is uncertainty about the exposure and responses of the interlinked human and natural systems to climatic changes over time. As such, climate information, financial services, and market information are key requirements for the development of nature-based value chains.

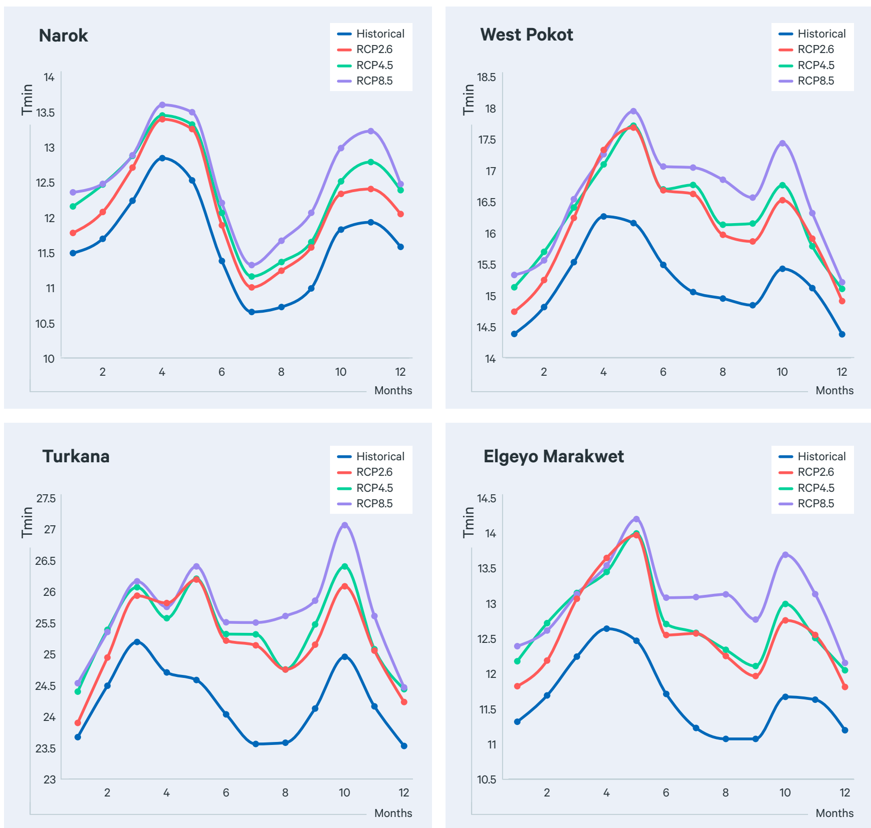
Table 3: Nature-based value chains in the study area

Nature-based value chains		Turkana (%)	West Pokot (%)	Elgeyo Marakwet (%)	Narok (%)	Average (%)
		N = 123	N = 122	N = 124	N = 170	N=539
Value chains	Fodder	4.7	9.6	11.5	15.3	10.3
	Bee/honey	5.7	11.2	15.6	13.3	11.5
	Indigenous poultry	36.4	49.7	57.9	56.4	50.1
	Gums and resins	9.1	1.2	1.8	1.1	3.3
	Aloe	10.7	3.4	1.9	2.3	4.6
	Indigenous livestock	89.3	68.3	56.4	87.7	75.4
	Fruits (mangoes)	2.3	3.1	23.2	5.2	8.5
	Beadwork	13.7	6.7	2.2	35.5	14.5
Access to primary services	Climate information	22.5	25.6	26.5	25.4	25
	Financial services	15.8	21.3	20.7	26.2	21
	Market information	27.3	32.9	32.3	36.7	32.3

3.3 Climate change patterns

Most plants and animals within the tropics thrive when close to their optimum temperature and rainfall conditions (Mumo et al., 2018). Changes in temperature and rainfall patterns may therefore affect the productivity and sustainability of nature-based value chains whose development depends largely on weather patterns.

Figure 8: Mean monthly maximum temperature time series



Source: Authors' own

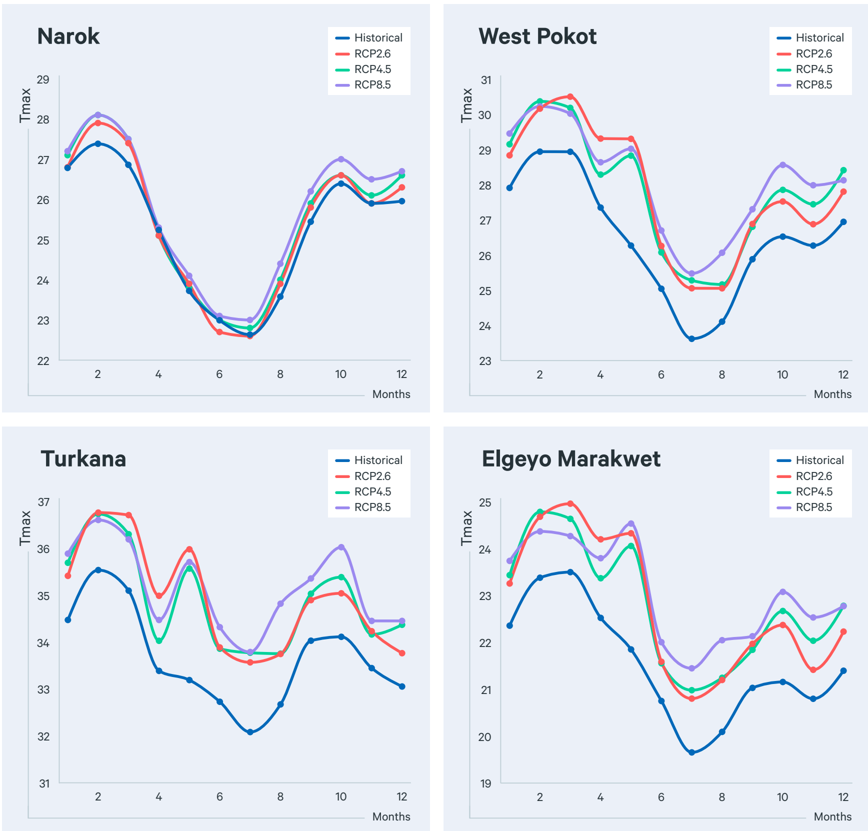
Minimum temperature

As shown in Figure 8, West Pokot, Elgeyo Marakwet and Narok will observe the highest mean monthly minimum temperature in April. Turkana will observe the highest mean monthly temperature in October. RCP8.5 emission scenario will record the highest increase in mean monthly minimum temperature compared to RCP2.6 and RCP4.5. Overall, mean monthly minimum temperature is expected to increase at rates of between 0.9°C and 1.5°C. This increase in mean monthly minimum temperature especially during the growing season may favor germination in crops and make some areas previously not suitable for agriculture become suitable. However, this is countered by the increase in maximum temperature, high variability and decrease in mean seasonal rainfall, and prolonged drought conditions that lead to increased water and heat stress, conditions that are unsuitable for crop growth.

Maximum temperature

The highest mean monthly maximum temperatures are expected between the months of January and February in all the study counties (see Figure 9). Turkana will observe the highest increase in mean monthly maximum temperature of between 1.2°C and 1.5°C, and Narok will experience the least increase in mean maximum temperature of between 0.4°C and 0.8°C. Overall, mean monthly maximum temperature will increase in all the study counties at rates of between 0.4°C and 1.5°C. The projected increase in temperature, particularly during the important phenological growth phases, will increase physiological stress in crops as well as livestock and poultry, thus reducing the prospects from these value chains.

Figure 9: Mean monthly maximum temperature time series



Source: Authors' own

Rainfall

As can be seen in the results in Figure 10, West Pokot is projected to experience a slight increase in mean monthly rainfall in April under all RCPs and a decrease in rainfall for the rest of the months. Turkana will observe a slight increase in rainfall in the months of April, May and November and a decrease in mean monthly rainfall for the remaining months. Elgeyo Marakwet will observe an increase rainfall for all the months except February, March, August, and October. Narok County will experience a decrease in rainfall in the months of May to October coinciding with the March-April-May rainfall season. Overall, the mean annual rainfall is expected to decrease in West Pokot, Turkana, and Narok. This decline and high inter-annual variability in rainfall will exacerbate evapotranspiration rates, soil moisture and water stress and the frequency and severity of droughts, reducing the prospects from these climate sensitive nature-based value chains.

Figure 10: Mean monthly rainfall time series

Source: Authors' own

4. Climate change impacts on value chains

From our analysis, the projected increase in mean surface maximum and minimum temperature and decrease in annual precipitation over the four counties will most likely exacerbate water stress, which according to Pachauri et al. (2015) has a significant impact on both crop and livestock productivity. According to Barnabás et al. (2008), increased water stress affects plant growth and development by shortening the plant reproductive stage, decreasing leaf area, and closing stomata to reduce water losses. These effects significantly lower crop (Adhikari et al., 2015) and pasture (P. Thornton et al., 2009) yields. In particular in the arid and semi-arid regions, increased water and heat stress will shorten the growing season; worsen the spread of weeds, pests, and pathogens; and make some areas unsuitable for agricultural production (Conway, 2009; Adhikari et al., 2015). These effects will have a negative impact on plant growth, productivity, and yields.

Figure 11: Pasture farm in Elgeyo Marakwet county

Source: Alphayo Lutta

4.1 Pasture/fodder value chain

Production of fodder (Figure 11) is becoming more and more popular as a means of providing households in all four counties with both money and feed for their livestock. The focus group discussion revealed that browsing and natural pastures, which are composed of grasses and readily available legumes as well as nearby trees and shrubs that provide nutrients for livestock, are the most common sources of feed in the four arid and semi-arid lands (ASAL) counties.

The availability of various feed supplies is determined by seasonal changes, with local climate conditions and soil conditions being the main determinants of production. Most areas have plenty of forage during the wet season, with scarcity during the dry season. Some challenges may exist in maintaining established pastures for planted forage species unless they are native species, appropriately fertilized, and well grazed. Discussions with farmers producing fodder in Narok, Elgeyo Marakwet, and West Pokot indicated that seeded pastures are let to grow, with weeding accomplished by manually removing undesired tiny woody species, herbs and shrubs. Despite the availability of organic manure, fertilizers and manure application are rarely used. The majority of farmers interviewed mentioned the potential spread of weeds and the labour needed as deterrents to applying manure.

Table 4: Impacts of climate change on fodder value chain

Value chain stages	Climate change impacts	Proportion of respondents (%) (N = 539)
Production	Reduced pasture yield per unit area	73.3
	Increased mortality rate	77.3
	Reduced soil fertility	88.2
	Increased cost of inputs such as seeds and pesticides	88.5
	Increased pest and diseases	73.3
	Shifts in production zones to other areas due to localized rainfall	24.5
	Invasive species affecting growth of pasture	77.3
	Increased labor costs	66.5
Processing and storage	Changes in the maturing timing/seeding and flowering	73.3
	Changes in management process	76.2
	Increased losses when processing	83.5
	Damage to infrastructure such as roads/stores	73.7
Marketing	Reduced pasture and seed supply	77.1
	Changes in the quality of pasture	73.3
	Financial losses by traders and retailers	67.1
	Reduced shelf life	73.3
	Increased transaction costs resulting from hazards such as land restoration costs	73.6
	Increased post-harvest losses	77.3
Consumption	Increase in prices of harvested hay due to scarcity	53.2
	Reduced quality of hay	63.8

As shown in Table 4, fodder production faces a myriad of challenges such as increased costs of inputs (88.5%), reduced soil fertility (88.2%), invasive species (77.3%), increased pests and diseases (73.3%), increased labour costs (66.5%), and shifts in production zones to other areas due to localized rainfall (24.5%). Most of the respondents noted increased losses during fodder processing (83.5%), reduced pasture and seed supply (77.1%), changes in the quality of pasture (73.3%), increased transaction costs (73.6%) and financial losses by traders and retailers (67.1%) in the fodder marketing phase.

Some groups of farmers allow pastures they have planted to mature in the fields before harvesting and then conserve them because they are interested in grass seeds. The main preservation methods used by the majority of pasture production groups in four counties are standing hay or cutting and balling. It was shown that most farmers do not conserve the harvested feeds, primarily because they lack the necessary expertise and conservation structures. For the majority of them, the primary techniques still involve harvesting the grass from the fields, leaving it to stand, and then storing it on tree branches, on wooden racks, or in small house granaries. However, according to (Koech et al., 2016), these approaches lead to forage with relatively little crude protein.

According to Ndathi et al. 2013, the best way to guarantee high-quality feed for livestock is to promote a feed utilization strategy in which farmers are given guidance on the best practices for feed conservation, preservation, and even utilization at optimal levels of nutritional value. Especially for species of rangeland grass, feed formulations and value additions like the inclusion of legumes would greatly enhance the quality of the feed. The directors of livestock in Turkana and Narok confirmed that, with the assistance of NGOs, the two counties had made investments in communal feed stores (hay barns) and hay harvesting machinery for use in producing livestock feed. However, because there is not any feed available for harvesting, processing, and storing, the stores stay empty, and the machinery is inactive for the majority of the year. In all four counties, there is no clear strategy in place for sourcing fodder for storage. Farmers and livestock keepers must therefore be informed about the needs of fodder production by being provided planting materials and technical know-how to create sufficient fodder. Local tailor-made hay storage facilities and small-scale mechanical harvesting technologies at the farmer level can be more advantageous than huge communal ones for the overall system's success.

According to focus group discussions, the main marketing agents of fodder and basic pasture seeds in Turkana, Narok, Elgeyo Marakwet, and West Pokot counties were individual farmers, independent grass seed traders, and government departments (parastatals such as Kenya Agricultural and Livestock Research Organization, or KALRO). Non-governmental groups play an essential role in a county's feed and pasture value chain. The majority of pasture seeds are sold to government agencies and non-governmental organizations for distribution to farmers for pasture establishment or reseeding degraded areas. According to farmer groups, the pricing of seeds varies depending on the species but range between KES 175 and 1000 (USD 1.75–10).

Some farmers who produce pastures highlighted the lack of a market and marketing plans for pasture seeds as a barrier to the effort to produce range pasture seeds by some farmers and supporting extension workers. In the pasture value chain, women make up the majority of the labour force because they handle most of the production and also play a role in marketing pasture, as they are often responsible for the sale and exchange of surplus forage resources, such as grass seeds and fodder. According to the key informant interviews conducted in Turkana and West Pokot, there is always a significant demand for range pasture seed right before the rainy seasons. Sellers that are unable to get rid of the seeds during this time eventually have to store them for longer periods of time, which lowers the quality. This discrepancy highlights the need to formalize range forage seed supply chains in the counties faster. Despite the shifting climatic conditions that barely favour sustainable crop development, the cultivation of fodder and fodder seed may generally be a successful endeavour.

To efficiently handle the bargaining power, ability to sell their pasture products, and revenue sharing, farmers need to organize into marketing groups and cooperatives. Marketing groups and cooperatives provide a platform for knowledge exchange, enabling farmers to access training and information that can improve the quality of their produce, negotiate better prices for their products and reduce costs through shared resources and economies of scale. However, since few farmers are currently organized into marketing groups and cooperatives in the counties, there is need to promote awareness about the benefits of marketing groups and cooperatives. Training sessions and workshops can be organized to educate farmers about the advantages of collective marketing and how to establish and manage these entities. This can be done through the local community leaders, agricultural extension services, and non-governmental organizations who can actively mobilize farmers to form groups or cooperatives.

Additionally, group constitutions and bylaws help direct the effective management and decision-making of these farmer organizations. Several large-scale farmers have started producing enormous amounts of fodder in several areas of Narok County, primarily to generate revenue. Fodder production for small-scale farmers takes place in groups, and the establishment of such groups results in the building of social capital which may have positive effects, especially when it generates income for impoverished households.

Although the drought that affected the counties clearly had a negative effect on production, discussions with livestock officials in the counties revealed that fodder production may be a lucrative business. Fodder production groups should expand their activities into non-farm industries to be able to deal with the ongoing droughts. Additionally, maintaining group activities like loaning schemes and regular contributions may keep the groups operating as a single entity during drought years and thereby aid to further create the social capital that is essential during such times. Farmers should be protected from the high price inclinations linked to monopolistic input markets by being exposed to more input and service providers in order to increase their profit. To protect farmers from fluctuations in prices, the issue of low pricing and unstable markets could be solved by promoting linkages between farmers and trustworthy grass seed markets. Promoting public-private partnerships could encourage more service and input providers to join the grass seed value chain, which could assist in lowering the high input prices brought on by the market's existing monopolistic nature.

The current communal grazing resources in pastoral areas should be maintained, if not expanded, as a complement to fodder production to protect pastoral households from livestock losses caused by drought. This is because participation in fodder production groups and access to communal drought grazing reserves are positively correlated. The focus group discussion suggested that individual producers of fodder are more persistent than producers of fodder in groups. Producers in a group identified group management, especially decision-making, as a significant issue. Lack of storage facilities, technical knowledge of fodder production (agronomic practices), a lack of harvesting tools and equipment, and a lack of a market for fodder and culture are a few of the challenges and barriers to fodder production.

Figure 12: Fodder value chain structure

Stages	Input Supply	Production	Bulking	Processing	Marketing
Actors	Producers, NGOs, CBOs	Producers, Private farms, CBOs, Extension officers, KALRO, Microfinance	Producers, Private service providers, KALRO, Extension officers	Producers, Private service providers, KALRO, Extension officers	Traders, CBOs, Producers, Private farms, Extension officers, KALRO
Services	Clearing, Fencing, Ploughing, Planting, Climate information services	Hay and grass seed production, Input supplies, Credit facilitation	Training and extension services, Climate information	Quality testing	Bulking, Transport and sale, Market Information

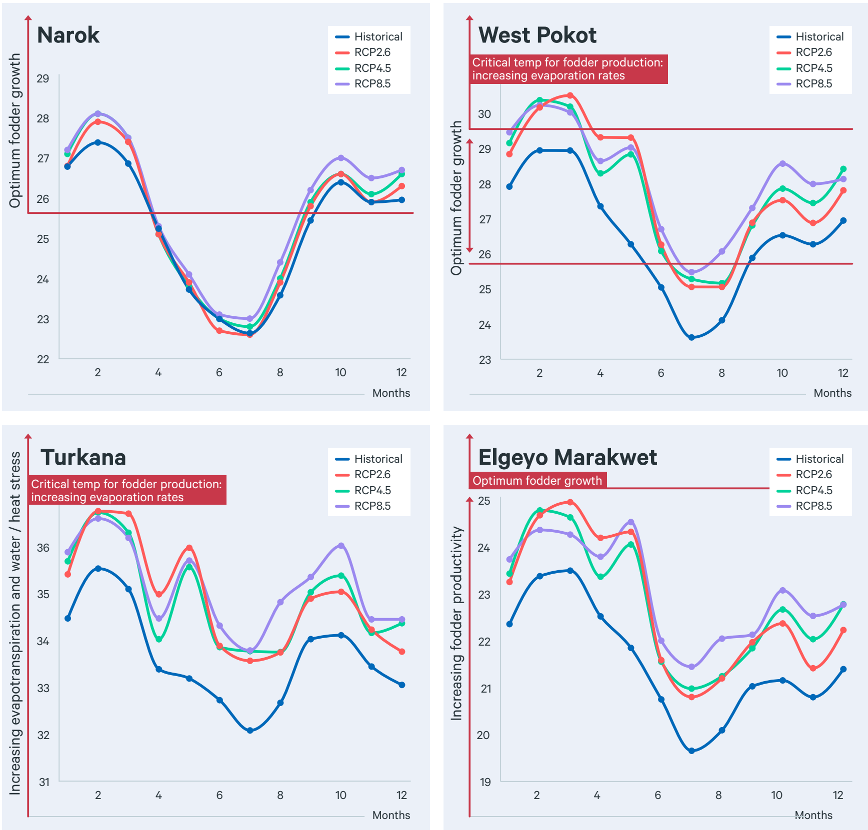
Source: Authors' own

Climate change risks along the pasture value chain

Large-scale rangeland vegetation patterns, forage quality, forage quantity and reliability, and water requirements for growing forage crops are all susceptible to climate change. The primary production of forage crops and rangelands will be most clearly impacted by climate change. Pasture shortage in pastoral communities is becoming a growing source of concern as never before. Discussions in groups with elders in the four counties revealed that pastoralists once had abundance of pastures for their livestock. They notice that the grass is no longer of high quality and that it disappears quickly, causing pastoralists to begin moving away from their houses in search of better grazing.

(Munkhtsetseg et al., 2007) noted that both rainfall and temperature have a strong relationship with pasture yields. However, rainfall has more effect on pasture yields than high temperatures, with sufficient rainfall coupled with a reduction in high temperature still accelerating fodder production. The threshold temperatures for optimum fodder production range between 2–30°C. Fodder production increases within a temperature range of 16–26°C (Hauze et al., 2016), reaching maximum growth at 30°C. The projected temperatures in Turkana and West Pokot will exceed the 30°C threshold temperature with an increase in number of days with temperatures above 30°C (increasing temperature stress degree days) (see Figure 13). Annual rainfall is projected to decrease in the four counties, with high interannual variability.

Figure 13: Impact of projected temperature on fodder value chain



Source: Authors' own

The combination of projected high temperatures and reduced rainfall will increase the need for water for cultivation, affect evapotranspiration rates and soil moisture, and increase water stress in fodder plants. This will negatively affect the quantity and quality of tillers produced, plant height, and vegetative/biomass growth. Extremely high temperatures over the threshold, as predicted by the three RCPs, will also lengthen temperature stress days, which will cause phenological phases to be incomplete, diminish the nutritional value and digestibility of fodder, and lead to poor yields of fodder as a result. The projected temperatures in the counties of Narok and Elgeyo Marakwet remain within the range of 26°C to 30°C, ideal for the best fodder production. However, projected decreases and high variability in rainfall in the two counties will negate the expected increase in fodder productivity/yields.

In addition to increasing the frequency and severity of future droughts and affecting water, soil moisture, and heat stress during the crucial stages of fodder growth, as well as the re-emergence of pests, weeds, and pathogens, the interaction between the projected increase in warming and decrease in rainfall will have additional and compounded negative effects on fodder quality, quantity, and productivity. Participants also noted that soil erosion was becoming a bigger issue. They claimed that the lack of vegetative cover left the area bare, which exacerbated soil erosion and let rainwater run freely. Under the projected scenarios for climate change, the expected increase in warming and drying will worsen the already precarious soil state, making it difficult for fodder crops to sprout and, in extreme cases, making some places altogether unsuitable for fodder production. This observation suggests that initiatives are required to solve the issue in the counties. Climate variability and change will have a significant impact on environmental security as well, as conflicts over the limited pasture, livestock and water resources that are frequently seen in these areas (especially in Elgeyo, West Pokot, and Turkana counties) are likely to worsen in the future due to changes in environmental conditions.

Given that precipitation has a greater influence on pasture than high temperatures, these counties should turn to irrigation farming to fulfill the expanding water demand for crops, increase pasture possibilities, and secure future fodder/pasture production sustainability. The expected negative impacts on fodder production and yields will affect the quality and supply of fodder in the market, raise fodder prices, negate desired outcomes, reduce fodder production prospects and income, and have additional negative effects on livestock/milk production, livelihoods and food security in these counties.

Enhancing resilience and competitiveness for the pasture value chain

To enhance the pasture value chain, it is important to:

1. Promote pasture production by providing pest- and drought-resistant seeds and species, training farmers, and buying the harvested grass from farmers for storage in strategic feed reserves to develop "grass banks" with village groups.

2. Improve pasture management through harvest and forage conservation, multi-species pastures, and grazing rotation.

3. Address soil and land degradation by promoting improved soil and land management practices and techniques.

4. Promote conservation agricultural practices that increase resilience to climate change.

5. Engage in feed formulations and value addition such as inclusion of legumes to improve feed quality.

6. Organize farmers into marketing groups and cooperatives to increase their bargaining power.

7. Support study tour exchange programs for various groups of producers involved in pasture production.

4.2 Livestock value chain

In arid and semi-arid regions, rearing livestock is a significant source of food and income for households (Mganga et al., 2013). Therefore, improving livestock productivity offers semi-arid community members a way out of poverty. The demand for the livestock sub-sector is anticipated to increase quickly, driven mostly by rising rates of urbanization and population growth. The consumption of milk and meat is anticipated to increase as a result (Thornton & Gerber, 2010). Low productivity in the livestock industry has been made worse by more severe and frequent heat waves and dry spells, caused by climatic variability and change, interspersed with periods of flooding. Pastures are deteriorating, especially in Turkana, Elgeyo Marakwet, Narok, and West Pokot, and insufficient attention is given to the governance structures needed to manage and safeguard them at the local level. Pastoralists are directly affected by factors such as including lower livestock production, an increase in livestock diseases and resulting greater mortality, as well as decreased grain quality and yields for animal feed.

The four counties' livestock production can be divided into two main value chains: the live animal, or beef, value chain and the milk value chain.

Beef value chain

Approximately 80–90% of the red meat consumed in Kenya is generated by pastoralists, making up the majority of the country's meat production (Amwata & Nyariki, 2021). Cattle that have been raised extensively on rangelands that belong to the community make up the majority of the beef value chain in all four counties. Cattle are transported by truck or foot from pastoral areas to main and secondary markets before being delivered to terminal markets in Nairobi. Inputs, production, trade, processing and the domestic market make up the value chain's primary nodes (see Figure 14). Water, pasture, feed, veterinary services, cattle breeds and labour are all inputs to the broader pastoral beef production value chain. The cattle breeds are a mixture of native and crossbreeds, with the native Zebu cattle being well adapted to dry conditions, despite the fact that crossbreeding with Sahiwal cattle is becoming more and more popular.

Results in Table 5 show that the main challenges facing livestock production are reduced pasture and fodder availability (89.1%), reduced milk and meat production (88.9%), increase in livestock mortality (88%), invasive species affecting livestock feeds (78.2%), and high costs of feeding (75.9%). Changes in processing costs (88.9%), increased losses when processing (81.6%), and damage to infrastructure (88.9%) are the main challenges during storage and processing. These, in turn, cause changes in the supply (84.5%), quality (88.9%) and shelf life (88.9%) of livestock products, increased transaction costs (88.9%), financial losses (74.5%) and increase in fodder prices (78.7%).

Table 5: Challenges along the livestock value chain

Value chain stages	Challenges	Proportion of respondents
Production	Reduced milk and meat production	88.9
	Increased livestock mortality	88.0
	Reduced pasture and fodder availability	89.1
	Increased pest and diseases	69.8
	Invasive species affecting livestock feeds	78.2
	High cost of feeding	75.9
	Increased labor costs	72.9
Processing and storage	Changes in the processing costs (need for cooling)	88.9
	Changes in management process	87.0
	Increased losses when processing	81.6
	Damage to infrastructure (roads/stores)	88.9
Marketing	Changes in the supply of livestock products	84.5
	Changes in the quality of products	88.9
	Financial losses by traders and retailers	74.5
	Reduced shelf life of animal products	88.9
	Increased transaction costs resulting from hazards	88.9
Consumption	Increase in prices	78.7
	Reduced quality of products	88.9

The focus group discussions revealed that the best time to sell live animals is determined by the availability of pasture and water, the ideal bodily condition of the animal, and the amount of money required to buy food during the dry season. The pastoralists in all counties agreed that keeping livestock has significant benefits for risk mitigation in addition to more market-oriented production. However, remote pastoralists who depend on traders and middlemen for access to the market or for pricing information are limited in their ability to access marketplaces for live animals. Inadequate and subpar livestock markets in these four counties make it difficult for farmers and traders to buy or sell livestock without traveling great distances.

This not only makes the livestock marketing process more expensive but also causes a loss in animal condition, resulting in decreased value during transportation. Even where market facilities do exist, they are poorly managed and structured. Other challenges to livestock marketing raised during focus group discussions include: a lack of animals in livestock markets; poor animal quality particularly during drought; brokers who sometimes exploit livestock buyers by manipulating prices to buy far well below the market value; a lack of feed and water supply in livestock markets, which leads to a loss of animal body condition and thus value; and insecurity, with buyers and sellers occasionally losing animals.

The creation of adequately functioning, transparent and competitive marketplaces is a critical prerequisite for promoting livestock commercialization. The principle of competition presupposes that both buyers and sellers have complete knowledge. However, findings from this study indicate that this assumption is primarily untrue in the case of the livestock sector in all counties.

Figure 14: Livestock market in Suswa Narok County

Source: Alphayo Lutta

Milk production

One of the most essential livestock products for pastoralists is milk. The quantity and distribution of milking animals, as well as the accessibility of natural pasture and water, all have an impact on the amount of milk produced. The seasons of the year also have an impact on milk production and productivity. According to both key informant interviews and focus group discussions, the seasonal fluctuation in milk production in the four counties was said to be greatly influenced by the amount and distribution of rainfall, which in turn impacts the availability of fodder and water.

Actors along the value chain include pastoralist producers, traders and consumers. However, the roles of the actors are not clearly delineated, as producers also serve as collectors and sellers, and traders also own livestock and produce milk. Even consumers who are primarily urban dwellers maintain livestock and produce milk on a smaller scale. However, their milk production is not sufficient for their household needs; hence the need to purchase milk from the local market. Hotels and eateries are also additional consumers.

This study generally showed that there are very low standards of hygiene among the participants in the market chain, from personal hygiene to the equipment used for milking, storing, and transporting cows. Traditional gourdes, plastic jerry cans and small numbers of aluminium cans are the major equipment used for milking, storing, and transportation. Traditional gourds meet hygienic requirements because they are usually smoked after use. However, the milk is often transferred to plastic jerry cans for transport and this contributes to milk spoilage as they are difficult to clean.

Very little of the total milk sold in the four pastoral counties makes it to the terminal markets in Nairobi, where it would ordinarily command substantial profits for the pastoralists. The majority of the milk is distributed to local markets in rural areas, and the market's viability depends on rural incomes, population, and sustained supply of milk in such regions.. Smallholder farmers in pastoral areas produced most of the milk in each of the four counties. However, due to marketing restrictions and a lack of techniques for processing for smallholder dairying, production is not market-oriented, and only a small amount of locally produced milk enters the commercial sector.

Efforts to boost milk production should be combined with efforts and knowledge to dispose of excess milk in the milk-producing villages in order to maintain milk output and meet the rising demand. Producing stable, marketable goods like butter, low-moisture cheese and fermented milks will give smallholder farmers a second source of income, encourage investment in milk production, produce by-products for domestic use, and allow milk to be stored for later sale or consumption.

It is also worth noting that through the informal market, which involves producers delivering fresh milk directly to consumers in the immediate neighbourhood, milk and milk products are distributed to consumers and sold to local vendors or collectors. Milk may go straight from farmers to consumers in the informal market or it may go through two or more market agents. The informal system is characterized by the absence of license requirements, low operating costs, higher producer prices than those found in the formal market, and a lack of operational regulation.

Climate risk assessment in the livestock value chain

Due to their complex and intertwined biophysical and socioeconomic conditions, which include significant temporal and spatial rainfall variability, all four of these counties are constantly threatened on a number of fronts. Variations in annual and interannual rainfall control the distribution of resources, such as water and nutrients, and as a result, the abundance and distribution of vegetation.

Direct impacts occur when temperature, precipitation intensity, climatic extremes such as drought and flooding, humidity, and pathogens' or vectors' metabolic processes, reproductive rates, and/or population densities increase, resulting in increased vector-pathogen-host contact and greater disease risk. These alterations occur within biologically determined boundaries. This is due to the fact that a rise in temperature or flooding above a certain threshold causes desiccation of arthropods or flushing of vector breeding areas, resulting in a reduction in disease transmission risk (P. K. Thornton & Gerber, 2010).

Diseases brought on by infections that spend a portion of their life cycles outside a mammalian host are frequently connected with direct impacts. These include fungus infections and vector-borne diseases. Changes in disease transmission patterns linked to ecological, sociocultural or behavioural disruptions caused by climate change are indirect consequences that are less obvious. Long-lasting droughts in pastoral areas cause more frequent and far-flung travels, which increase interactions between various animal species. Moving into places that were previously deserted could increase exposure to new disease pathogens. Diseases can also weaken animals, affecting their milk productivity.

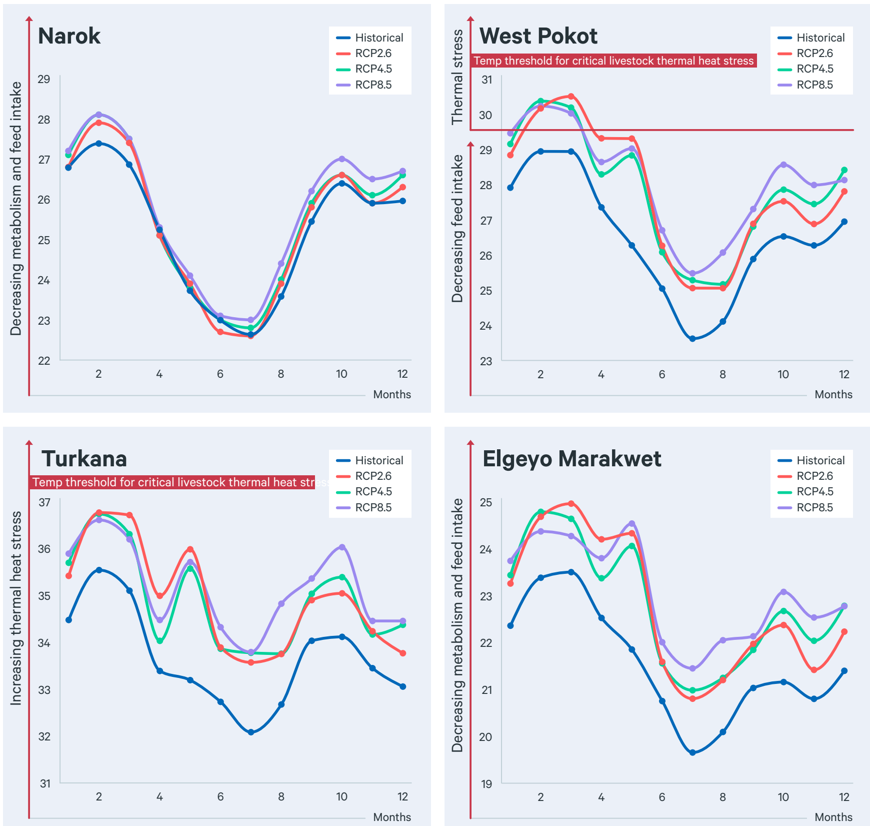
Since livestock are homeotherms (Sirohi and Michaelowa, 2007), they must maintain a body temperature in the thermoneutral zone, which ranges from 10° to 30° degrees Celsius (Said et al., 2019). Low temperatures often cause cold stress (severe hypothermia) in livestock, which causes their metabolism to speed up in order to meet their increased energy needs.

(Thornton et al. 2015) found that for temperatures above 30°C, every 10°C of warming causes a 1–3% reduction in feed consumption. According to a related study by Thornton et al. (2022), livestock typically experience thermal heat stress at temperatures exceeding 20°C, depending on the breed and species.

According to Figure 15, the mean monthly maximum temperatures for the baseline period in the four study counties range from 22°C to 33.7°C. Under all three future emission scenarios, the expected maximum temperatures in these counties will be higher than the 20°C threshold, accelerating thermal heat stress with varying consequences depending on the type and breed of animals kept. The number of days with temperatures above 20°C will rise as well in the projected scenarios, along with the number of days when animals will feel heat stress.

Livestock production is also reliant on the availability of water. The projected decline and inter-annual variability in monthly rainfall will cause water scarcity, accentuate the frequency and severity of droughts, and increase water and pasture shortages. These factors will trigger the movement of livestock to areas at higher risk of diseases, pests, and pathogens, increasing their susceptibility. Increased water stress in livestock will also result in decreased milk production, as well as weight and performance losses.

Figure 15: Impact of projected temperature on livestock productivity



Source: Authors' own

According to Thornton et al. (2015), for every 1°C increase in warming, livestock feed intake will decrease at rates of 1–3%. Consequently, the projected increase in mean monthly maximum temperature under the three RCPs of between 0.4°C and 1.5°C will reduce livestock feed intake by 1–3% or more in the study counties. To survive the warming, livestock will be compelled to consume less feed, which will dramatically reduce their body weight, fertility, reproduction, growth rate and productivity for milk and meat. Under the RCP8.5 emission scenario, it is also expected that there would be an increase in the number of days with temperatures above 30°C, adding more thermal heat stress to already stressed cattle.

The thermally stressed animals will experience further water stress as a result of the anticipated drop in rainfall, which will also result in less milk being produced. Given that the farmers lack facilities for refrigerating and adding value to their products, the rising temperatures will also shorten the shelf life of fresh milk produced. The poor current situation will get even worse as a result of the anticipated rise in temperature under the high emission scenario RCP8.5, which would also create favorable conditions for the re-emergence of cattle disease vectors and pathogens. Under the RCP8.5 scenario, the relationship between the anticipated rise in temperature and drop in precipitation will increase the intensity and frequency of droughts with the resulting physiological, pasture and water stress adversely affecting livestock welfare and productivity. Overall, these anticipated negative effects of climate change will severely disrupt the supply and demand in the livestock value chain, raise the cost of livestock products, diminish the prospects for livestock agriculture, halve the income, and worsen the situation of smallholder livestock farmers' access to food due to their lack of coping mechanisms.

Enhancing resilience and competitiveness for the livestock value chain

To improve the value chain and enhance its resilience and competitiveness, there is need to:

- Promote private sector investment. The creation of pastoral associations, identification of large traders and livestock buyers, and structuring around a formalized cooperative enterprise to provide training modules on ideal production systems should be given priority. To foster a more competitive environment, the promotion of more value-addition activities like the commercial abattoir, confinement feed lots, fodder production and improved holding ground management (in collaboration with county government) would probably go a long way toward boosting economies of scale and promoting trade and production. To ensure the success of these activities, enhanced advocacy is needed to promote more investment in sustainable land use and management. Further, linkages should be established and promoted between processors and local traders..

- Improve market management and governance. It is crucial to invest in co-management advocacy in every market to enhance the management and governance of most of the market infrastructure. Once co-management is prioritized and accepted for any given market, it is vital to work with livestock market councils and livestock market organizations to provide a participatory platform and effective management of market resources. The co-management of the markets will increase county government revenue, increase tax compliance by market participants, maintain the market infrastructure, improve the resolution of market disputes, enhance security, safeguard the interests of livestock traders, and instil and sustain an improved entrepreneurial culture in livestock markets (Anno et al. 2023). Grading and weighing facilities will also need to be installed as part of infrastructure improvement projects in the targeted markets. This would facilitate more efficient trade and assist in removing redundancy brought about by brokers in the marketplace (Ng'asike et al. 2020). Infrastructure improvements should involve direct participation from community-based co-management bodies, including livestock market associations (LMAs), to ensure sustainability of the same.

- With the risks of climate change, value addition in the value chain is essential. Commercial fattening, such as confinement feedlots, as well as the production of disease- and drought-resistant fodder have the ability to provide value and stimulate the market.

Table 6: Challenges and opportunities for livestock production

Challenge	Investment opportunity
Frequent drought and erratic weather patterns affecting supply of feed and water	Invest in a commercial abattoir and feedlots for livestock fattening
Livestock diseases	Improve livestock quality and productivity through cross-breeding and commercial sales (Sahiwal+Borana)
Poor management of the available pasture	Strengthen and support grazing management committees and institutions
Lack of and/or weak delivery of veterinary services	Establish livestock producer associations to diversify and improve rangeland production and market access.
High cost of inputs	Find strategies to ensure the availability of breeding bulls, bucks, and rams for use by farmers.
Absence of market infrastructure along trek routes and livestock markets	Improve the management of markets and holding grounds
Low funding for animal health and disease surveillance	Intensify disease surveillance and set up early warning systems

4.3 Bee value chain

Beekeeping is a low-investment, low-input business venture that directly generates economic gains and works well with farming. However, it is still mostly underdeveloped in the four counties, even though fodder for bees is known to grow easily in several of the counties. Most beekeeping far\ \mers who were interviewed did not completely understand its potential and worth as a business that can make money. In pastoral areas, where livelihoods often depend on diverse agricultural and livestock-related activities, beekeeping has the potential to be an additional source of income. However, the lack of awareness or understanding about the commercial aspects of honey production and marketing is hindering these farmers from fully capitalizing on this opportunity.

Production is primarily carried out using native methods in all four counties, with most farmers using the traditional log, grass and bark hives. Traditional hives are generally low yielding in terms of the key verifiable indicator of honey production due to their topology, background and design qualities. The Kenya Top Bar Hive and the Langstroth are two modern hives that are progressively gaining popularity, although some bee farmers in the counties of West Pokot and Narok claim that there have been some issues about their designs and component parts which have a detrimental effect on colonization rates and production.

Depending on the kind of hives the farmer owns, several harvesting methods are used. When working with native hives, producers sometimes harvest raw honey or honey that has been combined with larvae by cutting through and removing the centre comb. Many beekeeping farmers continue to use conventional hives despite the widespread knowledge of the advantages of adopting contemporary hives. According to the focus group discussions, this is mostly because many bee farmers are unable to afford the high acquisition prices associated with modern hives. Additionally, compared to other counties, the quality of the honey made from trees in these locations commands high rates, which presents a major opportunity for the sector.

Building local community resilience through the development of the honey value chain in these counties will also improve nutritional well-being, raise income and relieve pressure on the forest owing to deforestation brought on by unsustainable honey gathering practices. Exchanges throughout the community to share beekeeping success stories could enhance the training. Additionally, assistance with beehives, honey collection and processing equipment will enhance the value of the honey and lead to higher pricing, which will help towards improving living conditions.

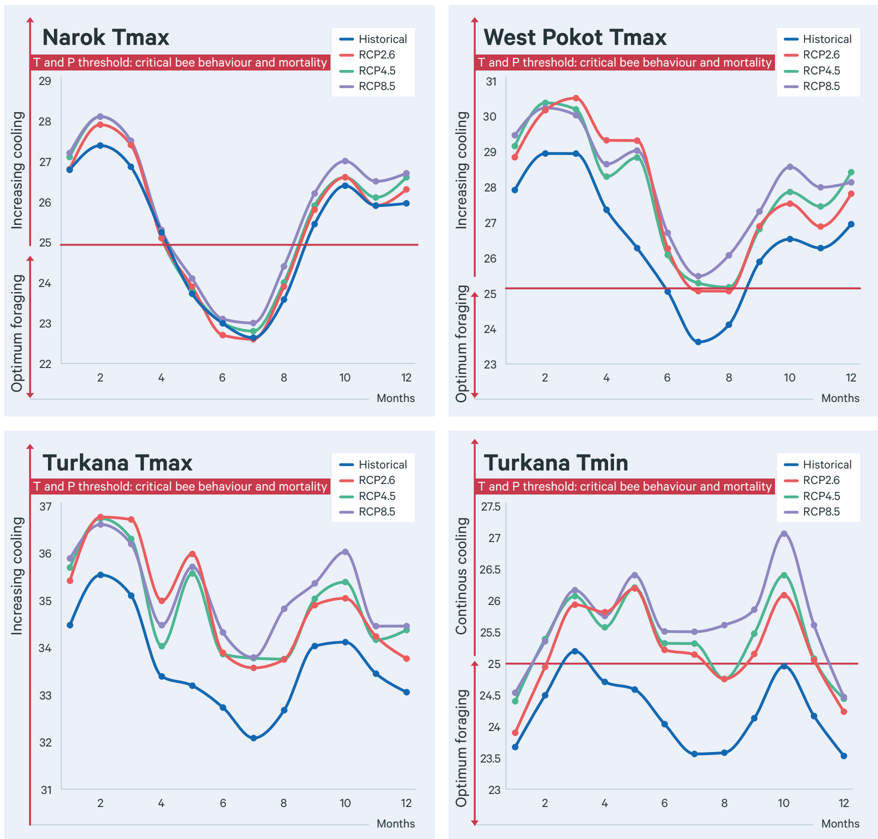
Climate change risk analysis

Temperature and bee colony activity are strongly correlated, especially during the flowering stage (Schriek et al., 2021). Increased bee mortality rates and much lower colony food reserves were shown to be caused by seasonally low rainfall and relatively high temperatures. The ideal temperature range for foraging is between 12°C and 25°C. When the temperature rises above 25°C, the nest experiences more heat stress, which requires more cooling to return the nest's temperature to normal.

Mean monthly maximum temperatures in the three counties of Turkana, West Pokot and Narok have already exceeded the 25°C threshold temperature in the baseline period and are projected to increase at rates between 0.4°C and 1.5°C by 2050 under the three RCP scenarios considered in this study (see figure 16). This projected increase in mean monthly maximum temperature above the 25°C threshold temperature is highly likely to increase evaporative cooling of the brood nest and gradually decrease foraging activity, resulting in a decrease in colony food stores and increased mortality of brood population.

Turkana will observe the highest increase in temperature, with mean maximum temperatures projected to be above 35°C under the high emission scenario (RCP8.5). This will require intense evaporative cooling to thermoregulate the beehive, increasing water collection by the brood and significantly decimating forage activity and colony food reserves and decreasing the bee population. Mean monthly minimum temperature in Turkana is projected to exceed the 25°C threshold temperature under the three emission scenarios, which will also require continuous cooling of the nest to survive the increase in heat stress, significantly limit foraging activity, deplete the available food reserves, and initiate massive decline in brood population sizes.

Figure 16: Impact of climate change on bee activity, behaviour, and mortality



Source: Authors' own

The four counties will see low honey production as a result of these effects brought on by climate change, which will also lower bee producers' income and return on investment. Bees still require rain for the flowers to bloom, even though they may not be as dependent on it as animals are. The amount and quality of honey produced will be impacted by the availability and dispersion of pollen, nectar, the time of flower blooming, and the mean monthly rainfall in these areas, which is predicted to decline and become extremely unpredictable. Since some intermediaries may choose to buy honey elsewhere because of the inconsistent production volume, this issue also has an impact on the market.

As shown in Table 7, apiculture faces several climate change-induced challenges in production, storage, processing, marketing, and consumption of honey, including migration of bees (75.6%), increased production costs (65.7%), reduced honey production (60.2%), changes in harvesting time (60.2%), increased mortality in bees (20.2%), reduced plant diversity (33.2%), reduced quality (60.6%) and supply of honey (65.2%), and increased financial losses (57.2%) and prices of honey (56.1%).

Table 7: Observed climate change impacts on apiculture value chain

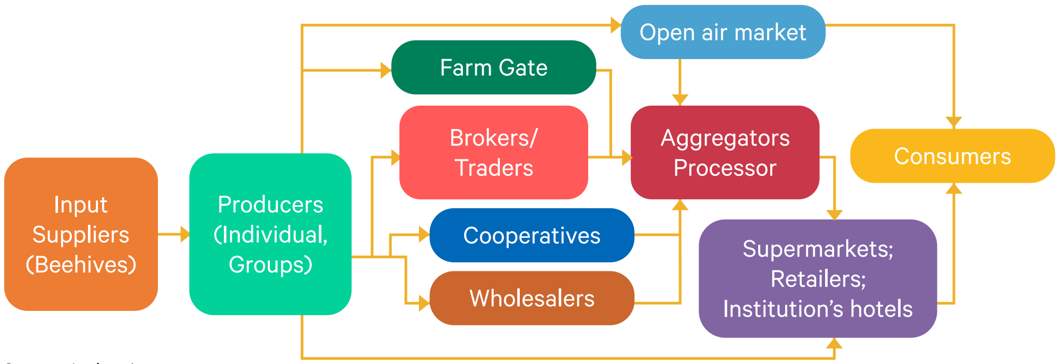
Value chain stage	Challenge	Proportion of respondents (%)
Production	Reduced honey production	60.2
	Increased mortality of bees	20.2
	Reduced plant diversity	33.2
	Increased cost of production (such as water provision for bees)	65.7
	Increased pests and diseases	70.1
	Migration of bees	75.6
Processing and storage	Changes in the harvesting time	60.2
	Changes in management process	19.2
	Damage to infrastructure (roads/stores)	60.2
Marketing	Reduced supply of honey	65.2
	Changes in the quality of honey	60.2
	Financial losses by traders and retailers	57.2
	Increased transaction costs resulting from hazards	60.2
Consumption	Increase in prices	56.1
	Reduced quality of honey	60.6

Additionally, 70.1% of the respondents claimed that the spread of unusual pests that harm plants is a result of climate change. Chemical sprays are mostly used to combat these pests, which, according to focus group discussions in West Pokot, have caused the bee population to decline. The normal pollination and breeding cycles, as well as the delicate bee nesting behavior, may be hampered or confused by seasonal fluctuations (Mudzengi et al., 2019), with illnesses, parasites, invasive species and chemicals also having an effect.

Climate has an impact on flower development, nectar production and pollen generation, which are all directly related to colonies, foraging behaviors and growth. Bees must accumulate enough honey reserves to last them throughout the season. The distribution of different flower types has changed, which has a substantial impact on honeybees. The various flower species provide food for bees; as a result, an excessively dry climate reduces pollen grain production and robs them of their nutritional value, having a severe negative impact on the habitat of bees. The future worker bees depend on the pollen diet to mature. Without sufficient nutrition, bees become malnourished due to a "famine", which lowers their immune systems and makes them more susceptible to diseases, shortening their lifetime (Gajardo-Rojas et al., 2022). A honey farmer in Narok County claims that honeybees must hasten the process of collecting honey in order to stockpile enough food to keep them alive throughout the drought.

Honeybees create a movement strategy to respond to seasons, flowering or disturbance if they are unable to accumulate enough stores. To avoid starvation, the bees abandon their nests and fly farther distances. After leaving their beehives for several months, the same honeybees go back to them. Honeybees are vulnerable to pathogens, parasites, and specialized pests and predators, and climate change has a significant impact on the virulence and transmission of diseases and pests. The pathogens have unique haplotypes with different levels of pathogenicity, and bees are more susceptible to numerous haplotypes due to climate change. Similarly, climate-related bee migration exposes them to previously unknown diseases (Picknoll et al., 2021).

Figure 17: Apiculture value chain structure



Source: Authors' own

Enhancing resilience and competitiveness for the bee value chain

Table 8: Challenges and adaptation options for the bee value chain

Main challenges identified	Options for enhancing value chain resilience and competitiveness
• Shortage of bee equipment supply • Unreliable market of bee products • Lack of capital for beekeeping investment • Pest and diseases • Lack of appropriate beekeeping knowledge • Lack of extension services • High costs of modern beehives • Lack of packaging materials and market instability	• Increase the use of improved hives and appropriate bee handling equipment • Introduce new bee research and demonstration centres • Provide training in the management of bee hives and enterprise development to bee farmers, farmer groups and extension workers. • Make credit available to individuals and community groups for startup • Begin processing of honey by community beekeeper groups • Preserve healthy ecosystems and use of bio-pesticides

4.4 Gum and resin value chain

The trade in gums and resins is gaining momentum in Turkana County. For some collectors interviewed, gums and resins have become a source of household income and their trade is substituting the need to sell livestock to earn income. Most respondents noted changing gum yields per plant (20.3%), increased pests and diseases (19.5%), changes in processing time (20.3%), damage to infrastructure (70.3%), changes in supply (71.1%), quality (20.3%) and increased post-harvest losses of gums/resins, increased transaction costs (70.3), and financial losses (71.3%) as some of the challenges facing gum and resin production, processing, marketing and consumption (see Table 9).

Table 9: Challenges and observed climate change impacts on the gum and resin value chain

Value chain stage	Challenge	Proportion of respondents (%)
Production	Changing yields per plant	20.3
	Reduced tree cover	3.5
	Increased pest and diseases	19.5
	Shifts in production zones	3.1
Processing and storage	Changes in processing timing	20.3
	Increased losses when processing	3.5
	Damage to infrastructure (roads/stores)	70.3
Marketing	Changes in gum and resin supply	71.1
	Changes in the quality of gum	20.3
	Financial losses by traders and retailers	71.3
	Increased transaction costs resulting from hazards	70.3
	Increased post-harvest losses	70.3
Consumption	Increase in prices	71.1
	Reduced quality of products	70.3

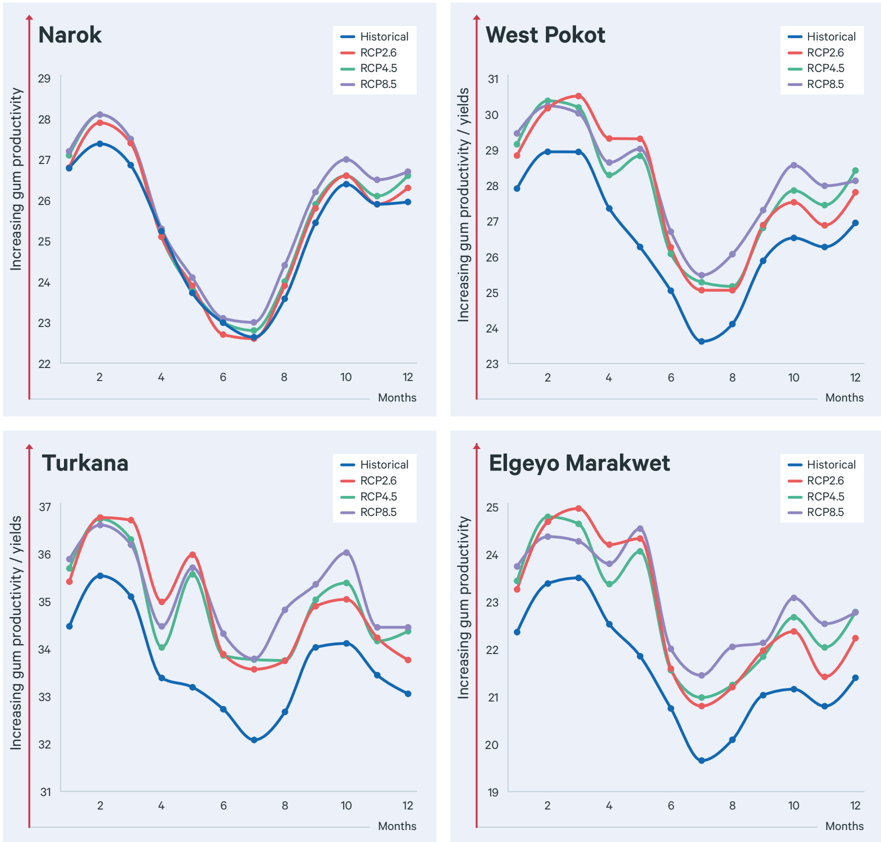
Currently, a regional aggregator buys the high-quality Acacia Senegal product for an average of USD 4 per kilogram. Four to five kilograms of this product may readily replace a full-grown sheep or goat at the market and aside from the time required in harvesting, it is almost completely free to produce. Focus group discussion with the youth revealed that young people frequently tap tree bark to release sap that hardens into gum and then come by a few days later to collect the gums. The county department of natural resources lists gums and resins as rangeland products with commercial potential and in need of conservation even though the activity does not appear to be regulated.

Fortunately, Acacia Senegal has the potential for economic production and grows widely throughout the mountain ranges. The natural secretion of various subspecies of Acacia trees and shrubs is known as gum arabic. It serves as an emulsifier, stabilizer, flavoring ingredient, thickening and coating agent in the culinary, pharmaceutical, printing, ceramic and textile sectors (Cunningham et al. 2008). There is a significant and expanding global need as a result of the lack of an effective synthetic substitute. The importance of gum arabic in the livelihoods of collectors stems from the period during which it is available for collection. According to the key informants, the actual income obtained from gum arabic collection, when looked at in terms of the total size of its contribution to annual income, was very small. Even so, despite having the potential to increase revenue, this potential has not yet been fully realized.

Climate change risks to the gum and resin value chain

Gum is a tropical tree that thrives best in dry climates with mean annual temperatures between 16.2°C and 27.8°C and yearly rainfall quantities between 380 mm and 2280 mm (Hauze et al., 2016). The tree is quite susceptible to cold temperatures, but it can withstand drought very well and gum yields have been seen to rise in challenging environments. The ability of gum to thrive in dry, semi-arid and arid environments is widely documented (Ballal et al., 2005), and the amount of gum harvested increases as the temperature rises during tapping. According to projections, the average monthly rainfall in the study counties will reduce (see Figure 10) and show high variability, resulting in frequent and severe droughts, a decrease in the amount of water available, and an increase in evapotranspiration rates, water stress and soil moisture stress. However, gum is a drought-tolerant tree that is extremely resistant to water stress and may therefore flourish in an environment with reduced rainfall. The three RCP scenarios' projected temperature increases (see Figure 18) are above the 27.8°C temperature threshold, which is likely to hasten gum productivity and yields and favor gum tapping in the four study counties, increasing income from gum as a substitute source of livelihood. Large-scale gum production should be strongly encouraged in the four counties as a conservation and livelihood diversification approach, given the flexibility and enormous gum output potential under increasing temperatures.

Figure 18: Impact of projected increase in temperature on gum productivity



Source: Authors' own

Enhancing resilience and competitiveness for the gum and resin value chain

Improved gum and resin collection and post-harvesting methods may lead to improvement of the value chain. Most collectors who were interviewed employed crude gathering techniques such as scraping using knives, chisels and/or bare hands to remove layers of bark until they reach the gum or resin. According to the key informants interviewed, more effective collecting methods, like tapping, could result in a significant increase in the amount gathered each day. Additionally, increased usage of post-harvest methods like drying, washing and sorting can raise the value of gum, providing yet another incentive to gather more of it. Interventions in collecting at the family level would improve the quantity and quality of gum collected, but they might only boost revenues when gum gathered is sold.

In Turkana, there are very few specialized traders and a highly underdeveloped gum arabic supply network. The majority of households buy their gum from general store proprietors. These stores only sell a small amount of gum arabic, and thus they have little experience with adequate storage procedures and standards of quality. Additionally, the market that the retailers may sell to is small; because there are no minimum standards for quality, selling higher-quality gum has little to no reward, eliminating incentives to raise standards. In addition, the few shops are resource constrained and rely on occasional and infrequent trader visits to sell their stock of gum. This limits the overall amount of gum purchased and lessens the incentives for collectors to expand supplies of gum arabic. The supply chain must therefore be improved in order to increase the quantity and quality of collected gum arabic and, as a result, the revenues of collecting families.

Increased access to dedicated traders who guarantee a gum market would promote gum use, improve market size and volume, and thus lower transportation and handling expenses per unit of product. This cost reduction, combined with increased competition inherent in expanding markets, should lead to higher prices and incomes for collectors (Muga et al. 2021).. By eliminating the unpredictability at the base of the gum arabic supply chain, collecting households would have another source of income during the toughest time of the year, when livestock is not enough to make ends meet. The terrible situation most collectors are currently in justifies interventions in the gum arabic supply chain. Once a reliable market has been established, collectors will have a strong incentive to increase the quantity and quality of gum arabic they sell. Interventions that attempt to enhance collecting and post-harvesting methods are currently likely to be well-received and successful, and helping the gum arabic market grow would give people a means of helping themselves, which is far more sustainable owing to increasing income.

4.5 Aloe value chain

Because of its therapeutic properties, substantial leaf gel content and robust growth history, aloe vera is a crucial species for commercial production in dry and semi-arid regions (Figure 19). Methods of aloe propagation vary by species, but the majority propagate via suckers and a smaller percentage through seeds. Aloe species have gained substantial popularity and importance in Turkana County among local residents who claim that a variety of products may be extracted from the plant's various components, transforming their way of life. According to the aloe farmers in Turkana County, different products may be made from different sections of the aloe plant, including: fermentation catalyst from stems and roots; processed gum and gel; herbal tea from flowers; and sap/exudate from leaves.

Aloe turkanensis is the most popular species found in Turkana. According to the producers, it has high sap yield per leaf which is beneficial for aloe soap processing. Aloe vera production in Turkana was initiated and implemented by a collaboration between Kenya Forestry Research Institute (KEFRI) and other partners. Apart from a few limited traditional uses like medicine and rituals, the community previously had no known economic benefit from the aloe plant. Additionally, prior to trainings from an aloe soap making initiative, the plants were more commonly thought of as invading bushes on rangelands. According to the group of producers interviewed, they harvest *Aloe turkanensis* to extract the sap and then mix it with chemicals to make liquid and solid soap, as well shampoo. The solid soap is stored for six weeks to ensure that the harshness of caustic soda used in the manufacturing process dissipates.

Figure 19: Aloe vera plantation in Turkana County

Source: Carol Mungo

Members of the group dealing aloe in Turkana County affirmed that they are knowledgeable about the production process, and that a manual with instructions on how to harvest the crop, extract the raw materials and measure the various ingredients is easily accessible. The group gathers *Aloe turkanensis*, also known as Echuchuka locally, from a lush natural forest that is home to numerous indigenous tree species. Some members have been trained on how to preserve the aloe vera species after harvesting to prevent their extinction.

The respondents indicated that because they are more cost-effective and last longer than traditional soaps, soaps made from aloe vera were the most in demand in towns including Lodwar, Kakuma Town, Kakuma Refugee Camp, Kalobeyei Integrated Settlement and Lokichogio Town. They reported that a liter of soap and shampoo costs USD 1.4, whereas solid soap costs USD 0.3. Aloe products are well-liked in the nearby towns and villages thanks to their low cost.

In addition to generating income, aloe vera plantations enhance the aesthetic value of the landscape and serve as a cover crop for the soil. Respondents claimed that after a protracted period of a lengthy dry season, they turned to aloe vera farming because other crops that depended on rainfall could not thrive in the tough climate. Most aloes need only 300 to 850 millimeters of rain every year and thrive in rich, rocky or gravel soil and have shallow roots. Aloes also thrive in soils with a pH range of 4.5 to 7.0 with a high nitrogen content (0.4 to 0.5%) (Mukonyi, 2020).

Table 10: Challenges and observed climate change impacts on aloe value chain

Value chain stages	Challenge	Proportion of respondents
Production	Reduced aloe biomass yield	20.1
	Increased mortality of aloe plants	23.5
	Increased pest and diseases	19.7
	Shifts in production zones	44.1
Processing and storage	Increased losses when processing	23.5
	Damage to infrastructure (roads/stores)	50.1
Marketing	Changes in supply of aloe products	82.3
	Changes in the quality of products	80.1
	Financial losses by traders and retailers	72.1
	Reduced shelf life	20.1
	Increased transaction costs resulting from hazards	80.1
	Increased post-harvest losses	80.1
Consumption	Increase in prices	68.1
	Reduced quality of products	80.1

Climate change poses several challenges in aloe production, processing, marketing and consumption, which include reduced biomass yield (20.1%), increased mortality of aloe plants (23.5%), shifts in production zones (44.1%), pests and diseases (19.7%), losses when processing (23.5%), changes in supply (82.3%), quality (80.1%), and prices (68.1%) of aloe products (see Table 10). Financial losses (72.1%) and increased transaction costs (80.1%) were also reported during marketing.

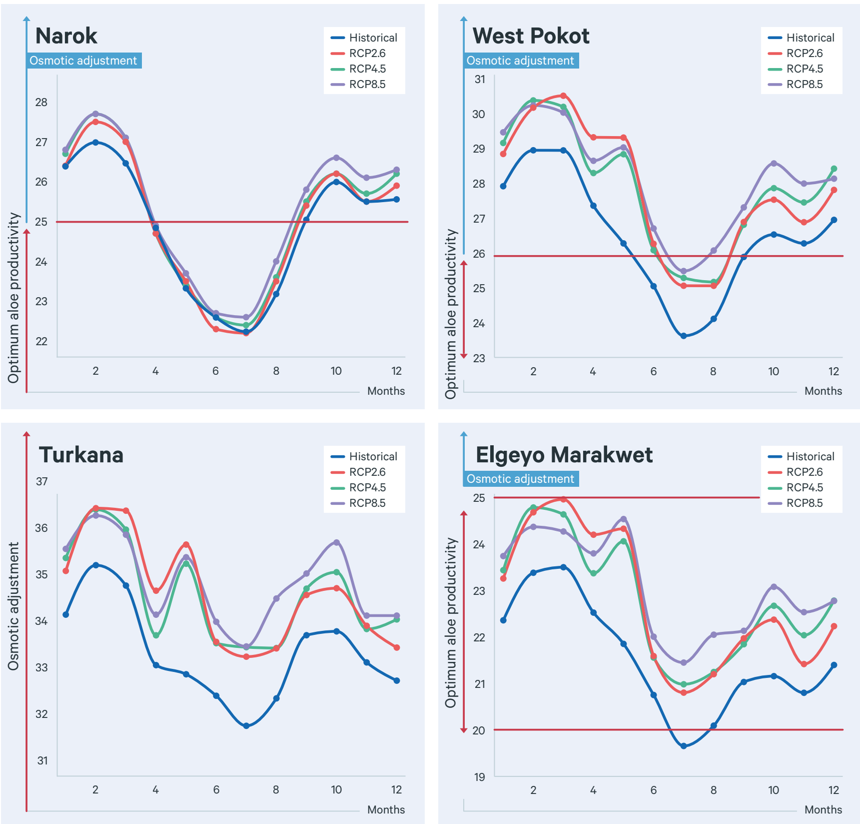
Even though aloe species are regulated plants, the focus group discussion with the producer group in Turkana revealed that farmers were unaware of national legislation for aloe commerce. According to the Wildlife (Conservation and Management) Aloe Species Regulations, 2007, anyone planning to propagate aloes for profit must seek to be included as an artificial aloe propagator in the Kenya Wildlife Service (KWS) register.

There was also an apparent gap of knowledge of aloe seedlings acquisition. Most participants in the aloe FGD had no idea how to obtain aloe seedlings, so they would remove them from vacant landowners' fields, road reserves, and other public areas—a behavior that is not sustainable. Aloes face difficulties in their management and conservation, particularly when they are plucked from wild populations and are not properly nurtured to maturity. The KEFRI guidelines for aloe propagation state that aloe cultivation activities include preparation of the land, spacing, transplanting, tending and management of pests and diseases, harvesting, and processing. However, very few of the producers were aware of these requirements.

Climate risks in the aloe value chain

Aloe is a succulent perennial plant that does well in dry and semi-dry environments. Temperatures between 20°C and 25°C and annual rainfall between 300mm and 800mm are ideal for aloe productivity. The most significant constraint on agricultural production in the ASAL counties is a lack of water, which has a negative impact on plant growth and output (Khajeeyan et al., 2019). The majority of plants in the equatorial region are already above the thresholds for a critical climate (Foden et al., 2007). Aloe is more susceptible to cold stress and readily tolerant of high temperatures, and it releases more phytochemicals during cold stress to withstand the harsh environment. Under stressful situations, aloe plants produce more flavonoids, anthocyanins, and mucilaginous substances (Kumar et al., 2017).

Figure 20: Impact of projected increase in temperature on aloe productivity



Source: Authors' own

The aloe plant has evolved mechanisms to withstand even the most severe droughts, including storing water in its leaves and stem (crassulacean acid metabolism), closing its stomata at night to prevent water loss, and having a low stomatal density to maximize water use efficiency. In order to endure heat stress and water shortages, aloe plants additionally produce unique proteins known as osmotic adjustments (Delatorre-Herrera et al., 2010). The interaction between the predicted rising temperatures, decreasing precipitation, and protracted drought conditions under the three RCPs will probably cause aloe plants to become more osmotically adjusted, which will affect how much aloe juice is produced, its distribution, phenolic content, quality, and overall aloe productivity (see Figure 20). Extreme circumstances could lead to the extinction of some vulnerable aloe species. Aloe, however, should be promoted as a substitute crop or adaptation in the study counties because it is extremely adaptable to drier environments, known to be drought resistant, and has the capacity to withstand the unfavorable climate conditions.

Enhancing resilience and competitiveness for the aloe value chain

The local pastoral community was persuaded that Aloe species were the most dependable and drought-tolerant plants that grew all year round. The county government of Turkana and community members have taken notice of the aloe plant species as a possible income-generating plant to support pastoral and agro-pastoral livelihood diversification methods.

The producers' group will benefit from being set up as cooperatives and unions. According to the director of cooperatives for Turkana County, grouping producers into cooperatives gives them the ability to share financial investments, increase their bargaining strength and uphold their contracts. In organizing themselves vertically, the producer groups will benefit not only by collecting but also by providing basic processing services to sell higher value aloe plant products on the market. At the same time, aloe soap production is restricted externally by the presence of input supply, fixed costs, lack of credit markets and the lack of infrastructures.

Training is required for an effective marketing and value chain system in the following areas:

- Post-harvest management. Aloe vera leaves should be processed as soon as they are harvested because they are perishable by nature. At various marketing phases, the decrease in post-harvest losses aids in effective value chain and marketing.
- Processing. To get a fair return on the market, processing, grading and cleaning are required. Aloe vera leaf cleaning and processing is a critical step in producing pulp and gel for numerous essential aloe products.
- Value addition. This will increase the value as well as the price of the produce and other necessary value-added goods for the market. The value addition can also reduce post-harvest losses.

To improve the value chain, there is need to:

- Create public-private partnerships that will aid in the infrastructure development for the market and support the marketing of the produce.
- Establish more processing facilities to reduce post-harvest losses and add value to the products.
- Ensure an effective marketing information system for the dissemination of marketing information to all actors in the value chain.
- Create a business incubator program that encourages innovation and entrepreneurship projects to help farmer cooperatives create and grow their businesses.
- Ensure vertical integration of farmers through cooperatives, contract farming and retail chains.

4.6 Indigenous poultry value chain

Maintaining an effective natural resource base is a problem for pastoral households as they pursue opportunities to increase revenues and improve food security. Most of the focus group interviews with women in Narok, Elgeyo Marakwet, and West Pokot revealed that native poultry is one of the most often raised animals and offers substantial disposable income to disadvantaged households in general, in particular to women and young people. According to the livestock director of Elgeyo Marakwet County, indigenous chickens can survive in a variety of conditions, are effective at turning feed into high-quality food, and have less environmental footprints than most other livestock. According to women groups in the counties, indigenous chickens are hardy and can endure extreme environmental changes like drought in which ruminants would not survive. In the ASAL counties, the domestic poultry industry has remained mostly undeveloped. Chicken ownership is diverse, although women currently possess a larger proportion of poultry. Focus group conversations with women's groups revealed that this industry relies on little input and does not require supplemental feeding, as chickens are allowed to roam free and forage for food.

The overall market structure is fragile and less predictable. Despite being sector-wide, there are a variety of concerns to market competitiveness. These include infections, pests, predation, the high price of medications resulting in farmers using herbs, market competition from exotic birds, and general bird mortality. Rarely are illnesses and pests treated with modern medications; herbs, which are often administered by farmers, are heavily utilized instead. Chicken prices are now quite low and are not anticipated to increase significantly anytime soon.

The state of value-addition as the indigenous poultry sector currently operates is quite minimal. Opportunities to upgrade the value chain include:

- Processing poultry into value-added products like sausages, smoked meats, or ready-to-cook meal to cater for diverse consumer preferences and potentially command higher prices

- Facilitating efficient linkages between poultry producers and market

- Streamlining the supply chain by proving transportation, storage and quality control services to ensure that poultry products reach consumers in optimal condition

- Reducing information gaps and promoting trust within the poultry value chain by developing transparent pricing mechanisms and fair trade practices.

Better supported services and reorganization would encourage producers and other actor categories to pay for services, though at the current state, willingness to pay remains fairly low. In all of the focus group discussions, women stated that watering chickens is not normally planned for, except when the owner places certain herbs in water for medicinal purposes. During epidemics, red pepper, neem and fresh aloe leaves are crushed and placed in a basin with water for the chicken. There are no veterinary officer consultations. According to Elgeyo Marakwet's director of livestock, this is due to three factors:

- Lack of information among poultry keepers about contemporary medications available for chicken illness control and related services

- Inadequate resources to obtain veterinary consultation and related services

- The use of herbal medicine to supplement traditional knowledge on poultry care.

There is little to no management and care provided for the chickens, and farmers frequently disregard and presume what their flock requires. Few homes have constructed pens specifically for their flocks, according to our focus group interviews with poultry breeders. The majority of people who kept chickens, on the other hand, allowed the animals to live in their homes with them, often sleeping under the bed or in the kitchen. Stock breeding is done at random, therefore there is no evidence or practice of selective breeding other than in very rare circumstances where informal breeders are involved. Inbreeding is frequent, and no particular controls are used. Families frequently borrow cocks from friends and neighbors to use for breeding, which undermines any deliberate disease control efforts. To build flocks, individuals buy pullets rarely or receive them as gifts from their kin.

Three marketing nodes are used by individual poultry keepers. They sell their poultry directly in local markets, opt for direct sales to consumers and bypassing traditional markets, or sell to local retailers such as butcheries or restaurants. At home, brokers come to buy chickens either on their own volition or at the farmer's invitation. The preference is to sell to brokers because it relieves the strain of having to take the chicken and wait for market day. The size, season, and sex of the chicken all affect price. The process for determining pricing is without a calibrated scale; rather, there is a propensity to weigh by lifting and analyzing the composition of the chest's flesh. During the dry season, the market is flooded with birds. Such times are also characterized by disease epidemics and acute food scarcity. Poultry keepers sell their birds for two main reasons: to meet household financial needs and, if necessary, to discharge the flock in order to shift the mortality burden.

Between domestic and exotic birds, there is competition for consumers' desire as well as the supply of chicken meat. Particularly in cities, more exotic birds are consumed than indigenous ones. Fast food restaurants that serve grilled chicken and potato chips are the major places where this trend may be seen. Significant indigenous chicken consumption was noted in bars and restaurants, both for soup-based recipes and in response to client demands. People who purchase birds from open markets to eat at home favour indigenous birds as well.

Table 11: Challenges and observed climate change impacts on the poultry value chain

Value chain stage	Challenge	Proportion of respondents (%)
Production	Changing yields per bird	22.2
	Increased mortality	14.3
	Increased cost of production (vet inputs)	32.1
	Increased pest and diseases	43.5
Processing and storage	Increased losses when processing (esp. packaging poultry products)	3.1
Marketing	Changes in poultry and poultry products supply	81.9
	Changes in the quality of products	22.2
	Financial losses by traders and retailers	71.8
	Increased transaction costs resulting from hazards	82.2
	Increased post-harvest losses	82.2
Consumption	Increase in prices	52.2
	Reduced quality of poultry products	82.2

The respondents reported that climate change affects poultry production, processing, marketing, and consumption. As shown in Table 11, notable climate change impacts on poultry include changing yields per bird (22.2%), pests/diseases (43.5%), increased mortality (14.3%), increased production cost (32.1%), changes in supply (81.9%), quality (82.2%) of poultry products, financial losses (71.8%), increased transaction costs (82.2%) and prices of poultry products (52.2%). Figure 21 shows the indigenous poultry value chain actors.

Figure 21: Indigenous poultry value chain actors

Stages	Input Supply	Production	Bulking	Processing	Marketing
Actors	Producers, Agrovets	Individual HH, Informal breeders, Extension officers, KALRO, Microfinance	Individual HH, Breeders, Traders, Brokers, KALRO, Extension officers	Producers, Live bird traders, Egg collectors	Roadside sellers, Bars, Restaurants, Market traders
Services	Supplemental feeds, Drugs, Herbs	Egg production, Live chicken rearing, Input supplies, Credit facilitation	Aggregation	Quality testing	Transport, Live chicken and egg sale, Market Information

Source: Authors' own

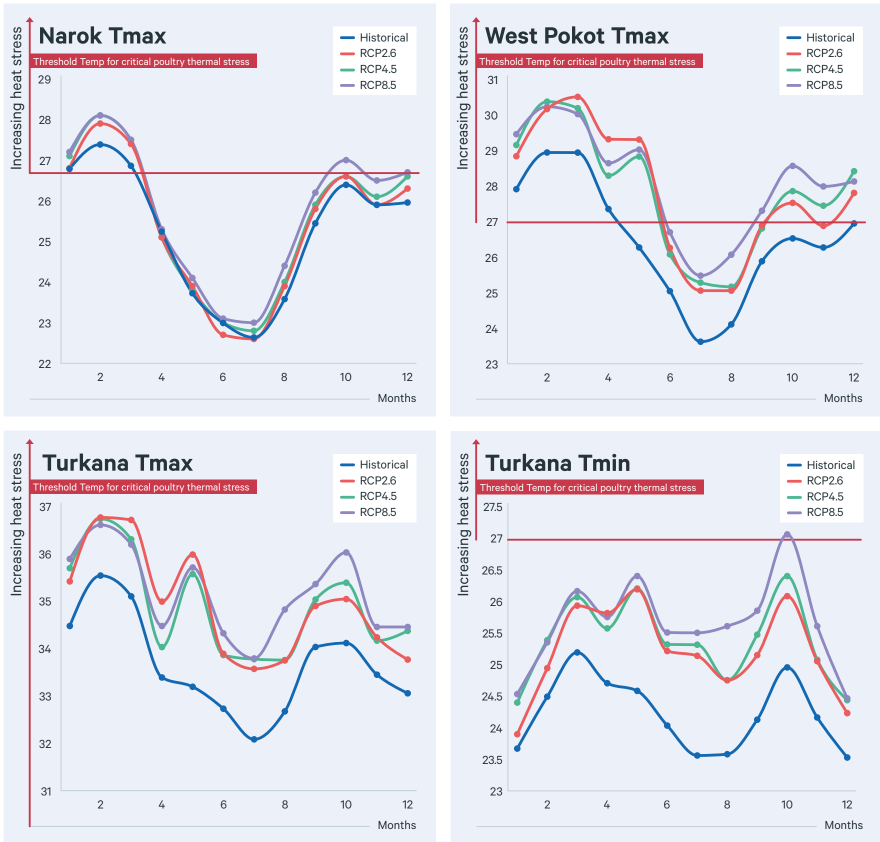
Climate change risks in the indigenous poultry value chain

Kim et al. (2021) stated that the greatest direct effect of climate change on indigenous poultry is the rise in heat stress brought on by increasing temperatures. The homeostatic balance is in equilibrium at normal temperature (22°C), and feed uptake, normal heat stress, and poultry productivity are all at their highest levels. Moderate heat stress begins to set in as soon as temperatures rise above 27°C. This stress has an impact on the poultry's thermal balance, feed intake, egg weight and production, and the quantity and quality of sperm in heat-stressed males.

Temperatures above 32°C were found to cause severe heat stress in poultry, causing a significantly lower the weight, number, internal and external quality of eggs; a significant decline in feed intake and digestibility; thermal imbalance; poor growth rate and hatchability; lower sperm count, quality, and concentration; and, in extreme cases, increased morbidity and mortality. Temperatures in West Pokot and Turkana have already exceeded the 27°C threshold during the baseline period, with temperatures expected to exceed 27°C under the three future emission scenarios (see Figure 22). Heat stress will be introduced as temperatures rise beyond 27°C, negatively impacting the weight, number, and quality of eggs produced, hatchability, growth rate, body weight, homeostatic balance, feed intake, and overall chicken production. Turkana will face the greatest climate hazards, with temperatures expected to exceed 32°C under all of the emission scenarios analyzed in this study. Poultry productivity is also affected by the availability of water for homeostasis balance and drinking.

The anticipated decrease in rainfall, high variability, and severe and frequent droughts would result in feed and water shortages, as well as increasing production expenses (feed, water and immunization). Poultry will experience severe physiological, feed, and water stress, which will have a substantial impact on their thermal balance, growth rate, body weight, fertility, egg quantity and quality, feed intake, sperm quality, count, and concentration, as well as increased morbidity and mortality. All of these impacts will dramatically raise the cost of chicken feed, reduce income from poultry product sales, and jeopardize the food security of smallholder poultry farmers in these study areas. Temperatures in Elgeyo Marakwet remain below the 27°C threshold, but the associated variability in rainfall and drought conditions threatens to destabilize the thermal balance and introduce physiological stress, water, and feed scarcity, affecting poultry well-being and productivity. The detrimental effects of climate change on indigenous poultry will severely disrupt the supply of quality chicken and poultry products in the poultry market, resulting in lower value chain income.

Figure 22: Impact of projected warming on indigenous poultry production



Source: Authors' own

Enhancing resilience and competitiveness for the indigenous poultry value chain

A number of key initiatives could help in improving the indigenous poultry value chain, such as:

1. Raising awareness and assessing the utility/value of indigenous poultry farming as a business.
2. Development and delivery of a comprehensive training program on "Indigenous Poultry Keeping and Management as a Business".
3. Technical assistance in the selection of breeds that are suited to the region (this can be done in collaboration with the Kenya Agricultural and Livestock Research Organization).
4. Formation of poultry producer groups based on cohesion, self-interest, and commercial vision, as well as developing capability for effective operation.
5. Improvement of phyto-sanitary conditions and reducing disease outbreaks through para-vet and para-professional training and induction of local brokers. This necessitates the identification of interested brokers as well as their training in standards and illness indicators.
6. Development of networks for sector linkages for credit provision and support.

4.7 Mango value chain

In Kenya, mangoes may be grown in a wide range of agroecological zones, from sub-humid to semi-arid, and they can flourish in places that are frequently unsuitable for other income crops (Kehlenbeck et al., 2011). According to the mango growers of Elgeyo Marakwet, mangoes are produced for income production and poverty reduction, as well as their twin functions of providing household nutrition and economic development prospects.

Despite being a significant fruit crop in Elgeyo Marakwet and some areas of west Pokot County, the majority of small-scale farmers surveyed know little about new production techniques and orchard management techniques, and they rarely use the best inputs to increase fruit yield and quality. Additionally, they have poor harvesting and postharvest management abilities, which results in significant postharvest losses. Few farmers reported having awareness of the ripeness indicator that determines when to harvest, with the majority of farmers gauging mango fruit ripeness by hand feeling and looking at the size of the fruit. The county director for trade asserted that this is a critical capacity deficit that necessitates farmers receiving training in mango harvesting in order to guarantee high-quality fruit and proper harvest and postharvest processing. According to key informants interviewed, mango cultivation is severely affected by pests and diseases like the fruits fly, but little is known about how to use bio-pesticides to address these issues. Mango farmer groups interviewed also mentioned how difficult it was to find high-quality seedlings because there were not many recognized and accredited fruit tree nurseries. However, some counties such as the Elgeyo Marakwet county administration are collaborating with youth organizations and others to build accredited tree nurseries.

Given that individual farmers only grow small quantities of various types of mangoes on a small scale which makes aggregation by traders expensive, the lack of organized mango farmer organizations contributes to market inefficiencies. The majority of farmers in the focus group discussions stated that they must deal with dealers and mango brokers on an individual basis since they frequently give cheap prices, particularly during the height of production.

A lack of aggregation centres, where exporters and traders can readily gather enough mango quantities, has an impact on marketing as well. Aggregation centres can contribute to higher profits for mango farmers by increasing their market reach, reducing costs, and improving the overall competitiveness of the mango value chain. By consolidating produce from multiple farmers, aggregation centres achieve economies of scale, which can significantly reduce the per-unit cost of handling and transportation (Abraham et al. 2022). This efficiency not only lowers operational costs for farmers but also reduces post-harvest losses, ensuring that more mangoes reach the market in optimal condition. Additionally, aggregation centres provide a platform for collective bargaining and negotiation, enabling farmers to secure better prices when selling their mangoes in bulk. They also enhance market access by connecting farmers to larger buyers, exporters, or processors who require larger quantities.

Inefficiencies in the current supply chain are due to a variety of causes, such as a lack of suitable storage facilities. Marketing is also costly and ineffective in the studied counties due to poor rural infrastructure, improper packaging, and inadequate transportation technology in addition to ineffective value chain development. Thus, creating and strengthening mango farming and marketing groups and opening mango collection aggregation centres in counties are essential to efficiently collect, sort, package, and process mangoes from smallholder farmers, thereby improving marketing effectiveness.

In Elgeyo Marakwet, growers, brokers, village assemblers, wholesalers, and retailers are among the actors in the mango value chain. The primary connection between farmers and the remainder of the value chain is made by village assemblers and brokers. They buy and sell directly to processors, wholesalers, retailers or hired agents. Wholesalers supply urban markets, where they sell to retailers or agents working for supermarkets, by buying directly from farmers or through brokers. Retailers are the last link, bringing mangos consumers directly. Given their capacity to access remote places in search of mangoes, rural mango assemblers and brokers are a crucial link to markets. They purchase direct from farmers and transport to urban centres, where they sell to retailers in wholesale markets or agents that supply supermarket chains. Mango marketing tends to be very inefficient.

Table 12: Observed climate change impacts on the mango value chain

Value chain stage	Challenge	Proportion of respondents (%)
Production	Changing mango yields per plant	20.5
	Increased mortality of mango trees	23.2
	Increased cost of production (Need for grafting)	55.5
	Increased Pest and diseases	20.7
Processing and storage	Increased losses when processing	53.5
	Damage to infrastructure (roads/stores)	80.5
Marketing	Changes in mango supply	83.2
	Changes in the quality of fruits for marketing	20.5
	Financial losses by traders and retailers	73.2
	Reduced shelf life	20.5
	Increased transaction costs resulting from hazards	80.5
	Increased post-harvest losses	80.5
Consumption	Increase in prices	58.3
	Reduced quality of mangoes	80.5

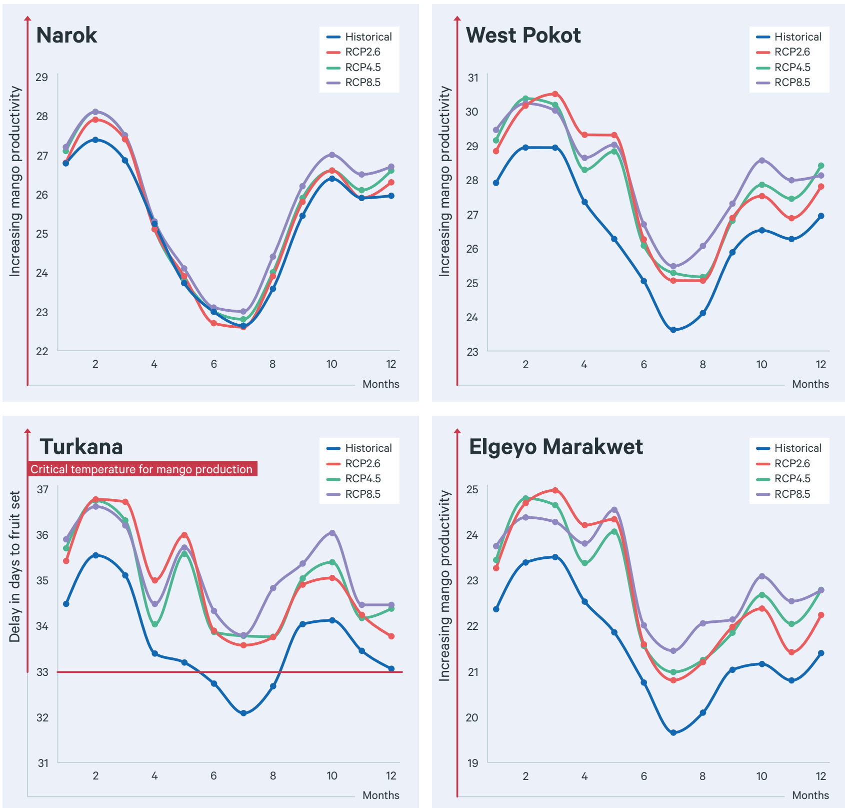
The most notable challenges induced by climate change on mango production, processing, marketing and consumption include increased costs of production (55.5%), changing mango yields per plant (20.5%), mortality of mango trees (23.2%), pests/diseases (20.7%), losses when processing (53.5%), changes in mango supply (83.2%), quality of mango fruits in the market (20.5%), reduced mango shelf life (20.5%), post-harvest losses (80.5%), increased transaction costs (80.5%), financial losses (73.2%) and increase in mango prices (58.3%) (see Table 11).

The small-scale nature of production with numerous varieties within each farm, a lack of a well-organized collection or aggregation system, bad rural access roads, improper packaging and transportation, and a general lack of quality and measurement standards all contribute to inefficiencies. The discussions with county authorities also made it evident that the industry's significant producer-to-consumer pricing differential is mostly caused by inadequate information flow and the influence of brokers and marketing agents. Since small-scale farmers are not organized into marketing groups and usually lack information on prevailing market conditions, farmer-village assembler relationships tend to favour the village assembler in terms of price and purchasing conditions. Therefore, measures to encourage weight and standards will aid in ensuring farmers receive fair pricing. It is crucial to increase farmer and marketing associations' capacities in order to attain high net investment indices and spur industry growth. Smallholder mango producers will have more negotiating leverage with traders and possibilities to forge long-term relationships with customers as their group cohesion grows. The county government should work with other governmental agencies and partners in the business sector to attain high standards that will allow access to the highly competitive local and international markets given that quality concerns are a developing limitation in the value chain while at the same time promoting good mango production practices.

Climate risks in the mango value chain

According to Makhmale et al. (2016), mango is a perennial crop that is well adapted to hot and semi-arid climates. It can thrive and survive temperatures between 0°C and 48°C. In contrast to higher temperatures, colder temperatures have a greater impact on mango productivity. Temperatures above 15°C result in the best possible germination, vegetative development, and pollen viability, with greatest number of leaves per growth flush and overall increase in mango yield. Germination and pollen tube growth are inhibited at temperatures below 15°C. Mango can withstand brief bouts of heat stress each day (temperatures above 48°C). Mango growers in Elgeyo Marakwet reported that rainfall patterns have an impact on the development of the flowers and fruits as well as the growth of mango plants. According to research, mango plants can tolerate between 1000 and 2500 mm of rainfall annually, with a dry season lasting between 4 and 6 months (*Litz, 2009*). However, the mango plant does not require a lot of moisture to flower because heavy rains might stunt fruit development and spread infections. Mangoes do best in regions that are warm to hot during fruiting and that have low to moderate rainfall and low relative humidity during flowering, fruit setting, and harvest (Ploetz et al., 2003).

Figure 23: Impact of projected warming on mango production



Source: Authors' own

The projected fluctuations in mean monthly rainfall (Figure 10) and associated drought conditions under the RCPs will likely affect the flowering and the important phenological phases in mango production. As mangoes require low rains during fruit formation, a decrease in mean monthly rainfall coinciding with the fruit formation phase will have a positive effect. As shown in Figure 23, the projected increase in temperatures under the three RCPs coupled with the projected decrease in rainfall will likely affect the germination of mango seedlings, number of days to flower initiation and fruit set, quality and quantity of mango fruits, mortality of mango seedlings/trees, and overall mango productivity.

Despite the negative climate impacts, mango is highly adaptable to drought and high temperatures, and is thus a suitable adaptation crop under future climate that should be encouraged among the communities in the study counties. At the same time, the projected temperatures for Turkana under the three RCPs are above the optimum mango productivity temperature thresholds; mango productivity there will likely be affected through increase in days to flower initiation, delay in days to fruit set, proliferation of pests, diseases and pathogens resulting in poor quality mangoes, lower mango yields per plant, mortality of mango seedlings, and increased costs of production.

Additionally, the projected decrease in mean monthly and annual rainfall will exacerbate drought conditions, increase water stress and evapotranspiration rates, and provide suitable breeding ground for pests and diseases. This will affect the quality, quantity, appearance and nutritional value of mangoes produced. Interaction between increase in temperature, decrease in rainfall and exacerbated drought conditions expected under the climate change scenarios will render some areas unsuitable for mango production. An increase in temperature of 0.7–1C will likely shift the areas suitable for quality mango production (Hoakip et al., 2020), and the projected increase in temperature of between 0.4°C and 1.5°C under the RCPs means some areas have already exceeded these thresholds, thus shifting their suitability for quality mango productivity.

Enhancing resilience and competitiveness for the mango value chain

To lessen the impact of climate change on seedlings and plant output, adaptation measures have been put in place at the farm and nursery level. While some of the current interventions concentrate on seeds and seedlings, others work to improve micro- and macroclimate factors that either directly or indirectly affect seedling survival. Micro/macroclimate technologies support busting, flowering and plant growth by, for example, boosting soil nutrient and water consumption, whereas seeds- and seedling-targeted adaption technologies concentrate on strengthening resilience through aspects such as soil moisture. Malik et al. (2021) found that controlling soil moisture considerably mitigated the effects of droughts and temperature increases on seedlings. According to the mango growers surveyed, farmers in the county frequently use grafting, agroforestry and excellent agricultural techniques like intercropping, mulching and irrigation to lessen the impact of climate change on mango production.

Figure 24: Mango plantation in a pastureland in Elgeyo Marakwet

Source: Alphayo Lutta

Agroforestry significantly reduces soil erosion and improves soil nutrient and water retention, which fundamentally enhances the growth of seedlings and crops. Additionally, as adaption methods, shading, fencing, and watering have a substantial impact on the survival rate of seedlings during prolonged dry spells (Apuri et al., 2018). To reduce the overall effects of climate extremes on seedling output, farmers in the county have increased the density of seedlings per unit area in nurseries and farms in addition to providing shade. As stated by the FGD participants, temperature has a significant impact on the growth of seedlings. Some of the participants have planted trees around their nurseries to act as shades and lessen the exposure of the seedlings to harsh sunlight in an effort to lessen its impacts.

4.8 Beadwork and craft value chain

Women's groups are particularly active in the craft and beadwork industries, supporting local economies in Narok County and areas of Turkana and serving as an alternative livelihood that diversifies their income. Both the local market and the tourism business are targeted by the crafts and beadwork industry. For the production of high-quality goods, bones, horns, and locally produced leather are now crucial raw materials. Ewaso Ngiro Tannery and Leather Processing Plant provides the training necessary to create such high-quality crafts. The Maa Trust assists several women's groups in beadwork training and marketing. The tools required for beading are inexpensive, as only a basic working shed is required, and women and young people acquire the necessary skills rather quickly.

The beads themselves are created from both natural and artificial materials. There are both organic and inorganic varieties of natural beads. Women in Narok County create organic beads using materials that come from animals, including as bones, wood, animal shells, and skins. While synthetic beads are made of ceramic and brass, inorganic beads are composed of minerals, metals and gemstones. The aesthetics and artistic nature of beadwork can make it a particularly appealing form of work in comparison to other forms of labor, and the market for beads has expanded significantly in Narok County. Women's groups reported that beads are used to adorn household items including bowls and baskets, coffee cups, boxes, cutlery and other tableware. Beads are often used to decorate earrings, bangles and necklace brushes, with the variety of bead shapes, sizes, and colors enabling designers to create a plethora of patterns on jewelry products.

According to Narok County government informants, this much-needed alternative income stream from beadwork helps women to make ends meet and improve the lives of their family without turning to environmentally harmful practices like charcoal manufacture. Women who reside in community conservancies in Narok County create distinctive, beautifully beaded jewelry, pendants, and key rings that are sold locally and as far away as Australia and the United States through agents that work with the crafters. According to the beading group that was interviewed, this additional income from alternative value chains helps reduce pressure on other natural resources, including wildlife.

According to the women's group in Talek, Narok County, each woman earns on average KES 4000, or USD 33, per month from the sale of beads. In addition to having a steady and regular source of income, the women also have access to credit through savings and loans groups they have established, some of which are affiliated with the Maa trust. Through these associations, the women are able to save their earnings and borrow money to fund additional entrepreneurial endeavors.

The county government office of trade in Narok County anticipates that the market for beaded jewelry will be driven by increased urbanization, shifting consumer buying patterns and growing digital innovation. As a result of the increased demand for inexpensive jewelry items globally, particularly in countries that are popular tourist destinations, the market for

Figure 25: Women display their crafted jewellery and beadwork in Narok County.

Source: Alphayo Lutta

fashion jewelry has grown. In addition, an expanding middle-class population with disposable income has been traveling to the Mara ecosystem in Narok County for tourism and driving the market for beaded jewelry.

The demand for the fashion business in recent years has reportedly been impacted by the growing e-commerce sector and internet penetration in urban and rural areas. The market is expanding due to the rising demand from women for fashion jewelry for a variety of occasions. Additionally, the growing popularity of beaded jewelry among working women for their everyday looks is likely to hasten category expansion. According to women groups involved in the beadwork value chain, beaded necklaces are becoming more and more popular among young people, especially working women, and because of this the market for necklaces has dominated and accounted for the greatest revenue share.

However, this increase in sales can be hampered by market fluctuations in raw material prices. According to county informants from the ministry of trade, the price of beaded product has suddenly increased as a result of an uncontrolled supply chain in the global market for beaded jewelry. To address this, women's organizations should be encouraged to invest in the introduction of new products and a wide range of styles in order to withstand the escalating trend of changing jewelry. Climate change will likely have an effect on tourism's viability by decreasing the advantages that Maasai communities receive from it (Laban, 2022). Due to reduced wildlife population because of climatic changes and other factors, visitor numbers in the reserve could decline, thus cutting down the number of consumers of the beadwork products in the tourism facilities within the game reserve.

5. Private sector involvement in climate-resilient value chain development

Rising quality and safety standards in high-value markets have prompted the establishment of increasingly complicated supply chains to control the flow of goods and information across channel participants. The private sector can play a critical role in enhancing supply chain links, particularly where market inefficiencies limit access by the poor. Through responsible business practices, corporate social responsibility, and inclusive business models, the private sector has the potential to address market failures, reduce inequality and improve the overall well-being of impoverished communities, ultimately contributing to a more equitable and prosperous community. By providing access to microfinance, small and medium-sized enterprises (SMEs) can stimulate job creation and income generation as well as enhance the affordability and accessibility of essential goods and services for low-income populations.

Historically, the private sector has been intimately involved in the production, marketing, and distribution of both livestock and crop products, with the rise in items of high value giving private actors an ever larger and more particular role. At the same time, the characteristics of high-value products, such as specialized production, knowledge, and capacity, drive private-sector actors away from smallholders and toward larger farms who can more readily meet foreign purchasers' stringent standards and food safety criteria.

This is strengthened by the need to create organizational connections, such as contracts, with supply chain actors. While private sector actors may wish to diversify their sourcing activities and procure from a mix of farmers, including smallholders, the income, credit and resource constraints of smallholders present a challenge. The formation of horizontal links to scale up producers through producer groups, in particular, presents challenges to both the public and commercial sectors. The challenges and barriers encountered in developing new high-value supply chains imply that there may be potential synergies in collaborating with the responsibilities of both the public and private sectors to develop creative solutions for smallholder involvement. The expansion of supply networks and successful supply chain management in high value pastoral products demands a slew of coordinating and integrating mechanisms that neither private nor public institutions are likely to be able to provide on their own.

The private sector will therefore be needed for:

- Offering agribusiness expertise to improve the productivity and financial success of diverse value chains and associated businesses.
- Giving managerial capacity and transferring technical and managerial abilities.
- Promoting product processing and value addition.
- Assisting producers in these counties with finding markets for their goods by facilitating market access.
- Encouraging investment in small businesses with a rural focus and generating employment for rural areas.

This can be done through partnerships with development partners and governments that offer opportunities for the transfer of economic power to small-scale producers through greater participation in and ownership of businesses. Therefore, the partnership model should consistently engage pastoralists in various enterprises as strategic partners in all decisions involving support towards their own development.

6. Gender inclusion in value chains

To respond to environmental, political, legal, cultural, and climatic challenges, it is crucial to comprehend the growing complexity of gender roles in dynamic pastoral and semi-pastoral communities. It takes more than analysis to achieve gender equality; it also calls for a conscious effort to level the playing field (Farnworth et al., 2016). It was evident in our research that men and women exert diverse rights and duties over various value chains in every county. The ability to source productive assets, including access to communal resources where appropriate and the ability to engage in horizontal (e.g. producer groups) and vertical (e.g. input suppliers and buyers) relationships along value chains, are all influenced by gender, and understanding these differences is essential to creating effective value chains.

The focus group discussions demonstrated that men own and control most productive assets like livestock, with women having little influence on decision-making. Women perform duties like constructing semi-permanent houses, milking, caring for animals like sheep, goats, and chickens, engaging in small-scale trade, cultivating crops, creating handicrafts, and gathering resources like water, firewood, fodder, wild food and non-timber forest products (NTFP). Men's duties in livestock production are still mostly limited to caring for and moving herds, managing grazing and water resources, gathering water, trading animals, maintaining security, hunting, fishing, ploughing, collecting specific NTFPs and creating charcoal.

Women's focus group discussions revealed that men are frequently regarded as the community's official decision-makers and exert authority and control over how natural resources are managed. Often, women are largely absent from decision-making on resource management issues despite being critical actors in natural resource management. Some women averred that their existing responsibilities don't allow them time to engage in such roles, and the roles they do take are often less visible than men's and are not formally recognized. Thus, overcoming power inequalities in value chains requires addressing gender inequalities.

7. Conclusion and recommendations

Climate change scenario forecasts show that climate-related hazards will worsen in the future, with severe and devastating consequences for the numerous nature-based value chains identified in the study counties. As a result, in order to fully realize the potential of rangeland value chain development for poverty reduction and food security, climate resilience must be actively included into value chain interventions. The study's findings identified some barriers, such as a lack of information on current and future climate-related risks, uncertainty associated with climate change projections, a lack of financial resources to invest in resilient value chains, and insufficient policy direction to provide incentives for value chain development. To overcome these barriers, a few key areas of action are needed.

- Increasing the capacity of value chain actors to manage climate risks by increasing climate change awareness and providing technical help for risk analysis by incorporating climate change problems into existing training and business development programs aimed at value chain actors.

- Partnering with private-sector organizations to improve access to and management of crucial resources for value chain activities, such as water and climate-resilient inputs like drought-tolerant seedlings.

The results also demonstrate the importance of service providers for the growth of value chains and the importance of their contribution to the establishment of value chains that are climate resilient. In order to generate, adapt and disseminate seasonal and weather forecasts and early warnings in a timely and accessible manner for various value chain actors, climate information service providers need to build their capacity. Partnerships with research institutions and agricultural extension services can also help to build knowledge about climate-resilient agricultural practices and technologies.

These means there is need to strengthen the technical and adaptive capacity of formal and informal governance structures in climate change adaptation through improved coordination between county and national governments and through capacity building, awareness raising and education and consensus building. Establishment of community-level resilience adaptation committees will enhance the capacity for community-managed disaster risk reduction in climate change. This shifts the community focus from reactive to anticipatory disaster risk reduction and climate action that can take advantage of the opportunities presented therein for localized transformational adaptation and resilience building.

Increased economic opportunities will also be realized with the development of a climate smart economy through market linkages, investment, and new business sector development. Development of market systems can be done by strengthening market linkages and opening new business and economic opportunities for men, women and young people. This can be achieved through market facilitation and financial inclusion strategies created through women and youth engagement with climate smart businesses, as well as in markets and livestock productivity. These linkages will enable income diversification, thus improving overall food security and nutrition. Financial inclusion can also be done by building the capacity of existing and potential savings for transformation groups and linking them to formal financial institutions.

Recognizing the importance of gender in the management of natural resources in rangelands, it is also important to reduce inequality and empower populations through strategies such as developing gender-inclusive policy, building social capital, reducing harmful cultural practices and creating alternative livelihoods for pastoralist. This can be achieved through increased investments in sustainable climate resilient value chain infrastructure and fostering their integration into markets and the wider economy. At the same time, developing product market chains and food systems with appropriate support systems to enhance productivity is critical.

References

Adhikari, U., Nejadhashemi, A. P., & Woznicki, S. A. (2015). Climate change and eastern Africa: A review of impact on major crops. *Food and Energy Security*, *4*(2), 110–132. https://doi.org/10.1002/fes3.61

Allen, S. L., Morales, M., & Gelli, A. (2019). *Food Value Chains for Nutrition, in Agriculture for Improved Nutrition: Seizing the Momentum*. International Food Policy Research Institute (IFPRI) and CABI. https://doi.org/10.1079/9781786399311.0027

Amwata, D. A., & Nyariki, D. M. (2021). Climate Variability, Land-Use, Pastoral and Agropastoral Livelihoods in Arid and Semi-Arid Areas of Kenya. World Journal of Innovative Research, 10(5). https://doi.org/10.31871/WJIR.10.5.38

Apgar, M., Kniveton, D., Naess, L. O., Orindi, V., Abuya, N., & Bonaya, M. (2017). *Improving the Impact of Climate Information Services in Kenya's Arid and Semi-Arid Lands*. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/13286

Apraku, A., Morton, J. F., & Apraku Gyampoh, B. (2021). Climate change and small-scale agriculture in Africa: Does indigenous knowledge matter? Insights from Kenya and South Africa. *Scientific African*, *12*, e00821. https://doi.org/10.1016/j.sciaf.2021.e00821

Ballal, M., Siddig, E. A., Elfadl, M., & Luukkanen, O. (2005). Relationship between environmental factors, tapping dates, tapping intensity and gum arabic yield of an Acacia senegal plantation in western Sudan. *Journal of Arid Environments*, *63*, 379–389. https://doi.org/10.1016/j.jaridenv.2005.01.024

Barnabás, B., Jäger, K., & Fehér, A. (2008). The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell & Environment*, *31*(1), 11–38. https://doi.org/10.1111/j.1365-3040.2007.01727.x

Carabine, E., & Simonet, C. (2017). *Value chain analysis for resilience in drylands (VC-ARID): Identification of adaptation options in key sectors*. https://idl-bnc-idrc.dspacedirect.org/handle/10625/57652

Conway, G. (2009). *The science of climate change in Africa: Impacts and adaptation*.

Delatorre-Herrera, J., Delfino, I., Salinas, C., Silva, H., & Cardemil, L. (2010). Irrigation restriction effects on water use efficiency and osmotic adjustment in Aloe Vera plants (Aloe barbadensis Miller). *Agricultural Water Management*, *97*(10), 1564–1570. https://doi.org/10.1016/j.agwat.2010.05.008

Emali E. (2023). Milk value chains maps identifying challenges and vulnerabilities in the pastoral and agro-pastoral areas of Narok, Kenya. *East African Journal of Science, Technology and Innovation*, 4. https://doi.org/10.37425/eajsti.v4i2.610

Erick, O., Jawuoro, S., Wasonga, O., & Simatele, M. (2019). Mapping and characterization of stakeholders in the fodder value chain in Southern Rangelands of Kenya: Understanding their roles, interactions and influences. *Journal of Agricultural Science and Practice*, *4*, 38–43. https://doi.org/10.31248/JASP2019.162

Fanzo, J., Downs, S., Marshall, Q., Pee, S., & Bloem, M. (2017). *Value Chain Focus on Food and Nutrition Security* (pp. 753–770). https://doi.org/10.1007/978-3-319-43739-2_34

Farmery, A. K., Brewer, T. D., Farrell, P., Kottage, H., Reeve, E., Thow, A. M., & Andrew, N. L. (2021). Conceptualising value chain research to integrate multiple food system elements. *Global Food Security*, *28*, 100500. https://doi.org/10.1016/j.gfs.2021.100500

Foden, W., Midgley, G. F., Hughes, G., Bond, W. J., Thuiller, W., Hoffman, M. T., Kaleme, P., Underhill, L. G., Rebelo, A., & Hannah, L. (2007). A changing climate is eroding the geographical range of the Namib Desert tree Aloe through population declines and dispersal lags. *Diversity and Distributions*, *13*(5), 645–653. https://doi.org/10.1111/j.1472-4642.2007.00391.x

Gajardo-Rojas, M., Muñoz, A. A., Barichivich, J., Klock-Barría, K., Gayo, E. M., Fontúrbel, F. E., Olea, M., Lucas, C. M., & Veas, C. (2022). Declining honey production and beekeeper adaptation to climate change in Chile. *Progress in Physical Geography*. https://doi.org/10.1177/03091333221093757

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

Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Mitigation of Climate Change: Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (1st ed.). Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

Intergovernmental Panel on Climate Change (IPCC). (2023). Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Kalele, D. N., Ogara, W. O., Oludhe, C., & Onono, J. O. (2021). Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Scientific African*, *12*, e00814. https://doi.org/10.1016/j.sciaf.2021.e00814

Kariuki, R., Willcock, S., & Marchant, R. (2018). Rangeland Livelihood Strategies under Varying Climate Regimes: Model Insights from Southern Kenya. *Land*, *7*(2), Article 2. https://doi.org/10.3390/land7020047

Kehlenbeck, K., Kindt, R., Sinclair, F., Simons, A., & Jamnadass, R. (2011). Exotic tree species displace indigenous ones on farms at intermediate altitudes around Mount Kenya. *Agroforestry Systems*, *83*, 133–147. https://doi.org/10.1007/s10457-011-9413-4

Khajeeyan, R., Salehi, A., Dehnavi, M. M., Farajee, H., & Kohanmoo, M. A. (2019). Physiological and yield responses of Aloe vera plant to biofertilizers under different irrigation regimes. *Agricultural Water Management*, *225*, 105768. https://doi.org/10.1016/j.agwat.2019.105768

Kidali, J., Omondi, S., Ogali, I., Rutto, J., & Orwa, M. (2023). Establishment of Multi-Institutional Model for the Delivery of Livestock Technology Needs in Arid and Semi-Arid Areas of Kenya. *Asian Journal of Agricultural Extension, Economics & Sociology*, *41*(6), 139–146. https://doi.org/10.9734/ajaees/2023/v41i61931

Kim, D.-H., Lee, Y.-K., Lee, S.-D., Kim, S.-H., & Lee, K.-W. (2021). Physiological and behavioral responses of laying hens exposed to long-term high temperature. *Journal of Thermal Biology*, *99*, 103017. https://doi.org/10.1016/j.jtherbio.2021.103017

Kinati, W., & Mulema, A. A. (2019). Gender issues in livestock production systems in Ethiopia: A literature review. *Journal of Livestock Science*, *10*(2). https://doi.org/10.33259/JLivestSci.2019.66-80

Kirui, L., Jensen, N., Obare, G., Kariuki, I., Chelanga, P., & Ikegami, M. (2022). Pastoral livelihood pathways transitions in northern Kenya: The process and impact of drought. *Pastoralism*, *12*, 23. https://doi.org/10.1186/s13570-022-00240-w

Koech, S., Mbevi, B., & Otipa, M. J. (2016). Mealybugs on mangoes-Kenya. *PlantwisePlus Knowledge Bank*, *Pest Management Decision Guides*, 20167800882. https://doi.org/10.1079/pwkb.20167800882

Kumar, S., Yadav, M., Yadav, A., & Yadav, J. P. (2017). Impact of spatial and climatic conditions on phytochemical diversity and in vitro antioxidant activity of Indian Aloe vera (L.) Burm.f. *South African Journal of Botany*, *111*, 50–59. https://doi.org/10.1016/j.sajb.2017.03.012

Lind, J., Sabates-Wheeler, R., Caravani, M., Kuol, L. B. D., & Nightingale, D. M. (2020). Newly evolving pastoral and post-pastoral rangelands of Eastern Africa. *Pastoralism*, *10*(1), 24. https://doi.org/10.1186/s13570-020-00179-w

Litz, 2009. Second Edition, Cabi Series, CABI, Wallingford, UK | Feedipedia. (n.d.). Retrieved June 12, 2023, from https://www.feedipedia.org/node/5336

Lugusa, K. (2020). *Institutions in public-private partnerships for natural resources conservation, management and use: A case study of the northern rangelands of Kenya*.

Lutta, A., Wasonga, O., Robinson, L., Nyangito, M., & Sircely, J. (2021). Determinants of livestock market participation among pastoral communities of Tana River County, Kenya. *Environment, Development and Sustainability*, *23*. https://doi.org/10.1007/s10668-020-00922-8

Machan, S. N., Agwata, J. F., & Oguge, N. O. (2022). Environmental Factors Influencing the Sustenance of the Camel Milk Value Chain in Isiolo County, Northern Kenya. *Resources*, *11*(3), Article 3. https://doi.org/10.3390/resources11030027

Makhmale, S., Bhutada, P., Yadav, L., & Yadav, B. (2016). *Article-21 Impact of climate change on phenology of Mango– The case study. 22*.

Mganga, K., Musimba, N., Nyariki, D., Nyangito, M., & Mwang'ombe, A. (2013). The choice of grass species to combat desertification in semi-arid Kenyan rangelands is greatly influenced by their forage value for livestock. *Grass and Forage Science*, *70*. https://doi.org/10.1111/gfs.12089

Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., van Vuuren, D. P., Carter, T. R., Emori, S., Kainuma, M., Kram, T., Meehl, G. A., Mitchell, J. F. B., Nakicenovic, N., Riahi, K., Smith, S. J., Stouffer, R. J., Thomson, A. M., Weyant, J. P., & Wilbanks, T. J. (2010). The next generation of scenarios for climate change research and assessment. *Nature*, *463*(7282), Article 7282. https://doi.org/10.1038/nature08823

Mudzengi, C., Kapembeza, C., Dahwa, E., Taderera, L., Moyana, s, & Zimondi, M. (2019). Ecological Benefits of Apiculture on Savanna Rangelands. *Bee World*, *97*, 1–10. https://doi.org/10.1080/0005772X.2019.1701797

Muema, E., Mburu, J., Coulibaly, J., & Mutune, J. (2018). Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya. *Heliyon*, *4*(11), e00889. https://doi.org/10.1016/j.heliyon.2018.e00889

Mugo, J. N., Karanja, N. N., Gachene, C. K., Dittert, K., Nyawade, S. O., & Schulte-Geldermann, E. (2020). Assessment of soil fertility and potato crop nutrient status in central and eastern highlands of Kenya. *Scientific Reports*, *10*(1), Article 1. https://doi.org/10.1038/s41598-020-64036-x

Mukonyi, K. (2020). Grow aloe for wealth, health and land rehabilitation. Kenya Agricultural Research Institute. https://www.kalro.org/fileadmin/publications/brochuresII/Grow_aloe_for_wealth.pdf

Mumo, L., Yu, J., & Fang, K. (2018). Assessing Impacts of Seasonal Climate Variability on Maize Yield in Kenya. *International Journal of Plant Production*, *12*. https://doi.org/10.1007/s42106-018-0027-x

Munkhtsetseg, E., Kimura, R., Wang, J., & Shinoda, M. (2007). Pasture yield response to precipitation and high temperature in Mongolia. *Journal of Arid Environments*, *70*, 94–110. https://doi.org/10.1016/j.jaridenv.2006.11.013

Ndiritu, S. W. (2021). Drought responses and adaptation strategies to climate change by pastoralists in the semi-arid area, Laikipia County, Kenya. *Mitigation and Adaptation Strategies for Global Change*, *26*. https://doi.org/10.1007/s11027-021-09949-2

Ngigi, M. W., & Muange, E. N. (2022). Access to climate information services and climate-smart agriculture in Kenya: A gender-based analysis. *Climatic Change*, *174*(3), 21. https://doi.org/10.1007/s10584-022-03445-5

Njiru, N., Wanyoike, F., & Baltenweck, I. (2021). *Enhancing market access through business-to-business platforms: Key lessons and insights from northern Kenya*.

Nyika, J. (2022). *Climate Change Situation in Kenya and Measures Towards Adaptive Management in the Water Sector* (pp. 1857–1872). https://doi.org/10.4018/978-1-6684-3686-8.ch092

Omolo, N., & Mafongoya, P. L. (2019). Gender, social capital and adaptive capacity to climate variability: A case of pastoralists in arid and semi-arid regions in Kenya. *International Journal of Climate Change Strategies and Management*, *11*(5), 744–758. https://doi.org/10.1108/IJCCSM-01-2018-0009

Pachauri, R. K., Mayer, L., & Intergovernmental Panel on Climate Change (Eds.). (2015). *Climate change 2014: Synthesis report*. Intergovernmental Panel on Climate Change.

Picknoll, J. L., Poot, P., & Renton, M. (2021). A New Approach to Inform Restoration and Management Decisions for Sustainable Apiculture. *Sustainability*, *13*(11), Article 11. https://doi.org/10.3390/su13116109

Ploetz, R. C., Thomas, J. E., & Slabaugh, W. R. (2003). Diseases of banana and plantain. In R. C. Ploetz (Ed.), *Diseases of tropical fruit crops* (1st ed., pp. 73–134). CABI Publishing. https://doi.org/10.1079/9780851993904.0073

Roba, G., Lelea, M., Hensel, O., & Kaufmann, B. (2019). Elusive profits: Understanding economic performance of local traders in the pastoral small ruminant value chain in Northern Kenya. *Nomadic Peoples*, *23*, 78–105. https://doi.org/10.3197/np.2019.230105

Said, M., Bedelian, C., Moiko, S., Muhwanga, J., Atela, J., & Abuya, R. (2019). *Projected climate change and its potential impact on cattle in Kajiado County*.

Sala, S. M. (2019). *An Analysis Of The Factors Influencing Participation Of Pastoralists In Commercial Fodder Value Chain For Livelihood Resilience In Isiolo County, Kenya* [Thesis, UoN]. http://erepository.uonbi.ac.ke/handle/11295/107167

Schriek, T. van der, Kitsara, G., Varotsos, K. V., & Giannakopoulos, C. (2021). *The impact of temperature and precipitation changes on honey bees (Apis mellifera) in the Aegean region under future climate scenarios* (EGU21-5579). EGU21. Copernicus Meetings. https://doi.org/10.5194/egusphere-egu21-5579

Thongoh, M. W., Mutembei, H. M., Mburu, J., & Kathambi, B. E. (2021). An Assessment of Barriers to MSMEs' Adoption of CSA in Livestock Red Meat Value Chain, Kajiado County, Kenya. *American Journal of Climate Change*, *10*(03), 237–262. https://doi.org/10.4236/ajcc.2021.103011

Thongoh-muia, W. M. (2022). *Analysis of Integration of Climate Smart Initiatives by Micro, Small and Medium Enterprises in Beef Value Chain in Kajiado County* [Thesis, University of Nairobi]. http://erepository.uonbi.ac.ke/handle/11295/161589

Thornton, P., Jones, P., Alagarswamy, G., & Andresen, J. (2009). Spatial variation of crop yield response to climate change in East Africa. *Global Environmental Change*, *19*, 54–65. https://doi.org/10.1016/j.gloenvcha.2008.08.005

Thornton, P. K., & Gerber, P. J. (2010). Climate change and the growth of the livestock sector in developing countries. *Mitigation and Adaptation Strategies for Global Change*, *15*(2), 169–184. https://doi.org/10.1007/s11027-009-9210-9

Thornton, P. K., Boone, R. B., & Ramirez-Villegas, J. (2015). Climate change impacts on livestock. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://cgspace.cgiar.org/bitstream/handle/10568/66474/CCAFSWP120.pdf

Thornton, P., Nelson, G., Mayberry, D., & Herrero, M. (2022). Impacts of heat stress on global cattle production during the 21st century: A modelling study. *The Lancet Planetary Health*, *6*(3), e192–e201. https://doi.org/10.1016/S2542-5196(22)00002-X

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