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VIABILITY OF HAY PRODUCTION AS A DROUGHT RESILIENT CLIMATE-SMART STRATEGY FOR THE PASTORALIST SYSTEMS OF KAJIADO

A THESIS SUBMITTED TO THE UNIVERSITY OF NAIROBI IN PARTIAL FULFILLMENT OF THE DOCTOR OF PHILOSOPHY DEGREE IN ENVIRONMENTAL GOVERNANCE AND MANAGEMENT

JUDY KIMARU (BVM, MSC)

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Candidate Declaration

Dr Judy Kimaru

Signature: ………………………………… Date: 5th May 2023

This thesis is my original work and has not been presented for a degree at any other university.

Supervisors Declaration

Prof. Henry Mutembei

Signature .... Date: 5th May 2023

Dr. John Kaunga Muthee

Signature.. Date: 5th May 2023

This thesis has been submitted for examination with our approval as university supervisors.

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Registration Number:	A82/54341/2019
College	Wangari Maathai Institute for Peace and Environmental Studies
Faculty:	Science and Technology
Department:	Earth and Climate Sciences
Course Name:	Doctor of Philosophy in Environmental Governance and Management
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DEDICATION

I want to dedicate this thesis first to God, without whom I would not have had the health and the incredible support team around me to complete the work. I would also like to thank my parent, Mr Peter Kimaru and Mrs Mary Kimaru and my children Ouko Kimaru Koga and Awuor Wanjiru Koga for their patience and unwavering support. I am indebted to my sister Doris Wairimu Kimaru who is an avid hay farmer and the inspiration for this study.

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LIST OF ACRONYMS

AU-IBAR	African Union Intergovernmental Bureau for Animal Resources
AHSA	Animal Health Strategy for Africa
ASAL	Arid and Semi-Arid Land
ASDS	Agricultural Sector Development Strategy
ASTGS	Agricultural Sector Transformation and Growth Strategy
AWSA	Animal Welfare Strategy for Africa
CBO	Community Based Organisations
CIDP	County Integrated Development Plans
CSA	Climate Smart Agriculture
CO2	Carbon Dioxide
CO2e	carbon dioxide equivalent
DRM	Disaster Risk Management
DRR	Cisaster risk reduction
EAC	East Africa Community
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	greenhouse gas
GOK	Government of Kenya
ICPAC	IGAD Climate Prediction and Applications Centre
ICPALD	Centre for Pastoral Areas and Livestock Development
IDDRSI	IGAD Drought Disaster Resilience and Sustainability Initiative
IGAD	Intergovernmental Authority on Development
IPCC	The Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
KCSAP	Kenya Climate Smart Agricultural Program
KCSAP	Kenya Climate-Smart Agriculture Strategy
KCSAS	Methane
KES	Kenyan Shillings
NGO	Non Governmental Organsiation
N2O	Nitrogen Dioxide
NEMA	National Environment Management Authority
NGOs,	Non governmental Organisation
NPV	Net Present Value
RECs	Regional Economic Communities
ROI	Return on investment

RRMSF	Regional Rangeland Management Strategic Framework
SFDRR	Sendai Framework for Disaster Risk Reduction
UNCBD	Conservation of Biological Diversity
UNCCD	United Nations Conventions on Combating Desertification
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	UN Framework Convention on Climate Change
UN-SDG	United Nations Sustainable Development Goal
USD	United States Dollar

THESIS ABSTRACT

Arid and semi-arid lands (ASAL) in Kenya account for over 83% of the country's land area, hosting over 70% of livestock and 85% of wildlife populations. Pastoralism is the primary livelihood practised in Kenya's rangelands. However, these rangelands' productivity and resilience to support pastoralism has worsened because of climate change, natural disasters, and land use changes leading to shrinking of communal grazing lands and disruption of traditional grazing migration routes. Climate vulnerability from cyclic climate variability in ASAL has led to drought and flood disasters, resulting in limited fodder, water, and tree cover for animal shelters. The Kenyan government has implemented climate-smart interventions, including hay production to mitigate climate variability. However, the financial analysis of growing hay as a private business in arid areas has not been well studied, potentially jeopardizing the success of the government's hay programs. This the study aims to examine the viability of growing hay as a sustainable drought resilience intervention in Kenya's arid and semi-arid areas, focusing on Kajiado County. The study methodology involved a desktop review of existing policies that support hay production in Kenya and Kajiado County, followed by a cost-benefit analysis of 23 hay farms spanning from 3 to 400 acres. The analysis compared two cultivation practices: (1) buying machinery, irrigating, and building permanent hay stores, and (2) hiring machinery, doing rain-fed growing, and building permanent or temporary hay stores. The study also conducted a purposeful sampling of hay farmers, hay marketers, and pastoralists and administered a survey to 354 pastoralists, including 25 key informants. The study found that the annual hay production deficit in Kajiado Central County is about 2,580,000 bales, valued at approximately KES 902 million. The survey showed that 86% of livestock keepers purchased hay only during the severest three months of drought. In contrast, farmers were growing hay annually, incurring operating costs, then storing the hay for two to three years, awaiting a drought to sell. The cost-benefit analysis indicated that farms buying machinery, irrigating, and building permanent hay stores were not profitable. In contrast, those hiring machinery, doing rain-fed growing, and building permanent or temporary hay stores were profitable, with 400-acre farms reaching a 23% return on investment (ROI) in the third year. Hay farms below 100 acres producing less than 4250 bales per year at a sale price of KES 180 per bale were unprofitable. The study provides practical recommendations that can help improve the viability of hay production as a private enterprise and encourage its adoption among pastoralists in the ASAL. These recommendations include actionable frameworks under existing policies, establishing strategic hay reserves, and promoting low-technology hay production methods. Moreover, the study recommends training commercial hay producers, encouraging feed diversification among pastoralists during droughts, and offering hay vouchers or subsidies directly to farmers. Although Kenya’s legal instruments and institutions support droughts disasters, the study found a significant disconnect between policy implementation and outcomes. Therefore, the government needs to bridge this gap to ensure that the recommended policies and strategies are effectively implemented and yield the desired results.

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background

Livestock provides many social, economic, and ecological services to rural communities, ranging from acting as a form of credit to buffering against climate emergencies and paying school fees. Sub-Saharan Africa has one person in two keeping livestock, of which one in three are considered poor livestock keepers (FAO, 2018a). Animals like small ruminants and chickens are also crucial for women's empowerment and equity. Livestock are negatively affected by climate change both directly and indirectly, with consequences such as reduced animal productivity, lower yields of forage and feed crops, harm to animal health, and loss of biodiversity. There is detailed research on the effects of climate change on animals and feed and forage readily available (FAO, 2015). Over the past three decades, animal populations in sub-Saharan Africa have declined by between 20% and 60% due to droughts (Niang, 2014). In South Africa, Niang et al. (2014) observed a 10% decline in dairy yields under different climate change scenarios. Additionally, one study found that supplying water to animals in Botswana would result in a 23% increase in costs (Niang, 2014).

Drought is the livestock sector's primary cause of economic loss, accounting for 86% of losses. Other factors contributing to losses include diseases (9%) and pests (5%). Drought leads to inadequate water supply, resulting in cows eating less feed, lowering milk production and increasing livestock deaths. Droughts significantly impact the economy, as the livestock sector provides food and livelihoods to millions worldwide (FAO, 2017). Kenya's 2008–2011 drought cost the country approximately KES 12.1 trillion, with 72% or KES 8.4 trillion being livestock losses. For every KES 100 invested in disaster risk reduction, there was a return of KES 106, highlighting the importance of investing in risk reduction measures to help protect communities and economies from the impact of disasters (GoK, 2012). The study found that between 1900 and 2017, Kenya experienced 28 droughts, with the severity and frequency of droughts increasing between 2005 and 2017, particularly in the country's northern region (Kimani et al., 2013). The future exposure to drought for livestock will increase from the current 16%-36% due to climate variability coupled with land-use changes, which will have significant consequences for the livestock industry, including reductions in livestock productivity and increases in the cost of livestock production (Roberto Rudari, 2018). In Kenya's ASALs, animal husbandry accounts for 40%-80% of pastoralist income. However, livestock keeping is vulnerable to drought, significantly reducing the amount of livestock and leading to a significant decline in revenue and overall well-being for pastoralists in these areas (King-Okumu, 2022).

Drought is a common natural hazard in Kenya, often attracting investment from the government. The leading cause of drought is a lack of precipitation, which can lead to water shortage, crop failure, and famine, negatively impacting the environment, livestock, and human health. Drought mitigation strategies include early warning systems, water conservation, and food security programmes. While significant investments in drought and climate resilience have recently been made, these actions have yet to offset the decreasing resilience of livelihoods to future droughts and climate change. The researchers noted that investments must be made more holistic, considering the diverse needs of different communities and calling for increased coordination between government ministries and agencies responsible for drought and climate resilience (Nyoka, 2016).

High-quality fodder production technologies have low adoption in Kenya's arid and semi-arid areas (ASALs) due to a lack of infrastructure, limited inputs, and poor extension services, which hinders producers' ability to adopt these technologies and reduces the overall quality of fodder production in these regions (GoK, 2021).

According to the 2021 study by Kimaru et al., hay farming is an essential source of livelihood for farmers in Kajiado, providing both income and feed for their livestock. The region's most commonly grown hay varieties are Rhodes grass and Boma Rhodes grass, with Rhodes grass being the most preferred due to its high yield and nutritional value. The study also reveals that hay farming in Kajiado faces several challenges, including the high cost of production, low prices, and limited market access. Despite these challenges, hay farming remains a critical enterprise for farmers in Kajiado. The study recommends implementing supportive policies to enable hay enterprises be profitable and sustainable (Kimaru J. et al, 2021b).

Despite heavy financial investments aimed at reducing the impact of droughts on livestock agriculture, there has been a limited preliminary cost-benefit analysis of livestock value chain investments at the farm level. Inadequate financial data can be attributed to a limited understanding of the complex interactions between different value chain components and the need for more data to make sound investment decisions. Cost-benefit analysis will inform decisions that increase efficiency along the value chains supporting livestock and enhancing the benefits of different interventions at different points in the chain. Thus, there needs to be more cost-benefit analysis regarding hay production in arid areas of Kenya to determine whether it is worth investing in this type of agriculture. Additional research in the economics of hay production would lead to improvements in the economy and livelihoods of people in these countries. On the other hand, other aspects within the livestock chain have received substantial support, such as the 2016 Kenya Agricultural Insurance and Risk Management Program, which has seen an increase in disaster resilience among smallholder farmers in the region (King-Okumu, 2022).

However, more data is needed to determine the effectiveness of climate-smart drought risk reduction activities in livestock. Early studies noted that these activities could effectively reduce drought risk to livestock producers. For example, providing farmers with early warning about drought conditions prepared them to protect their livestock while using decision support tools to help farmers manage their grazing land and increase livestock production during drought. This research addresses the indigenous knowledge of local communities, the financial performance of local and central governments, the ways various cities and countries use funds, and the processes involved in decision-making and notification, as well as the tools used for coordination and management by countries and institutions (UNDRR, 2019).

To determine whether hay production, a critical source of feed for pastoral beef cattle systems, is sustainable, we need to determine how profitable the production system is and the resilience of the hay consumers and producers within the hay value chain. Profitability is crucial in determining the long-term viability of this climate-smart strategy, messaging around awareness and knowledge of hay production and utilization, and creating public-private partnerships around hay production for drought risk reduction. Different adaptations are available for livestock production at different levels, ranging from small animals to low market integration to medium-sized livestock with high rates of market integration. Therefore, developing forage variety ideal for the climatic conditions in arid areas, especially heat-tolerant plants, is critical if countries adapt effectively to climate change. Of all available livestock breeds, these unique varieties' limited breeding and characterization have been chiefly responsible for the reduced adoption of the most adaptable to high temperatures and harsh environments (FAO, 2015).

Planners and policymakers can use cost-benefit, cost-effectiveness, and multi-criteria analysis to assess the effectiveness and sustainability of climate adaptation strategies that consider uncertainty, equity, and valuation. This analysis is vital in helping decision-makers use scarce resources when selecting the most optimal climate adaption model under which drought risk reduction strategies fall (UNFCCC, 2011).

The study focused on the hay component of the livestock value chain to determine whether it is a profitable enterprise for farmers in ASAL The study reviewed global, continental, regional, and national policies that address climate change and disasters, specifically fodder production, before narrowing it down to Kajiado County in Kenya, an arid and semi-arid county. In Kajiado, the study examined the cost-benefit analysis of growing hay across varying farm sizes. It also reviewed the cultivation practices, the challenges hay farmers faced, and how they affected the profitability of hay. The study also looked at other effects affecting profitability, such as how buyers' behaviour, specifically pastoralists, impacted the hay market and, by extension, the profits for the hay farmer. Finally, the study recommended decision-makers on the hay enterprise and how to support it better.

1.2 Problem Statement

Hay production is a crucial feed source for pastoral beef cattle systems in arid regions like Kajiado County, Kenya, particularly during frequent and prolonged droughts resulting from climate change. However, hay production's economic viability and sustainability in these areas still need to be unpacked. To bridge this knowledge gap, this study aims to evaluate the suitability of hay production as a climate-smart and drought-resilient option for pastoralist systems in Kajiado County. The study's findings can inform policy decisions and promote sustainable agricultural practices in arid regions.

1.3 Research Objectives

1.3.1 General Objective

To assess the viability of hay production as a drought-resilient climate-smart option in the pastoralist systems of Kajiado County**.**

1.3.2 Specific objectives

1. To analyse the existing hay production systems in Kajiado County
2. To conduct a cost-benefit analysis of hay production under different cultivation practices in Kajiado County
3. To evaluate existing policy and institutional frameworks that support hay production as a drought-resilient climate-smart option for pastoralist systems

1.4 Justification for the Study

The literature gap in economic studies on hay production in arid regions, such as Kajiado County, justifies the need for more knowledge on the viability of hay production in the area. This study addressed this knowledge gap by conducting a cost-benefit analysis of hay production under different cultivation practices and evaluating the existing policy and institutional frameworks that support hay production which is considered a climate-smart and drought-resilient choice for pastoralist systems. By doing so, the study aims to provide recommendations on supporting hay producers and improving the economic viability of hay production in Kajiado County. The findings of this study can inform policy decisions and promote sustainable agricultural practices in arid regions. Overall, this study is essential in providing insights into the economic viability of hay production in Kajiado County, which can inform policy decisions and promote sustainable agricultural practices in arid regions. The literature review highlights pastoralism's challenges, including marginalization and isolation, limited access to public services and infrastructure, resource conflicts, and natural disasters such as droughts and intense rainy seasons. Addressing these challenges requires a multidimensional approach considering pastoralists' unique cultural practices and ecological knowledge, incorporating sustainable land management practices, and providing adequate access to public services and infrastructure.

The challenges of fodder production in Kenya are diverse, affecting the quality and availability of rangeland forage for livestock and the growing of fodder hay. Climate change and droughts negatively impact the quality and composition of the fodder plants, reducing their nutritive value and making them less suitable for livestock feeding. The fodder value chain approach was used to assess the production, packaging, and distribution of animal feeds and to make informed decisions on improving availability and affordability. However, the challenges facing the fodder value chain in Kenya include inadequate grown fodder, low-quality feeds, inadequate processing and storage infrastructure, limited market access, and a lack of coordination among the various actors involved in the value chain, leading to inefficiencies and low productivity.

1.5 Study Hypothesis

Improved hay production practices and supportive policy and institutional frameworks can enhance the economic profitability and suitability of hay production as a climate-smart and drought-resilient option for pastoralist systems in Kajiado County, Kenya, making it a viable and sustainable option for livestock feeding and income generation.

Hypothesis testing is an essential statistical method used to verify the validity of a hypothesis or statement. In this study, the hypothesis is that adopting improved hay production practices, alongside supportive policy and institutional frameworks, can enhance the economic viability of hay production in pastoralist systems in Kajiado County. The primary objective is determining whether this enhanced economic viability is sustainable for livestock feeding and income generation, especially in climate change-induced droughts.

1.6 Scope and Limitations

The study had some limitations, as it focused only on the growing, storage, and marketing aspects of the hay value chain, without including other major stakeholders in the industry, including feed manufacturers, traders, and transporters. Additionally, the study only looked at the prices of hay grown within the area and did not consider hay imported from other counties. The scope of the research was restricted to hay growers and pastoralist consumers residing within the study area and did not include retailers and wholesalers of hay. Finally, the researcher only interviewed traders in Ibissil to gather information on the market prices of hay for different bale sizes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Pastoralism Trends in Africa

Pastoralism in Africa refers to herding livestock in arid and semi-arid regions for subsistence. Livestock is found near water sources and grazing areas, and the availability of food and water has been practised in Africa for thousands of years. It remains an important way of life for many people in the region. Pastoralism is a traditional cultural way of life that enables people to survive in areas with little rainfall and sparse vegetation. Herding animals provides people with milk, meat, hides, wool, and fertiliser. There are an estimated 268 million pastoralists in Africa, accounting for 25% of Africa's population and living in 40% of Africa's landmass (Union, 2010). Pastoralists are the indigenous custodians of critical natural resources in ASAL. In addition, pastoralism helps preserve and protect these resources (Union, 2010).

In Kenya, grassland and savannah habitats are collectively known as arid or semi-arid lands, making up 84% of the landmass. These habitats support more than 10 million people, 70% of the country's livestock, and 85% of the total wildlife population. The arid regions in Kenya include Baringo, Garissa, Isiolo, Mandera, Marsabit, Samburu, Tana River, Turkana, and Wajir, while the semi-arid regions comprise Embu, Kajiado, Kilifi, Kitui, Kwale, Laikipia, Lamu, Makueni, Meru, Narok, Nyeri, Taita Taveta, Tharaka Nithi, and West Pokot. (NDMA, 2022).

Kenya's livestock population comprises approximately 14 million cattle, 17 million sheep, 24 million meat goats, and 3 million camels, and they contribute about 30% to agricultural GDP, accounting for about 53% of the agricultural capital stock (GoK, 2009). The rangelands support various production systems, including pastoral, agro-peasant, and ranching (GOK, 2021a). The defining characteristic of Kenyan terrains is their aridity, characterized by low, erratic, and variable precipitation patterns with both low and high year-to-year variability. High temperatures are typical throughout the year, resulting in high transpiration rates. The soil is shallow, mainly composed of low fertility clay or loam, and prone to compaction, erosion, and capping. Kenya has rich grasslands that protect the soil by providing cover and economic and environmental value by providing animal fodder, firewood, and many other resources. The dominant vegetation types in the surrounding area are grassland, shrubland, and wooded terrain. This species helps in watershed activities, which attract tourists, support the development of nomadic tribes, and symbolise cultural identity (GOK, 2021a).

The policy and political context significantly influence the pastoralism landscape in Africa. Bollig et al. (2013) highlight that African pastoralist systems' colonial, pre-colonial, and post-colonial experiences shape trends and political and policy contexts. The legacy of the colonial period still influences pastoralism policy today, with significant differences visible between anglophone and francophone countries in the continent. Post-colonial laws and regulations partly emanate pastoralists' cross-border challenges that largely ignored their indigenous rights to their culture that transverses national boundaries over long distances. Global political dynamics like the cold war further influenced national policies. Market capitalism supplies pastoralists and incentivises private investment into the beef value chain. African states inherited different livestock supply chains, some developing into mass production and others leaving them underdeveloped (Catley et al., 2013).

Commercialising the beef value chain and privatising beef production have impacted livestock numbers, land use, and ecosystem utilisation. Catley et al. (2016) found that livestock production increased by introducing new breeds. However, there was over-exploitation of rangelands and loss of biodiversity. Many governments initially viewed traditional pastoralism as unfavourable and not in keeping with modern western values. However, further research found that traditional pastoralism positively supports biodiversity, range management viability, and carbon sequestration. As a result, researchers now view it as a viable option for dealing with these issues. The lack of a positive outlook on pastoralism meant that governments directed minimal investments to this livestock system. Hopefully, with more research on its importance, governments will direct more budgetary allocations towards supporting pastoralist production systems (Nyariki, 2019).

Pastoralists need more attention and resources from their governments and the impact of global and emerging trends on their lifestyles. Emerging trends, such as the localisation and decentralisation of formerly open borders, have impacted cultural livelihoods. Furthermore, education, Christianity, and Islam have profoundly affected the younger generation's view of traditional pastoralism, resulting in a loss of indigenous knowledge passed on livestock keeping to subsequent generations (Cheikh, 2019). Other global trends impacting local pastoralists' lifestyles include international remittances and migration, climate change, counter-terrorism acts, increased insecurity, organised crimes and emerging diseases (Nyariki, 2019).

Historically, pastoralists owned land-free tenure in Kenya, allowing for livestock migration over vast areas covering Kenya and Tanzania. Traditional grazing areas are designated as dry season grazing areas like Loitoktok and Narok, where cattle move because these areas are well watered. At the same time, homesteads express drought or a long dry season. Other areas are designated as wet season grazing areas nearer the homesteads as the rains have regenerated the pastures. One of the downsides of traditional pastoralism is that livestock deaths due to diseases and starvation were high when severe droughts depleted all the grass. Land-use changes in Kajiado have significantly reduced this type of free pastoralism. There are fewer places for the livestock to migrate to, and conflicts arise from livestock migrating into national parks and private farms and ranches. The long-term effect of land-use changes has been that pastoralists' livelihoods have become increasingly vulnerable to droughts and reduced productivity even in average years (Nyariki, 2019).

Today, global, local, and community pressures have led many pastoralists to adopt mixed farming practices. These pressures stem from the poor meat-to-grain market ratio, which makes it more expensive for pastoralists to access the grain and vegetables necessary to maintain a healthy diet. Furthermore, commercial farming has encroached on rangelands that were once used for pastoralism, leading to changes in land ownership from communal to private and reducing the land available for migrating herds (Galaty, 2019).

Modern pastoralism has adapted by combining traditional migration practices with paddocking and rotational grazing. Paddocking involves confining livestock to a small area or paddock for a certain period before moving them to another. This system helps evenly distribute the animals' impact on the land and provides them access to fresh forage. Paddocking is often used with rotational grazing, a management system that uses multiple paddocks to rotate livestock regularly. This system helps to maintain pasture quality by allowing plants time to recover after grazing and ensures that hay plants have access to sunlight, water, and nutrients. Moreover, the manure from livestock is evenly distributed, which can help to improve soil health. By utilising paddocking and rotational grazing practices, cattle on private farms can better manage their ranges (University, 2022).

2.2 Rangelands in Pastoralism Systems

Scientific concepts have highlighted the factors contributing to land degradation, and new models of ecological non-equilibrium dynamics are being applied. Incorporating local knowledge into land management and pastoralist settlements has had ecological benefits. However, gaps in information and data limit the adoption of new approaches among the government, pastoralists, and other stakeholders. Despite these revolutionary developments, the long-standing overgrazing problem persists (Galaty, 2019).

Communal grazing areas often fall victim to the 'tragedy of the commons,' leading to rapid land degradation. Good range management practices, like rotational grazing, are only sometimes practised. Pastures are depleted and damaged, forcing pastoralists to migrate with their livestock in search of new pastures. In some nomadic communities, burning is also practised before migration. When rain falls on the damaged, overgrazed pastures, it often results in runoff and soil erosion as no grass cover holds the rainwater. The soil quality deteriorates and cannot hold beneficial grass varieties; instead, invasive species creep in and take over communal grazing areas. Burning worsens the situation, releasing carbon gases into the atmosphere and destroying underground root forage, making the next season's regeneration poor and further depleting available grazing pastures (Boles, 2019).

Grasslands have a complex relationship with climate change, releasing and absorbing carbon dioxide (CO_2), releasing methane (CH_4) through grazing livestock, and releasing nitrous oxide (N_2O) from agricultural soils. When vegetation is cleared, it remains to be seen how the emissions from these three greenhouse gases from different grasslands globally will influence historic climate change or the dispersal of insects and parasites within these ecosystems. Due to expanding livestock farming, livestock farming has altered the character of grasslands from a carbon sink to an emission source, leading to increased loss of natural lands to pasture. However, industries that drive climate change by producing higher carbon dioxide and nitrogen emissions contribute to improved grass production and enhance the net carbon sink in the soil. The findings suggest that action is needed to alleviate emissions while balancing the growing demand for pasture products. Over the long term, sustainable grassland management improves forest-carbon storage and offsets greenhouse gas emissions from managed grasslands (Chang, 2021).

Agricultural livestock farming is rangeland regions' primary land area and livelihood activity. Nonetheless, the livestock industry is a major contributor to global greenhouse gas (GHG) emissions. The digestive processes of livestock result in the production of CH4, while the primary sources of GHG emissions from livestock are N_2O emissions from feed production. While carbon dioxide triggers ecological changes in grasslands and savannahs, cattle contribute 9% to 18% of such emissions. Livestock, particularly cattle, emit the highest greenhouse gases in East and Southern

Africa, followed by the West and Central Africa regions. Therefore, mitigating livestock greenhouse gas emissions is crucial (Mgalula, 2021).

Grazing is one of the most common ways to manage rangelands. However, grazing can affect soil properties in several ways. For instance, grazing can directly affect soil organic nitrogen and soil organic carbon, but its impact depends on grazing frequency, intensity, and duration. Researchers agree that livestock keeping and herding practices do affect the land. When livestock keepers practice modern grazing practices like rotational paddocking, it enhances the rangelands' ability to sustain livestock over a long time by carbon sequestration, leading to improved soil quality. Good farming practices that promote carbon sequestration include moderate and rotational grazing, reforestation on degraded land, implementing grazing practices such as enclosures, and using no-till farming. Other beneficial practices include growing drought-tolerant grass varieties, crop or livestock appropriation, and biomass harvesting to alter ecosystems' carbon balance in grasslands. However, harmful practices such as converting land to crop farming through deforestation, slash-and-burn, and overstocking pressure on the remaining land can reduce soil quality and release more carbon into the atmosphere. Carbon and nitrogen cycles, biological and abiotic processes, climate systems, and land-use changes alter the grasslands' ability to store carbon. In order to increase the potential of rangelands to sequester carbon, there is a need to restore damaged areas, manage and protect essential areas, and reduce livestock overstocking on degraded land to encourage natural reforestation (Mgalula, 2021).

In West Africa, various pastoral policies implemented by governments have protected rangelands and significantly improved livestock mobility, resulting in optimal usage of marginal lands compared to other agricultural uses. Moreover, it has a significant and positive influence on livestock mobility. These laws have led to the recognition of mobility through resource usage rights for pastoral communities and the productive usage of rural lands. Furthermore, in central Africa, various supportive policies for pastoralist communities have resulted in the optimal use of marginal lands (Turner, 2019).

Soil erosion is the leading cause of land degradation in agricultural and pastoral landscapes in African countries. The central government's policies aimed at agricultural development have disrupted the natural soil rhythm under agropastoral systems, leading to soil exhaustion, dwindling fertility, and increased soil erosion (Wynants, 2019). Unfortunately, policies that support urbanisation and industrialisation have led to pastoralists living sedentary and marginalised lifestyles on land they formerly owned. Moreover, these policies need more essential components to sustainably adapt the environment to local and global changes and pressures. As a result, populations continue to exploit natural and non-renewable resources excessively, further damaging grassland soils. Despite these challenges, authorities need to pay more attention to the complexity of soil erosion drivers, and sustainable land management plans still need to be developed. Sustainable land management solutions addressing population growth and food intensification can guide communities to use existing infrastructure while diversifying their economies by developing, not losing, links between the social, economic, and natural ecosystems. Additionally, locally adapted initiatives must be integrated into the national, regional, and international frameworks (Wynants, 2019).

Compared to passive land use, pastoralism functions better in dryland contexts. Mobile forms of land use are less risky when weather conditions and variability increase, making pastoral adaptation more flexible than other land uses without mobility and more prone to environmental changes, such as agriculture, intensive livestock farming, and tourism. This provides economic benefits and reduces poverty because development is less vulnerable to variations in climate (World Initiative for Sustainable Pastoralism, 2008).

2.3 Ecosystem Governance for Rangelands

An ecosystem is a complex network of living organisms and their environment, providing natural resources such as food and water. Governance of ecosystems involves managing natural resources, which can be challenging due to the diverse and often competing needs of different groups of people and animals. For example, ecosystems can support various trades, including fish, timber, crop growth, recreational activities, and commercial harvesting, each with different priorities and objectives. The management of ecosystems is further complicated by environmental threats such as habitat loss or harm from agricultural runoffs into streams (World Resource Institute, 2003).

Effective ecosystem governance in grassland habitats supports both livestock and wildlife. For instance, a grazing management plan that rotates livestock between pastures to allow for rest and regeneration of vegetation, mimicking the way wild herds graze, can also provide areas for wildlife to graze. This approach ensures the ecosystem's resilience, allowing it to recover from overgrazing and improve productivity (Teague Richard, 2020).

Ruminants, such as domestic livestock, have been accused of devastating biomes, ecological systems, and human health. However, with appropriate management, ruminants can reverse the global damage of human activities and environmental asymmetries. Unfortunately, most industrial businesses use chemicals in their livestock production, dramatically degrading grasslands worldwide and negatively impacting human well-being. Thus, robust agricultural policies are urgently required to guarantee rangeland viability and sustainability and maintain environmental balance. Regenerative agriculture, practised by local livestock farmers and ranchers, can restore ecosystem functions and produce cost-efficient, sustainable, viable, and resilient agroecosystems. This includes improved pasture management, which contributes to uniform manuring of the land, supporting plant growth and soil cover, thereby reducing soil erosion. Integrating forage and livestock manure also increases the organic carbon in the soil, restoring soil health and vitality. Regenerative agriculture practices also benefit soil health by reducing the need for annual tillage, inorganic fertilizers, and the overuse of pesticides. Ecosystem services that benefit from regenerative agriculture include soil stabilization, carbon sequestration, water and nutrient cycling, increased fauna and flora biodiversity, and wildlife conservation, collectively increasing ecosystem, economic stability, and resilience (Teague Richard,2020).

2.3.1 Ecosystem Governance for Livestock Production

The term ecosystem services describe the positive benefits humans derive from natural ecosystems' resources and processes, categorised into four groups: Provision, regulation, support, and cultural. Livestock has been a part of rangeland ecosystems for centuries in many countries and has profoundly impacted the environment. While rangelands are often considered natural wildernesses, many have been significantly modified through human management, such as animal rearing. Humans may intervene in the natural environment to maintain biodiversity and ecosystem functioning. For instance, conservation may be based on sustainable pastoralism (World Initiative for Sustainable Pastoralism, 2008).

Grassland conservation aims to preserve and manage grasslands to ensure their long-term health and sustainability, which is critical to the survival of all living species worldwide. Pastoralists have extensive knowledge of their surroundings, which enables them to manage resources more efficiently. They have established institutional frameworks for the management of natural resources on lands managed communally. The effectiveness of local knowledge relies on the functionality of pastoral institutions and their ability to discipline individuals engaging in inappropriate conduct. However, developmental planners have often needed help adapting their expertise to biophysical changes and uncertain habits on the rangelands. Due to this limitation, development partners have caused the formation of unsustainable changes that contradict the tried-and-tested pastoralist systems. Repairing pastoralism with other land is one of the leading causes of desertification and the loss of diversification of flora and fauna (World Initiative for Sustainable Pastoralism, 2008).

Livestock intensification has increased livestock diseases outbreaks like tick-borne vector diseases and contagious bovine pleuropneumonia, which negatively affect milk and beef production. It also decreases milk production per cow and leads to poor market prices. In contrast, livestock mobility in pastoralism can help regulate tick and insect populations and better adapt to disease surges compared to the intensification of animal production. Furthermore, pastoralism provides invaluable ecosystem services like significantly improving soil carbon sequestration and fertility. Studies suggest that seed dispersal and water regulation can also significantly improve pastoralism. Pastoralism positively influences pest and disease regulation, rangeland climate, biodiversity conservation, and fire management. Therefore, pastoralism significantly and positively contributes to global environmental and rangeland sustainability (World Initiative for Sustainable Pastoralism, 2008).

The study assesses the suitability of hay production as a climate-smart and drought-resilient option for pastoralist systems in Kajiado County. The study will analyse existing hay production systems, conduct a cost-benefit financial analysis of hay production under different cultivation practices, and evaluate existing policy and institutional frameworks that support hay production as a drought and climate resilient farming option. These issues are relevant because they relate to the potential benefits of hay production in pastoralist systems in Kajiado County.

One important concept that needs to be considered when addressing policies that support the production of climate-smart hay in arid areas is ecosystem governance for livestock. Livestock significantly impacts rangeland ecosystems, and human management, such as animal rearing, has often resulted in modifying these natural habitats. However, sustainable pastoralism practices can be implemented to maintain biodiversity and ecosystem functioning. Pastoralists have valuable knowledge about their territories and possess institutional arrangements that facilitate natural resource management on lands that are managed communally. This knowledge and institutional capacity are crucial in ensuring the effectiveness of local knowledge in managing resources more effectively.

Additionally, pastoralism positively influences pest and disease regulation, rangeland climate, biodiversity conservation, and fire management, making it an invaluable contributor to global environmental and rangeland sustainability. Therefore, policies that support sustainable pastoralism practices and grassland conservation can help preserve and manage grasslands, ensuring their long-term health and sustainability, and support the production of climate-smart hay in arid areas.

2.3.2 Ecosystem Governance for Wildlife Sustainability

The management and utilization of wildlife and rangelands involve both formal and informal processes and institutions. Effective governance is crucial to ensure that rangelands provide a range of benefits, including wildlife while minimizing negative impacts on ecosystems. For wildlife to thrive in rangelands, it is essential to comprehend the ecological dynamics of these lands and have management strategies that reflect this understanding (Sala, 2017).

Wildlife species are at risk globally due to the loss of wild spaces caused by human encroachment, such as deforestation and land degradation due to the expansion of agricultural land, the intensive harvesting of timber, the extraction of wood for fuel and other forest products, and overgrazing are some of the factors that contribute to the degradation of forested landscapes. A clear plan to protect wild spaces is necessary to recover vital ecological habitats. Pollution, mining, and infrastructure construction, such as roads, railways, and pipelines, among other human activities, are also significant causes of habitat loss (Niamir-Fuller, 2012).

Natural habitats such as forests and national parks, the primary habitats for wild animals, are being destroyed daily to construct projects, leading to the displacement of wild animals. In 2020, news broke that wildebeest migrating annually from Tanzania through the Mara River to Kenya could not cross due to a camp built along the Mara River, demonstrating the selfishness of humans towards wildlife (Standard Newspaper, 2020).

The interaction between wildlife and humans has negatively impacted animals. Competition for space and resources becomes an issue when human populations increase and overlap with established wildlife territories. Africa is a hotspot for wildlife, and human-wildlife conflicts are rising. Human predators, such as lions, cheetahs, and leopards, are among the primary examples of human-wildlife conflict, followed by the human-elephant conflict. Elephants often clash with humans on farms, damaging crops, infrastructure, or even people. Humans retaliate by killing them. However, predators exacerbate threats to humans by attacking people and livestock (Pierre Bonte, 2019).

Mitigating measures to reduce human-wildlife conflicts include erecting fences and barriers around homes to prevent predators and elephants from encroaching on human settlements. Additionally, community education and promoting harmonious living with wildlife are critical. Many communities unknowingly engage in activities that harm wildlife. For instance, the Maasai community considers their young people warriors only after killing a lion. Members of this community need to be educated that they can also be warriors by protecting lions through effective land-use practices. Minor encroachments of wildlife habitats will occur when humans use available land. Marking conflict hotspots will also help curb human-wildlife conflicts (Pierre Bonte, 2019).

The world cannot continue to lose global biodiversity for selfish gains; therefore, we must prevent wildlife trade and protect wildlife populations in their natural habitats. The public needs education and awareness about natural habitats and biodiversity. The growing human population has encroached on wild spaces, indirectly driving the global wildlife trade. To protect against further degradation of wildlife habitat corridors from fragmented habitats, policies that reduce the human population and limit land-use change expansion need to be encouraged (Rojas-Downing, 2017).

The research investigates the possible advantages of cultivating hay as a climate-smart and drought-resilient alternative in pastoralist communities located in Kajiado County. The study will analyse existing hay production systems, conduct a cost-benefit analysis of hay production under different cultivation practices, and evaluate existing policy and institutional frameworks that support hay production. These issues are critical because they can inform policies that support climate-smart hay production in arid areas and improve the livelihoods of pastoralist communities.

Moreover, the relevance of ecosystem governance for wildlife must be considered in this context. Effective governance is crucial to ensure that rangelands provide a range of benefits, including wildlife while minimising negative impacts on ecosystems. Human encroachment has led to depletion of wild spaces, leading to the displacement and competition of wildlife and people for space and resources. Human-wildlife conflicts are rising, and mitigation measures such as erecting fences and barriers, community education, and promoting harmonious living with wildlife are essential. Therefore, policies that limit land-use change expansion need to be encouraged to protect against further degradation of wildlife habitat corridors from fragmented habitats.

Climate-smart practices like hay production may efficiently use available land and address the need to expand land for free rangeland livestock grazing, as in traditional pastoralism. By introducing semi-intensification and better utilisation of farmland, hay farming can limit the need to encroach on wildlife habitats for pastoralism livestock keeping. In summary, the study aims to explore the potential benefits of hay production while highlighting the critical importance of ecosystem governance for wildlife in arid areas.

2.4 Challenges faced by Pastoralists

Pastoralist communities face numerous challenges, including spatial, political, and cultural marginalisation and isolation, which lead to low food security and human development indicators. They also have limited access to public services and infrastructure than agricultural and urban communities. Conflicts over resources, especially water and grazing, further exacerbate pastoralist communities' economic outlook and human well-being (Pierre Bonte, 2019).

In addition to conflict, the encroachment of human populations from congested areas onto pastoral lands has increased pressure on land, resulting in the conversion of grasslands to urban centres and other infrastructure. This land pressure denies pastoralist communities the land they need for traditional mobility with their animals, leading to a decline in their traditional land management practices (Nyariki, 2019). Natural disasters like droughts and intense rainy seasons have also impacted grasslands and pastoralism, forcing pastoralists to resort to unsustainable coping mechanisms like cutting down trees and burning charcoal (Pierre Bonte, 2019). These disasters have also led to a change in pastoralist culture, with women taking up menial jobs, exposing family members to risk and abuse, and engaging in illegal activities (Pierre Bonte, 2019).

Climate change has also affected pastoralist landscapes, altering the plant species and grasses they rely on for livestock fodder. As a result, they incur losses in production and profitability, further compounding their challenges (Pierre Bonte, 2019). Additionally, competition between wildlife conservation and pastoral living has emerged. International organisations promote wildlife as the centre of productive land use due to its higher ecological, economic, cultural, and social benefits. However, more research is necessary to understand the interdependence of pastoralism and wildlife, and past policies that ignored pastoralists' culture and indigenous knowledge of rangeland management have proved disastrous (AWF, 2019).

Overall, addressing the challenges faced by pastoralist communities will require a multi-dimensional approach that considers their unique cultural practices and ecological knowledge, incorporates sustainable land management practices, and provides access to public services and infrastructure.

Livestock feeding is crucial for the livelihoods of pastoralist communities, especially during droughts when grazing lands become scarce. Supporting effective climate-smart agricultural practices like hay production can address this challenge by providing a drought-resilient source of livestock feed. Hay production involves harvesting and storing forage crops like grass, alfalfa, or clover to feed livestock when dry or unavailable pasture lands.

Hay production is particularly relevant to pastoralist communities in arid areas because it provides a reliable feed source during drought. By adopting hay production, pastoralists can reduce their reliance on grazing lands, which are scarce in arid areas and are often subject to competition and conflict. Hay production can also help conserve grasslands and alleviate stress on natural resources such as water and soil, which are often limited in arid areas. However, several challenges must be addressed to make hay production viable for pastoralists. These challenges include limited access to credit and financing, insufficient expertise, and capabilities, as well as insufficient facilities and markets for producing hay. Addressing these challenges requires a multi-dimensional approach that considers pastoralist communities' unique cultural practices and ecological knowledge and incorporates sustainable land management practices.

The study explores the potential benefits of hay production as a drought and climate - resilient fodder growing option in pastoralist systems in Kajiado County include analysing existing hay production systems, conducting a cost-benefit financial analysis of hay production under different cultivation practices, and evaluating existing policy and institutional frameworks that support hay production. The study aims to inform policies that support climate-smart hay production in arid areas and improve the livelihoods of pastoralist communities.

2.5 Policies Supporting Pastoralism in Africa

2.5.1 Continental Polices Supporting Pastoralism

Africa is home to numerous pastoralist communities whose livelihoods depend on livestock production and transhumant movements. Several policies have been developed at the continental level to support pastoralist communities. The African Union Commission's Policy Framework for Pastoralism in Africa recognizes the intrinsic link between securing pastoralism and Africa's future. This policy seeks to secure, protect, and improve African pastoralists' lives, livelihoods, and usage rights (Africa Union, 2010). Similarly, the Comprehensive Africa Agriculture Development Programme (CAADP) recognizes the role of pastoralism in the agricultural sector of Africa and provides support for pastoralist communities (NEPAD, 2003).

The African Union's Agenda 2063 is another strategic framework that recognizes the importance of pastoralism in the continent's development. It calls for promoting pastoralist livelihoods and protecting their rights (African Union, 2013). Additionally, the African Charter on Human and Peoples' Rights recognizes that individuals' rights, including pastoralists, to participate in their countries' economic, social, and cultural development (African Union, 1981). Finally, the Convention on Biological Diversity recognizes traditional knowledge and practices, including those of pastoralists, in promoting the preservation and sustainable utilization of biodiversity (United Nations, 1992).

The Policy Framework for Pastoralism in Africa specifies the rights of pastoralists to land, cultural rehabilitation, security, infrastructure, and economic benefits in safe havens comparable to non-protected areas. The policy promotes security, livelihood enhancement, and the rights of pastoralist communities to equal development. It also acknowledges that pastoralism contributes to economic growth and should be addressed in a country's development plans (Union, African, 2010)

Implementation of the policy's objectives includes the development of appropriate land tenure policies, legislation that eases the mobility of pastoralists across states, disease control, and drought risk management. Trade of livestock products can be enhanced through certification, credit and financial facilities tailored to pastoralism, and livestock-based insurance. Recognition of ownership of indigenous livestock genetic material should also be patented to the benefit of pastoralists. These genetic inheritances need support through research, extension services, training, and documenting indigenous knowledge and practices (African Union, 2010).

In conclusion, the Policy Framework for Pastoralism in Africa is committed to making pastoralism more applicable to sustainable development. It promotes pastoralist communities' security, livelihood, and equal development and acknowledges their contribution to economic growth. The policy addresses the loss of pastoral livestock and aims to reduce rural poverty. Implementation of appropriate land tenure policies, legislation, and trade enhancement can ensure pastoralists' rights and promote sustainable development in Africa (African Union, 2010). Along with other continental policies, the policy demonstrates a commitment to supporting pastoralist communities and recognizing their contributions to the continent's development.

2.5.2 Policies that Support Pastoralism in Kenya

The 2010 Constitution of Kenya, in Article 43, enshrines the rights to food security and freedom from hunger. Articles 42 and 69 further emphasise the need to conserve and protect the environment through equitable principles and disaster management (GoK K.L., 2010). Kenya's Vision 2030 strategy and the Big Four agenda both support livestock production (GoK, 2020) and encourage climate-smart livestock practices, as elaborated in the 2016 Kenya Climate Change Act, the 2010 National Climate Change Response Strategy (NCCRS), and the 2017 National Climate Change Action Plan (NCCAP). This legislation emphasises that development with reduced carbon emissions is resilient to climate change and is critical for Kenya achieve its Sustainable Development Goal (SDG13). The NCCAP outlines Kenya's efforts towards the Nationally Appropriate Mitigation Actions (NAMAs) to support the livestock sector in reducing greenhouse gas emissions alongside disaster risk management towards coping with drought and floods impacts on livestock, as elaborated in the NCCAP 2018-2022 (GoK, 2018).

Contribution to the Nationally Determined UNFCCC commitments and implementation of these tools is broken down into the Kenya Climate-Smart Agriculture Strategy (KCSAS) of 2016-2026 (GoK, 2016). The Kenya Climate-Smart Agriculture Program (KCSAP), running from 2015 to 2030, has put in place projects to increase livestock productivity in Kenya's arid lands, where livestock-based livelihoods are the mainstay of the communities living there (GoK, 2018). The KCSAP also contributes to Sustainable Development Goals (SDGs) 1, 2, and 13. The 2010-2020 Agricultural Sector Development Strategy (ASDS) and the 2019-2029 Agricultural Sector Transformation and Growth Strategy (ASTGS) have similar objectives to the KCSAS. They both seek to improve livestock productivity by supporting the genetic improvement of livestock, modern grazing practices, clean energy technologies like biogas, high-quality inputs, appropriate mechanisation, improved fodder seed, irrigation, and stemming post-harvest losses of hay and fodder.

Although the ASTGS mentions hay production, only large-scale producers growing food crops on 2500 acres and above receive support (GoK, 2019a). The flagships need to be explicit and offer tangible support for producers ranging from 1000 acres and below by providing subsidies, private-public partnerships, and cooperatives to stabilise hay demand and supply. The five-year County Integrated Development Plans (CIDP) reflect how the KCSAP and ASTGS are being implemented by following the accountability of the money (GoK, 2017b).

The Range Management and Pastoralism Strategy 2021-2031 provides a clear framework for sustainable development in Kenya's rangelands, aiming to guide land use, planning, and investments for resource management. It emphasizes the active involvement of the national government, county governments, other organizations, and the community. The rangeland policy aligns with the national livestock policy, which aims to strengthen range resource utilization while complying with Kenya's Constitution, laws, and acts that prohibit the unsustainable use of natural resources. The strategy identifies gaps in existing policies and laws and presents solutions to address them (GoK, 2021b).

The Range Management and Pastoralism Strategy 2021-2031 seeks to improve coordination among stakeholders and inhabitants in the development and management of rangelands in Kenya. It aims to support ongoing efforts for better livelihoods, sustainable activities, and preservation of land productivity. The strategy has six specific objectives, including improving rangeland health, revitalizing pastoralism production systems, and establishing sustainable rangeland management mechanisms. Other objectives include enhancing climate change adaptation and mitigation activities, increasing marketing of rangeland resources, and promoting sustainable exploitation of alternative resources. To achieve these objectives, the strategy will be implemented through an Inter-Government Coordination Structure between the National Government and county governments, which will also mobilize investment funds from various sources. The county governments will primarily organize the implementation of the strategy, and a monitoring and evaluation framework will be established at various levels of implementation. The framework emphasizes improving range management and productivity of grazing resources through encouraging pasture production for livestock productivity (GoK, 2021b).

The Policy Sessional Paper No. 8 of 2012 on Kenya's Arid and Semi-Arid Lands (ASAL)aims to equalise the needs of all Kenyans through a flexible regulatory environment designed to accelerate development to reduce poverty, build resilience, and promote growth in ASAL The policy focuses on pastoral communities' challenges in the rangelands and proposes measures to manage drought and strengthen livelihoods. The planning sets a course for an integrated and long-term land, water, and natural resource governance arrangement that addresses the needs of traditional pastoral livelihoods. The core responses to the recommendations include integrating traditional systems for managing natural resources into all existing policies affecting the natural resources' habitat and giving legal credence to traditional institutions in resolving conflicts (GOK, 2012).

As a result of the Livestock Policy Act of 2019, the national policy recognises that although ASAL has considerable potential, it has poor development and income indicators. The policy endorses rangeland management through the promotion of appropriate grazing management practices and the conservation of fodder and pasture, thereby encouraging county governments to engage in initiatives aimed at increasing food availability. The national and County governments seek to provide irrigation for fodder and drought-resistant fodder seeds, prevent pollutants and minimise the impacts of insects and illnesses on the range environment. The strategists note that the quality of range resources is fragile, and they need to find ways to develop protection strategies. The policy recommends that county governments encourage communities' institutional involvement in planning, developing, utilising, and monitoring resources. It also encourages government support for pastoralism and agropastoralism and develops strategies to conserve resources (GoK, 2019).

The Ending Drought Emergencies (EDE) operationalises the Authority on Development's (IGAD) Drought Disaster Resilience and Sustainability Initiative (IDDRSI) in the eastern Africa at the national level. The country is already experiencing the ramifications of climate change, and droughts have been identified as one of the leading climate hazards. As a result, the implementation of EDE becomes even more critical. Northern and eastern Kenya has higher poverty and isolation levels than the rest of the country. These counties house 18 of the 20 poorest sub-counties in Kenya, where most of the population lives in poverty. With stunting rates above 26% in several counties, malnutrition remains unacceptably high in many Arid and Semi-Arid Lands (ASALs). Communities cannot sustain their livelihoods without adequate security of their food and nutrition. Therefore, strengthening resilience actions that target food and nutrition-insecure households must cover a broad spectrum of activities to alleviate food and nutrition insecurity and achieve a sustainable impact (GoK, 2017b).

2.6 Climate Change

Climate change results from environmental degradation due to increasing levels of greenhouse gases (GHG), which lead to global warming. Global warming, in turn, alters precipitation and sea levels, resulting in extreme weather events. Various gases contribute to the greenhouse effect, including methane (CH4), nitrous oxide (N2O), carbon dioxide (CO2), and ozone (O3). According to the Intergovernmental Panel on Climate Change (IPCC), human activities that generate greenhouse gas emissions are responsible for the rise in the global average surface temperature during the 20th century (IPCC, 2019).

The impacts of climate change on plant species include changes in distribution, abundance, and ability to thrive in certain climates. Climate change has already begun to impact plant varieties across the globe, with some plants becoming more prevalent in certain areas while others are disappearing. This shift in plant life impacts the water cycle, as plants require different amounts of water to flourish. For example, once lush and green grasslands become drier and more barren, trees and other plants that need more water take over. Climate change also affects plant root systems. Changes in temperature and precipitation can cause plants to lose access to water, which impacts the water cycle. The lack of water can ripple effect on local ecosystems, and plant root systems can impact the water cycle by holding onto water and releasing it slowly into the atmosphere. Plants can also improve water infiltration and reduce erosion, essential for managing water resources (Calleja-Cabrera J, 2020).

2.6.1 Effect of Climate Change on Livestock Farming Systems

According to the recent scientific consensus anthropogenic greenhouse gas emissions have reached their highest levels due to climate change. Worldwide, food demand generates about a quarter of all greenhouse gas emissions. Agricultural processes use about two-thirds of the earth's freshwater reserves. For example, intensive livestock systems require large tracts of land and irrigation to grow their feed, utilizing fossil fuels from mechanized machinery and plenty of fresh water for irrigation. On the other hand, pastoral systems are rain-fed and depend on manure dropped on open fields to naturally fertilize grass, using fewer fossil fuels and less freshwater compared to intensive livestock farming (IPCC, 2019). The effect of precipitation on grassy fields varies depending on rainfall. Climate change has led to dry weather in grasslands and mountainous areas and increased rains in savannahs. Subsequently, the difference in rainfall has caused desertification in some areas of Africa.

The livestock sector is responsible for 19%, 15%, and 1.35% of the greenhouse gas (CH_4, N_2O, and CO_2) emissions caused by human activities on a global scale (Rojas-Downing, 2017). More research is needed on the contribution of carbon emissions from pastoralism, with available studies pointing to disparities between acreage used and the concentration of greenhouse gases per kilogram of animal weight produced. Using the greenhouse gases per kilogram measure, scholars can argue that the amount of carbon emitted during milk production is highest in sub-Saharan Africa, followed by South Asia, and Western Europe being lowest in North America (FAO, 2018a). The argument is that highly (gastrointestinal) grain-fed systems beef production systems reduce by 45% the land needed and produce 30% fewer greenhouse gas emissions per kilogram compared to grass-fed beef systems. Nonetheless, pastoralist livestock systems may boost soil carbon (SOC) reservoirs and use fewer resources like fertilizers that emit carbon (Uddin, 2020).

Some research suggests that the impact of climate change on livestock production may be influenced by changes in the amount of biomass produced and the availability of pastureland. Global models predict that up to 74% of pasture may become less productive by 2050, posing a threat to the livelihoods of around 174 million ruminants in tropical regions such as Australia, Mongolia, China, and Uzbekistan (Uddin, 2020). Poor pasture quality is also a challenge in Australia and sub-Saharan Africa, particularly during the dry season when soil nutrient content and digestibility are low. Moreover, the transition from herbaceous to woody pastureland exacerbates the problem and requires herders to adapt their livestock species to align with changing vegetation patterns. For instance, sheep, goats, or horses would be more suitable for woody pastureland (Uddin, 2020).

Climate change affects the diversification of native pastoralists' livestock in two different ways. First, an increase in temperature affects local livestock (e.g., heat stress), altering the survivability of indigenous animals compared to exotic breeds. Exotic breeds tend to be better housed by farmers and well-protected from heat. The second reason is the rising food demand pushing farmers to adopt intensive farming methods while trying to reduce their environmental footprints. Intensive systems are expensive and will push out locally adapted livestock or breeds that grow slower and require more space (Uddin, 2020).

Heat stress caused by elevated temperatures and humidity is less severe in beef cattle than in dairy cattle. One sign of heat stress is an animal's reduced feed intake. Trained lactating animals typically require 1,300 kg of milk daily, but mild to moderate heat stress can decrease this to 900 kg. Researchers have used milk production in subtropical climates as a proxy for dairy production in pastoral systems and have found that heat stress can cause a 19% reduction in milk production. The impact of heat stress on milk lactose content requires further clarification, as different studies have reported conflicting results. Heat stress can also cause high mortality rates and alter animal behaviour, resulting in increased respiration rates, reduced activity, and diminished playfulness among cows (Uddin, 2020).

2.6.2 Effects of Drought on Livestock Farming in Kenya

Meteorological, agricultural, and hydrological droughts severely impact livestock production and systems. Drought is triggered by inadequate, infrequent, and erratic rainfall, leading to a disruption in the water cycle, and the effects are worsened by anthropogenic climate changes, resulting in global warming (UNDRR, 2019). Climate change has several impacts on drought conditions. For instance, if the average temperature increases, the air will contain more moisture, leading to heavier rains and flooding in some areas and drought in others. Climate changes could also impact how wind and ocean currents circulate, affecting precipitation patterns (IPCC, 2019).

Drought causes the most devastation, accounting for approximately 86% of the global economic damage in the livestock sector. In Kenya, the most significant cost impact of drought over the past decade was estimated at over KES 12.1 trillion, with the livestock sector alone accounting for a 72% loss of just under KES 8.4 trillion, requiring KES 1.06 trillion investment in disaster risk reduction to recover (GoK, 2012). Kenya has experienced 28 significant droughts since 1900, with the severity and frequency increasing over time (Kimani et al., 2013). As a result, more livestock is exposed annually to droughts, and the current average of 16% is expected to rise to 36% (Roberto Rudari, 2018). Animal husbandry is the primary livelihood source for most of the population in the ASALs of Kenya, contributing significantly to poverty alleviation. However, livestock farming remains highly vulnerable to drought, with

90% of pastoralists relying on livestock as their primary income source, contributing 40-80% of household income (King-Okumu, 2022).

Drought is Kenya's most frequent natural hazard. Despite heavy investments from the government, donors, NGOs, and local communities, the negative consequences on people's livelihoods and resilience to future droughts and climate change shocks continue to increase (Nyoka, 2016). High-quality feeds and water are the most critical inputs for successful livestock production. However, improved fodder production practices in the ASALs in Kenya need to be improved by various issues leading to farmers' low adoption of fodder technologies (Rajesh Kumar Singh, 2012).

Many people in Africa who rely on livestock for food and income are significantly affected by drought. The lack of water and reduced rangeland forage resulting from droughts lead to livestock dehydration and death, reducing crop production and water recharge. Rangeland forage and livestock are essential to pastoralism, a way of life that depends on grazing animals on natural pastures. The impact of droughts can be significant, mainly if they occur during critical times in the growth cycle of livestock. It can increase competition for water and other resources, reducing the rangeland quality (FAO, 2018a; FAO, 2015).

2.6.3 Carbon Sequestration in Livestock Production Systems

Carbon sequestration involves sequestering and retaining carbon dioxide (CO_2) from the atmosphere to prevent it from contributing to climate change. In livestock systems, carbon is sequestered from the atmosphere into a stable form, usually as soil organic matter or biomass. Carbon sequestration occurs when plants absorb carbon dioxide through photosynthesis and convert it into biomass, which can then be used as food by livestock or stored in soils. Enhancing carbon sequestration in soils can effectively lower greenhouse gas emissions and aid in combating climate change. Livestock systems incorporating trees or other perennial plants can aid in sequestering soil carbon. Grazing animals, on the other hand, can help spread manure containing plant nutrients and organic matter that enhance soil health (IPCC, 2013).

Ensuring food security is critical to improving crop production and introducing beneficial soil management practices in African rangelands is vital to enhancing carbon storage. Agronomic management practices such as conservation agriculture, manuring to restore degraded areas, and planting cover crops have long-term benefits for preserving soil. Carbon emissions from mechanized farmlands are higher than emissions from shifting cultivation farms. Moreover, livestock manure plays an essential role in no-till farming. Hay production that relies on weeding and removing bushes is a form of no-till cultivation (Mgalula, 2021).

Different agroecosystems have differences in sequestration capacities depending on soil type, climatic conditions, and the duration of agricultural practice on the land. Greater agroecosystem diversity provides more opportunities for carbon sequestration. Transitions from agricultural land to grassland or agricultural land to pasture have great potential to increase carbon sequestration. However, while transitioning from croplands to grasslands or fallow can enhance carbon sequestration, these adjustments have tremendous prospects. For example, no-till farming has a higher carbon sequestration capacity than cultivated and intensely managed croplands (Sharma, 2012).

For various types of transhumance rangelands in Eastern Africa, it is necessary to identify optimal strategies to increase carbon sequestration and rangeland productivity through careful consideration of the spatial features of the native terrain. When designing appropriate carbon sequestration strategies, researchers must consider specific regions with high carbon sequestration potential. Rangeland planners and users can utilize localized data to carry out adaptive land-use practices that encourage carbon sequestration, water retention, manuring, and efficient ruminant feeds to diminish greenhouse gas emissions and accumulate organic carbon in soil (Mgalula, 2021).

However, small-scale farmers in agricultural communities in Borana rangelands in Southern Ethiopia need help implementing these practices due to communal or government-owned land, poverty, and few economic opportunities. A study found that most farmers needed to be more specific about implementing recommended soil management techniques due to unclear land tenure (Elias, 2015). Greenhouse gas (GHG) emissions associated with crop growing in such areas pose a challenge because these areas rely on the community's stewardship, which is determined by their local culture. Productive flood-prone areas like riparian zones are increasingly being converted into food farming. Researchers can use high-resolution data from aerial and remote sensing technology to map the extent and trends of this land use conversion. Field research can help determine the carbon balance sheet of a converted landscape (Mgalula, 2021).

2.6.4 Carbon Sequestration in Fodder Production

The pastoral and agropastoral communities residing in Kenya's rangelands are increasingly embracing hay production due to the scarcity of pasture, which frequent droughts have worsened. Hay has helped households supplement their incomes, mitigating their risks when livestock production is affected by droughts. The profitability of hay production and selling hayseeds has improved household incomes in the arid areas of southern Kenya (Ouma, 2017).

Agricultural livestock farming is the most critical land area and livelihood activity within rangeland areas. However, livestock production systems contribute significantly to global greenhouse gas (GHG) emissions. CH_4 from digestive system fermentation and N_2O from fodder production are the principal sources of emissions from livestock. While carbon dioxide invokes ecological changes to grasslands, land, or savannah, cattle contribute about 9 to 18% of such emissions. In Eastern and Southern Africa, livestock, especially cattle, produce the highest 0.6 t CO_2e/yr per-capita greenhouse gas emissions, while in West Africa and Central Africa, the corresponding figures are 0.4 t CO_2e/yr per capita and 0.3 t CO_2e/yr per capita, respectively, in 2010 (Mgalula, 2021).

The emissions per output unit, referred to as Emission intensity (Ei), are expressed in kg CO_2 -eq per output unit (e.g., kgCO_2 -eq per kg of egg). CO_2-eq emissions refer to the amount of greenhouse gas emissions that cause an integrated radiative forcing effect over time and are calculated by multiplying the emissions of each gas by its global warming potential (GWP) for a specific time period. The CO_2-equivalent emission metric compares gas emissions of different GHGs (IPCC, 2013).

A great deal of livestock-related activities injects GHGs like methane, carbon dioxide, and nitrous oxide into the environment. Such activities include grazing, manure dropping, urine or concentrations in riverbeds, or crop farming activities, including turfing and burning biomass or leftover plants. Researchers must understand and quantify the sources of gas emissions, and the potential rangelands have to sequester carbon in Eastern African rangelands to develop mitigation strategies (Mgalula, 2021).

The emission sources specific to land-use changes include crop farming, livestock keeping, slash and burn, and other ecosystem biological processes. The incentives of using rangelands to increase carbon sequestration capacity have found that many practices enhance carbon sequestration potential and carbon sink capacity. However, researchers must consider how local land conditions, rainfall patterns, and the number of livestock herds affect carbon sequestration potential. Land management may help develop carbon sequestration in rangelands to mitigate the effects of climate change. By using improved farming or grazing management approaches or renovating the degraded areas of rangeland, the region has increased the capacity to sequester carbon. Rangeland's resources are multifaceted, necessitating various practices and processes (Mgalula, 2021).

The study analyzes existing hay production systems, conducting a cost-benefit analysis, and evaluating policy and institutional frameworks that support hay production as a crop that is able to withstand drought are highly relevant to the potential benefits of hay production in pastoralist systems in Kajiado County. By understanding the viability of hay production and the policy and institutional support available, farmers can make informed decisions about incorporating hay production into their livelihoods and increasing their resilience to droughts.

Moreover, the study objectives are also linked to carbon sequestration in livestock production systems. Hay production involves cultivating plants, which can absorb carbon dioxide through photosynthesis and store it in biomass or soils. Therefore, by adopting improved farming and grazing management practices, planting nitrogen-fixing plants, using conservation tillage, and using compost or manure as a fertilizer, farmers can increase the amount of carbon sequestered in the soil and mitigate the impact of livestock-related greenhouse gas emissions on the environment.

The study's objective of assessing the current policy and institutional frameworks that promote hay production as a climate-smart option resilient to drought is pertinent to carbon capture. Policies and institutional frameworks can encourage the implementation of advanced farming and grazing practices that enhance carbon sequestration and decrease greenhouse gas emissions. Therefore, by understanding the policy and institutional support available, farmers can better incorporate carbon sequestration practices into their hay production systems and contribute to mitigating climate change.

2.7 Fodder Production

2.7.1 Types of Fodder

The Kenya Agricultural and Livestock Research Organisation reports that fodder crops grown in Kenya include maize, sorghum, millet, green grams, cowpeas, and velvet beans (Mumina Shibia, 2021). These crops are cut and fed directly to the livestock or conserved as hay and silage. In order to provide the most effective nutrition to the animals, the feeds must be easily digestible, allowing for proper absorption of nutrients. Like humans, livestock requires a balanced diet, including vitamins, for healthy body growth and reproduction. Livestock also requires energy from feeds with high carbohydrates and fats to produce milk and eggs and to maintain their body condition. Additionally, livestock requires energy for metabolic and physical work. Any excess carbohydrates not used for growth and production are stored as fat in the animal's body. Young animals and milking adults require a significant amount of protein for building and maintaining the body and for milk production. Ruminants should maintain healthy populations of microorganisms to sustain a healthy rumen. All feeds should be clean and free of dust or soil. The composition of an animal's diet depends on its age, development stage, and expected productivity level (Smith, 2019).

Ruminants, such as cattle, goats, and sheep, are well adapted to digesting rough mature fibres and young coarse fibres. Forage species choices depend on intended use, climatic adaptation, type of livestock management, forage requirements, and whether one variety or mixed forage is desired. Fodder seeds suitable for arid areas include *Eragrostis Superba*, *Andropogon gayanus*, *Chloris roxburghiana*, *Cenchrus ciliaris*, and *Panicum maximum* (Mutwedu, 2020). In semi-arid areas like Kajiado, the Boma Rhodes grass is an ideal option due to its drought resistance and reasonable growth rates in poor soil conditions. Boma Rhodes grass is a perennial grass that grows in the hot tropics, with a tufted or creeping, erect or decumbent habit, bright white culms, and a deep root system. It can grow up to one to two feet tall and has 12 to 50 centimetres long culms and 10 to 20 millimetres wide. The seed head comprises 2-10 leaves 4-15 centimetres long, which are bright greenish brown and become dark brown as they ripen as shown in figure 1 (FAO, 2014). Boma Rhodes grass is commonly used for grazing livestock and as a cover crop. It is mainly a high-quality forage used as hay or for direct grazing. Boma Rhodes grass grows best in loamy or sandy soil with a pH of 5.5-6, good drainage, and a good nutrient level, receiving at least 800mm of rain annually (Mumina Shibia, 2021).

Figure 1: Rhodes grass (Chloris gayana)
Source: S. Reynolds

2.7.2 Forage Quality in Rangelands of Africa

The Rangelands ecosystem consists of open areas dominated by grasses and indigenous plants. For this ecosystem to produce an adequate water supply, enough heat, sunlight, and soil to support plant growth are necessary. Rangelands provide critical ecological services, including carbon sequestration, soil stabilisation, and habitat for wildlife. They are vast, semi-arid areas in Africa used for grazing livestock. Grazing over vast rangelands is a sustainable way to use the land, as the animals can eat what they need, and trampling helps keep the grassland healthy. Livestock keeping is a traditional practice in Africa that helps ensure food security and supports economic development. Rangelands are an essential part of the African landscape, and livestock keeping has been an important part of African culture for centuries (Coppock, 2017).

The quality of rangeland forage for livestock in Africa is determined by several factors, like the amount and type of vegetation present, soil fertility, and climate. The presence of shrubs and trees can make it difficult for livestock to access the grasses and other plants they need to eat, and the lack of nutrients in the soil can make it hard for plants to grow healthily and robustly. The quality of rangeland forage depends on the rainfall. If an area has had a long dry season, the forage will be lower quality than with consistent rainfall. The composition of the plant community can also affect forage quality, with some species being more nutritious than others (Getabalew, 2019).

There is evidence that drought is the most severe consequence of climate change affecting rangelands in Africa. Climate change has made these areas drier and hotter, leading to more frequent and intense droughts. The lack of precipitation resulting in water shortages leads to the degradation of vegetation and soil, reduces fodder and food availability, and increases the risk of wildfires. These effects ultimately impact local people's and wildlife's livelihoods, leading to decreased food production, loss of livelihood, and increased poverty (IPCC, 2019). For instance, in 2022, the UN-OCHA noted that approximately 7 million livestock belonging to pastoralists across East African rangelands are affected by drought, of which over 1.5 million are in Kenya, and with southern and south-eastern Ethiopia having around 2.5 million, while Somalia, has 3 million (OCHA, 2022).

Prolonged drought can lead to low-quality hay from unimproved tropical grasses that become fibrous due to a lack of nutrients in the soil and extreme weather conditions. The lack of nutrients makes grasses weak and unable to take up the water they need from the soil, making them dry and fibrous. Additionally, the extreme weather conditions cause the hay to become brittle and break apart easily, making it difficult to transport and store. The low quality of hay from interrupted rainfall is likely because the plants cannot grow sufficiently dry before being baled. Moisture can cause the hay to spoil more quickly, have a lower nutritive value, and generally be lower quality (Latimore, 2008).

Additionally, if the weather stays wet for an extended period, it can lead to mould growth and other fungi on the hay. The low quality of hay from interrupted rainfall is because when the rain stops, there is a drought, and the hay dries out and becomes brittle. When harvested, brittle hay can shatter into small pieces, making it challenging to feed livestock. In addition, the lack of rain can also lead to a decrease in the hay quality since it will have fewer nutrients than it would if it had been raining (Latimore, 2008).

Overgrazing refers to excessive and continuous grazing by livestock on a piece of land until the vegetation cannot recover. This practice can lead to a decline in the quality and availability of forage for livestock and a loss in soil fertility. In addition, overgrazing can cause erosion, further reducing the quality and availability of forage, damaging infrastructure, and contaminating water supplies (Getabalew, 2019).

The loss of soil fertility can also significantly impact rangelands, affecting the composition, diversity, and quality of rangeland forage. Overgrazing by cattle or other grazing animals can deplete the soil's nutrients, contributing to the loss of soil fertility (Getabalew, 2019). Fires can negatively impact rangelands, whether caused accidentally by wildlife hunters and honey harvesters or intentionally for land clearing and improvement of visibility. These fires can spread rapidly and cause significant environmental damage, losing valuable natural resources. They can also kill or injure livestock and damage their fodder and water sources, causing short-term respiratory distress due to smoke and long-term problems due to lack of access to food and water (Ellie Wood, 2022).

In recent years, Africa has experienced locust and armyworm infestations that have devastated the quality of rangeland forages. These insects feed on plant leaves, leaving only stems and branches behind. This diminishes the plant's overall biomass and nutritional quality, making it less suitable for livestock grazing. For example, in Kenya in 2018, 27 of the 47 counties were affected by fall armyworm, which destroyed 250,000 hectares of maise, a supplementary forage used by pastoralists, especially during droughts (Abrahams et al., 2017).

2.7.3 Fodder Production in Rangelands of Kenya

The severe drought in Kenya from 2009 through 2011 affected more than 3 million pastoralists in the northern region, resulting in significant livestock losses and the sale of cattle at reduced prices, causing an estimated economic loss of KES 8 trillion (Opiyo & Mureithi, 2011). Many pastoralists formed communal ranches to grow fodder in paddocks and practised rotational grazing within the ranches to mitigate feed shortages arising from inadequate and erratic rainfall. The government of Kenya has been promoting fodder production in the drylands to support pastoralist communities (GFDRR, 2017).

Another strategy Maasai pastoralists use in Kajiado County is regulating the watering schedules of livestock to minimize water consumption. When grazing and browsing resources are depleted, the Maasai purchase wheat and Rhodes Boma grass hay from neighbouring Narok County. They also migrate their cattle to Narok County or even across the border to Tanzania when their areas dry out (NDMA, 2022).

In Kenya's various ASAL counties, fodder growing is promoted as a critical feeding strategy during droughts. For instance, in Mandera County, fodder groups plant Sudan grass and Nappier grass along rivers Juba, Data, and Bisan Adhi, producing up to two tons of fodder on 13 hectares of land using communal grazing areas (Nangole, 2013). In Garissa County, farmers plant sorghum and Boma Rhodes using conservation agriculture, producing excess grass that can be sold within the local community (Kuria, 2015).

In Tana River County, low-technology systems have been introduced to irrigate Boma Rhodes, Sudan grass, and Napier grass using water from the Tana River. In Makueni County, various grass species are grown, including African foxtail grass, Horsetail grass, Bush rye, Maasai love grass, and Rhodes grass (Nangole, 2013). Small groups in Baringo County use paddocks to grow a variety of grass species, which act as fodder banks during the dry season. Enhanced community resilience to drought innovation in Baringo County has used a market-based systems approach to help create new fodder production businesses. Communal pasture development has also reduced community conflicts over grazing areas and farmer-herder conflicts, as farmers with paddocked areas can rent them out to livestock owners during droughts (Lugusa, 2015).

In West Pokot County, some pastoralists have adapted to growing fodder using enclosures, which optimizes land use, improves food security, reduces transportation costs, and enhances soil health and water retention. The paddocking practice minimizes the impact of livestock on the land and allows it to rest and replenish its nutrients (Wairore, 2015).

2.7.4 Fodder Conservation, Silage Making and Hay Production

In 2020, guidelines for producing fodder, developed by International Livestock Research Institute (ILRI), for the extension staff and farmers located in the provinces of South Kivu and Tanganyika in the Democratic Republic of the Congo, recommend the following procedures for fodder conservation, silage making, and hay production. Growers can preserve forages to feed animals when environmental factors such as inadequate pasture growth or poor climatic conditions cause fodder scarcity. However, even though several methods have been proven practical for storing forage, it should be noted that even the best methods provide a different nutritional value than fresh forages due to the depletion of moisture and other nutrients. Forage conservation aims to reduce post-harvest losses. When deciding on the ideal conservation method, a farmer's top priority should be the forage variety, appropriate conservation process, storage facilities, weather, and utilization purposes for the forage. Fodder conservation aims to maximize nutrient preservation (Mutwedu, 2020).

The dry matter (DM) concentration levels of hay and silage differ. Silage is harvested at the appropriate DM concentration level for quick fermentation, which retains as much moisture as possible while keeping the original structure of the fibres. Hay is appropriately harvested with dry matter (DM) to discourage mould development. However, reducing dry matter content, as with the hay, means reducing the weight of the fodder stored (Mutwedu, 2020).

Three moisture levels can be attained for silage: high, medium, and low. High-moisture silage is made with forage with a moisture content of 30%, while medium-moisture silage has a 30-40% moisture content. Low-moisture silage is made with forage with a moisture content of 40% or higher (Kumar, 2019). Low-moisture silage is a type of forage that has been fermented and stored under anaerobic conditions. It is typically made from grasses or legumes and has less than 30% moisture content. When low-moisture silage is baled and wrapped it is called bale silage, a type of forage that is baled and wrapped to preserve for later use. The risk of seepage losses is higher in silages with high moisture content (i.e., effluent or leachate from the silage) due to the increased water content. This can lead to decreased feed quality and yield and increased storage and transportation costs. To minimize these losses, it is essential to ensile at the proper moisture content for the specific crop being harvested. Secondary silage fermentation can lead to butyric acid production, which in turn can cause the silage to develop a rancid smell. This is undesirable because it can make the silage unpalatable and may even lead to it being discarded. To prevent silage spoilage, monitoring the fermentation process closely and taking steps to control the growth of bacteria that can produce butyric acid is essential. Achieving strong packing at preservation varies by obtaining adequate density (high compactness). It is challenging to cope with haylage in dry fodder and remove gas. However, it is essential for maintaining anaerobic conditions by keeping enterobacteria and clostridia population density in check and reduced (T.F. Bernardes, 2018).

Silage is the preserved fodder of green plants, composed of herbage and other green leaves, used as animal feed. It is chopped and stored in an airtight environment, usually in a silo, to prevent spoilage and preserve nutrients. The primary purpose of making silage is to provide animals with a nutritious food source during periods when fresh grass is unavailable, such as during droughts (Kumar, 2019). In addition to providing a feed source, silage-making can also help farmers save money by reducing the need to purchase costly feed during periods of scarcity. Hay production, on the other hand, involves the harvesting and drying of forage crops for animal feed. The goal is to harvest the forage at the optimal time to ensure maximum nutrient content and minimal spoilage. To achieve maximum nutritional value, the forage should be cut when it has reached a suitable growth stage but before it has matured and developed tough stems. The forage should also be dried quickly and thoroughly to prevent mould and fungal growth (Mutwedu, 2020).

Hay comes in various types, which include grass hay and legume hay. Examples of legume hay are clover and alfalfa, are typically higher in protein and other nutrients than grass hay, making it a valuable feed source for livestock. Grass hay, such as timothy or brome, is also a good source of nutrition but typically contains less protein and other nutrients than legume hay (Kumar, 2019).

In summary, conserving forage is essential to ensure that livestock has access to nutritious feed during periods of scarcity. The choice of conservation method is influenced by several factors, such as the type of forage being conserved, the available storage facilities, and the intended use of the forage. Silage making and hay production are two popular methods of forage conservation. Silage making involves the fermentation of chopped forage in an airtight environment to preserve its nutrients, while hay production involves the harvesting and drying forage crops for animal feed. Both methods require careful attention to detail to ensure maximum nutrient preservation and minimize spoilage.

2.7.5 Key Practices and Considerations in Hay Production

Plants cut, dried, and stored as animal feed are called hay, which is a type of forage that is dried and used as animal food. Drying hay helps preserve the plants' nutrients, making it an ideal food source for animals like cattle, camels, and sheep and goats (Mumina Shibia, 2021). Hay can also be fed to rabbits, guinea pigs and pigs, although they need to efficiently digest it as they do not have rumens. Hay can be fed to animals that cannot access pasture grass, for instance, animals in stables during winter (Mumina Shibia, 2021).

The grass is cut in the field at the right time for optimal hay quality. Growers strive to maximise the quantity of hay they gather while optimising the quality by monitoring the dry matter (DM) content. The accumulation of DM is highest during the growing season and starts to peak towards the end. Typically, the quality of forage is inferior in the initial stages of the growing season, and it tends to get better towards the end of the season. This is likely because plants can store more nutrients as they mature. Cutting aims to determine the point at which the quality of the DM and the DM intersect. This point is typically determined by graphing the two variables and finding the point of intersection. For instance, when alfalfa grass has 10% flowers on the plant, it is ideal for cutting, as the point of DM and quality intersect to ensure optimal quality and yields. Many leaves mean the plant is healthier because more leaf material means more nutrients. Growers must mow before the grass grows old when the plants are still full of nutrients and carbohydrates before they reach their prime. Crude protein yields decrease as forages mature, but palatability and nutritional values are reduced immediately after the heading forage (anthesis stage). Therefore, farmers must harvest the hay to achieve a well-balanced and desirable quality (Donald Njarui, 2004).

Hay must also be cut at the start of a 3-5 days of bright sunshine to ensure optimal drying to make it suitable for livestock. The harvest height must be at its peak, or the cut will look extra rough or damage the plant. The swathing process helps ensure that long stubble remains, which in turn helps to promote air circulation to the windrows. This is beneficial as it helps to reduce the risk of windrows becoming compacted and difficult to manage. Swathing also helps to control weeds and pests and can improve the overall quality of the crop. Windrows are hay rows raked up to dry before being stored or baled (Njenga, 2018).

The utilization of swathes can additionally aid in the conditioning of hay by compressing the surface tissues or cuticles of the plants. This is done by breaking down these protective barrier layers, which exposes the plant to drying and other weathering forces (Kallenbach, 2022). As a result, the plant begins to lose moisture and nutrients, making it more susceptible to damage and death. A conditioning machine manipulates the plant material to break down the cell walls and release the essential oils. This process of "squishing" the plant material helps extract a higher-quality oil. This method clarifies nutrients and makes the digestive process easier for cows. The process of squishing can enhance both the pace and excellence of hay drying, resulting in a moisture content of approximately 15% (Kallenbach, 2022). Forage can be up to 90 % moisture, so much drying must occur. Forage stacked to ensure hay dries thoroughly, evenly, and completely. Turning the swaths (hay grass arranged in long lines) enhances drying out. Rolling out hay in a tumbleweed style (circular rolled) decreases leaf value and is not encouraged. Excessively hot weather conditions can lead to rapid dehydration of leaves. Brittleness leads to the loss of leaf matter and lowers the quality of hay. To facilitate the ruffling process, forage managers might discontinue irrigation a few days before swath collection to allow the plants and ground to dry out and to ensure suitable weather conditions (Kallenbach, 2022).

After drying, the hay is baled and stored for future use. The act of baling compacts the hay into smaller, more convenient bundles, safeguarding it against moisture and other forms of weathering. The size and shape of bales vary depending on the equipment used and the farmer's preferences. Small square bales, typically weighing 50-70 pounds, are popular in areas with limited storage space. In contrast, large round bales weighing several hundred pounds are more common in areas with more extensive livestock operations as shown in figure 2 (Kallenbach, 2022). The bales are stored in a dry and well-ventilated area, such as a barn or a shed. It is crucial to keep the hay dry, as excess moisture can lead to the growth of mould, which can be harmful to the animals that consume it (Oscar & Staline, 2021).

Figure 2: Hay rolled in tumbleweed style
Source: Denys Razumovskyi

In conclusion, producing hay involves several steps, including cutting, drying, conditioning, and baling. Each step ensures that the hay retains its nutrients and quality. Growers must monitor the dry matter content and the hay quality to determine the optimal time for cutting. Swathing and conditioning the hay help promote air circulation and speed up drying. Baling compresses the hay into smaller packages and helps to protect it from moisture and other weathering forces. Proper storage is crucial for maintaining the quality of the hay and ensuring that it is safe for animal consumption.

A hay rake is a tool for raking hay into windrows or turning over-drying windrows. This process is crucial for even drying, preventing rotting or moulding, and aerating the hay. The process of baling is typically carried out on dry grass, with square bales being utilized to condense feed into smaller portions (Fig. 3). For feeding cattle, round bales are employed, which are compressed tightly by a baler machine and can be picked up from the front (Fig. 2). The outer covering of the thatch layer on a bale of straw is usually around 5 cm (2 inches) thick, serving as a protective barrier for the inner layers of straw and preventing damage or dislodgment. Usually, the hay is arranged in stacks consisting of approximately 170 bales per pile for easy transportation and storage in a barn or shed, with the piles usually stacked on top of each other. Handmade hay boxes' dimensions can vary based on the hay bales they are meant to hold, with a width and length of 1.5 to 2 times the bale's length and width, respectively, and a height of approximately one-third of the bale's height for proper ventilation and even drying. Sisal twine, made from the fibres of the sisal plant, is used by farmers to secure hay into a tight bundle with a typical bale weight of around 15 kilograms (Ogillo B. P., 2017; Kallenbach, 2022).

Figure 3: Box hay stacked in a pyramid method in Kajiado County

2.8 The Sustainable Food Value Chain Approach

Policymakers have developed the sustainable food value chain approach, which involves three principles for measuring performance: (i) integration of environmental, economic, and social sustainability data, (ii) robust governance-based and market-driven, and (iii) aims to improve and scale the performance of the value chain by making it multistakeholder (FAO, 2021). The characteristics of the economy, ecology, and governance systems determine the sustainability of a value chain. Socially and economically inclusive value chains are necessary for small-scale businesses to benefit and participate like large-scale enterprises. Inclusive value chains allow small-scale producers to participate in the economy, benefit from economic growth, and promote economic and social empowerment (FAO, 2021). The sustainable food chain development strategy, which focuses on creating a more efficient and environmentally friendly food production system, includes the sub-component of the fodder value chain approach, which focuses on improving livestock feed quality and quantity, helping to reduce environmental impact and increase food production.

FAO (2021) states that evaluating the performance of a value chain across economic, social, and environmental dimensions can help identify the root causes of problems. In the fodder value chain, harvesting and drying are typically the first steps, followed by aggregation. In order for small-scale producers to access markets and receive support with pricing, information, and other resources, inclusive value chains require strong connections between them and the market. Developing sustainable growth and income interventions with all stakeholders can help reduce poverty among small-scale farmers, increase their sustainability and resilience to environmental disasters and climate change variability, and promote their economic and social empowerment (FAO, 2021).

2.8.1 The Fodder Production Value Chain Approach

The fodder value chain approach was developed by technocrats to understand the production and distribution of animal feeds and to make informed decisions on improving their availability and affordability (Fig. 4). Lessons from several case studies in different countries were used to identify the key activities and actors along the fodder value chain. (FAO, 2021).

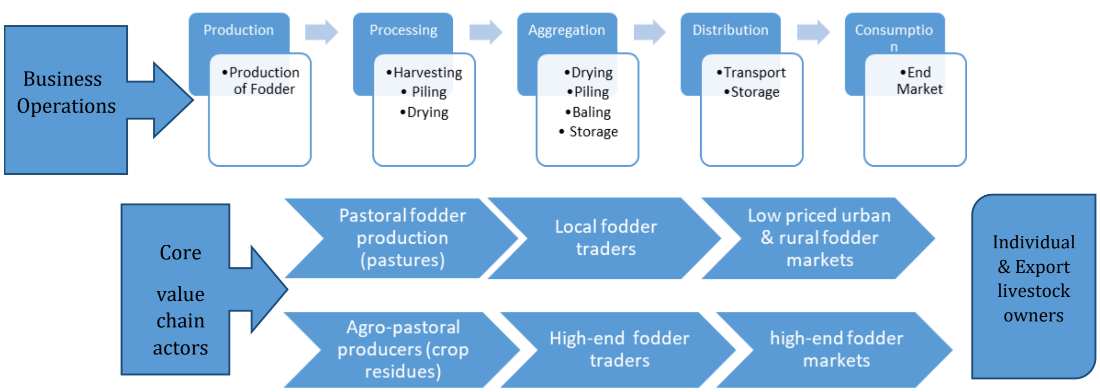

Figure 4: A structured illustration of the value chain for fodder, including its connections and participants (FAO, 2021)

In Africa, the fodder value chain encompasses the entire process from producing to distributing animal feeds to farmers and feeding their livestock to derive animal products. The chain begins with producing feed ingredients such as maize, soybeans, and hay, which are then processed into feed pellets, bales, or blocks and distributed to farmers through dealers or retailers. Livestock consumes the feed and produces meat, milk, and eggs that can be sold in local or international markets (Auma, 2018).

In the pastoralist livestock systems of Africa, hay plays a critical role in the fodder value chain by providing a high-quality, nutrient-rich feed source for livestock. Hay, made from dried grass, legumes, and other plants, is harvested during the early part of the growing season when the plants are most nutritious. It provides nutrients and energy to livestock and can improve their health and productivity. Moreover, it is a valuable source of income for pastoralists, sustaining their livelihoods (Auma, 2018).

2.8.2 The Fodder Value Chain in Kenya

Agricultural diversification is crucial for sustaining growth and ensuring resilient agrarian livelihoods. Agricultural diversification allows farmers to respond to changes in market demand, climatic conditions, and other factors affecting crop production. By diversifying their crops and adopting new technologies, farmers can increase their productivity and incomes while reducing risks. Agricultural diversification plays a crucial role in guaranteeing the sustainability of agriculture and securing the livelihoods of those dependent on it in the long run (USAID- KAVES,2017).

Kenya's landmass is approximately 83% ASALs, and only 17% of the land receives medium to high rainfall, which is suitable for crops. In Kenya, most farms are small. 87 percent of farms are less than 2 hectares, and 67 percent are less than 1 hectare. This is likely due to various factors, including the lack of access to land and capital and the limited availability of labour. Given the small size of most Kenyan farms, it is not surprising that they are relatively unproductive. In Kenya, 57% of the income is generated by the 20% of farmers, with minor holdings coming from farming. This could be attributed to the fact that these farmers require additional land and resources, thereby increasing their dependence on agriculture as a source of income. Simultaneously, Kenya's small farms face a precarious future, including a growing population, land-use changes, food shortages, increased poverty, and climate change (Kimongo, 2017).

When assessing the various actors involved in fodder production, it is crucial to consider the entire value chain approach. This means considering all the steps involved in producing fodder, from growing and harvesting the crops to transporting and selling the finished product. By understanding each actor's role in the process, it is possible to identify areas where improvements can be made to increase efficiency and optimize productivity (Auma, 2018). For arid areas and smaller-holder farmers, the quality and quantity of forages without expensive commercial feed can produce 20 litres of milk. This is because forages are a source of nutrients essential for milk production and are also relatively inexpensive. Commercial feeds, on the other hand, are often quite expensive and may contain only some nutrients necessary for milk production. Therefore, forages can be an excellent alternative to commercial feeds (USAID- KAVES, 2017).

In Kenya, especially in the ASAL, 55% of small farmers grow at least one fodder type. Fodder is the food fed cattle, pigs, goats, and sheep. The main types of fodder grown in Kenya are maize, sorghum, and millet. These crops are grown for both human consumption and animal feed. Small-scale farmers in Kenya often grow multiple crops to diversify their income sources and reduce risk (Auma, 2018). According to a recent study, Kenya faces significant shortages in livestock feed, especially forage intended for dairy cattle with a hay shortage of around 3.6 billion bales. This shortage is estimated to be worth 9 trillion Kenyan shillings. The reasons for this shortage vary, including climate change, poor agricultural practices, and a lack of investment in the hay industry. This shortage has devastated the Kenyan economy, with farmers struggling to keep up with demand and prices skyrocketing (USAID- KAVES,2017). The demand for hay will increase due to the increasing demand for fodder by other countries, according to the Ministry of Agriculture, Livestock, and Fisheries (MoALF) in 2017. Other factors contributing to this demand are the increased price of hay and the increased number of livestock (MoALF, 2017).

Despite the growing demand for fodder in Kenya and globally, the fodder value chain in Kenya faces various challenges. These include low-quality feeds, inadequate processing and storage infrastructure, and limited market access. Additionally, there needs to be coordination among the different participants engaged in the value chain., which leads to inefficiencies and low productivity (USAID-KAVES, 2017).

To address these challenges, various initiatives have been implemented. For example, the Kenya Agricultural and Livestock Research Organization (KALRO) has new technologies for improving the quality and yield of fodder crops. These technologies include high-yielding varieties, better crop management practices, and improved post-harvest handling. Additionally, the government has established various policies and programs to support a robust fodder value chain, such as the National Livestock Policy and the Livestock Development Fund (MoALF, 2017).

The indigenous perennial grasses of Baringo County provide a significant source of income for the local population. Each year, 10 tons of these grass seeds are harvested and sold, generating 1.5 million Kenyan shillings in revenue. This is a significant contribution to the local economy and underscores the importance of indigenous plants in supporting sustainable livelihoods. For instance, 1kg of grass seed in sells for KES 350 in Baringo County, while in Makueni County, a kilo sells for KES 1000. Rye seed can fetch as high as KES 1800 per kilogram. In addition, there are ecological benefits arising from rehabilitating degraded lands through pasture growing and enclosures (Ouma, 2017).

Smallholder dairy farmers in Kenya cultivate a range of fodder crops and sell any surplus to their neighbours and local markets. The most widely grown varieties include Napiergrass, Boma Rhodes grass, and natural grasslands, with Napier grass being the most dominant. Hay from Napier grass or Boma Rhodes grass and Lucerne are the most traded fodder. However, the introduction of Brachiaria grass, a drought and pest-tolerant forage grass, in Makueni, Kitui, and Taita Taveta counties, has improved the productivity of small-scale farmers by providing a more dependable source of feed for their livestock. This grass was developed as part of a collaborative research project involving the International Livestock Research Institute and international partners. In addition, some parts of Makueni County have seen the emergence of commercial maize silage production (Auma, 2018).

Seed-input merchants are the first link in the fodder value chain, providing farmers with seeds, planting materials, and other inputs (Nangole, 2013). This group includes agro-vet retailers, cooperatives, and state institutions like the Kenya Agricultural Research Institute (KARI), Kenya Farmers Association (KFA), and the Kenya Seed Company. Livestock farmers engaged in fodder production may sell cattle and fodder or grow hay for their cattle and sell only the surplus. Middlemen traders connect individual hay farmers with buyers in local markets, such as roadside fodder markets, agro-vets, general shops, and cooperatives. Prominent traders source hay beyond the district, supply smaller local traders, and participate in trading as wholesalers or retailers of hay. More prominent traders also own trucks that buy hay inputs in bulk and deliver them to smaller markets for small hay farmers to access and purchase. These more prominent traders are diverse and include commercial cooperatives and companies operating ships, tractors, trucks, locomotives, motorcycles, and bicycles. These traders benefit most from feeds from local communities and nearby markets as they can bulk the hay, enjoy economies of scale, and maximize their profit margins (Nangole, 2013).

Feed the Future Innovation Lab, a USAID-funded program, partners with the Bill and Melinda Gates Foundation to improve livestock production in developing countries by creating new technologies and methods to strengthen livestock farming, nutrition, and health. One of the program's primary goals is to help farmers in developing countries become more self-sufficient and reduce their reliance on imported food products. Feed the Future Innovation Lab aims to achieve this by increasing access to better feeds, vaccines, and other interventions (Balehegn, 2020).

2.8.3 Challenges facing the Fodder Value Chain

In West Pokot, Baringo, and Southern rangelands, various studies have examined the role of hay in household income (Ouma, 2017). The findings from earlier research varied, depending on the socio-demographic characteristics of the participants. To ensure appropriate fodder production in arid areas, it is crucial to generate information that is specific to the location. This information can help assess the potential for fodder production, identify factors influencing fodder uptake, and determine the most appropriate management practices to maximize production. Climate, soil, topography, and water availability must be considered (Ouma, 2017).

While feed and fodder are critical in livestock production, few studies comprehensively analyse the animal compound feed and fodder value chains (Auma, 2019). Existing studies mainly focus on manufactured feeds, fodder production, and marketing policy and regulation concerns, neglecting other aspects of the value chain. Fodder production in Kenya's drylands faces several constraints, such as high input costs, poor seed quality, weed problems, and capital limitations, all of which must be carefully considered to ensure a successful outcome (Smith, 2019).

Although some challenges exist, livestock keepers and traders in Kenya have experienced advantages from fodder marketing (Ouma, 2017). The primary constraint is the need for more reliable price information, making it difficult for farmers to determine when and where to sell their fodder. The lack of transportation also makes it difficult for farmers to get their fodder to market. Despite the obstacles, fodder marketing has been beneficial for many livestock keepers and traders. Significant variation in grass seed prices across different locations indicates that the markets need to be more streamlined and regulated (Ouma, 2017).

2.8.4 Proposed Solutions

A value chain approach is valuable for identifying and addressing specific issues, although it can be complex as it involves several value chains. Currently, most support for the fodder value chain is directed toward the fodder production component. It is provided by NGOs and government bodies, with the private sector needing to be fully engaged in the hay-growing part of the hay value chain. For instance, in 2017, by utilizing a value chain approach, the Kenya Agricultural Value Chain Enterprises (USAIDKAVES) project funded by USAID aimed to identify challenges facing actors in producing and supplying compounded feeds and fodder for dairy cattle (Auma, 2019). In the same vein, the Enhanced Livelihoods in the Mandera Triangle (ELMT) initiative assisted pastoral communities in Mandera County by educating them and providing resources for fodder farming, resulting in an increase in their fodder output to feed their animals. Any surplus was then sold to generate additional household income. Supporting fodder growers in Baringo County has provided feed for cattle, improving livelihoods and reducing community conflicts over grazing areas (Ouma, 2017).

The Kenya Agricultural and Livestock Research Organization (KALRO) has programs to support hay growing and other fodder value chains, including fodder marketing. For example, KALRO provides improved fodder seeds that can grow in the drylands, makes hay forage available during droughts, and sells the surplus when the demand is at its highest. The few growers with a surplus can take advantage of the increasing demand for fodder as many livestock keepers cannot grow and preserve enough fodder on-farm, creating a demand for hay and a new commercial fodder sector in Kenya (Auma, 2018).

Extreme and unpredictable weather patterns can cause insurmountable financial losses in agriculture. The impacts of climate change are felt throughout the Food Value Chain (FVC), affecting everything from seed quality and planting to processing, transportation, and consumption of food. To increase the resilience of the fodder value chain to climate change, the World Bank, FAO, International Institute for Sustainable Development, Oxfam America, World Food Programme, and other industry players use a value-based approach (Vangimalla, 2017).

2.9 Evaluation of Agriculture Sustainability, Climate Change Adaptation and Ecosystem Services.

2.9.1 Evaluating Agricultural Sustainability under UNSDG 2.4.1

The Sendai Framework aims to reduce risk, enhance resilience, and prevent disasters for communities and their productive assets (UNDRR, 2015). Traditionally, disaster responses focused on protecting people; however, the Sendai Framework emphasizes reducing the risks people and systems face, particularly for the poor and most vulnerable populations. The framework recommends investing in disaster resilience by protecting and enhancing capacities to protect people's ability to make a living and their assets that contribute to productivity, such as livestock, working animals, tools, and seeds.

The United Nations' Sustainable Development Goal (UN-SDG) Goal 2 aims to eradicate hunger, promote sustainable agriculture, ensure food security, and improve nutrition. Target 2.4 specifically focuses on the development of sustainable and resilient food production systems that enhance productivity, efficiency, and production while preserving ecosystems and promoting climate change adaptation. FAO's (2020) Indicator 2.4.1 measures the proportion of agricultural areas that practice sustainable and productive agriculture (FAO, 2020).

In 1988, the Food and Agriculture Organization defined sustainable agriculture as the management and conservation of the natural resource base of the soil and its adaptation to technological changes to satisfy human needs sustainably. These activities are non-degrading, technically appropriate, economically viable, and socially acceptable, and they conserve land, water, plant and animal genetic resources. However, assessing the impact of agriculture can be challenging because the concept and its specifics vary by location and continuously evolve. Since sustainability measurement is context-specific, a single tool would not be sufficient for comparing agricultural sustainability across countries. Therefore, a recommended approach is to establish an environmentally relevant set of context-specific indicators that enable countries to compare their agricultural sector's status with others.

In 2015, the FAO recommended the establishment of universal performance metrics to ensure that all relevant variables were related to the socio-economic and bio-geographical conditions of each country. This set of metrics enabled the attainment of internationally comparable results, while individual countries were free to supplement the official global indicators with metrics that were not limited to this core set. It has been suggested that a new set of context-specific indicators be introduced for various contexts to enable countries to compare the sustainability of their agricultural sectors. UN-SDG selected farm surveys as a measurement instrument to capture sustainable agriculture production because it was flexible and practical in helping countries identify priorities and challenges within the three sustainability areas: environmental, economic, and social. Farm surveys carried out in pilot countries elaborated the three broad areas - environmental, economic, and social - into six specific sub-areas to help standardize measurement. The areas selected are policy relevance, measurability, cost-effectiveness, state of the environment, and economic and social factors associated with the flow of costs or benefits and awareness, practice, perceptions, and knowledge of those engaged in the value chain. Table 1 illustrates how indicator 2.4.1 has 11 sub-indicators to quantify better and measure the indicator (FAO, 2020).

Table 1: Sub- Indicators Economics, Environmental, and Social under UN-SDG Indicator 2.4.1

Sub-Indicator	Aspect Measured
Land productivity	Value of farm output per hectare
Profitability	Net farm income
Resilience	Risk mitigation approaches
Soil health	Degree of soil degradation
Water use	Water availability and access
Fertiliser pollution	Control of fertilizer usage
Pesticides	Control of pesticides usage
Biodiversity	Biodiversity- practices
Decent employment	Wages
Food security	Food insecurity experience scale (FIES)
Land tenure	Land secure tenure rights

Source: FAO

A 2018 study in Molvania found that out of the 11 sub-indicators for indicator 2.4.1, profitability (40%) and the lack of resilience (35%) were the most significant constraints to agricultural sustainability. Based on this, UN-SDG recommended that profitability be used as a standalone measure to determine agricultural sustainability (Gennari & Kalamnrezo, 2019).

The investigation of the expenses and returns associated with hay production in the pastoral livestock industry in Kajiado will provide insights into the economic sub-indicators of the sustainability measure for agriculture Indicator 2.4.1. It will shed light on three of the 11 sub-indicators, namely, (1) land productivity, which is measured by the output value per hectare, (2) profitability, which is indicated by the net farm income, and (3) resilience, which pertains to the mechanisms in place to manage risks.

2.9.2 Evaluating Climate Change Adaptation in Agriculture

There are two approaches to evaluating the viability of projects to adapt to the adverse effects of climate change. The first approach involves assessing climate change's costs on agricultural production, assuming only autonomous adaptation. In contrast, the second approach estimates the costs and benefits of planned adaptations, including technological, institutional, behavioural, economic, and structural changes. When assessing the possible effects of climate change on agriculture, two modelling methods have become prevalent, that is, in-country studies and evaluation of impact models and adaptation in agriculture: the agro-ecological (agricultural) and the Ricardian (hedonist) models (Fezzi, 2013).

Biophysical crop-production models simulate plant-soil-atmosphere elements known to affect crop production and allow an accurate assessment of how climate change affects agricultural productivity, making them helpful in researching the potential effects of adaptation strategies. The Ricardian theory of land values, which asserts that land's long-term viability is reflected in its value, is consistent with economic theory. The Ricardian method uses cross-sectional data to evaluate the effects of various factors on the value of land. Notably, the Ricardian method accounts for net climate influences when finding longer-term climate impacts. Evaluating the two approaches independently can help researchers determine which one to use for their intended purpose (Prevention Consortium, 2008).

In addition to these two approaches, a method has been developed within the disaster risk reduction field and the benefits of adaptation efforts for estimating expected economic losses due to climate change caused by climatic extremes such as floods. Although initially developed for natural disasters, researchers can adapt the technique to other disasters (Prevention Consortium, 2008).

Researchers can employ various methods to estimate the economic benefits of agricultural innovations, including estimating anticipated economic losses associated with climate change. In determining adaptation costs, one approach is to examine costs of past projects that have effectively financed comparable adaptations through an extensive documentation analysis. When conducting monetary evaluations, co-benefits are also important to consider in adaptation projects, especially when they are in the form of public goods. For example, investment in improved water management to reduce resource-based conflicts among pastoralists can further reinforce agricultural adaptation efforts (World Bank, 2010).

Decision-makers often need to compare various options in various situations, and agricultural practices and climate change are no exception. Comparisons of adaptation projects can help reduce climate change on several interrelated social, ecological, economic, and impact indicators. Researchers can account for uncertainty by analysing the possible scenarios of events and their likely corresponding results. Specific adaptation initiatives' cost-effectiveness can be estimated by examining whether they reduce the risks and projected losses related to an adverse agricultural impact. Another approach concerning financial evaluation resulting from uncertainty is real options analysis, which considers a mixture of complexity. One approach to estimating the economic benefits of agricultural innovations is to consider the potential impacts of climate change on economic losses. Additionally, the costs of adaptation measures can be estimated based on past projects that successfully implemented the same adaptations. When evaluating adaptation projects, it is important to consider co-benefits that cannot be easily reflected in monetary valuations, especially if they have the nature of public goods. For instance, investment in enhanced water management can help reduce resource-based conflicts among pastoralists and strengthen adaptation in agriculture. Examining a project's potential to enable a community to remain in place rather than migrate due to future climate change is another way to evaluate risk. Robust decision-making (RDM) is a decision-analytic method that can provide a quantitative approach to evaluating various actions. By generating thousands of probabilities based on the consultant's estimation, RDM can help systematically assess the performance of different actions. (World Bank, 2010).

Inadequate time, money, and data limit the methods discussed here. However, investing in a more in-depth analysis of adaptation to the local climate can be beneficial when deciding on crops to grow and designing project components to promote beneficial outcomes. Simplified versions of some methodologies exist to examine project-level data.

An agronomic or crop model is a tool used in agriculture to simulate the growth, development, and yield of crops under different environmental and management conditions. Building biophysical crop models allows for monitoring and analyzing crop productivity, climate change effects, and adaptation, among other factors. These models consider agronomic practices including changes to planting and harvesting techniques, fertilization methods, irrigation practices, crop rotation, and adjustments to cropping patterns. They can also be integrated into more complex models, including climate, water balance, plant production, and economic modules. Agronomic models can be used to determine the vulnerability of local or regional agricultural production systems to the impact of climate change to potential decrease in crop yields. These models consider seasonal dynamics and inter-annual variability of climate factors and predict the impact of floods and altered land conditions. Furthermore, agricultural models can incorporate economic components to evaluate how climate change may affect agriculture economically and identify adaptation practices that can help farmers mitigate financial losses (World Bank, 2010).

While cost estimates at the farm level can be accounted for when autonomous adaptation is considered, the costs of a reservoir planned for irrigation cannot be included in the farm-level assessments as their costs often fall on individuals or groups of farmers. These fiscal models are flexible and can be modified to reflect regional conditions more accurately, with yield outputs used as inputs to be modelling frameworks that estimate the economic benefits associated with farmer production or income. Nevertheless, it is crucial to calibrate the historical relationships between independent variables like soil profile, management practices, climate data, and production output when using such models for project-level analysis Overestimating the consequences of climate change can occur, as these relationships need to account for the adaptation capabilities of affected farmers whose actions are being modelled (World Bank, 2010).

One challenge is the bias that arises from the damage caused by crop models. Climatologists often underestimate the effect of without-project damage on change. Models overestimate the positive impact of planned adaptation, partly because autonomous adaptation already offsets some impact of unfavourable climatic changes (World Bank, 2010). The range of options available for people studied to carry out autonomous adaptation will determine the seriousness of this bias. Similarly, estimating the contribution of soft adaptation efforts, which change soil moisture, rainfall, temperature, and other variables related to agricultural output, can be challenging. The models require data such as soil profile, weather, and local management information throughout the project. The costs of benchmarking and running a model may be substantial regarding time and resources. However, if data is unavailable, less data-intensive agro-meteorological calculations, such as crop evapotranspiration, can be used to assess impacts on crop yield (World Bank, 2010).

The Ricardian technique is a method that evaluates the long-term consequences of climate differences on the value of agricultural land. It assumes that land productivity over time is reflected in its asset value. Assuming given weather patterns, prices of factors, and other limitations, the observed annual net revenue from selling crops or livestock will be equal to the farm rental for the land (or farmland value). The Ricardian method uses cross-sectional data from farmland located in various areas at a specific time to calculate the impact of other variables, including socio-economic characteristics, soil quality, and geographic features, on land value. This method can be used to assess the effect of climate conditions, such as temperature or precipitation, on farmland value and productivity, providing insights into the effects of climate change on farmland value (Seo, 2009).

Moreover, this method has also been used to examine the longer-term implications of climate variability on dynamics around livestock market. An advantage of this approach is that it considers the adaptive responses farmers may make to changing weather conditions. The method posits that changes in ambient climate will result in the geographic redistribution of agricultural activity based on how farmers adapt to varied climate circumstances in different locations (World Bank, 2010).

Analysing the economic aspects of climate adaptation projects presents various challenges, especially when assessing the costs and benefits of such projects. To promote clarity and consistency in the literature, it is essential to standardize the terminology used to describe disaster risk management. The concept of risk to disasters refers to the likelihood that a household or social unit will experience losses, which can be quantified using a range of metrics due to the impact of external factors such as climate change. To determine the potential losses, factors like vulnerability to risk and exposure also have a significant impact. After implementing both internal and external risk management strategies, the success of a project will depend on its vulnerability, risk level, and effectiveness of its risk management strategies. Climate change adaptation is a type of risk management strategy that can help to mitigate potential losses (Prevention Consortium, 2008).

Households or governments can implement various adaptation activities, and the degree to which the outcomes of these activities are considered a public good can vary. Examples of physical adaptation efforts include investments in physical infrastructure and natural resources, such as irrigation and terracing of land. Meanwhile, soft adaptation efforts involve investments in human capital, such as literacy training, veterinary services, and healthcare. Each type of financial investment requires a unique evaluation style that considers the anticipated effects of a behaviour shift on the social and economic sectors. By anticipating the potential impact of changes in behaviour, it is possible to accurately value the different aspects of social and economic investments (Prevention Consortium, 2008).

2.9.3 Evaluating Ecosystem Services

Ecosystem services refer to the advantages humans gain from ecosystems, including provisioning services such as food and water, regulating services such as pollination and climate regulation, supporting services such as soil formation, and cultural services such as recreation and aesthetic enjoyment, as explained by Pascual (2017).

The concept of ecosystem services is essential for several reasons. First, it provides a way to value the benefits that ecosystems provide to humans. The knowledge about the supply of ecosystem services is greater than the understanding of the demand from beneficiaries of various ecosystem services. The function of ecosystem services from rangeland landscapes varies over time and space. This variation is due to several factors, including the geographical location of the landscape, the type of ecosystem present, and the time of year. For example, a rangeland landscape in the arctic tundra will have different ecosystem services than one in the Congo rainforest (Pascual, 2017).

To gain a comprehensive understanding of the demand for specific ecosystem services in various landscapes, it is crucial to enhance our comprehension of the beneficiaries' groups. The human driving factors of demand and supply within ecosystem services in rangelands can be understood by looking at the various stakeholders involved and their respective interests. For example, on the demand side, some value the benefits of rangelands (e.g. for grazing, recreation, or aesthetic reasons) and are willing to pay for them. Another example is the ecosystem service in grasslands provision of clean water. The supply of this service depends on the ability of the ecosystem to filter pollutants and maintain a consistent flow of water. The demand for this service increases as the population grows, and climate change renders other water sources less reliable. To meet this increased demand, the ecosystem must adapt to changes in temperature and precipitation (Armitage, 2012).

Similarly, the demand and supply of grasslands for wildlife habitats depend on the proportion of the urban population pushing into the grassland (the driver) and the sensitivity of grasslands to compensate for adverse effects of urbanisation and still maintain the wildlife (the response to the driver) (Yahdjian, 2015). There is also a need to understand what rangeland stakeholders want from grasslands at different levels, from local to regional. This understanding will help develop management strategies that consider the values and perspectives held by those vested in these landscapes. Clarifying rangeland stakeholders' preferences will also help identify potential conflict areas and possible win-win solutions. Stakeholder needs and want can range from as small as a local paddock to counties to cross-border livestock movement across regions and national boundaries. The concept of ecosystem services helps guide how the stakeholders will balance their cultural needs against the fauna and flora of the grasslands (Yahdjian, 2015).

In the past, business guidelines for ecosystem services were used to supply a defined niche. However, this approach is no longer sustainable, as it fails to consider the dynamic nature of ecosystems. A comprehensive approach is required to acknowledge the significance of ecosystem services in promoting human welfare (Sala, 2017). To ensure the sustainable use of ecosystem services, businesses can adhere to the guidelines laid out in the Business Guide to Ecosystem Services. These guidelines aim to help businesses comprehend the value of ecosystem services and integrate them into their operations while minimising adverse impacts and maximising positive contributions. The guidelines also provide a framework for businesses to engage with stakeholders to identify opportunities for collaboration and mutually beneficial outcomes (Berkes, 2009).

Governance and socioeconomic conditions contribute to this theoretical framework. Ecosystem governance is the process by which stakeholders unite to manage and protect an ecosystem. This process often requires cooperation between multiple jurisdictions, as stakeholders may have different interests and priorities. Ecosystem governance must consider the needs of all stakeholders and find a way to balance these needs. This consideration can be facilitated by effective communication, negotiation, and collaboration between stakeholders (Bodin & Crona, 2009).

Furthermore, socioeconomic conditions can impact the effectiveness of ecosystem governance. In some cases, economic incentives or disincentives can encourage or discourage behaviours that may impact the ecosystem. For example, a government may offer financial incentives to farmers who adopt sustainable agricultural practices that help protect nearby wetlands (Stern & Holder, 2014). Similarly, regulations can be implemented to discourage harmful activities, such as pollution, that can damage ecosystems (Repetto & Austin, 1997).

Overall, the theoretical framework of ecosystem governance considers ecological and socioeconomic factors to promote the sustainable management of ecosystems. By considering the needs of all stakeholders and finding ways to balance competing interests, ecosystem governance can help protect and preserve ecosystems for future generations. Fig. 5 illustrates the interaction between ecosystems, ecologies, and services sourced from rangelands.

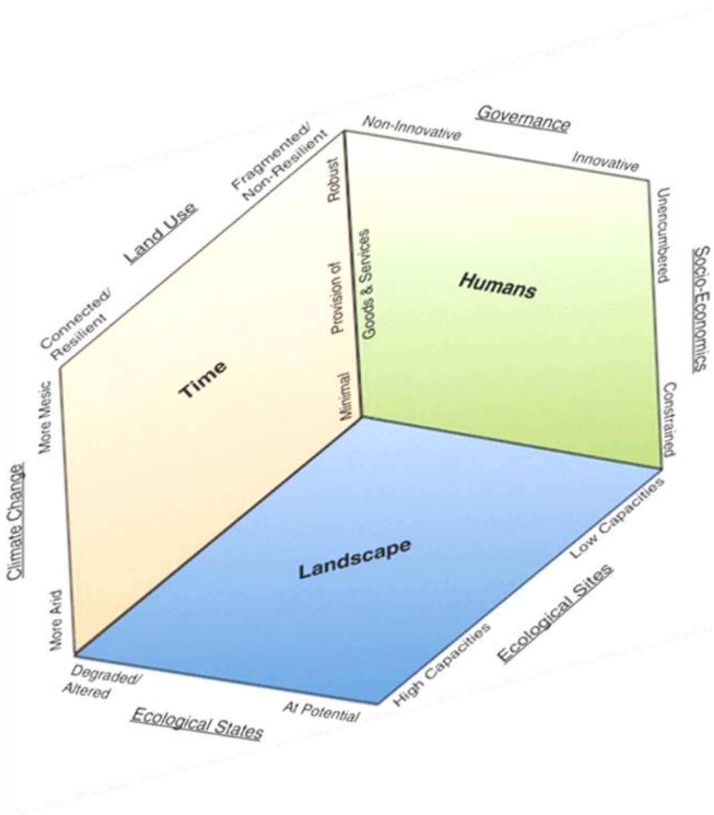

Figure 5: Conceptual diagram of ecosystem, ecologies, and forfeitable services sourced from rangelands (Sayre, 2013)

The formulae of measuring land use in ecosystem services:

Land use=∫∑nj=1[(ESjsupply), (∑mi=1(ESjDemandstakeholder i∗PoliticalPowerstakeholder i))]Land use=∫∑j=1n[(ESjsupply), (∑i=1m(ESjDemandstakeholder i∗PoliticalPowerstakeholder i))]

The management of rangeland, like other forms of land use, is influenced by the availability of various ecosystem services (ES) ranging from ES1 to ESn. In addition, the overall demand for these ES from i to m also plays a crucial role. The allocation of these services to different stakeholders is further determined by their respective political influence.

2.10 Gaps in the Literature Review addressed by the Study

The review of existing literature highlights numerous challenges facing rangelands in Kenya, which undermine productivity and threaten the stability of livelihoods. These challenges include climate change, persistent droughts and floods, land degradation, rural-urban migration, and biodiversity loss. Pastoralists, who rely heavily on rangelands, encounter various issues such as insufficient access to forage and water, encroachment of crop production onto pastoral land, land alienation, inadequate commercialization infrastructure and markets, poor extension service delivery in arid and semi-arid lands (ASAL), and limited research on rangeland resources. Moreover, the absence of a suitable regulatory framework and the threat of insecurity pose additional challenges.

Despite the potential benefits of hay production in promoting sustainable development and adaptation to climate change, there is a gap in the literature on the feasibility of hay production as a private enterprise. Therefore, there is a need for economic data to ensure that policies aimed at encouraging private sector involvement in range management and climate change adaptation programs are successful.

To fill this literature gap, this study seeks to provide economic data on the viability of hay production and the factors driving hay demand from the perspective of pastoralists in the arid regions of Kenya. By analyzing how policies translate into actions that improve livestock productivity and resilience in these regions, this study will make a significant contribution to the existing literature. Additionally, this study will focus on the challenges faced by hay farmers while examining their contributions to the broader rangeland ecosystem.

2.11 Theoretical Framework

2.11.1 Theoretical Framework for Agricultural Sustainability under UNSDG 2.4.1

The Theoretical Framework for Agricultural Sustainability under UNSDG 2.4.1 acknowledges that while there is no complete measurement of the different dimensions and aspects of agricultural sustainability, the SDG indicator 2.4.1 provides a consensus perspective from policy practitioners, academics, and statisticians for measuring the sustainable development of the agricultural sector (Seré et al., 2020; Tilahun et al., 2017). This indicator involves a specific set of metrics agreed upon internationally, selected through a sound and practical methodological process that includes thresholds presented with a consensus from scientists. The theoretical framework offers a comprehensive, practical, and non-exhaustive system of assessment for the sustainability of farms and the overall agricultural sector. It addresses practical methodological procedures while considering essential factors and dimensions of agricultural sustainability, including environmental, economic, and social sustainability. This framework focuses on hay growing and not other aspects of the hay value chain. It encompasses environmental issues related to fodder production systems used in Kajiado and covers the economics of hay production.

The study on the cost-benefit of hay production in the pastoral livestock sector in Kajiado will contribute to the agriculture Indicator 2.4.1 sustainability measure in economics. The study's specific contribution will focus on three of the 11 sub-indicators, which are (1) Land productivity measured by farm output value per hectare, (2) Profitability assessed by net farm income, and (3) Resilience gauged by risk mitigation mechanisms.

2.11.2 Theoretical Framework for Climate Change Adaptation

The Theoretical Framework for Climate Change Adaptation recognizes that assessing all aspects contributing to hay profitability at the farm level and then comparing them to other farms within the same country, region, or globally is daunting due to the site-specific nature of the variables affecting the calculation. To address this challenge, the study adopts the theoretical framework from the World Bank agronomic models, which uses the Ricardian (hedonic) models to analyse how crop productivity, specifically hay, is affected by climate change (drought), adaptation technologies (growing hay in arid areas as a drought risk reduction strategy), and behaviour change and practice (supply and demand for hay). The agronomic models also consider the seasonality of demand and supply of hay, traditional pastoralist practices like drought migration, factors affecting the quality of rangeland grasses, and support given to hay production and other ecosystem services like carbon sequestering and wildlife conservation (World Bank, 2010).

The theoretical framework identifies environmental, social, political, and climate-related factors determining whether fodder grass growing is economically viable for the farmer. The agronomic analysis method is flexible enough to allow the researcher to consider how other on-farm hay production practices can benefit pastoralists and wildlife and how hay production can have positive carbon-sequestering practices. The flexibility of these fiscal models is beneficial as they can include, modify, or omit modules to reflect regional conditions in more detail accurately. At this stage, yield outputs can take on the position of inputs to modelling frameworks that estimate the economic benefits associated with the production or income of farmers.

2.11.3 Theoretical Framework for Ecosystem Services

The Theoretical Framework for Ecosystem Services acknowledges that hay production methods in Africa range from no-till (using local indigenous grasses) to cultivated crops like Boma Rhodes grasses. The grasslands used to grow hay provide services to free-ranging livestock and wildlife and to the communities that live there, who use these areas for hunting, beekeeping, and gathering wood. Grasslands also generate significant revenue from tourism and mineral exploration at the government level. No-till grasslands are also highly effective at sequestering carbon.

For researchers to assess the effectiveness of hay production from an ecosystem service perspective, including carbon sequestering, it is essential to focus on land use and competition for land use from livestock, wildlife, and people. Therefore, the cost-benefit of hay production must consider the ecosystem services from an opportunity cost perspective and a socio-cultural perspective. The study also incorporates the impacts of hay production on the ecosystems into the study design.

2.12 Conceptual Framework

Hypothesis testing is a statistical method that evaluates the validity of a hypothesis or statement. In this study, the hypothesis is that improved hay production practices and supportive policy and institutional frameworks can enhance the economic viability of hay production in pastoralist systems in Kajiado County, Kenya, making it a sustainable option for livestock feeding and income generation in the face of climate change-induced droughts. To test this hypothesis, the study proposes using the conceptual framework presented in the study.

The conceptual framework identifies the dependent variable as the quantity of hay production, which is influenced by independent profitability variables. The number of hay bales sold determines the viability/profitability of the hay enterprise. Independent variables include demand drivers, such as pastoralist buying behaviour and the severity of drought, and supply drivers, such as capital costs of buying machinery and building barns and irrigation, rain-fed versus irrigated hay, hay cultivation practices, acreage under hay growing, adequate market demand for hay, and the availability of extension services for hay growers. Additionally, the independent variables also impact ecosystem factors such as wildlife conflicts, invasive weed species, risk hazards like fire, locusts, armyworms, climate variability, and drought cycles. By measuring these drivers, the study aims to determine whether improved production practices, supportive policies, and institutional frameworks lead to greater economic viability. The conceptual framework also highlights the presence of mediators, factors that could influence the relationship between independent and dependent variables. Therefore, by considering these mediators, the study aims to obtain a more nuanced understanding of the relationship between improved hay production practices and economic viability (Fig. 6):

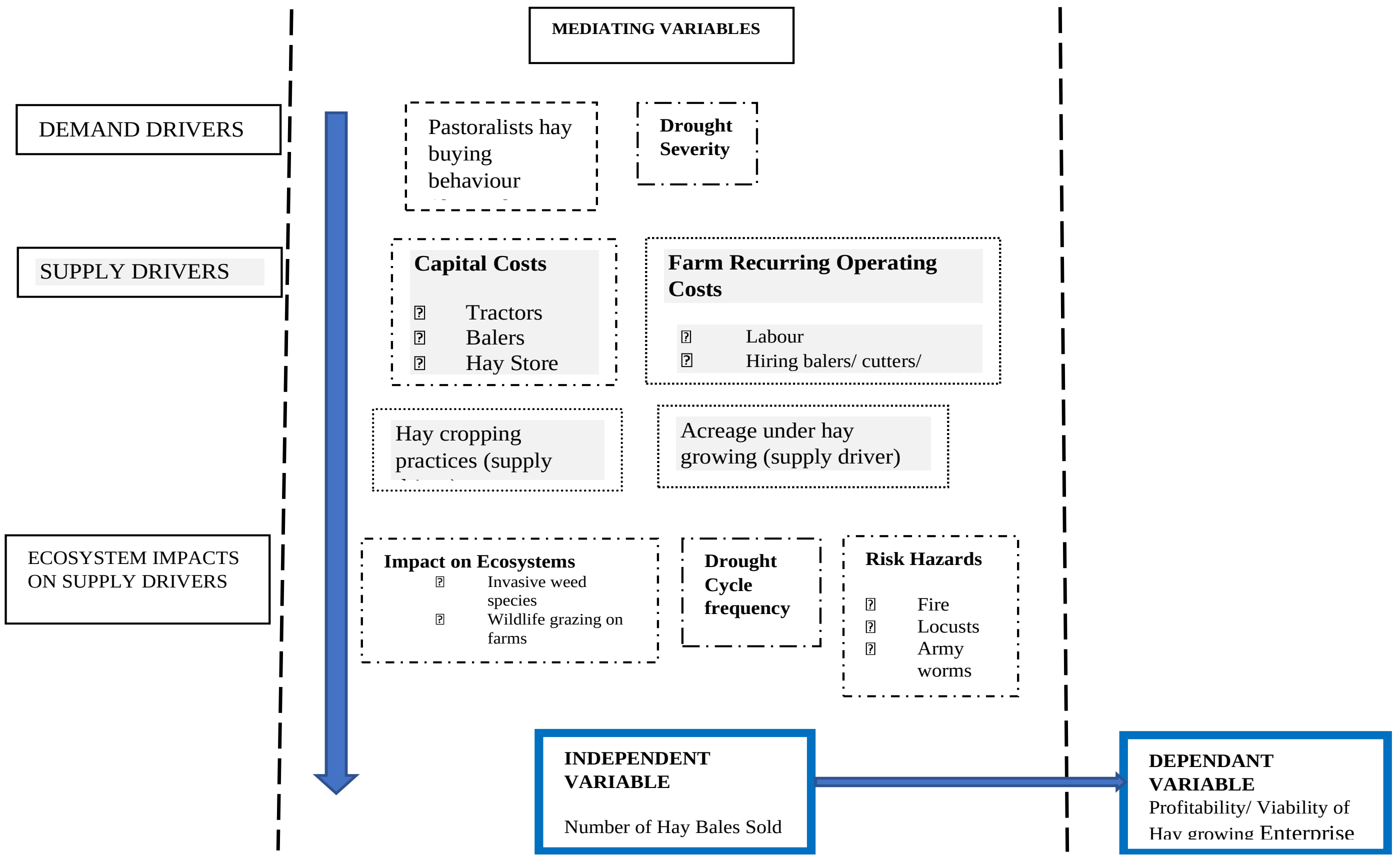

Figure 6: Conceptual framework for the study

The formulae of profitability were derived through consensus, and practitioners and researchers have proposed that net profit be used to calculate the profitability in the agricultural sector. The most commonly used formula is:

Net profit = *Gross farm income – costs*

This net profit refers to the gross income of the farms, represented by the gross farm receipts or the total revenue from the farm. It includes the net profit by excluding all of the production and operation costs of running the business (Reid *et al*., 2014 and Schilling *et al*., 2012).

Furthermore, the internal rate of return also provides an effective formula to calculate the extent of agricultural profitability; in the formula provided below, NPV represents the net present value, whereas N represents the total number of periods. Furthermore, n represents the non-negative integer, C_n represents the cash flow, whereas **r** represents the internal rate of return (Seré *et al*., 2020; Tilahun *et al*., 2017).

$$NPV = \sum_{n=0}^{N} \frac{c_n}{(1+r)^n} - C_O$$

C_n=Net cash inflow during the period t

*C*0=Total initial investment costs

r=The internal rate of return

t=The number of periods

An alternative formula that can be implemented and utilised to calculate the profitability of the agricultural sector is the net present value formula; it is presented below where Rt represents the net cash flow at the time t, i represents the rate of discount, whereas t is describing the time of the cash flow.

$NPV = R_t / (1+i)^t$

Moreover, the formula of return on investments is also used to determine the extent of agricultural sector profitability. It involves the following formula: the net profit is divided by the total investment, then multiplied by 100 (Seré et al., 2020; Tilahun et al., 2017).

ROI = *Net Profit / Total Investment * 100*

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Study Area

The research was carried out in three sub-counties of Kajiado County, namely Oloili茂loi, Kajiado Central, and Mashuru. Kajiado County has a total of seven sub-counties, namely Kajiado East, Kajiado West, Kajiado North, Kajiado South, Kajiado Central, Oloiliiloi, and Mashuru. It is a vast region covering approximately 19,600 km2 and is inhabited by a significant number of animals, with over 90% under pastoralist systems. Other economic activities in the area include crop farming, mining, tourism, and manufacturing. Kajiado Central, which has a population of 372,335 people and 584,643 livestock, is among the five sub-counties in Kajiado County. The region is mostly arid and semi-arid, with an average annual rainfall of between 300 and 800 mm and temperatures ranging from about 34°C around Lake Magadi to 22°C in Ngong Hills (Fig. 7).

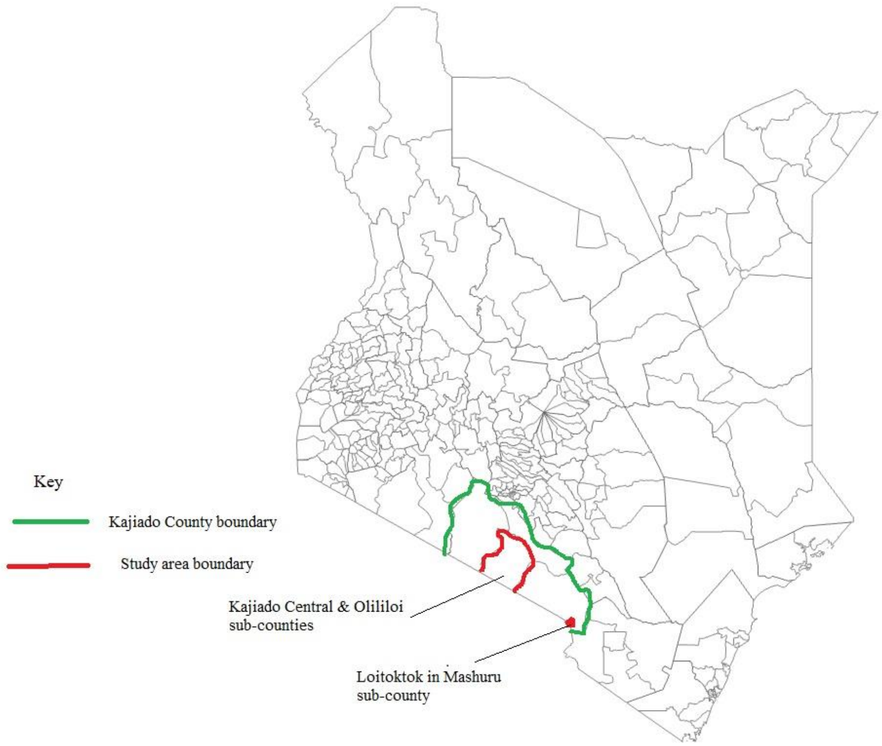

Figure 7: Map of Kajiado County in Kenya

3.2 Research Design

To collect data from 2015 to 2021, a non-experimental research design with a cross-sectional approach was employed in this study. A mixed approach was employed, involving a literature review, field study, field observations, and key informant interviews. The study conducted a comprehensive desktop literature review of published and unpublished materials on international, continental, regional, and national legal instruments supporting climate change, disasters, rangeland management, and fodder production. It then analysed how these instruments are integrated into existing Kenyan laws and strategies.

3.3 Sampling and Sampling Size

A field survey was conducted in the Oloililoi, Kajiado Central, and Mashuru sub-counties (Fig. 7). According to Cohran (1977), when the population of the study area exceeds 100,000, a minimum sample size of 204 at a 7% precision and 95% confidence rate is recommended (Cohran, 1977). The study employed the purposeful sampling method to select 354 livestock owners, key informants, and hay farmers and then administered structured and semi-structured survey questionnaires. There were 385 respondents (354 in Oloililoi and Kajiado Central and 31 in Mashuru sub-counties) comprising pastoralists, hay farmers, and key informants.

3.4 Data Collection

The researcher also utilized field observations followed by key informant interviews to understand the cropping and management practices of the hay farms. The survey data was collected between 2005 and 2021. The study aimed to identify years with average rainfall and those with drought. In this study, the participants were requested to recollect the severe drought years in Kajiado and compare them with normal rainy seasons. To validate the responses of the participants regarding past and recent drought periods, the data from several sources were cross-checked, including the National Drought Management Authority (NDMA), the 2019 National Housing and Population Census, and the 2009 Kenya National Bureau of Statistics livestock data.

The researcher could define drought and regular years by triangulating data on animal migration patterns, productivity, prices, water availability, health, deaths, diseases, and grazing conditions. The researcher also established that during a regular rainy season, the dry period lasted about three months, when livestock migrated to other regions. To analyze a regular year's dry season migration and a drought year's migration, the period was standardized to allow a comparison of three months of the driest regular season with three months of a drought year to establish comparable hay demand by pastoralists, animal losses, and costs incurred during migration.

To evaluate the economics of hay production in Kajiado Central and Oloililoi sub-counties, a cost-benefit analysis was carried out in 23 farms, which represented 88% of all farms in the area. The participants in the study were classified into three categories: eight large producers (135-400 acres), seven medium producers (20-50 acres), and eight small producers (3-15 acres). To gather data on their agricultural and business practices, a structured questionnaire and key informant interviews were used during the survey. For a robust cost-benefit analysis, financial information on farm accounts was collected through focus discussions. Market data from the hay markets in Ibissil was also gathered.

3.5 Data Analysis

The study undertook a comprehensive cost-benefit analysis of hay production in Kajiado Central and Oloililoi sub-counties, aiming to evaluate the profitability and economic feasibility of this agricultural activity. An in-depth analysis of the eight large farms grouped them into 400 acres (2 farms), 200 acres (3 farms), and 150 acres

(3 farms). The two 400-acre farms were further analyzed as they had similar hay cropping and operational practices, which allowed for the identification of fixed and variable costs. The cost centres were standardized to depict an ideal farm, referred to as a 'farm-like-this,' based on farm size for comparison purposes rather than widely varying management practices.

The two 400-acre farms had similar variable costs, including (1) labour, hiring machinery, and basic cultivation practices such as land clearing and harvesting, (2) amenities, repairs, fencing, and storage, and (3) cropping and management practices. The study found that most utility costs were associated with consumption in the farmhouse and workers' quarters and not directly with hay production. As a result, the study only calculated the utility costs associated with maintaining farm housing and assigned these costs to the staffing recurrent cost centre. The analysis did not consider other utility costs related to non-agribusiness and non-hay production activities on the farm.

These variable costs were standardized and used in all farm sizes ranging from three to 400 acres. This approach had several advantages: First, it allowed for comparative profitability analysis across farm sizes with similar cultivation practices. Second, it eliminated the influence of different managerial styles, procurement procedures, and staff policies on profitability. Third, it freed the study from an administrative and financial audit of individual farm practices.

The study involved an econometric analysis that explored different costs associated with farm machinery and hay production. Firstly, Machinery Repair and Maintenance costs were evaluated, which encompassed fuel (petrol or diesel) and other expenses associated with operating tractors and farm machinery. Secondly, Repair costs were assessed, which included the purchase of broken or worn-out ploughs, grass cutters, and balers for farms over 100 acres that owned their machinery for hay production. The third cost analysed was Fencing costs, which were primarily incurred in the base year when fencing hay farms. This cost was estimated at KES 2,500 per acre and included the purchase of a chain link (or barbed wire) and fencing poles. It's worth noting that this cost was derived from larger farms above 200 acres, and the accuracy might vary as the farm acreage decreases. In addition, the study examined Machinery Purchase Costs, which involved buying new tractors and farm equipment like balers, ploughs, grass cutters, and irrigation equipment, mainly by large farm owners to facilitate ploughing and harvesting (Table 2).

Table 2: Cost of Machinery

Machinery	**Cost KES**
Tractor (NEW HOLLAND TS 6140 4WD)	6,200,000
Manual baler/Haymaker and rake (new)	12,000
Baler(new)	900,000
Grasscutter (new)	400,000
Mould Board Plough Tiller 3 F(new)	200,000
Gun- irrigation system @KES 55,000 per acre	5,500,000

The other costs the study defined were the machine hire costs, general utilities costs, fencing repair costs, bush clearing costs, tractor ploughing costs, irrigation costs, weeding costs, permanent and temporary staff costs, and machinery repair costs. Machine hire costs are incurred by farmers who cannot afford to purchase equipment for hay production. The general utilities costs include water, electricity, and other utilities, and the cost increases with an increase in farm acreage. Fencing repair cost is the cost of repairing chain link fences around hay farms, and bush clearing cost is the cost of clearing bushes and trees in preparation for ploughing and planting hay. Tractor ploughing cost is incurred when hiring a tractor to plough a piece of land for hay farming, and the cost is relatively smaller for larger farms. Irrigation cost is the cost of water per litre and is only done in drought years. Weeding cost is the wages for temporary workers hired to weed hay farms, while permanent staff cost is the monthly cost of permanent staff employed to work on hay farms. Finally, hiring tractor and baler cost and machinery repair cost are incurred annually.

In the next step of the cost-benefit analysis, the study identified all fixed and variable costs and benefits related to each option for the hay farming project. The data used in the study was spread across six years (2015-2020). The costs and benefits were quantified in Kenyan shillings and standardised to represent a "farm-like-this" rather than "this-farm"(Kimaru J. ,et.al, 2021a).

The present values of the costs and benefits were then calculated by discounting the future values. The total present value costs and benefits were obtained by summing the present value costs and benefits across the years. The net present value (NPV), Return on Investment (ROI), and Internal Rate of Return (IRR) were then calculated as significant indicators of the project's worth, in addition to the payback period.

In the next step, a sensitivity analysis was carried out to establish the best hay price that would make the operation viable for large farms. The price sensitivity was also used to calculate the profitability of the enterprise for years with no hay sales, such as those with average or above-average rains (2019, 2020). These steps were all critical in determining the profitability and viability of the hay farming project.

Certain assumptions were taken into account while calculating the financial profitability of various sizes of Hay farms, which involved measures and interpretations. Key financial Parameters used in the analysis included (1) Revenue which is computed by multiplying the unit price per bale by the number of bales harvested in a particular year. The calculations had the grazing income. (2) Total costs are the sum of variable and fixed hay production costs. (3) Net benefits are the difference between the total revenue and the total costs incurred each year. (4) Net Present Value (NPV) is the difference between the total discounted benefits minus the total discounted costs. Projects with positive net benefits are viable. The higher the NPV, the more feasible the project.

$$NPv = \sum \frac{C_t}{(1+K)^t} \text{ -I0}$$

Where:

C = Cash flow in time t

K = Discount rate

IO = cost of investment/ initial cash outlay

When NPV>0, Accept the project, and when NPV<0, reject the project. When NPV$=0$ be indifferent

In addition, the (5) Discounted net benefits = Net benefits/ (1+Discount rate) ^year

While the (6) International rate of return (IRR) is the rate of return (discount rate) equates to the NPV of the project to zero. The rate of return (discount rate) equates the present value of cash flows to the project's initial cost.

IRR= r% $+\frac{positive\ NPV}{Absolute\ sum\ of NPV}$ (R%$-r\%$)

If IRR$>$ cost of capital, accept the project. If IRR$<$ cost of capital, reject the project, and if IRR$=$ Cost of capital, be indifferent.

The Return on Investment (ROI) was also computed as a comparison. The ROI indicates the total benefit of the entire investment, while IRR is the annual growth rate. While the two numbers will be similar for one year, they may start to differ with time and be different over many years. Furthermore, the (7) Payback (Cumulative PV) is the time required for a project's total discounted costs to surpass the total discounted benefits. The researcher used cumulative discounted benefits and costs for each consecutive project year to calculate cumulative PV. When the cumulative benefits surpass the cumulative costs, the year following is the project's payback period – when net profits or benefits are realised (Kimaru J. ,et.al, 2021a).

The results from the field survey and cost-benefit analysis were evaluated through the utilization of statistical software such as SPSS and Microsoft Excel Data Analysis Tool. The collected data was validated by two researchers who cleaned and re-checked the findings twice. The data was coded in Microsoft Excel and then imported into IBM SPSS for further analysis, where frequency tables were generated. A Data Saturation Analysis Grid was used to identify common topics from specific discussion points provided by participants during a semi-structured interview. Frequencies were used to describe the quantitative data while ranking and ratings explained the qualitative data. Furthermore, the findings from these analyses were summarized in tables and illustrated using bar graphs and pie charts.

CHAPTER FOUR

Study Objectives addressed in paper: Objective One To analyse the existing hay production systems in Kajiado County

Published paper: Analysis of Hay Demand from Pastoralism Systems on Viability of Hay Production as a Climate Adaptation Strategy in Kajiado County, Kenya

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4.0 HAY PRODUCTION SYSTEMS IN KAJIADO

4.1 Abstract

The production of hay in arid and semi-arid regions is a crucial element of Kenya's strategies for mitigating drought risks and adapting to climate change. To support decision-making and project implementation, planners need to understand hay production and supply drivers and challenges. This research carried out an economic assessment of 23 hay farms through a cost-benefit analysis and a structured survey of 354 pastoralists in Kajiado Central County. It provides insight into hay production figures, deficits, and feeding options utilized during droughts by pastoralists. The research discovered that in 2017, during a severe drought, Kajiado Central County experienced a 48% deficit in hay bales equivalent to 2.580 million bales, which amounted to about KES 902 million to cover three months of the worst weeks of the drought. The total supply of hay was made up of 49,138 locally grown bales and 3,292 purchased bales, as well as 6,177 bags of commercial feed and forage. During the 2017 drought, hay made up 62% of the total feed and commercial feeds, but it dropped to 38% of the total feed used by pastoralists to feed their cattle. Hay is predominantly sold in drought years for about three months. Over the period between 2005 and 2020, four years of severe droughts led to the elimination of 67% of the grass hay required in Kajiado. Hence, farmland requiring hay production must adopt global warming mitigation and adaptation strategies focusing on better hay production and less crop loss. Disaster management planners need to integrate hay

supply into their disaster planning by addressing the challenge of hay production and considering the lower-than-average hay supply. Moreover, disaster planning coordinators can use the purchase data to identify the triggering points of animal feed responses.

Keywords

Hay, livestock production, cost-benefit analysis, disaster resilience, climate change, pastoralism.

4.2 Introduction

In Kenya's arid and semi-arid lands, the livestock economy is crucial, providing up to 90% of incomes and employment for pastoralists. Droughts in these areas have increased, making it harder for cities and growing communities to recover and regain their property and resilience. Pastoralists' primary drought mitigation strategy is to ensure adequate forage supply for livestock, herds are typically moved to different grazing zones during dry and wet seasons. However, due to global warming and land-use changes, fewer options are available for feeding livestock than in previous years, resulting in livestock lost due to drought valued at approximately US $1.08 billion (World Bank, 2015).

Although research shows that smallholder farmers with high exposure to alternative food sources in Kenya have increased, only 55% cultivate fodder on their farms. The depletion and degradation of natural pastures have been exacerbated by drought and inadequate agricultural land-use practices. Kenya has a significant deficit in livestock feed and forage, estimated at 3.6 billion hay bales, which significantly constrains the country's livestock sector and economy. The lack of feed forces farmers to sell their animals earlier than they would like, increasing the cost of meat and milk products. Reducing this deficit would positively impact the country’s economy. Furthermore, the fodder demand is expected to increase from neighbouring counties, requiring an estimated 15 million acres of land in arid and semi-arid rangelands to meet the hay demand (Auma, 2019).

Sustainable and intensive grazing has damaged the land's regenerative capacity, adversely impacting ecosystems. Thus, stakeholders have implemented a cattle enclosure system in Kenya. Empirical trials demonstrated that restoration of the degraded features of land by enclosures had reduced the impacts of soil erosion and increased the efficiency of land and water drainage. People living near Lake Baringo have benefited by reviving enclosure vegetation and transforming the environment. Restoring range through owning fencing in West Pokot County has helped pasture workers increase their animal species by encouraging grass growth and dry season grazing. Agro pastoralists in Makueni County, like other dryland communities, have adopted fodder production to enhance their livestock productivity and ensure sufficient feed during dry spells. They also sell grass and hay seeds to earn extra income. Previous research indicates that fodder production considerably boosts household income. In Baringo, for instance, pastoralists have earned up to KES 1.5 million annually from the ten tons of indigenous perennial grass seed harvested per acre each year. In addition to increased and diversified livelihood sources resulting from enhanced livestock productivity, households also benefit from selling hay and local grass seed and rehabilitating degraded lands via pasture establishment and enclosures (Lugusa, 2015). However, several challenges, such as high land preparation costs, grass seed and weed problems, poor seed quality, high input costs, lack of seed harvesting skills, and inadequate working capital, hinder fodder production in Kenya's drylands (Ouma, 2017).

The insufficient quality and quantity of animal feed, particularly during droughts, and the increasing demand for fodder have spurred the government's efforts to promote the establishment, production, and marketing of fodder. As a result, some communities have started planting various grass species to enhance feed availability in the dry season and generate additional income streams by selling hay and grass seed. These initiatives, coupled with the demand for fodder and the need for economic sustainability due to the shortage of fodder on-farm, have resulted in the development of a commercial fodder industry in Kenya (Auma, 2019).

This study will examine the cost-benefit analysis of hay farming across varying farm sizes in Kajiado Central. The research will review cultivation practices and challenges hay farmers face and how this affects the profitability of hay. The study will also explore other factors that affect profitability, such as the behaviour of buyers, specifically pastoralists, and its impact on the hay market and, in turn, the profits for hay farmers.

4.3 Materials and Methods

For a detailed explanation of the materials and methods, refer to chapter 3.

4.4 Results

4.4.1 Hay Grass Varieties are grown in Kajiado Central

Rhodes grass (*Chloris gayana*) is grown on only one farm in Kajiado Central (Fig. 8).

Figure 8: Farm growing Boma Rhodes grass in Ibissil, Kajiado Central

The grass varieties grown on 96% of the farms and communal rangelands are a mixture of indigenous and introduced forage grass varieties like red oat grass (*Themeda Trianda),* big bluestem, guinea grass, buffalo grass, switch grass (*panicum virgatum*), beaked panicgrass (*panicum anceps*), windmill grass, blue oat grass. This study will refer to all these varieties as local varieties.

4.4.2 Non- Commercial Hay Production

In Kajiado Central, 8/23 (35%) of the non-commercial hay production is grown on farms below 50 acres. In 2015, commercial feeds represented 76% of total livestock feeds, while hay comprised 23% of total feeds. Hay's percentage of total livestock feeds in 2017 varied, being 62%, while commercial feeds dropped to 38% of total feeds. The number of livestock being fed by their own homegrown hay doubled, from 1% in 2015 to 22% in 2017 (Fig. 9).

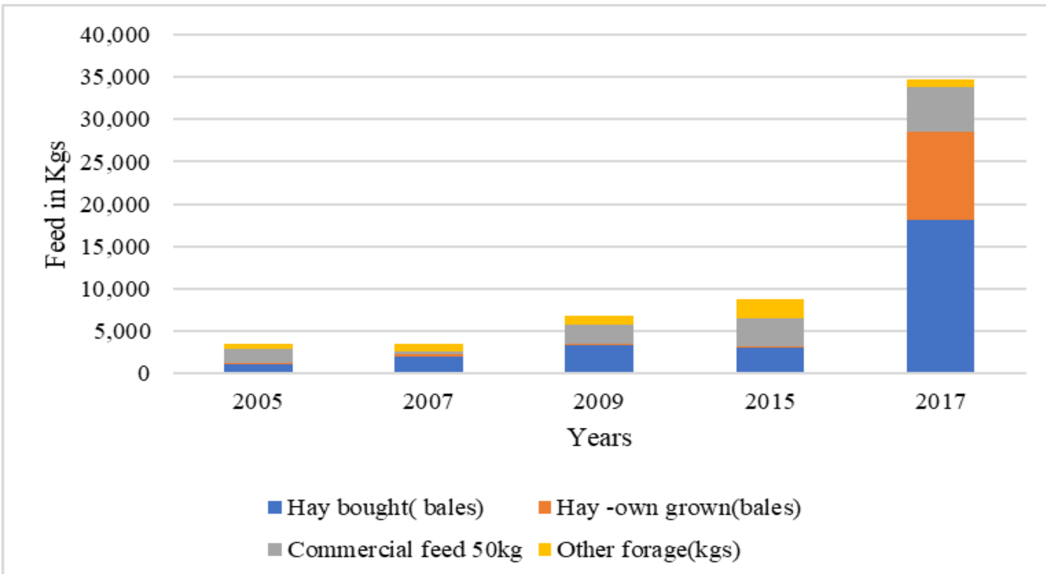


Figure 9: Livestock Feeding options during drought

4.4.3 Commercial Hay Production System

Table 3 shows the 23 farms engaged in commercial hay production, accounted for 23/26 (88%) of all farms in Kajiado Central. The 23 farms were categorised into acreage, hired or bought machinery, and the number of harvests per year.

Table 3: Categories of Farms engaging in Commercial Hay Production

Actual hay Acreage	No. of Farms	Machinery	No. of harvest per year
400	1	owned	2/3
390	1	hired	1
200	1	owned	1
200	2	hired	1
175	1	hired	1
150	1	hired	1
135	1	hired	1
50	1	owned	1
25	1	hired	1
20	5	hired	1
15	1	hired	1
10	2	hired	1
5	3	hired	1
3	2	hired	1
	23 farms		1

In Kajiado Central, there are nine farms growing hay commercially on 50 acres and above. Of all the farms 22/23 (96%) cultivate the local variety using rainfed irrigation and prefer to hire machinery, such as tractors and balers. Only three farms own their own machinery, and just one has an irrigation system. The cropping practices of these commercial farms incurred significant expenses in capital equipment acquisition, to acquire and maintain the necessary equipment. This included:

- Balers and Cutters: Three farms bought balers and cutter machines, while 20 farms hired these machines. Most farms prefer hiring machinery because the cost of repairing and replacing damaged components of the cutter and baler can wipe out a season's profits. Spare parts are costly, with a single slashing blade costing KES 60,000 to replace as they need to be imported and have few specialised suppliers in Nairobi. Repair costs were very high for farms with machinery, while private providers bore repairs.

- Tractors: It was cheaper for the three farms to buy tractors than hire a tractor to ferry hay from the field to the store. The cost of hiring tractors was much higher than fuelling tractors. Also, repairs and spare parts of tractors are cheaper, locally, and readily available – even second-hand and prefabricated pieces. However, farmers cited that buying a new tractor is a high capital cost.
- Irrigation equipment: The one farm growing Boma Rhodes utilised an elaborate irrigation system comprising the rain-gun overhead irrigation system.
- Hay Storage: Only 5//23 (20%) of the farms had sturdy all-weather storage, while most 18/23 (80%) had open or poorly constructed stores. Of the farms, 4/18 (20%) practised the open pyramid method covered by plastic trapline to store hay (Fig. 3). Another 4/18 (20%) having corrugated sheets and roofs to stone walled stores with corrugated roofs. From cost calculations provided by three farms, corrugated iron sheet stores that can store 20,000 hale bales cost approximately KES 2 million.

One-off activities were conducted on the farms as part of their cultivation practices included:

- Land preparation: All the farms cleared virgin land of large trees and shrubs, especially trees that attract insects and termites. Clearing the land and removing tree stumps and rocks allowed the tractor baler to manoeuvre during harvest with minimal damage to the cutters on the baling tractor. Clearing the land allows the roots of grasses to have enough space, nutrients and sunlight to grow.

- Fencing: All farms had fences. The fences were made using local thicket bushes, barbed wire or electric fences. The type of fence did not matter as all fence types provided delineation from outside grazers. Discussions with respondents on installing electric fences found that initial high capital costs deter farmers. Also, respondents noted that the effectiveness of electric fences in keeping out herders and wildlife could be better. Farms with electric fences suffered the same fate as other farms because illegal herders had devised ways to jump electric fences. The benefit of electric fencing outweighs the cost of setting up an electric fence.

To maintain their production, the farms undertook recurrent seasonal activities that included:

- Seasonal wedding: The ipomoea weed was removed manually on only the large farms of 400 acres. Chemical pesticides were not used because they poisoned grazing livestock and were expensive. Most farms did not actively undertake seasonal weeding, and Ipomoea had overrun communal grazing areas.

- Manuring: Most farms used cattle manure broadcasted or through seasonal post-harvest grazing. All the commercial farms used cattle manure. The farm with Rhodes Boma practised planting and ploughing back a fast-growing high, protein plant to provide mulching and increase the soil's humus content. The respondents explained that hay yield in virgin land was high but progressively declined by year three if no manuring was done.
- Seasonal grazing: Farmers allowed post-harvest grazing to outside herders for a fee of KES 10 per cow per day. Farmers also prevented their herds from grazing the field hay at all stages of grass growth.
- Post-harvest treatment of hay: post-harvest farms used minimal treatment to prevent hay quality deterioration. The large and small farms reported spraying the store floor with termite repellents.

To ensure smooth operations and maintenance of hay production, the farms carried out various daily and monthly activities. This included conducting farm patrols during the day and night to prevent illegal grazing by outside herds.

The farms incurred costs for both staffing and utilities, which included:

- Farm staff: Farms had permanent and temporary staff. Permanent staff included security, herders, and managers, while temporary staff undertook bush clearing, harvesting, weeding, fencing, and repairing damaged fences. The cost-benefit analysis found that labour costs ranged from 47% to 79% for

400 acres to 10 acres (hiring machinery), respectively, and 55% to 87% for 400 acres to 150 acres (with own machinery), respectively, of total recurring costs.

- Farm utilities: for all farms, the water and electricity utilities ranged from 0.25% to 2% of recurring expenses. The large farms over 100 acres all had boreholes to supply water.

4.4.4 Hay Cropping Practices in Large, Mechanised Farms

The cropping practices of the 400-acre farms that employed irrigation and purchased their machinery are discussed below, with a particular focus on the Boma Rhodes cultivation practices. The Boma Rhodes farm was equipped with permanent hay storage facilities, uses irrigation, and is fully mechanized with purchased equipment.

- Cultivation Method: For the farm that cultivated Boma Rhodes, the land under cultivation was 400 acres. The farmer was interviewed on how he cultivated hay. He explained that before switching to hay farming, the farm previously cultivated beans and therefore went into hay production with well-tilled land and did not require clearing the land of trees and shrubs. The farmer explained that ploughing was done using their tractors and seeding with the Boma Rhodes variety. Two crop cycles were done annually. Manual labour was used to weed the farm, although this was minimal because the Boma Rhodes grass variety proliferates and covers the land's surface, eliminating the need for weeding.

- Manure fertiliser: Cattle belonging to the local community grazed the land after harvesting crops for a fee. The cattle droppings added manure to the land and additional income for the farm. Every consecutive year, on October's third planting, a high protein-containing legume was planted and ploughed back into the soil to become humus and fertilise the land.
- Irrigation: During the dry season of insufficient rainfall, the farm irrigated its hay crop using gun sprinklers, allowing it to have three crops per year (two Rhodes Boma and one legume)
- Harvest: Boma Rhodes harvest was done in February and June.
- Storage: The farms employed various storage methods for their hay harvests. Permanent stone-walled stores with iron sheet roofs were the most common. However, when the harvest exceeded the stores' capacity, farmers had to resort to open storage using the pyramid stacking method, covered with a tapeline. In exceptional cases such as during heavy rains, farmers converted other buildings on the farm to hay storage. The researcher noted that none of these storage methods adequately preserved the hay's quality. The open pyramid method, in particular, resulted in the fastest quality deterioration. Additionally, hay stored for more than two years turned black, as observed by the researcher.
- Sale of Hay: The farm stored hay for 1-3 years before selling on-farm. For the period under study, the farmers said they sold hay in 2015, 2016, and 2017,

with negligible sales realised in 2018 and absolutely no sales in 2019 and 2020.

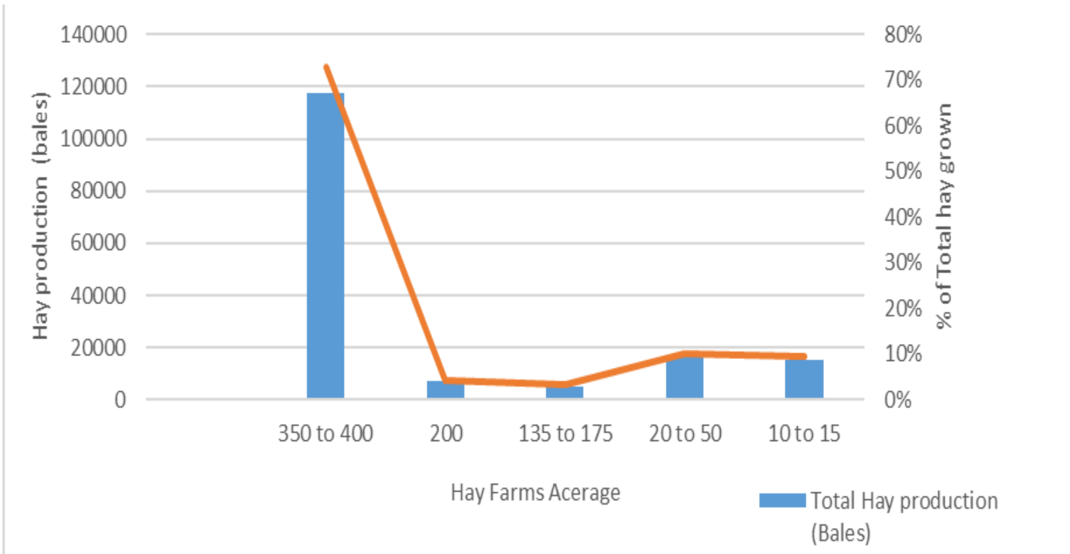
The farms that grew local grass varieties utilized a combination of rain-fed and mechanized techniques for cultivation. The process involved hiring tractors and balers. Additionally, these farms have permanent hay storage facilities available. Their cropping practices included:

- Cropping Method: Most (96%) farms ranging from 50 to 400 acres grew the local grass varieties. For these farms, the cropping practiced consisted of clearing trees and shrubs in year one and subsequently expanding acreage under hay by the additional clearing of trees.
- Cropping practices differed from farm to farm; the techniques ranged from basic activities like clearing the land and fencing to advanced methods, including removing trees and shrubs, weeding invasive species, adding cattle manure and maintaining fences. Farmers also cited other practices like renting post-harvest grazing, which has the additional benefit of fertilising the land. Furthermore, farms were forced to hire security personnel to keep out illegal cattle grazing from the growing grass.
- Weeding: All the farms used manual labour to weed out invasive species of the local grass varieties.
- Fertilising the Land: Farmers noted that they allowed the local Maasai cattle to graze the land for a fee after the hay harvest.

- Harvest: Farmers said that harvest was done annually, in June and July.
- Storage: A significant proportion (23%) of the farms stored their hay in durable structures made of iron and stone. On the other hand, the remaining 67% of the farms use raised wooden structures that have sheet-iron roofing and open walls. In the case of the 400-acre farm, when the storage space could not hold all the harvested hay, the excess was stored outside in the open, covered with tapeline. However, the open pyramid and open wall storage methods led to quality deterioration, with some hay bales turning black and even mouldy after storage for over two years.

4.4.5 Hay Production in Kajiado County

The study was conducted in Oloililoi sub-county of Kajiado County to gather information from hay farmers. Most hay farmers in the area, which comprised 23/26 (88%) of the total, were included in the survey, with only three farmers not participating. Out of the 23 farms surveyed, it was found that 2 of them, or 2/23 (9%,) had between 350-400 acres of hay, 6 farms or 6/23 (26%) cultivated on 135-200 acres, 7 farms or 7/23 (30%) farmed on 20-50 acres, while 8 farms or 8/23 (35%) had 3-15 acres of hay. A significant proportion of the total hay production, amounting to 73%, came from the farms that grew between 350 and 400 acres of hay (Fig. 10). Hay Production by Farm Acreage Since 2015, 60% hay production increase peaked in 2018 before dropping in 2019. In 2019, one 400-acre farm did not harvest their field grass for hay. The farmers cited that they left it to grow because there was no demand for hay in average rain years.



Since 2015, a 60% hay production increase peaked in 2018 before dropping in 2019. In 2019, some big farms that were chosen did not cut their hay grass during the harvesting period. The farmers cited that they left it to grow because there was no demand for hay in average rain years (Fig. 11).

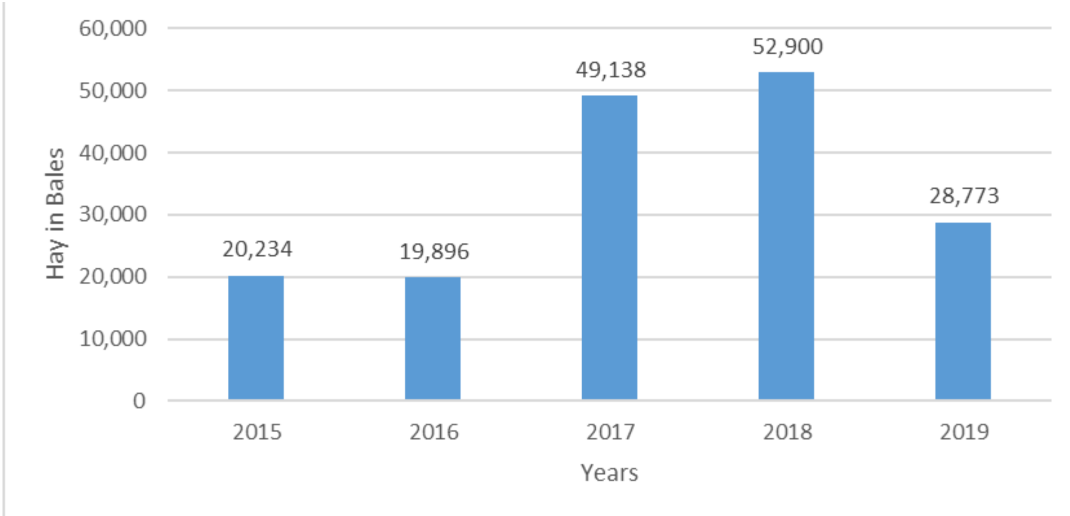


Figure 11: Hay yield between the period of 2015 and 2019

4.4.6 Hay Deficit in Kajiado Central County

In 2005, 2007, and 2009 droughts, the hay deficit was over 95%. Hay production increased by 60% from the droughts of 2015 to 2018. By 2017, 49,138 hay bales were harvested, this represented about a quarter (24%) of the overall hay bales that were needed during the drought year. Nonetheless, in 2019, the total hay production decreased due to the non-harvesting of grass on some of the major farms. The farmers cited that they left the hay unharvested because there was no market demand from livestock owners for hay as that yar the rainfall was good and there was plenty of free communal grass to graze livestock on.

Figure 12 below illustrates the hay demand: hay bales required for a three-month dry season. The shortage of hay in 2015 amounted to 86%, while in 2017 it was 48%, with an average hay deficit of 67% during the recent droughts of 2015 and 2017. This implies that a similar hay deficit can be expected in the upcoming droughts after 2020.

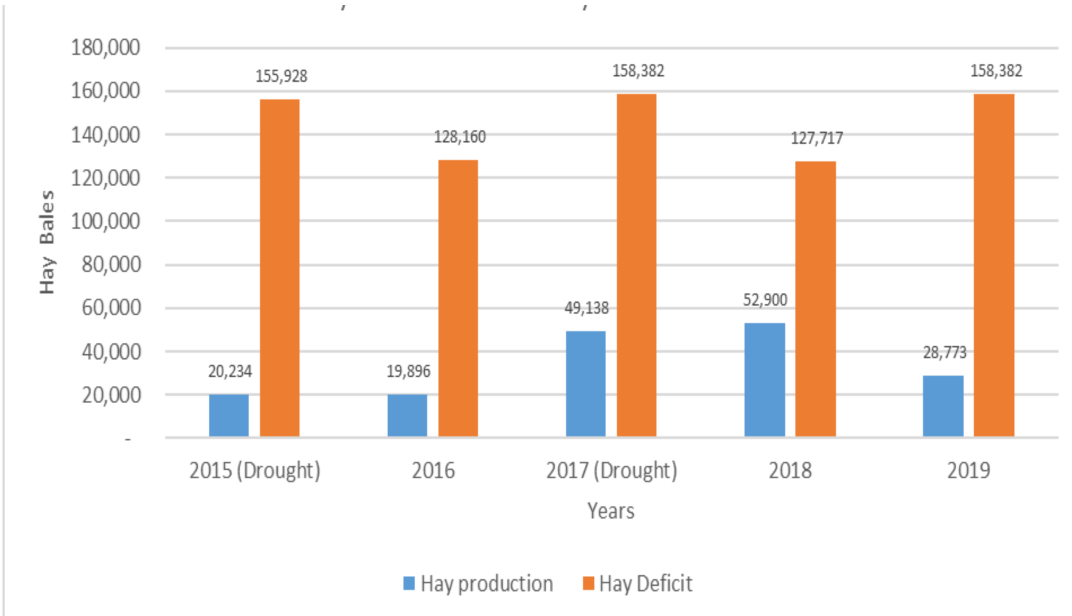


Figure 12: Hay Production against Hay Deficit

4.4.7 Challenges of Hay Production

During the key informant interviews with hay farmers, they all agreed there was no demand for hay during years with average or good rainfall. However, hay sales increased in periods of drought, which happen every two to three years. Nevertheless, farmers also reported that herders have ample access to free grazing resources during non-drought years and therefore do not buy hay. As a result, farmers said they must store hay for 1 to 3 years before selling it, which renders hay cultivation unprofitable. In 2015, 2016, and 2017, hay was sold, but in 2018, hay sales were low and collapsed in 2019 and 2020, which had good rains. Farmers responded that building hay stores was a high capital cost for farms. The farmers further explained that hay stores were necessary to protect the hay from the weather and pests and to allow hay to dry properly. Upon probing further, the researcher found that the cost of a hay store can vary depending on the size and type, but constructing a store is typically a significant investment for a farm. The respondents from the large farms explained that they build permanent stores using iron sheets and stone. In contrast, the respondents from the smaller farms constructed wooden structures with iron roofs, completely open walls, or intertwined with twigs. Farmers stacked their excess hay in a pyramid shape in the open and then covered with a plastic tarpaulin when a bumper harvest exceeded the stores' holding capacity. However, hay stored for over one year was mouldy.

All farms faced challenges with illegal livestock grazing on hay farms by neighbouring pastoralists, leading to a significant source of conflict between farmers and herders. Hay growers cited that hay was depleted, leading to revenue losses.
During the key informant discussions, farmers explained how they handled the challenge of farmer-herder conflict by allowing post-harvest grazing of local cattle at a small fee. Another challenge cited by the farmers who owned their machinery was that the purchase of machinery and the operation of tractors, balers, and irrigation equipment entail substantial capital expenditures In this study, approximately 50% of respondents reported that a lack of meaningful government support was a factor in their farming. However, some farmers were aware of and used the government tractors and baler services from the discussions. Nonetheless, they discovered that the

private providers were more dependable, cost-efficient, and effective, and therefore, chose to utilize their services instead. Farmers also raised concerns about the need for extension services to grow hay. Farmers further noted that the programs under KCSAP needed to align with their needs. For example, the technical discussions on introducing standards for hay needed to be more in touch with the reality of trying to grow hay, as introducing quality standards would negatively impact hay profits. Any additional operating input costs that do not factor in the market realities would collapse the farmers' already growing hay. From the key informant interviews, farmers said the meagre profits from hay resulted in landowners looking for alternative ways to utilize their land, such as selling off a portion of it or carrying out other non-farming related businesses. The question of profitability was the main driver for land-use changes moving away from hay farming. Interestingly, when asked, farmers were not interested in setting up hay cooperatives to address their marketing issues because of corruption in cooperatives.

Farmers have emphasized that they deserve recognition as hay farms play a crucial role in the ecosystem and offer various social and ecological services. Specifically, they provide fodder and grass for pastoralists' livestock and support wildlife that frequently grazes on the farms. During the researcher's observation, wild herbivores such as antelopes, zebras, elephants, and elands were grazing on the hay farms. The farmers reported that these animals could stay on the farm for up to four months annually. The researcher spotted ten antelopes and fifteen zebras on two larger farms during the interview. However, the farmers observed that neither the Kajiado County government nor the Kenya Wildlife Services (KWS) compensated or involved them in any conservation efforts.

Farmers had realized that the population of herbivores visiting their farms was rising annually, as their natural habitats were decreasing due to human settlement. The interviewed farmers believe this trend will persist and lead to more severe issues, such as crop damage and disease. The investigator also noted that the hay farms were devoid of Ipomoea, whereas the surrounding regions were infested with weeds.

4.5 Discussion

Hay is a crucial tactic for reducing the risk of drought, which can assist in relieving the burden of livestock on grazing lands and the losses incurred by pastoralists during conventional livestock migration. Nonetheless, the amount of hay obtained from self-cultivated and purchased sources needs to be increased, resulting in an average estimate of a 67% hay deficit. In 2015, the hay shortage was 87%, but this improved to a scarcity of 48% in 2017 owing to increased hay production. The significant lack of hay indicates that the existing hay cannot substantially reduce or fully replace pastoralists' traditional migration strategy during droughts. Due to insufficient hay production, financial losses to livestock during droughts remain high, resulting in low resilience in the livestock systems of pastoralists. These findings correspond with the Ministry of Agriculture's 2017 report (MoALF, 2017).

Livestock keepers explained that grasses are either grown and consumed in the field or harvested and stored for livestock feeding during droughts. On average, the grasses are grown for subsistence on farms ranging from 5 to 50 acres, producing between 50 and 700 bales, depending on individual cultivation practices. These findings align with hay production in other arid areas (Kimongo, 2017). The calculations show that this production rate would last from one day to 10 days for a cattle herd of 20 animals. Respondents explained that when their hay stock is exhausted, they must either buy hay, migrate their herds in search of grazing pastures, or do both. Pierre Bonte et al. also noted the need to migrate due to limited feed in 2019 (Pierre Bonte, 2019).

The survey found that devastating droughts occurred in 2005, 2007, 2009, 2015, and 2017 over the previous 15 years, while 2008, 2012, 2018, 2019, and 2020 had normal rains and slight dryness. These droughts followed patterns similar to those described by Kimani et al. (Kimani, Njeru, & Ndirandu, 2013). From the responses of livestock keepers, the study found that during droughts, the distances livestock migrated increased substantially. Over 85% of pastoralists in Kajiado Central practice livestock migration as the primary drought resilience strategy alongside other complementary strategies like buying hay, paddocking, and livestock feed. The national drought management authority (NDMA, 2022) also reported this migration pattern. The study observed that in Kajiado, the grass available through migration, rotation grazing, and paddocking is rain-fed and mixed with local varieties.

The cultivation practices for hay in Kajiado Central start with clearing the land of trees and bushes to allow indigenous grass to grow and receive enough nutrients. For farms growing Rhodes Boma, this is followed by ploughing and seeding Rhodes Boma. Once the rains fall, farms weed out several invasive species of weeds, including the aggressive species of Ipomoea, which, if not removed, overruns the local grasses and makes the soil hostile to grass growth. Farms that remove invasive species and other weeds have higher hay yields, while those that do not weed out lose hay harvests. In the study area, respondents noted that the invasive plant species, Ipomoea, is a challenge and reduces the hay yield per acreage by up to 47% if not removed (Mworia, Kinyamario, & John, 2008). Removing weeds is done manually by permanent and temporary workers and contributes to the high labour costs of high-performing farms. Chemical pesticides are discouraged as they can affect grazing livestock and are expensive. From the researcher's general observation, most farms did not actively undertake seasonal weeding, and Ipomoea had overrun communal grazing areas. Farms are fertilized annually using cattle. The respondents explained that hay yield in virgin land is high but progressively declined by year three if no manure was added. The practice of manuring was found to have the most significant impact on yield per acreage. Hay yields ranged from 26 - 48 bales/acre with manure, compared to 2 bales/acre without manure. The productivity rate of hay per acre in Kajiado Central is far below that of 337 bales per acre for Boma Rhodes cultivated in Mariakana, Kilifi County, a semi-arid county with about 300-1300 mm of rainfall over six months every year (KALRO, 2014).

The most common method of grazing cattle post-harvest has several advantages: (i) cattle droppings manure the farm, (ii) reduced conflicts between farmers and local herders, (iii) improved relationships between farms and locals, (iv) provides a low-cost, culturally acceptable drought/dry season mitigation strategy for the pastoralists. These findings are similar to what Auma reported in 2018 (Auma, 2018).

After weeding, the grass grows for about four months before harvesting using tractor cutters and balers. The hay is transported by tractors to the hay store awaiting sale to livestock owners. Only one farm growing Boma Rhodes, utilized an elaborate irrigation system comprising the rain gun overhead irrigation system that cost KES 550,000 per acre. Another irrigation system in the market used for vegetable farming by smaller farms is drip irrigation, which costs KES 120,000 per acre (Rain Gun Sprinklers, 2020). However, even smaller farms did not use drip irrigation to irrigate hay, instead relying on rain. Although good stores made of corrugated iron sheet stores that can store 20,000 bales cost approximately KES 2 million, the materials used to construct the store greatly influence post-harvest losses from damage caused by weather, rain, and insects. Spoiled hay accounted for a loss in revenue.

In commercial hay farms, the most significant management action to prevent outside herders from illegally grazing within the hay fields is to secure the area with fencing. However, this security measure incurs high recurring costs for the farm, such as the employment of permanent security personnel. These costs are fixed, regardless of the farm's size. Illegal grazing by cattle, goats, and sheep results in significant losses due to the grass being eaten while in the field, damage to growing grass, and damage to fences. On average, a cow can consume 5 kgs of grass daily, while goats and sheep consume 3.5 kgs daily. If 50 cattle and 50 goats and sheep invade the farm daily, they will eat the equivalent of 850 bales per month.

Auma (2018) emphasizes the importance of area-specific cropping practices to understand the hay enterprise's commercial viability better. KALRO (2014) also provides Rhodes Boma cropping practices. The study discussed in this passage contributes to this recommendation by elaborating on the cropping practices of Kajiado Central.

Hay farmers need to be recognized for their social and ecosystem services, which support livestock keepers and wildlife. One instance of wildlife migration involved animals from Amboseli National Park grazing on hay farms for four months each year. While the tourism industry benefits from this, it leads to reduced hay production on the farms. These findings are consistent with the research conducted by Sala (2017) and Pierre Bonte (2019). Another ecosystem service, hay cropping, provides the weeding of invasive plants like Ipomoea, which prevents them from overrunning indigenous grass varieties and destroying grazing lands. Additionally, hay cropping improves soil quality and reduces erosion and compaction during floods.

The feeding practices favoured by pastoralists illustrate that hay constitutes less than 60% of the available feed. Buying hay is the preferred option for pastoralists instead of growing it themselves because purchasing hay from local farmers is a more effective approach. The study found that, of the few (6%) who grew hay, their harvest lasted less than one week, so they still had to use other feeding options. Moreover, growing hay requires significant time and resources, such as land, water, and labour. Buying hay instead allows pastoralists to focus on their primary occupation of raising livestock. These findings were similar to those of Lugusa's study in Baringo (2015). Additionally, buying hay in bulk allows pastoralists to benefit from economies of scale.

In 2015, commercial feed accounted for 76% of the total feed for pastoralists, while hay feed comprised only 23%. However, in 2017, the feeding ratio reversed, with hay accounting for 62% of the total feed and commercial feed dropping to 38%. This feeding trend indicates a growing preference for feeding livestock with hay during droughts as it becomes more available in the market. In contrast, the percentage of livestock fed using self-grown hay increased by only 1%, reaching 22% of the total feed. The low percentages of hay grown suggest that pastoralists still require more hay. The study surveyed 354 pastoralists and found that only 6% grew hay commercially or for personal use. Most preferred to purchase hay rather than grow it during normal and drought years.

In Kajiado, there is still a high demand for hay that still needs to be met, consistent with a study conducted in 2017 that identified a 3.6 billion hay deficit in Kenya (Auma, 2018). The research also found that the demand for hay is at its peak during the most severe drought period, which typically lasts for three months. In terms of supply, the hay market is only in demand every 15 years, occurring within five years and lasting for three months during severe drought. This spread-out demand makes commercial hay production unattractive. The research showed that the hay deficit stagnated at around 67% in the two droughts of 2015 and 2017. This indicates that the private sector still needs to take up commercial hay farming to meet the demand despite an improvement from the previous drought 2009. These findings align with the Baringo fodder growing groups, where income from hay selling was minimal (Lugusa, 2015).

It is crucial to provide commercial hay supply to livestock during droughts. As a result, the government is promoting hay production among pastoralists for their consumption. However, the unique practice of pastoralists of purchasing hay only during the severe drought period and for a brief period of three months creates an unpredictable and unstable market for farmers every year. Instead of using hay as a significant feeding option, pastoralists still prefer migrating their livestock and accessing free grazing, as found in the Opiyo study (Opiyo & Mureithi, 2011). The significant correlation for drought resilience planners needs to be factored into the Kajiado County Strategic Plan (KCSAP) activities. On the one hand, KCSAP encourages hay growing against low demand during years of average rainfall. Pastoralists have a significant demand for hay for three months during severe droughts, which creates a challenging market for farmers. To address this, the government needs to provide incentives for large commercial hay growers to increase their acreage. The government can also encourage pastoralists to purchase hay throughout the year to enhance livestock productivity and increase resilience during droughts. These findings differ from the CGAIR study that recommends upscaling commercial hay production (Suzanne van Dijk, 2018).

According to the study, a mere 6% of the interviewed pastoralists in Kajiado grow hay despite receiving training in hay farming. The low uptake suggests other factors prevent pastoralists from successfully growing and harvesting hay, including the high cost of hay-growing equipment. The county should map the hay growers and provide them with additional training and support to improve their skills. This mapping will help them be more efficient and productive and benefit the entire industry. Additionally, the mapping will ensure that they can meet the market's needs and the needs of their customers. The research revealed that the current large hay farmers had not received any training. The County Integrated Development Plans (CIDP) must incorporate the farmers' production support needs, and the pastoralists' hay-buying behaviour patterns play a role in determining the price of hay. These two factors will interact to determine the final price of hay. However, the CIDP prioritizes training pastoralists, assuming they will start hay farming. The strategies should be further elaborated into practical work plans to reconcile the plans and what is happening in the field. The research supports the idea that it would be beneficial to take the time to develop more detailed plans for how to implement the strategies that include demand drivers and supply patterns of hay production. The technical staff needed to implement these activities at the current staffing levels of counties need to be adequate to take on additional workload. The staff require useful information that does not require further processing. In other words, they need ready-to-use information.

A case in point is the hay production flagship project, which highlights how CIDP supports disaster risk reduction (DRR) activities in the field. The hay flagship activities have several implementation gaps and challenges that need addressing. One gap is the need to categorize hay farms into groups: those that grow for commercial purposes and those that grow for subsistence. Another gap is the need for more consideration of the seasonality of hay supply and demand and its impact on the stability and reliability of the hay market. Moreover, the pastoralists tend to purchase hay instead of cultivating it on their own, a preference needs to be reflected in the current CIDP, which currently focuses on encouraging pastoralists to grow hay.

It is imperative to conduct a comprehensive evaluation of the direction of the hay production flagship to ascertain whether the current trajectory is sustainable and whether any changes need to be made. The review will examine all hay production aspects, from seed selection and planting to harvesting and packaging. Once the review is complete, a report will provide recommendations for the future direction of the flagship. One suggestion is to have large farms specialize in production while encouraging small-scale hay producers and pastoralists to feed their livestock with hay regularly to improve livestock productivity and resilience to droughts. The project needs to reallocate funds to support hay farmers if the ambitions of the Kajiado County strategic plan and KCSAP are to be realized. An additional inadequacy is the requirement for enhanced training for the sizeable hay farmers with more than 100 acres of hay, who presently rely on experimental methods for learning. Practical hay production knowledge in arid areas with different climatic and soil conditions is also not readily available. These gaps and challenges are contributing to low hay production levels.

The CIDP needs to address the challenges large hay farms face, primarily related to high production costs and the need to reduce them. The CIDP does not relieve high production costs nor includes research and development provisions to improve hay production productivity. Other challenges that need addressing include an unstable hay market and low profits. The 400-acre hay farms comprise 73% of all hay grown in Kajiado Central, so their challenges must be addressed. If they abandon hay farming, the county will experience an over 90% hay deficit during subsequent droughts. Despite this reality, the CIDP, as currently constituted, does not support large hay farmers. One glaring weakness of the CIDP is its focus on constructing stores and fencing only within the county's demonstration farms. Another area that requires improvement is the exclusion of large hay growers from the training of pastoralist groups. Currently, there is a lack of clarity in the implementation of policies within the CIDP and their operations. This mismatch is likely due to different interpretations of the policies by different actors, which can create confusion and frustration. The lack of clear communication between different parts of the CIDP can lead to inefficient or ineffective policy implementation. These findings are unique because they make specific recommendations on what strategies should be implemented to enhance hay production.

To achieve higher hay production levels, the pressing issues affecting hay producers, such as pests and diseases, a lack of research and development, and a shortage of funding, need to be addressed. Addressing these concerns will require the cooperation of many groups, including researchers, farmers, and policymakers. Collaborative efforts are vital to enhance hay production levels, and it is essential to allocate funds specifically for private landowners to carry out adaptation and mitigation measures. Additionally, supporting farms to act as temporary conservancies to protect wildlife during droughts and providing best practices training for hay farming is necessary.

Considering that most hay farms are relatively small, less than 10 acres, and receive minimal direct government assistance, attaining the required level of hay production to effectively mitigate drought and become a fundamental aspect of livestock production practices may still pose a challenge in the future. This will require direct government intervention to promote commercial large-scale hay farming, marketing, transport, and storage along the hay value chain. Furthermore, since hay growing still has low uptake in arid areas, it is crucial for the limited resources within projects like KCSAP to directly support hay producers and fill this gap (Ouma, 2017).

4.6 Conclusions

The study highlights the significance of hay as a crucial strategy for mitigating the risks associated with drought in Kajiado Central, Kenya. The findings indicate an average estimate of a 67% hay deficit, implying that the existing hay cannot substantially reduce or fully replace pastoralists' traditional migration strategy during droughts. The findings further revealed that livestock migration is the primary strategy used by over 85% of pastoralists in Kajiado Central, with other complementary strategies like buying hay, paddocking, and livestock feed.

The study suggests that the productivity rate of hay per acre in Kajiado Central is far below that of other semi-arid regions. However, appropriate cultivation practices such as seasonal weeding and manuring can improve productivity. Advanced irrigation systems, such as drip irrigation, can also be adapted to increase hay production and reduce the cost of production. The government should consider intervention activities and support for sustainable hay production are necessary to enhance the resilience of pastoralists' livelihoods in Kajiado Central, Kenya.

The study finds that the demand for hay is at its peak during severe drought periods, which last for three months, creating an unstable and unpredictable market for farmers. Therefore, providing commercial hay supply to livestock during droughts is crucial. Collaboration between pastoralists, the government, and the private sector is needed to address the hay deficit in Kenya and promote sustainable livestock production practices.

The study recommends that mapping hay growers and providing additional training and support to improve skills will help increase efficiency and productivity and benefit the entire industry. The county Integrated Development Plan (CIDP) should consider incorporating farmers' production support needs, consider pastoralists' hay-buying behaviour patterns, and develop detailed plans for implementing strategies that include demand drivers and supply patterns.

To increase hay production levels, pressing issues affecting hay producers, such as pests and diseases, a lack of research and development, and a shortage of funding, need to be addressed. Collaborative efforts involving researchers, farmers, and policymakers are vital to enhance hay production levels. Direct government intervention may be necessary to promote commercial large-scale hay farming, marketing, transport, and storage along the hay value chain. Supporting farms as temporary conservancies to protect wildlife during droughts and providing best practices training for hay farming is also necessary.

In summary, addressing the challenges facing hay production in Kajiado County requires a comprehensive approach involving various stakeholders, government intervention, and clear communication between different actors within the CIDP. The recommendations outlined in this study provide a starting point for enhancing hay production and mitigating the impact of droughts on livestock production in the region. Future studies can explore the economic viability of commercial hay production, the potential impact of climate change on the hay market, and the role of technology in enhancing hay production and storage.

4.7 Recommendations

According to this research, there is a significant hay shortage of approximately 67% in Kajiado County, and hay production is still well below the desired levels, meeting only 20-26% of the requirements. To address this issue, planners should consider supporting hay producers and livestock keepers during droughts and address the challenges hindering hay production. Private hay producers should also invest in arid areas with vast tracts of land available to increase production and meet the demand for hay during droughts. The availability of hay during severe droughts can reduce livestock migration and resource-based conflicts, as evidenced by previous research. However, the low demand for hay in good rainy years forces hay producers to store their stock for extended periods, waiting for severe droughts, which results in significant economic losses. As a resilience strategy for the government and communities, the hay production enterprise is still in its infancy and requires significant support. The demand for hay from pastoralists, albeit only during the peak of the drought, means planners can match supply and demand to create a viable hay enterprise.

CHAPTER FIVE

Objective paper addressed: Objective Two - To conduct a cost-benefit analysis of hay production under different cultivation practices in Kajiado County

Publication: The cost-benefit analysis of hay production in different Farm sizes in Kajiado County, Kenya

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5.0 THE COST-BENEFIT ANALYSIS OF HAY PRODUCTION UNDER DIFFERENT CULTIVATION PRACTICES IN KAJIADO

5.1 Abstract

Implementing modern grass enhancement methods in reducing drought risks in pastoral livestock systems is essential. However, further empirical evidence is required to support the scaling up of hay production in arid and semi-arid lands (ASAL). In Kajiado County, a cost-benefit analysis was carried out by researchers through surveys of 354 pastoralists and 23 hay farms to determine the profitability of cultivating hay using different techniques, including owning or hiring farm machinery, using rain-fed or irrigation systems, and building hay barns. The study found that the profitability and viability of hay production were negatively impacted by purchasing machinery, setting up irrigation systems, and building hay barns. However, hay farms that hired machinery and practised rain-fed agriculture were profitable by the third year. Those that cultivated 100 acres or fewer and produced fewer than 4,250 bales per year were not profitable, considering the average sale price of KES 180 per bale. Hay prices varied, with the highest prices noted during drought seasons/years. The construction of hay barns incurred high costs but was deemed necessary for storing hay for over one year. The study also revealed that the sale of hay every subsequent two years did not offset the annual operating costs within farms. Pastoralists only purchased hay during severe droughts every two to three years. The erratic hay market needs to be addressed to cushion the farmers against profit loss from hay storage and the high costs of building hay stores. The study recommends public-private partnerships to establish hay off-take schemes and stabilize production, markets, and distribution. External financial support for hay production in ASAL areas is recommended as a potential sustainability strategy. The study concluded that hay farms that hired machinery and practised rain-fed agriculture while building hay stores were economically viable by the third year.

Keywords

Hay production, Drought Risk Reduction, Climate-Smart strategies, Livestock, Pastoralism.

5.2 Introduction

According to Nyoka (2016), drought is a frequent natural hazard in Kenya that adversely affects the livestock industry and raises the possibility of future shocks. The Kenyan government launched the Agricultural Sector Transformation and Growth Strategy (ASTGS) in 2019 to achieve food security by creating a robust, profitable, and modern agricultural sector that can withstand environmental shocks, particularly in arid and semi-arid regions. One of the flagship projects under the ASTGS aims to provide pastoralists with inputs, improve post-harvest handling, enhance aggregation and market access, and support associations and cooperatives. The strategy also seeks to establish large farms over 2500 acres, sustainably irrigate more than 150,000 acres, and increase household resilience (ASTGS Strategy, 2019-2029). As an enterprise, the profitability of large-scale hay production is determined by conducting cost-benefit analyses (Ouma, 2017).

The Kenya Climate-Smart Agriculture Project (KCSAP) from 2017 to 2022 aims to achieve sustainable agricultural growth through improved productivity, reduced greenhouse emissions, and enhanced resilience. Kajiado County has implemented the ASTGS and KCSAP and launched a flagship project to encourage private-sector hay production and storage to feed pastoral livestock systems during drought (County K., 2018a).

This study's conceptual framework for analysis is based on United Nations Sustainable Development Goals (UN-SDGs) target 2.4, which promotes sustainable and resilient food production systems and agricultural practices that increase productivity and production by 2030. Sustainable agriculture helps maintain ecosystems, strengthens adaptation to climate change events, and progressively improves land and soil quality. UN-SDG 2.4.1 measures the agricultural acreage under productive and sustainable agriculture. To ensure standardized reporting for UN-SDG 2.4.1 outputs, the Food and Agriculture Organization (FAO) recommends measuring the sustainability of agricultural practices using economic values of land productivity (farm output value per hectare) and profitability (net farm income). Therefore, profitability can be a standalone measure to determine agriculture sustainability (FAO, 2020). The hay farms data analysis followed these FAO guidelines and had three objectives: establishing the optimal hay output that will make hay farming profitable, determining how sensitive the price of a hay bale is to changes in the demand and supply chain of hay, and identifying the major cost centres of hay production.

The study evaluated the financial feasibility of hay production by conducting a cost-benefit analysis of farms ranging from three to 400 acres that employed or acquired machinery (balers, cutters, tractors), grew rain-fed or irrigated grasses, and constructed permanent or temporary hay stores. The findings provided a cost layout, profitability, and long-term viability of hay production as a drought risk reduction strategy under the Kajiado hay flagship project. Furthermore, the study provides policymakers and technocrats with data to enhance the implementation of the hay flagship project under the ASTGS and KCSAP programs administered by the Ministry of Agriculture in arid and semi-arid lands (ASAL), including Kajiado County.

5.3 Materials and Methods

The study area and methodology are described in Chapter 3.

5.4 Results

5.4.1 Cost Centres

The study found that capital costs were the most significant cost centre. These capital costs comprised the purchase of machinery (tractors, balers, and cutters) and building hay stores. Irrigation equipment was an additional capital cost for the farm growing Boma Rhodes. The study calculated the recurring costs for the farms comprised of hiring machinery for cutting and baling plus labour costs. The Analysis found that the second biggest cost centre was temporary, seasonal labour for weeding and baling and permanent labour like security, managers, and farm hands.

Furthermore, the Analysis found that both permanent and temporary labour accounted for the most significant component of recurring cost centres. The Analysis further found that labour costs to total recurring costs decreased as hay acreage increased, whether the farms hired or owned machinery. For farms over 150 acres, the labour costs were not significantly different for both farms, that is, 47% to 79% for machine-hiring farms compared to 55% to 87% for farms that bought machinery (Fig. 13).

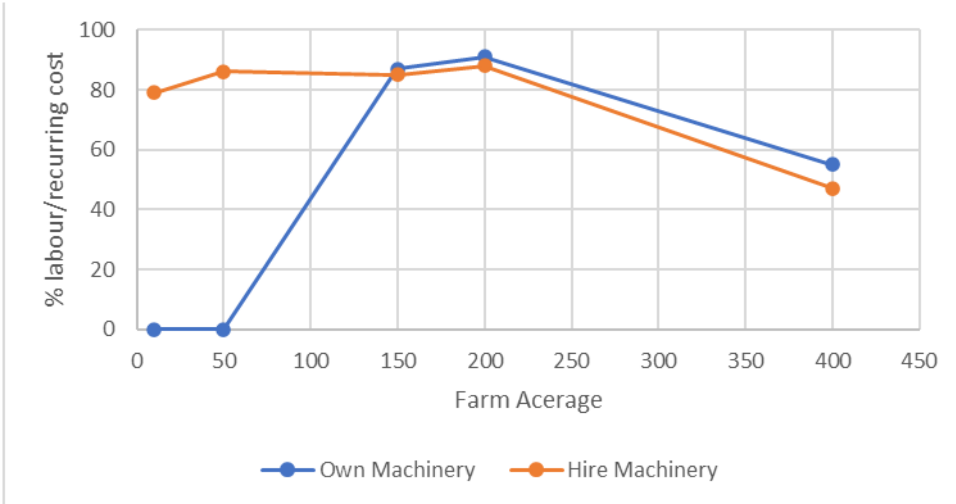

Figure 13: Ration of Labour to recurring costs (%)

The analysis revealed that the third most significant cost centre was the income from the sale of hay and seasonal grazing of livestock post-harvest. Interviews with the respondents also indicated that all farms had additional income sources unrelated to hay farming that substantially supplemented their farm income, allowing them to operate. The respondents further noted that the non-hay-related income was derived from cattle and shoat rearing, water sales, formal employment, and farm-based businesses.

5.4.2 Cost-Benefit Analysis of the 10-acre to 200 Hay Farms

The researcher computed the NPV, IRR, and ROI analysis of the 10-200 acres farms with or without hay stores and either hiring or buying machinery. When the researcher did the Analysis, the IRR calculation produced a Nil result because the negative figures were too significant. The farms were unprofitable and unviable at the recorded production rates for 10 to 200 acres. The operations cost exceeded the income. Table 4 shows the NPV and ROI of the different farm sizes which have not constructed hay stores.

Table 4: Profitability of Farm Sizes (10-acres to 200-acre) without Hay Stores

Farm Size	Net Present Value (NPV)	Return on Investment (ROI)
200	-3,133,650	-0.79
150	-2,034,386	-0.79
50	-323,496	-0.46
10	-1,087,873	-0.74

5.4.3 Cost-Benefit Analysis of 400-acre Farms

The Analysis found that the 400-acre optimal production rate of 48 bales per acre required 90 acres to produce 4250 bales. Figure 14 that shows the optimal production against the standardized profitability across different farm sizes.

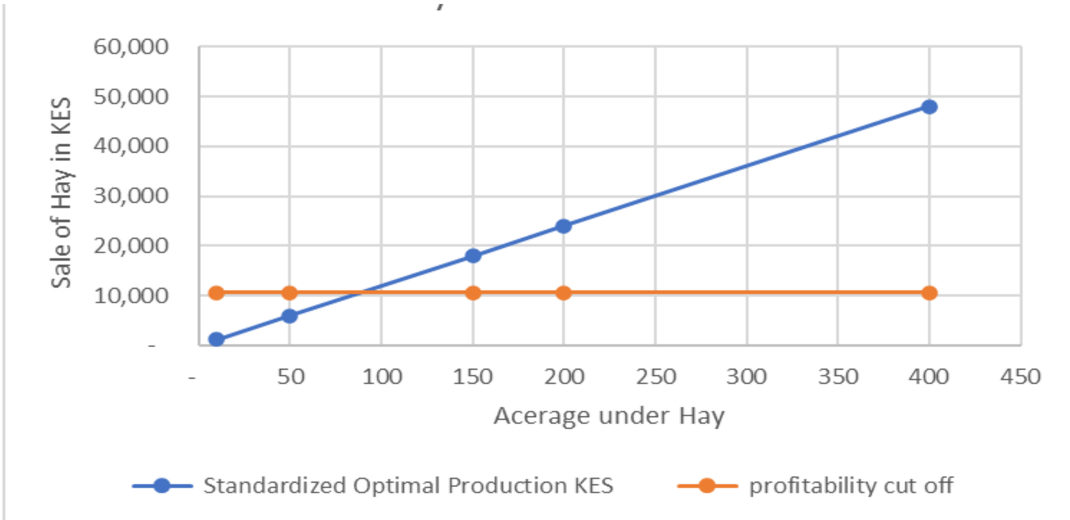

Figure 14: Profitability 10-acre to 400-acre farms sizes

The cost-benefit Analysis of the mechanized 400-acre farm hay production farm is presented in table 5. The cost-benefit calculations found that the 400-acre mechanized farm, growing Boma Rhodes, with bought machinery, had a payback period that exceeded five years. The NPV was negative, so we rejected the enterprise; the IRR is negative and, therefore, less than the cost of capital invested. This farming method is not viable and should be avoided.

The cost-benefit Analysis of the non-mechanized 400-acre hay production farm based on hired machinery is presented in table 6. This farm grew a variety of local hay grasses and not seeded. The payback period for this non-mechanized farm is in the third year; the NPV is positive, so we accept the enterprise, while the IRR is positive, meaning this farming method is viable.

Table 5: 400 acres of the farm (own machinery)

CBA 400 Acres own Machinery (Rhodes Boma)

Discount rate	10%						
The initial cost of capital	17,412,000						
			2015	2016	2017	2018	2019
Cash in-flows		Year	0	1	2	3	4
Sale of Hay			1,800,000	2,000,000	4,500,000	4,800,000	2,625,000
Grazing income			150,000	150,000	150,000	150,000	150,000
Cash inflows			1,950,000	2,150,000	4,650,000	4,950,000	2,775,000
PV of cash inflow			1,950,000	1,954,545	3,842,975	3,719,008	1,895,362
Cumulative cash inflow			1,950,000	3,904,545	7,747,521	11,466,529	13,361,891
Costs							
Ploughing Cost			400,000	400,000	400,000	400,000	400,000
Gen Utility Cost			30,000	30,000	30,000	30,000	30,000
Fencing Repair Cost				10,000	10,000	10,000	10,000
Permanent staff cost			600,000	600,000	600,000	600,000	600,000
Weeding Cost			30,000	30,000	30,000	30,000	30,000
Irrigation costs			32,000	32,000	32,000	32,000	32,000
Machinery repair cost			30,100	30,100	30,100	30,100	30,100
Temporary staff for hay			21,000	21,000	21,000	21,000	21,000
Cash outflow			1,143,100	1,153,100	1,153,100	1,153,100	1,153,100
PV of Cash Outflow			1,143,100	1,048,273	952,975	866,341	787,583
Cumulative cash outflow			1,143,100	2,191,373	3,144,348	4,010,689	4,798,272
Discounted total cash outflow							22,210,272
Net Cash flow/Benefit			-16,605,100	996,900	3,496,900	3,796,900	1,621,900
PAYBACK(CUMULATIVE PV)			-16,605,100	-15,608,200	-12,111,300	-8,314,400	-6,692,500
NPV of project	-8,848,381						
IRR	-17%						
ROI	-40%						

The initial cost of the capital cluster (KES)

Machinery Purchase Cost	7,712,000
Irrigation equipment	5,500,000
Store construction cost	2,000,000
Fencing Cost	1,000,000
Bush Clearing Cost	1,200,000
	17,412,000

No. of bales sold	Years	Price per bale	Revenue in KES
6000	2015	300	1,800,000
8000	2016	250	2,000,000
15000	2017	300	4,500,000
19200	2018	250	4,800,000
10500	2019	250	2,625,000

Notes:

PV of cash inflow-Is the Present value of cash inflows, i.e., yearly cash inflow discounted at a discount rate of 10%

PV of cash inflow-Is the Present value of cash outflows, i.e., yearly cash outflow discounted at a discount rate of 10%

Payback Period, i.e., the project starts to get positive net benefits.

Table 6: 400 acres farm (hired machinery)

CBA 400 Acres Without Machinery

Discount rate	10%						
The initial cost of capital	4,200,000						
			2015	2016	2017	2018	2019
Cash in-flows		Year	0	1	2	3	4
Sale of Hay			1,800,000	2,000,000	4,500,000	4,800,000	2,625,000
Grazing income			150,000	150,000	150,000	150,000	150,000
Cash inflows			1,950,000	2,150,000	4,650,000	4,950,000	2,775,000
PV of cash inflow			1,950,000	1,954,545	3,842,975	3,719,008	1,895,362
Cumulative cash inflow			1,950,000	3,904,545	7,747,521	11,466,529	13,361,891
Costs							
Tractor+Baler harvesting cost			480,000	640,000	1,200,000	1,536,000	840,000
Gen Utility Cost			30,000	30,000	30,000	30,000	30,000
Fencing Repair Cost				10,000	10,000	10,000	10,000
Permanent staff cost			600,000	600,000	600,000	600,000	600,000
Weeding Cost			30,000	30,000	30,000	30,000	30,000
Temporary staff for hay			21,000	21,000	21,000	21,000	21,000
Cash outflow			1,161,000	1,331,000	1,891,000	2,227,000	1,531,000
PV of Cash Outflow			1,161,000	1,210,000	1,562,810	1,673,178	1,045,694
Cumulative cash outflow			1,161,000	2,371,000	3,933,810	5,606,988	6,652,682
Discounted total cash outflow							10,852,682
Net Cash flow/Benefit			-3,411,000	819,000	2,759,000	2,723,000	1,244,000
PAYBACK(CUMULATIVE PV)			-3,411,000	-2,592,000	167,000	2,890,000	4,134,000
NPV of project	2,509,210						
IRR	38%						
ROI	23%						

The initial cost of the capital cluster (KES)

Store construction cost	2,000,000
Fencing Cost	1,000,000
Bush Clearing Cost	1,200,000
	4,200,000

No. of bales sold	Years	Price per bale	Revenue in KES
6000	2015	300	1,800,000
8000	2016	250	2,000,000
15000	2017	300	4,500,000
19200	2018	250	4,800,000
10500	2019	250	2,625,000

Notes:

PV of cash inflow-Is the Present value of cash inflows. i.e. yearly cash inflow discounted at a discount rate of 10%

PV of cash outflow-Is the Present value of cash outflows, i.e., yearly cash outflow discounted at a discount rate of 10%

Payback Period, i.e., the project starts to get positive net benefits in year 3 with KES 167,000

The Analysis found that the 400 acres farm that hired machinery had a positive ROI of 23%, while the 400-acre farm that owned machinery had a significant negative ROI of (-40%) as shown in figure 15. The farmers interviewed explained that the positive ROI is because farms hired machinery from private providers who charged KES 70 per 15 kg bale. The farmers further explained that they preferred the private providers because they were readily available and provided more efficient services than government services.

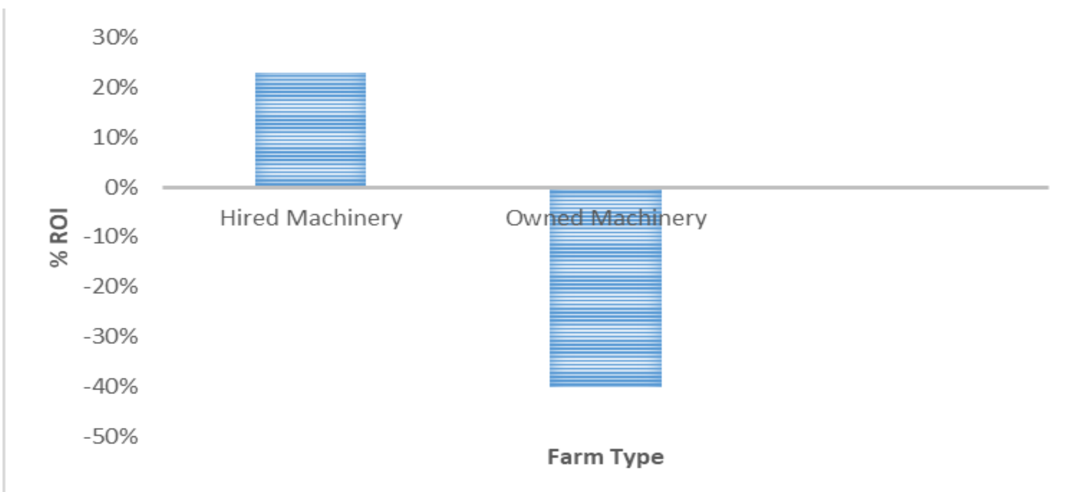

Figure 15: ROI of farms that hire versus own machinery.

The cost-benefit analysis calculations found that the high initial setup and subsequent irrigation-system operating costs resulted in a negative cumulative payback period beyond year 5. When the researcher removed the irrigation equipment and running fees, the computed IRR improved from -17% to -4%, while the ROI improved from -

40% to -19% (Table 7). However, the IRR and ROI remained negative due to the capital costs of machinery (tractors and balers) buying.

Table 7: Irrigation Systems costs on profitability

	Irrigation System in the same 400-acre farm in KES	
	With Irrigation system	**Without Irrigation system**
Net Present Value (NPV)	(88,484)	(32,150)
Internal Rate of Return (IRR)	-17%	-4%
Return on Investment (ROI)	-40%	-19%

The Price sensitivity analysis found that hay prices ranged from KES 120 in 2020 to KES 350 in 2017. Price sensitivity analysis revealed that KES 180 per bale is the cut-off for profitability (Fig. 16).

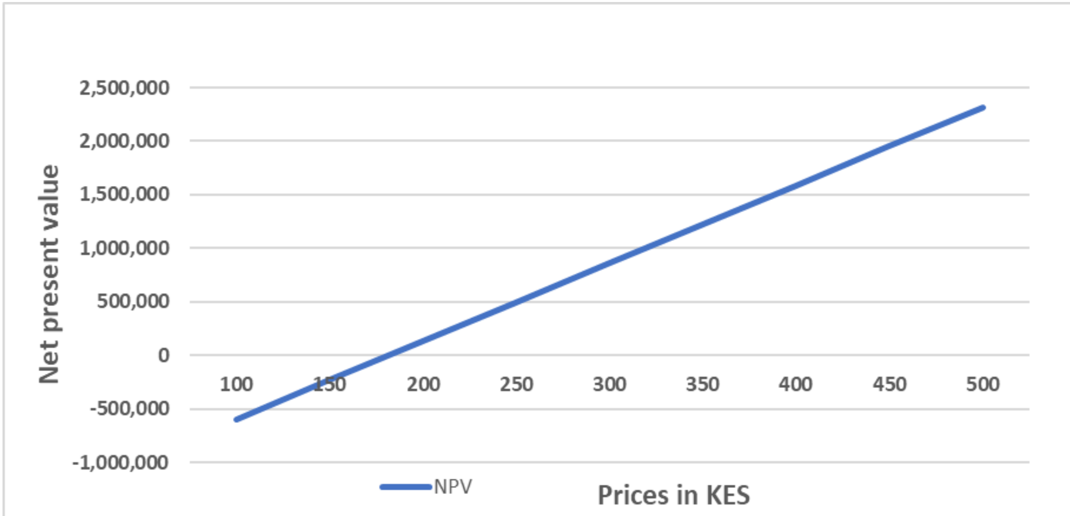

Figure 16: Optimal price for profitability (When NPV=0)

Figure 17 shows that the minimum number of hay bales needed to be harvested on a 400-acre piece of land to **break even** is 4,250 bales at the minimum price of KES 180 (Fig 16).

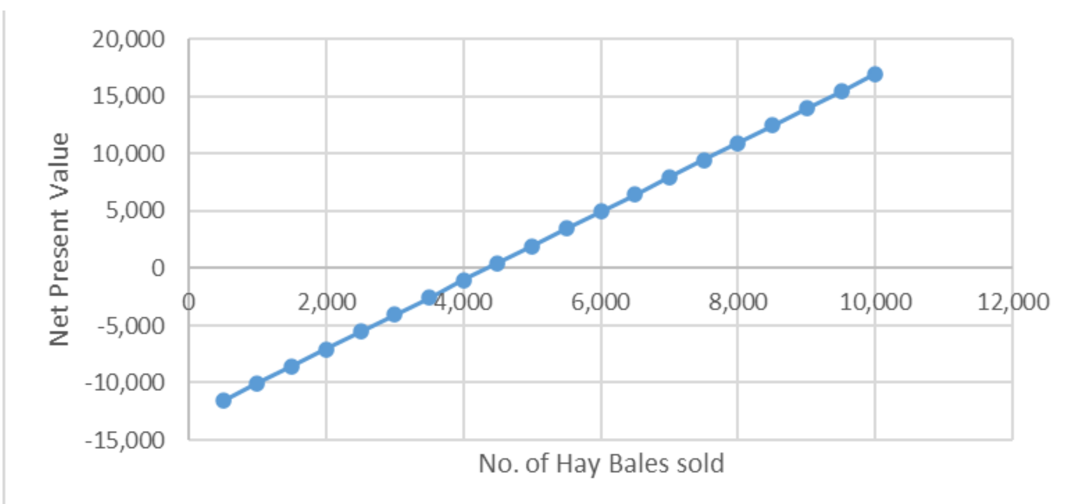

Figure 17: Optimal production per acreage (Number of bales sold when Net present value equals zero)

5.4.4 Insurance against Hazard Risks

From the interviews, one of the 400-acre farms had a fire burn in the first quarter of 2019, burning all their 2018 stored harvest. Although the farmhouse was insured, it did not cover hay as it was high-risk. The farmer bore the cost of construction and the loss of potential sales. Table 8 was the actual cropping practice, including the fire hazard and how it impacts profitability of cultivating local indigenous grasses on a 400-acre farm. The financial Analysis shows that the farm's profitability was very sensitive to no hay sales and hazards (like fire). These incidents, when computed, result in negative NPV, IRR and ROI, making the enterprise unprofitable.

Table 8: Impact of Fire Hazard on the Profitability of a 400-acre Farm (Growing Local Variety Grasses, Hiring Machinery, and Rain-fed)

Cultivation Strategy	No. of Bales Sold	Year	Price per Bale (KES)	Revenue (KES)
Harvest	6,000	2015	18,000	108,000
Harvest	8,000	2016	20,000	160,000
Harvest	15,000	2017	45,000	675,000
Harvest	19,200	2018	0	0
Barn fire destroying 2018 hay; 2019 hay harvest	10,500	2019	0	0
No harvest; increased grazing hires	0	2020	0	0
No harvest: sold hay stored; increased grazing hires	10,500	2021	3	31,500

CBA 400 Acres without Machinery - FIRE HAZARD in 2018

Discount rate	0						
The initial cost of capital	4,200,000						
	2,015	**2,016**	**2,017**	**2,018**	**2,019**	**2,020**	**2,021**
Year	**-**	**1**	**2**	**3**	**4**	**5**	**6**
Cash in-flows							
Sale of Hay	1,800,000	2,000,000	4,500,000	-	-	-	3,150,000
Grazing income	150,000	150,000	150,000	150,000	150,000	600,000	600,000
Cash inflows	**1,950,000**	**2,150,000**	**4,650,000**	**150,000**	**150,000**	**600,000**	**3,750,000**
PV of cash inflow	**1,950,000**	**1,954,545**	**3,842,975**	**112,697**	**102,452**	**372,553**	**2,116,777**
Cumulative cash inflow	**1,950,000**	**3,904,545**	**7,747,521**	**7,860,218**	**7,962,670**	**8,335,223**	**10,452,000**
Costs							
Reconstruction Fire hazard - hay stores				200,000			
Tractor & Baler harvesting cost	480,000	640,000	1,200,000	1,536,000	840,000	-	-
Gen Utility Cost	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Fencing Repair Cost	-	10,000	10,000	10,000	10,000	10,000	10,000
Permanent staff cost	600,000	600,000	600,000	600,000	600,000	600,000	600,000
Weeding Cost	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Temporary staff for hay	21,000	21,000	21,000	21,000	21,000	21,000	21,000
Cash outflow	1,161,000	1,331,000	1,891,000	2,427,000	1,531,000	691,000	691,000
PV of Cash Outflow	**1,161,000**	**1,210,000**	**1,562,810**	**1,823,441**	**1,045,694**	**429,057**	**390,051**
Cumulative cash outflow	**1,161,000**	**2,371,000**	**3,933,810**	**5,757,251**	**6,802,945**	**7,232,001**	**7,622,053**
Discounted total cash outflow							**11,822,053**
Net Cash flow/Benefit	(3,411,000)	819,000	2,759,000	(2,277,000)	(1,381,000)	(91,000)	3,059,000
PAYBACK(CUMULATIVE PV)	**(3,411,000)**	**(2,592,000)**	**167,000**	**(2,110,000)**	**(3,491,000)**	**(3,582,000)**	**(523,000)**

NPV of project	**(1,370,053)**
IRR	**-4%**
ROI	**-12%**

The initial cost of the capital cluster (KES)

Store construction cost	2,000,000
Fencing Cost	1,000,000
Bush Clearing Cost	1,200,000
	4,200,000

Notes

PV of cash inflow-Is the Present value of cash inflows..i.e. yearly cash inflow discounted at a discount rate of 10%

PV of cash outflow-Is the Present value of cash outflows yearly cash outflow discounted at a discount rate of 10%

Payback Period, i.e. the project starts to get positive net benefits in year 3 with KES 167000

2018 hay stored - stacking method and fire destroyed it. 2019 hay stored and sold in 2021

No sales saw profits drop to negative within one year.

5.5 Discussion

According to the analysis, production level rather than farm size was found to be the key factor in determining profitability. Our findings indicated that farms need to produce a minimum of 4,250 bales per year at a price range of KES 180 per 15 kg bale in order to achieve profitability. Figure 2 shows farms can achieve this target on a 90-acre farm under hay. However, the study found that even farms of 200 acres had cropping practices resulting in harvests far below the optimal rate of 48 bales an acre, making them unprofitable. These farmers require training in good cropping practices to increase their output. The analysis also revealed that larger farms over 150 acres enjoyed economies of scale, evening their labour costs.

The study found that hiring machinery instead of owning it had a positive impact on the profitability of a 400-acre farm. Within three years, the farm that hired machinery reached profitability compared to the farm that bought and maintained its own machinery. The former had a positive ROI, while the latter had a negative ROI. Farms that hire machinery have significantly higher NPV (NPV 25,100) than those that own machinery (NPV -88,484). The IRR and ROI of the farm that hires machinery are 38% and 23%, respectively, whereas the farm that owns machinery has an IRR of -17% and an ROI of -40%. The equipment examined in this study included balers, cutters, and tractors.

The cost of repairing and replacing damaged components of cutters and balers wiped out a season's profits. The owners of balers bore the cost of repairs. While owning a tractor was cheaper than hiring one to ferry hay from the field to the store, hiring tractors costed much more than fuelling them. Repairs and spare parts of tractors were cheaper, readily available locally, and even as second-hand and prefabricated pieces. However, the high capital cost of buying a new tractor pushed the ROI to negative.

At the 400-acre Boma Rhodes farm, the hay crop is irrigated using gun sprinklers during the dry season with insufficient rainfall. This allows for three crops per year: two Boma Rhodes and one legume crop. However, the high cost of initial setup and subsequent operating costs of the irrigation system resulted in a negative cumulative payback period beyond year 5. In contrast, the farm without irrigation systems saw a positive cumulative payback by year three. Furthermore, the cost of purchasing irrigation equipment produced a negative IRR and ROI. Had the farm not invested in the irrigation system, its NPV, IRR, and ROI would have improved by year five but remained negative due to the purchase of other types of machinery.

The Boma Rhodes farm used the rain gun overhead irrigation system, which costs KES 550,000 per acre, while drip irrigation costs KES 120,000 per acre (Rain gun sprinklers, 2020). The study concluded that farmers should have carefully considered an appropriate irrigation system relative to the farm's size before setting them up. The study revealed that pasture irrigation resulted in negative net present value (NPV), internal rate of return (IRR), and return on investment (ROI) and should not have been used in hay pasture cropping practices in arid and semi-arid lands (ASAL).If it is to be used, government subsidies should be considered.

The Malabo Montpellier Panel concurs with the research findings that the high initial cost of irrigation equipment for farmers needs to be offset by having a reliable and profitable market for the produce, adaptable private-public partnerships to access financing, and commercially supply water to smaller farmers with appropriate technology. The panel also notes that irrigation is a long-term capital investment (Panel, 2018.). While irrigation of hay may be desirable in theory, failed irrigation schemes in Kenya have led to a low political risk appetite that may affect options for private-public partnerships in irrigation (Lebdi, 2016).

The cost of hay stores depends on the materials used. For the 400-acre farms, hay stores consist of a combination of stone, wood, and aluminium iron sheet, costing KES 2,000,000 for a 20,000-bale storage capacity. The most significant capital cost incurred in hay production was the construction of hay stores, as it was necessary to store hay for 1-2 years before selling it. The demand and supply of hay depended on the drought cycle, with demand highest during droughts. Therefore, hay stores played a crucial role in maintaining hay quality and supply during these periods of high demand. In the study period, hay farmers had not sold their hay in 2019, 2020, and the first half of 2021 due to good rains leading to a collapse in demand for hay, forcing farmers to keep it in their stores.

The study found that the inclusion of strategic feed reserves would have been beneficial in addressing hay storage challenges. This measure could have encouraged the storage of hay by both the government and the private sector. Developing private hay feed strategic reserves would also meet Kajiado County's strategic goals, seeking appropriate food security strategies that support relevant value chains like hay production while addressing post-harvest losses (County K. , 2018b). Our findings are consistent with CGIAR, which notes that hay stores are essential in having a viable hay value chain to allow farmers to store and sell hay when prices are high (CGIAR, 2018).

The hay farming industry was susceptible to hazards such as fire, flood damage, and post-harvest losses due to moisture mould, locusts, armyworms, and insect infestation. These hazards could occur during the growing stage, field harvests, or in storage. Insurance companies viewed the hay business as high risk and either did not cover risk hazards like fire or floods or offered limited coverage.

5.6 Conclusions

In conclusion, this study found that production level, rather than farm size, is critical in determining profitability in hay farming. Farms need to produce a minimum of 4,250 bales per year at a price range of KES 180 per 15 kg bale to achieve profitability. Larger farms over 150 acres enjoyed economies of scale, evening their labour costs. The study also found that hiring machinery instead of buying was more profitable for the 400-acre farm. Irrigation of hay resulted in negative net present value, internal rate of return, and return on investment and should not have been used in hay pasture cropping practices in arid and semi-arid lands. The most significant capital cost incurred in hay production was the construction of hay stores. Including strategic feed, reserves would have been beneficial in addressing hay storage challenges. The hay farming industry is also susceptible to fire, flood damage, and post-harvest losses due to moisture mould, locusts, armyworms, and insect infestation. The findings suggest that farmers need to improve their cropping practices, consider hiring machinery, and carefully consider appropriate irrigation systems relative to the farm's size before setting them up. Developing private hay feed strategic reserves would also meet the county's strategic goals of supporting relevant value chains like hay production while addressing post-harvest losses. Further research should investigate how to reduce hay production hazards and determine strategies to address them.

5.7 Recommendations

- The government should consider establishing hay strategic feed reserves. Demand for hay is seasonal. While hay is in high demand during severe drought, it sees zero to negligible sales during average and good rain years. In 2018, hay farmers sold all their harvest, but in 2019 and 2020, the seasonal rains were adequate availing plenty of free communal grazing for the pastoralists livestock, resulting in no hay sales. The sale of hay resumed in November 2021 when drought set in. Researchers need to factor in a lack of sales, which can wipe out the hay production enterprise's profitability within a year. Negative profitability after one year shows that the enterprise is susceptible to shock (of no sales) and has no resilience. Establishing strategic hay reserves would address this challenge.
- The government should consider supporting hay farmers by providing subsidies or effective cooperatives. The entire enterprise is not profitable when the annual variable costs of operating the farms during good rain years with no hay sales are factored in. Without external support, hay production left to economic forces is not a viable risk mitigation strategy at the national level. Decision-makers need to address this to make this strategy resilient. Setting up effective hay cooperatives that provide subsidies to farmers would be a possible solution.
- The government should consider setting up private-public partnerships (PPP) focusing on stable markets, hay storage, outsourcing baling, and hay-offtakes. Hay needs to be accorded the same safety net support options as livestock. Hay-offtake means the government buys the hay in good years (average-good rain

years) and stores it to be re-distributed in drought years. The PPP should consider using the farms as hay banks and compensate the farmers for taking this role. Another alternative to PPP is directly subsidizing the hay farmers with cash to offset the loss years. The government should support hay farms to provide other ecosystem services, like drought-season grazing access for wildlife.

- The government should consider introducing insurance that supports hay farmers. As a risk mitigation strategy, both government and private sector should expand agricultural insurance (crop and livestock) to pastoralist communities. In October 2015, the national government launched the Kenya Livestock Insurance Program (KLIP), which protects pastoralists against weather risks. The insurance goal is to reach about 65,000 livestock-dependent Kenyan farmers by 2022 (World Bank, 2015).

CHAPTER SIX

Objective publications address: To evaluate existing policy and institutional frameworks that support hay production as a drought-resilient climate-smart option for pastoralist systems.

Publication 1: Policy recommendations for promoting the viability of hay production in the arid rangelands of Kenya.

Journal Title: African Journal of Food, Agriculture, Nutrition and Development

ISSN Online: 1684 5374

Date Published: 27th March 2023

Citation: Kimaru J, Mutembei H, Kaunga JM. Policy recommendations for promoting the viability of hay production in the arid rangelands of Kenya. Afr J Food Agric Nutr Dev. 2023;23(3):22751-22769. https://doi.org/10.18697/ajfand.118.23045

Publication 2: Effectiveness of Drought Risk Reduction Policies: Case Study of Hay Production in Kajiado County, Kenya

Journal Title: American Journal of Climate Change

ISSN Online: 2167-9509

Publication date: 8th December 2021

Citation: Kimaru, J. , Mutembei, H. and Muthee, J. (2021) Effectiveness of Drought Risk Reduction Policies: Case Study of Hay Production in Kajiado County, Kenya. *American Journal of Climate Change*, 10, 512-532.

doi: 10.4236/ajcc.2021.104026.

6.0 THE POLICY AND INSTITUTIONAL FRAMEWORKS SUPPORTING HAY PRODUCTION IN KAJIADO

6.1 Abstract

Kenya has implemented policies and strategies at the international, continental, and regional levels to mitigate the effects of climate change on pastoralist livestock systems. This study examines how policies integrated into local laws support drought risk mitigation, hay production for food security, and disaster prevention. The study involved a desktop review of policies and how they are integrated into implementing Disaster Risk Reduction (DRR) projects in Kajiado County. Additionally, a survey was conducted to assess beneficiaries' satisfaction with the ongoing DRR activities in the county. The study revealed that Kenya has adequate legal instruments to support climate-related disasters like drought. However, the policies and strategies need to be expanded into practical guidance for better implementation at the county level. The study found that an estimated 76% of the beneficiaries are dissatisfied with the ongoing disaster risk reduction projects in Kajiado. Moreover, hay farmers receive little to no support. The challenges the hay industry faces, such as an unstable market, costly capital assets and machinery, and a shortage of quality forage seeds and training, need to be addressed by the County Integrated Development Plans (CIDP). The planners should review the ongoing hay flagship projects' implementation, starting with evaluating the relevance of the proposed activities in the CIDP. This

review will help to address pastoralists' preferences for disaster mitigation training and rangeland reseeding and support hay farms in achieving profitability.

Keywords

livestock, pastoralism, hay, drought, disaster risk reduction, Climate change adaptation,

6.2 Introduction

Pastoralism is a crucial aspect of the economy of Africa's rangelands, with approximately 43% of the continent's population being pastoralists who rely on livestock for their livelihoods. This way of life is prevalent in 36 countries across the continent, and these nomadic communities often move with their herds in search of pasture and water. Pastoralism is a traditional way of life in Africa practised for centuries and continues to play a vital role in the continent's economy today (FAO, 2018a).

Pastoralists in arid areas with frequent droughts and conflicts face significant challenges due to policy neglect and land-use changes, leading to limited mobility. Managing rangelands effectively is crucial for sustaining pastoralism, and adapting and mitigating against climate change can increase animal-based food security. Hay cultivation is an excellent climate adaptation strategy for rangelands, as it reduces greenhouse gas emissions, improves soil health, and conserves water. Growing hay can also help sequester carbon in the soil, offsetting greenhouse gas emissions. Furthermore, hay fields can act as buffer zones, protecting against erosion and enhancing water quality. Cultivating hay also enhances soil health by providing organic matter and nutrients that boost fertility. However, land-use changes from crop agriculture, extractive industries, and real estate have limited traditional livestock mobility, which is critical for maintaining rangeland productivity. Hay production in rangelands supports the livelihoods of livestock keepers, counteracts environmental degradation, promotes wildlife conservation, preserves traditional cultural practices, and conserves ecosystem services (FAO, 2009).

Africa's livestock sector is subject to natural and artificial hazards, including drought, flooding, forest fires, armyworms, locusts, earthquakes, heat stress, overgrazing, pollution, and habitat loss. These hazards can lead to significant losses in livestock productivity and, in some cases, death. Diseases are also a significant constraint on livestock production in Africa, with contagious bovine pleuropneumonia being highly infectious and endemic in many parts of the continent (FAO, 2015).

Drought is a significant natural hazard, accounting for 86% of the African livestock sector losses (FAO, 2015). Drought can have direct and indirect effects on livestock, including dehydration, starvation, heat stress, increased susceptibility to diseases and parasites, reduced reproductive rates, and changes in the quantity and quality of feed like pasture, forage, and grain. The impacts of drought on livestock can be severe, leading to death or decreased productivity. To overcome the erosion of their livelihoods caused by frequent and recurrent droughts, poor households need to grow economically by 3% annually (African Risk Capacity, 2021).

Animal fodder and feed are critical to building livestock resilience as they maintain animal health and welfare before, during, and after a disaster. Hay is a critical component in livestock and community resilience against droughts. When drought conditions persist, hay becomes a vital forage source for livestock, and it can also be used to create mulch, which helps reduce evaporation and protect plants from the harsh effects of drought. However, the development of feed sources in Kenya has needed to be faster due to a lack of infrastructure and technology (FAO, 2019a).

Kenya's semi-arid land (ASALs) occupies about 83% of the country's total land area and receives little rain. It is home to around 600,000 pastoralists who heavily depend on their livestock for their livelihoods. Droughts occur every two to three years in the ASALs, resulting in the decimation of livestock herds and making it difficult for pastoralists to restock their livestock in time, resulting in reduced livestock holdings and poverty (FAO, 2018a). Droughts affected 16.3 million Kenyans between 1964 and 2004, costing KES 12.1 trillion between 2008 and 2011 and more than KES 180 trillion from 2009 to 2017 (GOK, 2017c; Africa Risk Capacity, 2018).

The transformation of land use in Kajiado County has been rapid, primarily attributed to population growth and urbanization. This transformation significantly impacts the local environment and ecology as the amount of land used for residential and commercial purposes and infrastructure development increases. The legal land tenure status of land and the competing land uses significantly affect how communities respond to and invest in climate change (Moiko, 2019). The land tenure system dictates the pastoralist's choices towards building their climate resilience. Over time, the land tenure systems have changed from communal rangelands to private ranches leading to investments in livestock shifting from extensive low-cost systems to high-cost intensive systems, making them unattainable for poor pastoralists. Pastoralists' knowledge is aligned with extensive mobile pastoralism, which is essential for their survival. The communal, private, or conservancies land tenure systems allow for using natural resources in an area while protecting the environment—especially wildlife habitats, thereby promoting tourism (Moiko, 2019).

According to Joseph Auma (2018), only 55% of smallholder farmers in Kenya grow at least one fodder variety. Kenya has been facing more frequent droughts recently, leading to a deficit of 3.6 billion hay bales, a severe problem for the country, as hay is a vital resource for livestock. The lack of hay has resulted in many livestock deaths and has also led to higher prices for hay. The hay deficit is a problem for Kenya and needs to be addressed urgently (Auma, 2018).

Furthermore, emerging fodder demand by neighbouring counties is expected to increase, requiring 15 million acres of land to grow hay in the arid areas of Kenya to meet the population's needs. Insufficient animal fodder and increased demand for hay have led to government projects on fodder production, rangeland reseeding, and improved grass varieties for communities living in the ASALs. The demand, in turn, has led to an increased demand for fodder against a deficient supply, thereby creating a commercial fodder sector in Kenya. One project aimed at addressing the issue of hay production is a flagship project described in the Kajiado County Integrated

Development Plan. This project is funded by the Kenya Climate Smart Agriculture Project (KCSAP) and the Agricultural Sector Transformation and Growth Strategy (ASTGS) (Auma, 2018).

The aim of the project implementation is to provide support for hay production, which will assist in effectively implementing drought risk reduction strategies, leading to increased livestock resilience in pastoralist systems. The study reviewed the opportunities and risks of international, continental, and regional integration and indigenous policies in Kenya's legal and regulatory tools to promote the effective implementation of activities to support hay production.

6.3 Materials and Methods

The study areas are as described in chapter 3.

A desktop review was conducted on published and unpublished documents to assess the integration of international policy instruments into national policies, strategies, and laws. The review was carried out in three stages.

The initial phase of the study involved an analysis of how international, continental, and regional policies related to disaster risk reduction (DRR) and climate change are incorporated into national DRR policies. In the second stage, the study assessed how national DRR policies are implemented in Kajiado County, focusing on how these policies are reflected in the County Integration Development Plan (CIDP). All counties in Kenya must develop a five-year CIDP, a critical tool for monitoring effective policy implementation. To accomplish this, the County Integrated Development Plan (CIDP) evaluates yearly development plans, county fiscal strategy papers, and annual budget estimates while emphasizing strategies and policies for the upcoming five years. By examining how funding is allocated across activities under the KSCAP project, the study sought to determine how effectively national policies are reflected in county policies.

To obtain a more comprehensive understanding of the effectiveness of policy roll-out at the County level, an investigation was carried out to evaluate the awareness, quality, and preferences of disaster risk reduction programs and activities executed by the government, NGOs, and other actors. Thirty-one pastoralists and key informants from the Loitoktok sub-county were interviewed. Based on the findings from the CIDP review and survey analysis, recommendations have been made to policymakers, farmers, and extension officers on how to improve hay production.

6.4 Results

6.4.1 DRR and Climate Change Policy and Strategies

Kenya has ratified several global policies that support disaster and climate change and incorporated them into its national policies. Table 9 shows the continental and regional policies and institutions reflected in the national and national institutions.

Table 9: Reviewed policies

Category	Policy
Global Policies	
	Sendai Framework for Disaster Risk Reduction 2015 - 2030
	United Nations Sustainable Development Goals 2030
	Paris Agreement on Climate Change 2030
Africa – Continental Policies	
	Africa Agenda 2063
	The Comprehensive Africa Agriculture Development Programme Framework (CAADP)(2010)
	Policy Framework for Pastoralism in Africa (2010)
	The Livestock Development Strategy for Africa (LiDeSA)
	Animal Welfare Strategy for Africa (AWSA) 2017
	Animal Health Strategy for Africa (AHSA) 2019
Regional Economic Communities (RECs) Policies - Intergovernmental Authority on Development (IGAD)	
	IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI)
	IGAD Regional Strategy (2016)
	ICPAC Strategic Plan (2016)
	IGAD Regional Climate Change Strategy (2018)

Category	Policy
	IGAD Regional Disaster Risk Management Strategy (2019)
	IGAD Regional Rangeland Management Strategic Framework (RRMSF)
Regional Economic Communities (RECs) Policies - East African Community	
	EAC Protocol on Environment and Natural Resources Management (2006)
	EAC Climate Change Strategy (2011)
	EAC Climate Change Masterplan (2015)
	EAC Disaster Risk Reduction and Management Act (2016)
	EAC Development Strategy (2020/21)
Kenya	
	Constitution of Kenya 2010
	Kenya's Vision 2030
	Big 4 agenda
	National Climate Change Response Strategy (NCCRS) 2010
	National Climate Change Action Plan (NCCAP) 2017
	Kenya Climate-Smart Agriculture Strategy (KCSAS) 2016-2026
	Ending Drought Emergencies (EDE) 2014-2022
	National Drought Management Authority (NDMA) Act 2016
	Common framework for Ending Drought Emergencies (EDE) 2014-2022

Category	Policy
	National Drought Management Authority (Amendment) Bill (2019)
	National Drought Management Authority (NDMA) Strategic Plan (2018-2022)
	Agricultural Sector Development Strategy (ADSD) 2010-2020
	Agricultural Sector Transformation and Growth Strategy (ASTGS) 2019-2029
	Northern Rangelands Trust Rangelands Strategy 2019-2022
	Range Management and Pastoralism Strategy 2021-2031
Kajiado County, Kenya	
	Kajiado County Integrated Development Plan 2018-2022 (CIDP)
	Kajiado County Climate Change Bill 2020
	Kajiado County Environmental Protection Bill 2020
	Kajiado County Pastoralist Development Centres Bill 2020
	Kajiado County Disaster Management Bill 2015
	Kajiado County Emergency Fund Bill 2014

There is older national legislation relevant to disaster risk reduction and climate change, which existed before the Constitutional of Kenya changed in 2010. Most of these laws are being updated to align with the Constitution and the global, continental and regional policies Kenya ratified after 2010 (Table 10).

Table 10: Kenya Policies enacted before 2010 relevant to DRR and climate change

Legislation	Purpose of Legislation
Animal Disease Act (CAP 364)	This Act focuses on preventing and controlling animal diseases and pests/parasites to prevent them from getting to epidemic levels.
Rabies Act (CAP 365)	This Act provides for the suppression of rabies and prevents an epidemic.
Veterinary Surgeons and Veterinary-Paraprofessionals Act (CAP 366)	This Act details the training, registration and licensing of veterinary surgeons and paraprofessionals in animal health services and welfare and veterinary public health for connected purposes. The personnel are essential in animal disaster risk management.
Cattle Cleansing Act (CAP 358)	This Act regulates the cleansing of cattle of ectoparasites, which is critical in preventing animal epidemics.
National Drought Management Authority Act (No. 4 of 2016)	The National Drought Management Authority (NDMA) Act provides guidance for the coordinated implementation of initiatives aimed at managing drought risks and adapting to climate change for the purpose of promoting sustainable livelihoods. NDMA's area of operation is primarily within the Arid and Semi-Arid Lands (ASAL) counties, where livestock production is the primary source of livelihood.
Prevention of cruelty to animals (CAP 360)	This Act defines animal offences and upholds animal welfare and freedoms, supporting animal DRM.
Wildlife conservation and management Act	This Act protects, conserves and manages wildlife in Kenya and related matters supporting animal DRM by ensuring that wild animals and their habitats are well managed. The Act supports animal DRM by ensuring that wild animals and their habitats are well managed.
Fisheries management and development Act	This Act of Parliament provides for the conservation and management of aquatic animals by ensuring that aquatic animals and their habitats are well managed.

Legislation	Purpose of Legislation
Kenya meat commission act (CAP 363)	This Act of parliament supports animal DRM during livestock off-take when drought disasters occur.
Meat Control Act (CAP 356)	It is an Act of Parliament that supports animal DRM when disasters such as drought are predicted or when livestock is converted to meat and value-added meat products.
Public health Act (CAP 242)	This Act secures and maintains health. It supports animal DRM in safeguarding food safety before or after an animal disaster, especially in counties where meat inspection is under the Ministry of Health.
National disaster risk management policy	Kenya's disaster risk reduction policy is an important step in mitigating the effects of climate change and other natural disasters. The policy outlines a comprehensive approach to reducing disaster risks through improved planning, land use management, and infrastructure development. It also includes measures to improve early warning systems and response capabilities. The implementation of this policy will help to protect Kenya's people and resources from the increasingly severe impacts of natural disasters.
Environmental management and coordination Act (CAP 387)	This Act establishes the appropriate legal and institutional framework for managing the environment and related matters. It supports DRM because environmental management has a positive effect on climate change. Further, this mitigates climatological and biological animal disasters.
Veterinary policy	The veterinary policy is designed to improve the health and welfare of animals in the country. The policy includes measures to control and prevent diseases, promote responsible animal ownership, and improve the quality of animal products. The policy also seeks to strengthen the capacity of the veterinary profession to deliver quality services to animal owners and producers.
Livestock policy	The policy in question addresses a range of important topics related to farm animal genetic resources, livestock nutrition and feeding, animal inputs, management of animal diseases

Legislation	Purpose of Legislation
	and parasites, livestock marketing, research and extension, as well as food safety and security. Its overarching objective is to support animal disaster risk management by addressing both infectious and non-infectious animal concerns.
Guidelines for delivery of veterinary services in Kenya	The guidelines detail the delivery of veterinary services in a devolved governance structure, which is crucial for animal DRM because it standardises the functions of DVS and CDVS.

6.4.2 State and Non-State Actors

Table 11 shows the state actors involved in disaster risk reduction and climate change.

Table 11: State and non-state actors in DRR and climate change in Kenya

State Actors	Role
Director of Veterinary Services (DVS)	Authority in charge of coordinating animal-related disasters in Kenya
National Drought Management Authority (NDMA)-	the agency that the government mandated to establish mechanisms to ensure that droughts do not result in emergencies and that the impact of climate change is sufficiently mitigated.
Department of Livestock Production (DLP)-	the state department of livestock is mandated to make sure animal production and productivity are secured in Kenya
National Disaster Operations Center (NDOC)-	The focal point for coordinating the response to emergencies and disasters in Kenya
Security Agencies-	Authority ensures the safety, resource support and securing of the intervention protocols.
Ministry of Health-	To support in control and management of epidemics of zoonotic nature
Kenya Meat Commission;	livestock off-take during a disaster

State Actors	Role
National youth service	provision of technical and resource support
Kenya forest service	provision of technical and resource support
Kenya Defense Force	provision of technical and resource support
Kenya Police Service	provision of technical and resource support
Kenya Wildlife Service	provision of technical and resource support
County Government-	Authority in charge of declaration of sub-county and county level disasters, resource mobilisation and re-allocation, human resource support, provision of disposal, holding and shelter grounds
National government-	Authority in charge of declaration of national disaster, resource mobilisation and re-allocation and human resource support
National Non-State Actors with Acts of Parliament	
Kenya Society for the Protection and Care of Animals (KSPCA)	technical support and animal welfare
Kenya Veterinary Association (KVA) and Kenya Para-professional Associations (KVPA)	technical support and animal health and welfare
Kenya Red Cross (KRC)	animal welfare and animal health
Authority In-Charge	
SUBCOUNTY	the sub-county vet officer shall oversee level disaster here COUNTY the County Director of Veterinary Services shall oversee the level of disaster here to refer.
MULTIPLE COUNTIES	When more than one County is affected here, referred to as a national-level disaster, the Director of Veterinary Services shall be the overseeing authority.
	Role of Authority In-Charge
	Identification and reporting of animal-related disasters to the relevant authority
	Develop and coordinate intervention and prevention programs
	Collect, collate, analyse and maintain surveillance data on animal-related disasters
	Mobilising resources

State Actors	Role
	Register and keep records of the intervention players Provide technical support and proposals to enhance recovery Keep records of all disasters and the economic and social losses associated with the disaster.

6.4.3 Case Study Kajiado County

The Kajiado County Integrated Development Plan (CIDP) has initiated a flagship project aimed at promoting hay production. This project is being implemented under the Agricultural Sector Transformation and Growth Strategy (ASTGS) and the Kenya Climate-Smart Agriculture Project (KCSAP). The CIDP, which is a medium-term plan spanning five years, seeks to increase hay cultivation and improve hay storage to enhance the resilience of pastoral communities in times of drought.

By 2020, the County had developed disaster management laws to implement its ambition to manage disasters' negative impacts and build resilient livelihoods, focusing on pastoral livelihoods. One such activity is the hay production flagship project with plans to set up hay stores, build a training centre in email, train pastoralists on hay growing, and upgrade the Kajiado demonstration farm.

After conducting interviews with 31 pastoralists in Loitoktok, it was found that a significant number of respondents (44%) could not provide examples of any local disaster risk response activities in their communities. Furthermore, only 30% of respondents were aware of disaster preparedness advocacy from either government departments, NGOs, or non-state actors to reduce deaths and prevent animal injury and livestock diseases during droughts. Those aware of DRR activities mentioned destocking, hay and pasture growing, vaccinations, and community training. However, it was noted that only some farmers practised the DRR methods they learned. An overwhelming majority of respondents (76%) expressed dissatisfaction with the help offered for their livestock during disasters from the government, NGOs, or other local organizations. Only a tiny fraction of respondents (19%) expressed satisfaction with disaster mitigation interventions (Fig. 18).

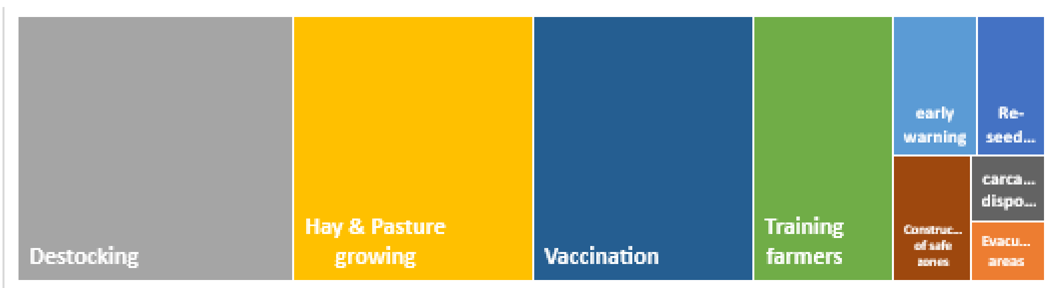

Figure 18: DRR programs undertaken by Government and NGOs

When respondents were asked to list the disaster preparedness assistance practices and their preferred methods, the majority mentioned destocking and hay planting. Approximately 62% preferred the capacity building of pastoralists and the provision of fodder storage facilities (Fig. 19).

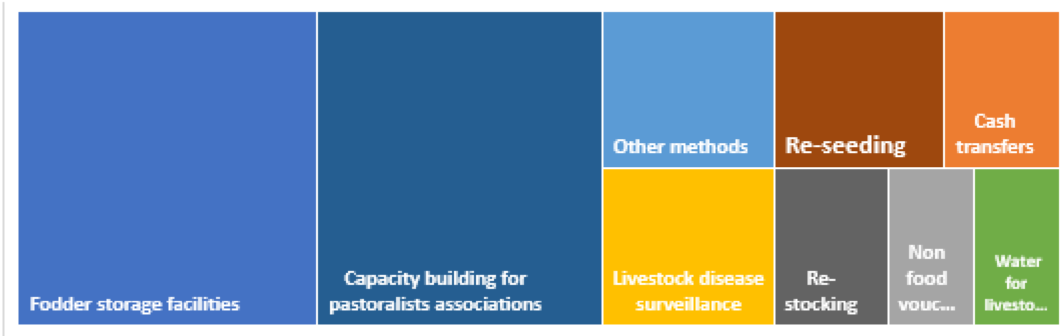

Figure 19: DRR programs pastoralists would prefer to receive

6.5 Discussion

6.5.1 Global, Continental, and Regional Policy integration into Kenya's DRR and Climate Change Policies and Strategies

Kenya has demonstrated progress in aligning its national policies, plans, and programs with global, continental, and regional frameworks on disaster risk reduction (DRR) and climate change. The country has ratified international agreements such as the Sendai Framework for Disaster Risk Reduction, the Paris Climate Change Accord, and the United Nations Sustainable Development Goals, emphasising reducing disaster risks and building resilience. Additionally, Kenya has signed treaties such as the Conservation of Biological Diversity, the Framework Convention on Climate Change, and the United Nations Convention to Combat Desertification, which promote sustainable land management practices and address the causes and effects of desertification and land degradation.

To implement these agreements effectively, Kenya requires substantial funding, estimated at KES 40 trillion, to finance adaptation and mitigation interventions in six critical sectors by 2030. Kenya has also implemented several national policies under Agenda 2063, including the East African Community Climate Change Policy and the 2010 Policy Framework for Pastoralism in Africa, emphasising sustainable land and water usage, research, dissemination of technologies, and reductions in agricultural greenhouse gas emissions. Moreover, Kenya mainstreams animal welfare into disaster risk mitigation within the animal resources sector, promoting climate adaptation activities within pastoral systems.

The IGAD's Centre for Pastoral Areas and Livestock Development (ICPALD) is a regional organisation that works to improve the livelihoods of pastoralists and advocates for their rights, including access to services and resources. The organisation's efforts focus on improving pastoralism livelihoods in the Horn of Africa through research and development initiatives to increase resilience to climate variability and change. The IGAD Regional DRM Strategy aims to reduce disaster risk and losses incurred by people, animals, and the environment in line with the Sendai Framework for Disaster Risk Reduction.

The challenges of sustainable rangeland management in the IGAD region are addressed through the Regional Rangeland Management Strategic Framework (RRMSF). The framework promotes the harmonisation of policy and practice among states of the region and proposes interventions based on ten strategic objectives. The East Africa Community (EAC) has developed disaster management, climate change management, and environmental protection management strategies to address the challenges of poor livestock nutrition. The Africa Feed Production Action Plan (2019) encourages better quality feed production in pastoralist systems to mitigate the factors limiting livestock feeding, such as recurrent droughts, high livestock mobility, overstocking leading to overgrazing, and erratic rainfall.

6.5.2 Kenya's National DRR and Climate Change Policies and Strategies

The Constitution of Kenya recognises the importance of disaster risk reduction and management to achieve food security, as referenced in Article 43, which guarantees the right to adequate and good-quality food. Additionally, the Constitution protects the environment, emphasising equitable and sustainable conservation and management of natural resources, as seen in Articles 42 and 69 (GoK K. L., 2010). Kenya's Vision 2030 strategy promotes agriculture, while the government's Big Four agenda prioritises food security and nutrition (GoK, 2020).

To achieve sustainable agriculture, Kenya has adopted several climate-smart agriculture (CSA) legal instruments, including the 2010 National Climate Change Response Strategy (NCCRS), the 2016 Kenya Climate Change Act, and the 2017 National Climate Change Action Plan (NCCAP). These instruments align with global and continental climate-change commitments and operationalise the NCCRS. The

NCCAP aims to achieve low-carbon and climate-resilient development and contribute to attaining SDG 13, which combats the impacts of climate change. Disaster risk management to support livestock and wildlife in arid rangelands is one of the seven priorities in the 2018-2022 NCCAP (GoK, 2018).

To implement climate change adaptation, Kenya has developed five-year strategies, such as the 2016-2026 Kenya Climate-Smart Agriculture Strategy (KCSAS), as part of the country's commitments under the UNFCCC. The KCSAS enhances the adaptive capacity and resilience of farmers, pastoralists, and other vulnerable groups to climate variability and change. The strategies involve diversifying livelihoods, investing in early warning systems and risk management, and improving access to financial services. The KCSAS strengthens institutional and regulatory arrangements and builds capacity (GoK, 2016). The Kenya Climate-Smart Agriculture Program (KCSAP 2015–2030) aims to increase productivity in the livestock sector and disaster-proof infrastructure associated with livestock production, focusing on arid and semi-arid lands, home to pastoralists. KCSAP achieves this through better range management and water conservation for livestock and wildlife (GoK, 2018).

The successful implementation of KCSAP will contribute to food security and poverty alleviation, as detailed in SDG 1, SDG 2, and SDG 13 (GoK, 2018). KCSAP aligns with Kenya's Vision 2030, which includes several initiatives, one of which supports the livestock sector. The government has been working to improve livestock productivity through various programs and policies and investing in infrastructure projects to help the sector grow. The Agricultural Sector Development Strategy (ASDS) (2010-2020) targeted an annual 7% growth in the agricultural sector while aligning with the World Bank's Climate Business Plan (World Bank, 2017). The ASDS is a government-led initiative supporting developing countries' livestock industry. The objectives of the ASDS are to improve the livestock sector's productivity and competitiveness and contribute to poverty alleviation and food security. The ASDS prioritises improved livestock diversification and grazing systems, breeding, and biogas utilisation for livestock. These priorities are achieved by providing financial and technical assistance to livestock farmers and businesses and supporting research and development activities to improve livestock productivity (GoK, 2019a).

The Kenyan government's Agricultural Sector Transformation and Growth Strategy (ASTGS) for the period 2019-2029 aims to improve rural prosperity by focusing on the challenges faced by 600,000 small-scale pastoralists, such as high input costs, low-quality inputs, low mechanisation, and limited adaptation of technologies such as improved fodder seed, irrigation, and artificial insemination (GoK, 2019a). While the ASTGS has a framework, targeted programs are required to address hay producers' challenges. The ASTGS supports four flagship projects that aim to increase hay production in arid and semi-arid pastoral areas (GoK, 2019a). However, subsidies are needed to purchase machinery, build modern hay stores, and cover the high costs of tilling land and harvesting to improve private sector participation in these projects.

Additionally, support to the private sector should focus on stabilising the hay market through buy-back programs. Unfortunately, the ASTGS excludes hay farms below 2500 acres, resulting in the existing hay growers needing more meaningful support under the ASTGS (GoK, 2019a).

The Northern Rangelands Trust rangelands strategy 2019-2022 is based on integrating traditional livelihoods, governance, and coexistence between livestock, people, and nature. The approach involves the integration of traditional institutions with modern technology, practices, and concepts through a behavioural change in pastoralists to achieve better management and recovery of the rangelands (The Northern Rangelands Trust, 2019). Pastoralist areas of Kenya face complicated challenges, including poverty, insecurity, extreme degradation of rangelands, population growth, and wildlife extinction. To address these challenges, the Rangelands Programme comprises peace, security, livestock marketing, business development, resource management, wildlife conservation, and conservancy governance. The approach aims to improve rangeland management by increasing grazing quality and management practices, enhancing governance, and improving awareness about native livestock (The Northern Rangelands Trust, 2019).

An analysis conducted from 2002 to 2008 found that livestock grazing in northern Kenya affected 40% of the pasture area, much of which was overgrazed in areas with high human population densities along significant roads, settlements, and the Ewaso

Nyiro River. Where grazing management plans were practised, such as in the conservancies, there was a visible, positive impact from 2011 to 2015. Overgrazing areas decreased by less than 20% (compared to 40% pre-2009) and less than 10% in core and buffer areas in these four years. However, the productivity of rangelands still needed to return to levels pre-2005, suggesting interventions to improve grazing management did not keep pace with the increased human population and emerging numbers of smaller cloven animals. Rangeland rehabilitation, including invasive Acacia reticulans and grass regeneration, has also been effective. However, the cost involved in scaling up these efforts is high, and post-treatment management of rehabilitation sites is essential to ensure that the improvements are sustained (The Northern Rangelands Trust, 2019).

The Range Management and Pastoralism Strategy 2021-2031 involves planning a rangeland ecosystem to achieve specific objectives through grazing, fire, and land management. The strategy aims to sustainably manage rangeland livestock populations while minimising negative environmental impacts to provide food, fibre, and other products. Its transparent and structured methodology helps ensure that rangeland resources are sustainably exploited and that all stakeholders, including the government, county governments, companies, NGOs, and individuals, are involved in the process (The Northern Rangelands Trust, 2019).

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The Kenyan Constitution and national laws provide the foundation for the range-land policy, emphasising stakeholder engagement to identify policy, law, and practice gaps and improve coordination across sectors. The policy's objectives are to enhance the health of sustainable rural habitats, rejuvenate pastoralism production systems, improve mechanisms for managing rangelands sustainably, and promote the localization of resources to generate more opportunities for rural livelihoods (GoK, 2021b).

In October 2012, the Kenyan government released the ASAL Policy Sessional Paper No. 8 of 2012, which outlines the government's approach to addressing the development needs of arid and semi-arid lands (ASALs) in the country. The policy aims to enhance access to infrastructure, social services, and economic opportunities in ASALs, focusing on bolstering food security and generating employment opportunities (GoK, 2019b).

6.5.3 Kenya's National Disaster Management Structures

In 2016, the Kenyan government established the National Drought Management Authority (NDMA) to manage droughts effectively. The NDMA is responsible for coordinating the activities of various stakeholders to mitigate the effects of drought and provides information and advice on drought preparedness and relief measures. The 2014-2022 common framework for Ending Drought Emergencies (EDE) sets out a comprehensive approach to address the root causes of drought and build the resilience of affected communities. The framework guides assessing drought risk, developing early warning systems, implementing effective preparedness and response measures, supporting rehabilitation and recovery, and mainstreaming drought risk management into planning and development processes. The National Drought Mitigation Act of 2016 initiated the implementation of the National Drought Emergency Fund (NDEF), which provides financial assistance to eligible entities for drought relief and mitigation activities. The Act allows grants from the NDEF to eligible entities for drought relief and mitigation activities (NDMA, 2017). The 2018-2022 NDMA Strategic Plan enhances climate change adaptation and drought resilience (GoK, 2020).

In Kenya, several departments are responsible for disaster response. These include the National Drought Management Authority (NDMA), the National Disaster Operations Centre (DOC), the State Department of Special Programmes, the National Disaster Management Unit, and the National Platform for Disaster Risk Management. The DOC is responsible for coordinating all fast-onset disasters. Other authorities participating in drought or flood responses include the Livestock State Department, the Kenya Food Security Steering Group, the Inter-Governmental Technical Committees, and the Kenya Food Security Meetings (KFSM). Additionally, the Disaster and Risk Management Unit, under the director of veterinary services (DVS), is responsible for handling animal disease emergencies and collaborates with the National Disaster Operations Centre (DOC), the County Disaster Management

Committee, the County Disaster Operation Centre, and the County Steering Groups (GoK, 2020).

6.5.4 Case Study of Kajiado County

The study revealed that Kajiado County has drafted sub-national legislation, including the Kajiado County Integrated Development Plan (CIDP) of 2018-2022, to align with its commitment to policy roll-out. The CIDP in Kajiado is in alignment with Kenya's national 'Big Four' agenda, which is focused on improving hay production, reducing post-harvest losses, expanding irrigation, encouraging the use of modern farming technologies, and mitigating the impact of climate change. Implementing the ASTGS and the KCSAP under the CIDP contributes to SDGs 1,2, and 15 by increasing livestock productivity, ensuring ecosystem sustainability, stemming biodiversity loss, and protecting wildlife.

In addition, the CIDP supports efforts to combat desertification, restore degraded lands and soil, and address droughts and floods. The five-year plan aligns with the Sendai framework. It aims to deliver disaster management in Kajiado through various bills developed by the County assembly, including the Kajiado County Emergency Fund Bill 2014, Kajiado County Disaster Management Bill 2015, Kajiado County Climate Change Bill 2020, Kajiado County Pastoralist Development Centres Bill 2020, and the Kajiado County Environmental Protection Bill 2020. These bills govern how disasters at the county level will be handled and how the County will liaise with relevant national structures supporting disaster management. For instance, the Environmental Bill provides guidelines on handling environmental contamination by mass carcasses following a disaster. The integrated bill mentions the cross-cutting nature of disaster management and disasters. The Centre for Pastoralist Development incorporates the pastoralists' indigenous knowledge into disaster management training. Training livestock owners is further supported in agricultural training and cooperative bills. The Animal welfare bill also notes that considering animals' welfare in production systems and disasters is central to animal health (Kajiado, 2018).

Although there are policies and bills in place to support hay production, there is a need for better conceptualization and implementation of strategies with specific deliverables that can have an impact on the entire hay value chain. In this regard, the Kajiado County Disaster Management Bill of 2015 and the Kajiado County Emergency Fund Bill of 2014 are crucial in supporting disaster management by providing a framework for responding to and managing disasters within the county. The bills outline the roles and responsibilities of various county departments and agencies in disaster management and establish a fund to support disaster response and recovery efforts.

To support hay production as a drought mitigation and response option, the researcher recommends developing a work plan to implement short-term drought relief efforts and longer-term hay production measures. This finding is supported by Ouma (2017), who also recommends supporting the private sector in fodder production to fill the hay deficit.

Most of the respondents, 76%, expressed dissatisfaction with the government's assistance for their livestock during disasters. Instead, they preferred activities aimed at supporting hay and fodder production and capacity-building training conducted by both governmental and non-governmental organizations (NGOs) involved in disaster risk reduction (DRR) and hay production. Although the programs focus on livestock destocking, with some reseeding and hay production, there is a need for better alignment with the actual needs of pastoralists within DRR programs. A 2021 study by Kimaru et al. on hay production revealed several gaps and challenges in implementing the hay flagship project, such as addressing pastoralists' pain points like the invasive species *ipomoea cairica* that destroys grazing land. Additionally, the study highlighted the need for a stable market for hay, a priority pain point for producers. The county government should support hay producers by making access to machinery, irrigation, and storage more affordable and providing good extension services and training (Kimaru et al., 2021a). Ouma (2017) and Moiko (2019), who emphasized the need to re-engineer land use in Kajiado to support fodder production, supported these findings of inadequate support for hay growers.

Kenya has made commendable efforts in adapting global, continental, and regional policies to the local context, with notable progress in the implementation of the hay flagship program in Kajiado County. However, there needs to be more planning and designing of these strategies, and the implementation methods should be enhanced. The engagement of the private sector could be enhanced, and there is room for improvement in providing direct assistance to agricultural livelihoods. Unfortunately, the finances are directed to government agencies like demonstration farms, leaving the hay farm business to adopt low technology, which results in lower than optimal productivity.

A review of the existing strategies, such as the KCSAP, ASTGS, and the Kajiado Hay production flagship project, is necessary to address these issues. Hay farmers should be supported with the necessary finances to expand hay production for drought risk reduction and livestock productivity. Moreover, traditional migration strategies practised by pastoralists should be integrated into the resilience strategy of providing feed for livestock during droughts. The preferences of pastoralists when it comes to the activities they prefer, like hay growing and reseeding, must be reflected in the KCSAP implementation. One can draw support for these findings from the recommendations on land-use transformation in the Kajiado County report (Moiko, 2019).

6.6 Conclusion

Kenya has taken significant steps towards aligning its national policies, plans, and programs with global, continental, and regional frameworks on disaster risk reduction

(DRR) and climate change. The country has ratified international agreements such as the Sendai Framework for Disaster Risk Reduction, the Paris Climate Change Accord, and the United Nations Sustainable Development Goals. The Constitution of Kenya recognises the importance of disaster risk reduction and management to achieve food security and protect the environment. However, Kenya needs substantial funding, estimated at 40 trillion Kenyan shillings, to finance adaptation and mitigation interventions in six critical sectors by 2030.

Kenya has developed several national policies, such as the East African Community Climate Change Policy and the 2010 Policy Framework for Pastoralism in Africa, to promote sustainable land and water usage, research, dissemination of technologies, and reductions in agricultural greenhouse gas emissions. Additionally, the country has developed five-year strategies, such as the 2016-2026 Kenya Climate-Smart Agriculture Strategy (KCSAS), to enhance the adaptive capacity and resilience of farmers, pastoralists, and other vulnerable groups to climate variability and change. However, more funding and more resources are needed for Kenya to implement these policies effectively.

To mitigate the adverse effects of climate change and reduce the impact of disasters, Kenya has achieved sustainable development by enhancing institutional and regulatory arrangements, building capacity, and promoting research and development initiatives. Recurrent droughts devastate the country's economy, environment, and population. Therefore, the Kenyan government has taken measures to address the challenges posed by drought by developing policies, frameworks, and bills to enhance drought resilience and promote disaster management.

Kajiado County provides an excellent example of how sub-national legislation can align with national policies to promote disaster management and mitigate drought impacts. The county has developed an Integrated Development Plan (CIDP) incorporating various bills to enhance disaster management, including the Kajiado County Disaster Management Bill of 2015 and the Kajiado County Emergency Fund Bill of 2014. However, this study reveals a need for a better alignment of government disaster risk reduction (DRR) programs with the actual needs of pastoralists in Kajiado County. There are gaps and challenges in implementing the hay flagship program, such as inadequate support for hay growers and insufficient finances directed to government agencies instead of the private sector.

To support hay production as a drought mitigation and response option, the study recommends developing a work plan to implement short-term drought relief efforts and longer-term hay production measures. Supporting the private sector in fodder production can also fill the hay deficit. The government should support hay producers by making access to machinery, irrigation, and storage more affordable and providing good extension services and training.

Traditional migration strategies practised by pastoralists should be integrated into the resilience strategy of providing feed for livestock during droughts. Pastoralists' preferences regarding the activities they prefer, like hay growing and reseeding, must be reflected in implementing the Kajiado County Spatial Plan (KCSAP) and other DRR programs. Furthermore, the existing strategies, such as the KCSAP, Agricultural Sector Transformation and Growth Strategy (ASTGS), and the Kajiado Hay production flagship project, need to be reviewed and enhanced to address the issues faced by pastoralists in Kajiado County.

In conclusion, this study recommends a more comprehensive approach to support the agricultural livelihoods of pastoralists in Kajiado County. The engagement of the private sector could be enhanced, and there is a need for more direct assistance to agricultural livelihoods. By implementing these recommendations, Kenya can mitigate the adverse effects of climate change and reduce the impact of disasters, ultimately contributing to sustainable development.

6.7 Recommendations

The Kajiado County report (Moiko, 2019) recommends that to achieve the goals of the Kajiado Hay Flagship projects. The County must address the pressing issues negatively impacting hay producers and better reflect the actual needs of pastoralists in the projects. To implement these recommendations, the following actions are suggested:

- Develop public-private partnerships that support primary hay producers to ensure a stable and sustainable supply of hay. These partnerships can provide producers with necessary financial and technical support and create markets for hay produced on private lands. Furthermore, these partnerships can promote best management practices for hay production to improve quality and reduce environmental impacts. The County can buy hay during peak production and redistribute it during droughts. Buying hay can be a program on disaster preparedness and response under one of the Kajiado County Bills.
- Allocate funds for hay as a strategic feed reserve, a government-held grain stock that can be released in the event of a supply shock. The reserve can be managed as a purely public function or under a public-private partnership. Under a purely public model, the government would be responsible for procuring, storing, and distributing the grain in the event of a supply shock. This model has the advantage of being centrally controlled and coordinated, but it may be less efficient than a private model. The County must involve hay producers in developing these strategic feed reserves to ensure that all activity aligns with the subsection's needs.
- Allocate financial resources and investments to help landowners use mitigation and adaptation techniques.
- Provide extension training using best practices in hay farming.

CHAPTER SEVEN

7.0 OVERALL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

7.1 Overall Discussion

Kenya has made significant progress in devolving regional, continental, and global policies to enhance local livestock herding, as evidenced by the review of Kajiado County. One example of this progress is the implementation of a national pasture flagship. However, there still needs to be an implementation gap in designing and rolling out policies and strategies, which calls for the adequate engagement of private entrepreneurs in the hay-growing value chain. Budgetary allocations mainly support government agencies, such as demonstration farms and the creation of legislation within government agencies, which may not directly benefit hay producers.

The use of low technology in hay farming is a significant contributor to low productivity levels. To address this issue, the Kajiado County Integrated Development Plan (CIDP) for 2018-2022 aims to increase agricultural productivity through various measures such as investing in hay production, reducing post-harvest losses, expanding irrigation, and aligning with the National 'Big Four' Agenda. The plan targets explicitly enhancing hay production, minimizing post-harvest losses, encouraging irrigation, promoting modern technologies, and reducing the impacts of climate change. The CIDP is being implemented alongside the Agricultural Sector

Transformation and Growth Strategy and the Kenya Climate-Smart Agriculture Project.

The CIDP is aligned with the United Nations Sustainable Development Goals (SDGs) 1 and 2, which aim to enhance livestock production and tackle climate change challenges. Additionally, the CIDP aligns with SDG 15, which focuses on safeguarding and promoting sustainable land ecosystems and reversing biodiversity loss. The CIDP also prioritizes wildlife conservation by reducing human-wildlife conflict, ending poaching, and stopping the illegal wildlife trade. It further addresses issues of desertification, land degradation, droughts, and floods, all aligned with the Sendai Framework.

Despite adequate legal instruments and institutions in Kenya to support general disasters and droughts, implementing policies and strategies remains challenging. For instance, the benefits of the ongoing hay flagship project do not necessarily reach hay producers or buyers. As such, the study recommends re-examining the implementation of the hay flagship project to address the challenges that hay producers face, including the absence of a stable hay market and profitability concerns. To ensure the survival of private hay enterprises and meet their objective of building resilience for pastoral livelihoods, targeted relevant projects are essential (Kajiado, 2018).

Hay production in Kajiado Central has experienced significant deficits, with a deficit of over 95% recorded between 2005 and 2009. However, the situation improved during the droughts of 2015 and 2017, when 49,138 bales were harvested, accounting for 24% of the total bales required to sustain livestock for three months. The hay deficit was 86% in 2015 and 48% in 2017, with an average of 67% for the recent droughts. Based on the 2009 national livestock census, Kajiado Central requires 2,580,000 hay bales valued at approximately KES 902 million to cover three months during droughts.

In Kenya, pastoralist communities have traditionally employed livestock migration as the primary drought mitigation strategy. However, despite efforts to improve range management practices to expand pasturelands, widespread adoption still needs to be improved. As a result, pastoralists still face significant livestock losses due to disease and wildlife predation during drought migration. Furthermore, hay availability during droughts presents a significant challenge for pastoralists. According to a study, less than 60% of the available feed options for livestock comprise hay. During the droughts of 2005, 2007, 2009, and 2017, pastoralists relied on commercial feeds, other forages, own-grown hay, and purchased hay to feed their livestock. While the percentage of pastoralists growing hay has increased over time, rising from 2% in 2005 to 21% in 2017, the percentage of those buying hay has also increased significantly, from 13% in 2005 to 37% in 2017. The use of other forages to feed livestock averaged 28% from 2005 to 2017. Notably, the preference for commercial feeds dropped from 60% in 2015 to 35% in 2017, indicating an increasing reliance on hay as a feeding option. However, most livestock keepers prefer buying hay rather than growing it themselves.

One of the critical challenges facing hay production enterprises is farm size, which is the primary determinant of production and profitability. The study found that a farm must produce at least 4,250 bales per year to be profitable. The focus should be on hay production per acre rather than farm size. With proper cultivation practices such as weeding, manuring, and clearing invasive weeds, farms can achieve the desired production level on 90 acres. Another challenge is the cost of machinery used in hay production, such as balers, cutters, and tractors. The study found that purchasing and maintaining machinery was more costly and took longer to become profitable than hiring machinery. The net present value (NPV) of a 400-acre farm that hired machinery was significantly higher than that of a farm that bought and maintained its machinery. High capital expenditures and the cost of running tractors, balers, and irrigation equipment made the farms unprofitable. In addition, the County government's tractors used for harvesting and baling are often unavailable and unreliable as they frequently break down. As a result, private baling service providers from neighbouring Narok County are readily available and preferred by farmers due to their experience in harvesting wheat and barley (Table 12).

Table 12: Comparison of profitability between rain-fed and machinery hiring versus irrigation and machinery buying farms

Metric	400-acre Farm with Machinery Hiring and Rain-fed	400-acre Farm with Machinery Buying and Irrigation
Net Present Value (NPV)	25,092	-88,484
Internal Rate of Return (IRR)	38%	-0.17
Return on Investment (ROI)	23%	-40%
Payback Period	3 years	Beyond 5 years

In this study, the comparison between irrigation and rain-fed farming practices was conducted on a 400-acre Boma Rhodes farm. The study found that while irrigation can improve soil fertility and potential crop yields, the high setup and operational costs make it challenging for farmers to recover their investment, taking more than five years. In contrast, a rain-fed farm has a payback period of only three years. The cost of purchasing irrigation equipment also means that a farm without irrigation systems would have had a positive net present value (NPV), internal rate of return (IRR), and return on investment (ROI) by year five. However, the study showed that the farm's NPV, IRR, and ROI remained negative due to the cost of purchasing other types of machinery.

To determine the appropriate irrigation system for a farm, farmers and governments must consider the farm's size carefully. For instance, the Boma Rhodes farm uses the rain-gun overhead irrigation system, which costs KES 550,000 per acre, while a drip irrigation system costs KES 120,000 per acre. The study also revealed pasture irrigation has a negative NPV, IRR, and ROI and should not be used in hay pasture cropping practices in ASAL. However, if used, government subsidies should be considered.

Storing hay for 1-2 years before a sale is essential, but constructing hay stores is expensive. For 400 acres of the Boma Rhodes farm, constructing hay stores costs roughly KES 2,000,000 and has a capacity of 20,000 bales. Developing strategic government and private sector hay feed reserves would encourage more people to store hay and decrease post-harvest losses. Addressing hay storage issues while considering post-harvest losses is a strategic goal in Kajiado County.

The demand for hay is high during droughts when pastoralists buy hay, when their rangelands are depleted, and their livestock starts starving. However, sales are low when average rainfall, as pastoralists have free grazing resources to feed their livestock. Despite the lack of hay sales, farms still have recurring annual overheads and costs. To offset losses incurred when hay was in the store, one of the 400-acre farms chose not to harvest in 2020 and 2021, instead selling off stored 2019 hay in 2021. The same farm increased its income by renting the land for grazing in 2020 and

2021. Illegal grazing by neighbouring pastoralists causes farmer-herder conflicts, which can become a security problem in the area. It also results in fence repair costs, hiring security personnel to patrol the farms, and time spent in court cases at the local chief office.

According to the farmers, their contribution to protecting the wildlife and removing invasive weed species for the benefit of social and ecological services was not acknowledged by the government. During the dry seasons, wild animals migrate from Amboseli National Park to the hay farms, where growing hay is plentiful. Large herds of antelopes, elands, zebras, elephants, and dik-diks reside on the hay farms for four months yearly. Some herds have made the farms their new permanent residence. Herbivore herds also prefer to give birth on the farm for protection, safety, and hay. One such elephant calving on the farm was reported. Hyenas and leopards follow the herbivores and attack domestic goats and sheep in the surrounding villages and farms. Although the farm owners, who are animal lovers, bear the costs of lost revenue from hay sales and predation from the carnivores, the wildlife sector does not support them. Still, it reaps all benefits from tourism revenue through wildlife protection.

Hay farms provide an essential ecological service by attracting an increasing number of herbivores each year, particularly during droughts, which makes them unsung heroes in reducing the risk of wildlife drought. Farmers attribute this to changes in wildlife migration patterns that now include hay farms. However, despite their contribution, the Kenya Wildlife Services (KWS) and the County government have yet to engage with farmers on wildlife issues. Hay farms also contribute to removing invasive species, such as ipomoea, which have spread throughout Kajiado Central County. To combat this, hay farms must invest heavily in annual weeding efforts. As a result of their efforts, the farms are free of ipomoea, whereas surrounding areas are overrun with weeds.

According to half of the survey respondents, farmers needing more training and extension services emerged as a major challenge hindering the hay value chain's growth. Despite the County government of Kajiado's effort to support hay farmers by purchasing tractors and balers for hire, some farmers opted for private providers who offered more reliable and efficient services. In addition, farmers noted a need for more communication between hay growers and the County government, with no reported attendance of meetings between the two parties. The absence of effective communication channels prevented hay producers' concerns and potential solutions from being incorporated into the County Integrated Development Plan (CIDP) implementation. Furthermore, farmers called for the provision of extension services for hay production.

The farmers expressed dissatisfaction with the government policies being implemented, indicating they were unsuitable for their needs. For instance, technical discussions regarding hay quality standards were deemed irrelevant as they needed to reflect the hay-growing process. According to one farmer, implementing quality requirements would negatively impact hay profitability. Moreover, the study highlighted a need for more subsidies for hay farmers, contributing to poor profitability and leading some to consider selling off their land. Despite the importance of forming cooperatives under the Kajiado County CIDP and the Agricultural Sector Growth and Transformation Strategy, farmers rejected the idea, citing corruption as the primary reason.

The study explored other forms of support, and farmers noted they would like the government to intervene by providing markets, for example, buying hay from farmers during years with average rainfall and selling it to pastoralists at a subsidized price. Another suggestion was to provide farms over 100 acres with cash subsidies every two years, amounting to KES 1,500,000 - 2,000,000. The study also found that the support from NGOs to the disaster risk reduction sector that pastoralists receive needs to match their preferences.

7.2 Overall Conclusions

Kenya has made considerable progress in aligning its national policies, plans, and programs with global, continental, and regional frameworks on disaster risk reduction (DRR) and climate change. One such national policy is the Kenya Climate-Smart Agriculture Strategy (KCSAS), which aims to enhance farmers' and other vulnerable groups' adaptive capacity and resilience to climate variability and change.

The study in Kajiado Central, Kenya, found that hay can be an effective strategy for mitigating drought-associated risks. However, the study also revealed that the current hay deficit of 67% indicates that traditional migration strategies used by over 85% of pastoralists can only be partially replaced by hay. The study recommends collaborative efforts among various stakeholders, including researchers, farmers, policymakers, and the private sector, to address the challenges faced by hay producers, such as pests, diseases, and funding shortages.

The study also found that production level, rather than farm size, is critical in determining profitability in hay farming. Appropriate cultivation practices, such as seasonal weeding and manuring, can improve productivity. Farmers should consider hiring machinery instead of buying for profitability. Developing private hay feed strategic reserves is also recommended to support relevant value chains, including hay production while addressing post-harvest losses.

The study recommends mapping hay growers and providing additional training and support to improve skills, efficiency, and productivity to benefit the entire industry. Direct government intervention may be necessary to promote commercial large-scale hay farming, marketing, transport, and storage along the hay value chain. The study calls for further research to reduce hay production hazards through tailor-made insurance for hay production.

Although Kenya has made significant progress in developing policies and strategies to support hay production, the study found a gap in designing policies that involve private entrepreneurs in the hay-growing value chain. The ongoing hay flagship project does not necessarily benefit hay producers and buyers. Thus, it is essential to revisit the implementation of the hay flagship project to address the challenges that hay producers face, such as the lack of a stable hay market and low profitability.

Moreover, the study identified significant challenges facing pastoralists during droughts, including livestock losses during migration and hay shortages. The study recommends that the government provide markets, buy hay at a subsidized price, and provide cash subsidies to farms over 100 acres to improve the profitability of hay farming.

In conclusion, Kenya has implemented policies and strategies to support hay production in Kajiado County and beyond. However, the government should design policy implementation that effectively engages private entrepreneurs in the hay-growing value chain. To achieve its goal of increasing hay production and enhancing the livelihoods of pastoral communities in ASAL, Kenya needs to address the challenges faced by hay producers and engage private entrepreneurs in the hay value chain.

7.3 Overall Recommendations

The policy recommendations arising from this study include the following:

- Increase hay production and meet demand during drought years to support private hay producers in ASAL.
- Translate policies and frameworks into actionable plans that engage hay farmers and address pain points, such as the erratic hay market, expensive capital assets, and lack of training.
- Establish public-private partnerships that address pain points, maintain good quality hay, and make it available for systems at risk in drought applied to small farm sizes.
- Establish strategic hay feed reserves to address post-harvest losses and erratic demand for hay.
- Focus on low-technology production methods like manuring, weeding, and fencing that achieve a good output and do not encourage the uptake of expensive technology like irrigation and purchasing tractors and balers.
- Provide extension training for commercial hay producers, including current and prospective hay growers.
- Encourage pastoralists to diversify feeding options during droughts and include hay in their regular feed to improve animal health and increase productivity.

- Consider voucher-based interventions for pastoralists to access hay during drought and cash-based subsidies directly to hay farmers to cater for the years they need to store hay.
- Encourage drought insurance policies for hay farmers and pastoralists to protect them from catastrophic losses and reduce environmental pressures.

8.0 REFERENCES

Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., . . . Day, R. (2017). Impacts and Implications for Africa. *Outlooks on Pest Management*, *28*(5), 196-201. doi:10.1564/v28_oct_02

Africa Risk Capacity. (2018). *Kenya Drought Operation Plan 2018-2020.*

Africa Wildlife Foundation. (2019). *Africa Wildlife Foundation Strategy 2020-2030.* Africa Wildlife Foundation.

African Union. (1981). *African Charter on Human and Peoples' Rights.* Retrieved from https://au.int/en/treaties/african-charter-human-and-peoples-rights

African Union. (2010). *The policy framework for pastoralism in Africa.* African Union. Retrieved from https://au.int/sites/default/files/documents/31301-doc-policy_framework_for_pastoralism_in_africa_-_eng.pdf

African Union. (2013). *Agenda 2063: The Africa We Want.* Retrieved from https://au.int/agenda2063

Alvarez Aranguiz, A. C. (2019). *Quick Scan of Ethiopia's Forage Sub-Sector, Working Paper.* Wageningen: Wageningen UR-Livestock Research. Retrieved from https://edepot.wur.nl/504124

Armitage, D. d. (2012). Environmental governance and its implications for conservation practice. *Conservation Letters*, *5*(4), 245-25. doi:10.1111/j.1755-263X.2012.00246.x

AU-IBAR. (2017). *Animal Welfare Strategy for Africa (AWSA).* African Union Intergovernmental Bureau on Animal Resources. Retrieved from http://repository.au-ibar.org/handle/123456789/543

Auma Joseph, R. J. (2019). USAID-KCDMS Feed and Fodder Value Chain Assessment Report-2018. doi:10.13140/RG.2.2.14770.66249

Auma, J. (2018). Dairy Compound feed and Fodder value chain analysis. 21-23.

Balehegn, M. D. (2020). Improving adoption of technologies and interventions for increasing supply of quality livestock feed in low- and middle-income countries. *Global Food Security, 26*. doi:https://doi.org/10.1016/j.gfs.2020.100372.

Bank, W. (2010). Economic Evaluation of Climate Change Adaptation Projects : Approaches for the Agricultural Sector and Beyond. Retrieved from https://openknowledge.worldbank.org/handle/10986/27752

Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning . *Journal of Environmental Management, 90*(5), 1692-1702. doi:doi: 10.1016/j.jenvman.2008.12.001

Boles, O. S. (2019). Historical Ecologies of Pastoralist Overgrazing in Kenya: Long-Term Perspectives on Cause and Effect. *Human Ecolology*, 6-8. Retrieved from https://doi.org/10.1007/s10745-019-0072-9

Calleja-Cabrera J, B. M.-S. (2020, May). Root Growth Adaptation to Climate Change in Crops. *Fronters in Plant Science*, 544. doi:doi: 10.3389/fpls.2020.00544. PMID: 32457782; PMCID: PMC7227386.

Capacity, African Risk. (2021). *The cost of Drought in Africa.* Retrieved from Africanriskcapacity.Org.: https://www.africanriskcapacity.org/wp-content/uploads/2016/11/arc_cost_of_drought_en.pdf.

Chang, J. C. (2021). Climate warming from managed grasslands cancels the cooling effect of carbon sinks in sparsely grazed and natural grasslands . *Nature Communications*, 2. Retrieved from Chang, J., Ciais, P., Gasser, T. et al. Climate warming from managed grasslands cancels the cooling effect ohttps://doi.org/10.1038/s41467-020-20406-7

Chantelle Garritty, G. G.-S. (2021). Cochrane Rapid Reviews Methods Group offers evidence informed guidance to conduct rapid reviews. *Journal of Epidemiology*, *130*, 13-22. Retrieved from https://doi.org/10.1016/j.jclinepi.2020.10.007.

Cheikh, A. W. (2019). Herders, Traders and Clerics: The Impact of Trade, Religion and Warfare on the Evolution of Moorish Society. In *Herders, Warriors, and Traders* (p. 27). New York: Taylor & Francis Group l. Retrieved from https://doi.org/10.4324/9780429045615

Cohran, W. (1977). *Sampling Techniques third edition.*

Coppock, D. e. (2017). Rangeland Systems in Developing Nations: Conceptual Advances and Societal Implications . In: Briske, D. (eds) Rangeland Systems. *Springer Series on Environmental Management. Springer, Cham.*, 319-467. doi: https://doi.org/10.1007/978-3-319-467

County, K. (2018a). *Kajiado County Integrated Development Plan 2018-2022*. Kajiado County Government.

County, K. (2018b). *Kajiado County: One year progress report.*

Donald Njarui, P. W. (2004). Effect of cutting frequency of five selected herbaceous legumes and five grasses in semi-arid tropical Kenya. Tropical Grasslands. *Tropical Grasses*, *38*(3). Retrieved from https://www.researchgate.net/publication/266183274_Effect_of_cutting_frequency_of_five_selected_herbaceous_legumes_and_five_grasses_in_semi-arid_tropical_Kenya

East Africa Community. (2022). *EAC Climate Change Policy Framework*. Retrieved from https://www.eac.int/environment/climate-change/eac-climate-change-policy-framework

East Africa Community. (2022). *EAC Document Manager.* Retrieved from East Africa Community: https://www.eac.int/documents

Elias, M. O. (2015). Land conversion dynamics in the Borana rangelands of Southern Ethiopia: An integrated assessment using remote sensing techniques and field survey data. *Environments*, 11,19. doi:10.3390/environments2010001

Ellie Wood, M. M. (2022). Intentions behind common and risky fires. *African Journal of Range & Forage Science*, 131. doi:10.2989/10220119.2021.2000026

FAO. (2009). *Review of evidence on drylands pastoral systems and climate change.* Land Tenure and Management Unit . FAO.

FAO. (2014). *Feedipedia - Animal Feed Resources Information System*.

FAO. (2015). *Climate change and Food Security: Risks and Responses.* FAO.

FAO. (2017). *The impact of Disasters and Crisis on agriculture and food security.*

FAO. (2018a). *Pastoralism in Africa's drylands: reducing risks, addressing vulnerability and enhancing resilience.*

FAO. (2018b, January 8). *Climate change and the global dairy cattle sector-The role of the dairy sector in a low-carbon future.* Italy. Retrieved from http://www.fao.org/3/CA2929EN/ca2929en.pdf

FAO. (2019). *East Africa Animal Feed Action Plan: Sustainably developing animal based livelihoods in East Africa.* FAO. Retrieved from http://www.fao.org/3/ca5965en/ca5965en.pdf

FAO. (2020). *FAO - Sustainable Development Indicators*. Retrieved from http://www.fao.org/sustainable-development-goals/indicators/241/en/

FAO. (2021). *Food and Nutrition Security Resilience Programme: Report of the multidisciplinary context and fodder value chain analysis in Sool and Sanaag (Somaliland).* FAO.

Feed the Future. (n.d.). *Feed the Future Innovation Lab for Livestock Systems/about us*. Retrieved from Feed the Future Innovation Lab for Livestock Systems: https://livestocklab.ifas.ufl.edu/

Fendo, S. (2000). *Characterisation of the soils of Mashuru area with respect to their genesis and classification.* University of Nairobi. Nairobi: University of

Nairobi, Department of Soil Science. Retrieved from http://erepository.uonbi.ac.ke:8080/xmlui/handle/123456789/20906

Fezzi, C. I. (2013). The Impact of Climate Change on Agriculture: Nonlinear Effects and Aggregation Bias in Ricardian Models of Farm Land Value. *Journal of the Association of Environmental and Resource Economists, 2*(1), 57-92. doi:DOI: 10.1086/680257

Gennari, P., & Kalamnrezo, D. (2019). The challenge of measuring agricultural sustainability in all its dimesions. *Hopres Journal of Sustainability Research*.

Getabalew M, A. T. (2019). Factors Affecting the Productivity of Rangelands. *Journal of Plant Science and Agriculture, Vol.3 No.1:19*, 3-8.

GFDRR. (2017). *Kenya Post-Disaster Needs Assessment for the 2008-2011*. Nairobi: GFDRR.

GoK. (2012a). *Kenya Post Disaster Needs Assessment 2008-2011*. Government of Kenya.

GOK. (2012b). *Sessional Paper No. 08 of 2012 on National Policy for the Sustainable Development of Northern Kenya and other Arid Lands.* Ministry of State for Development of Northern Kenya and Other Arid Lands.

GOK. (2015). *Common Programme Framework for Ending Drought Emergencies.* Govt. of Kenya.

GOK. (2016). *Kenya Climate Smart Agricultural Project 2017-2022.* Ministry of Agriculture, Livestock, Fisheries.

GoK. (2017a). *Kenya Climate Smart Agriculture Strategy - 2017-2026.* Ministry of Agriculture, Government of Kenya.

GoK. (2017b). *Ending Drought Emergencies in Kenya: Progress Report.* Ministry of Devolution and Planning.

GOK. (2017c). *Ministry of Devolution*. Retrieved from County Integrated development Plans (CIDPs): https://www.devolution.go.ke/county-integrated-development-plans/

GoK. (2018). *National Climate Change Action Plan 2018-2022.* GoK, Ministry of Environment and Forestry.

GoK. (2019a). *Agricultural Sector Transformation and Growth Strategy 2019-2029.* Ministry of Agriculture, Livestock, Fisheries and Irrigation.

GoK. (2019b). *The Livestock Policy revised 2019.* Ministry of Agriculture, Livestock and Fisheries.

GoK. (2020). *Implementation status if the Big Four agenda 2018/2019.* The national Treasury and Planning State.

GOK. (2021a). *State Department for Development of Arid and Semi Arid Lands*. Retrieved from https://www.asals.go.ke/asal-info/

GoK. (2021b). *Range management and pastoralism strategy 2021 – 2031.* Ministry of Agriculture, Livestock, Fisheries and Cooperatives.

GoK, K. L. (2010). *Constitution of Kenya/ Bill of Rights.* Retrieved from Kenya Law Reform Commission: https://www.klrc.go.ke/index.php/constitution-of-kenya/112-chapter-four-the-bill-of-rights/part-2-rights-and-fundamental-freedoms/208-42-environment

GoK, S. (2020). *Committee report on the national drought management authority (amendment) bill.* Senate, Government of Kenya.

IGAD. (2015). *IGAD Regional Strategy, Vol 2.* Djibouti: Intergovernmental Authority on Development. Retrieved from https://igad.int/download/igad-regional-strategy-volume-2-implementation-plan-en-fr/

IGAD. (2020). *Regional strategic framework: rangeland management in arid and semi-arid lands of the IGAD region (RRMSF).* Djibouti: Intergovernmental Authority on Development.

infonet-biovision. (n.d.). *Hay Making*. Retrieved from https://infonet-biovision.org/AnimalHealth/Hay-Making

IPCC. (2013). *Glossary of Terms* . Retrieved from https://archive.ipcc.ch/pdf/special-reports/srex/SREX-Annex_Glossary.pdf

IPCC. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fifth Assessment.* Cambridge University. IPCC.

IPCC. (2019). "Summary for Policymakers'," in Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. IPCC.

John G. Galaty, P. B. (2019). The Current Realities of African Pastoralists. In *Herders, Warriors, and Traders* (p. 26). New York: Francis & Taylor Group. Retrieved from https://www.taylorfrancis.com/books/edit/10.4324/9780429045615/herders-warriors-traders-john-galaty-pierre-bonte?refId=84896d88-79b6-4a07-92a4-82a6352fa98d&context=ubx

Kajiado County Assembley. (2020). *Kajiado County Assembly - Bills*. Retrieved from https://kajiadoassembly.go.ke/bills/

Kajiado, C. G. (2018). *(CIDP) County Integrated Development Plan.* County Government of Kajiado.

Kallenbach, R. (2022). *Extension: Making and Storing Quality Hay.* University of Missouri. Retrieved from University of Missouri : https://extension2.missouri.edu/g4570

Kenya Bureau of Statistics. (2009). *Census 2009: Livestock by County.* Kenya Bureau of Statistics.

Kenya Bureau of Statistics. (2019). *2019 Kenya Population and Housing Census Volume I: Population by County and Sub-County.* Kenya Bureau of Statistics.

Kimani, M., Njeru, M., & Ndirandu, G. (2013). Regional variations in contraceptive use in Kenya: comparison of Nyanza, Coast and Central Provinces. *African Population Studies*, *27*(1). doi:https://doi.org/10.11564/27-1-6

Kimaru, J. ,. (2021a). Analysis of Hay Demand from Pastoralism Systems on Viability of Hay Production as a Climate Adaptation Strategy in Kajiado

County, Kenya. *Agricultural Sciences, doi: 10.4236/as.2021.1210070.*(12), 1089-1102.

Kimaru, J. ,. (2021b). Effectiveness of Drought Risk Reduction Policies: Case Study of Hay Production in Kajiado County, Kenya. *American Journal of Climate Change,, 10*, 512-532. Retrieved from doi: 10.4236/ajcc.2021.104026.

Kimongo, A. N. (2017). *Methane gas emissions by enteric fermentation from cattle production in Kenyewa location of Kajiado County in Kenya: a study on potential climate change mitigation strategies.* UoN Research Archive. University of Nairobi. Retrieved from http://hdl.handle.net/11295/102215

King-Okumu, C. O. (2022). *Drought management in the drylands of Kenya: what have we learned?.* GFDRR. doi:10.1016/B978-0-12-814820-4.00019-5

Kumar Balwinder, B. N. (2019). Nutritious feed for farm animals during lean period: silage and hay: A review. *Forage Research, 45*, 10-45.

Kuria, S. G. (2015). Adapting dryland livestock production to meet climate change. 16.

Latimore, M.-A. (2008). *Producing quality Lucerne hay*. Rural Industries Research and Development Corporation.

Laura Yahdjian, O. E. (2015). Rangeland ecosystem services: Shifting focus from supply to reconciling supply and demand. *Frontiers in Ecology and the Environment, 13*(1), 44–51. doi:https://doi.org/10.1890/140156

Lebdi, F. (2016). *Irrigation for Agricultural.* African Centre for Economic Transformation and Japan International Cooperation Agency Research institute (JICA-RI).

Limited, G. (2020). *Rain gun sprinklers*. Retrieved from grekkon.com: https://grekkon.com/rain-gun-sprinklers-2/

Lugusa, K. O. (2015). Fodder Production as an Adaptation Strategy in the Drylands: A Case Study of Producer groups in Baringo County, Kenya. doi:10.13140/RG.2.1.3027.3363

Maarten Wynants, C. K. (2019). Drivers of increased soil erosion in East Africa's agro-pastoral systems: changing interactions between the social, economic and natural domains. *Regional Environmental Change, 19*(7), 1909-1921. Retrieved from https://doi.org/10.1007/s101

Mendelsohn, R. (2006). The role of markets and governments in helping society adapt to a changing climate. *Climatic Change, 28*, 203-215. doi:https://doi.org/10.1007/s10584-006-9088-4

Mgalula, M. W. (2021). Greenhouse gas emissions and carbon sink potential in Eastern Africa rangeland ecosystems: A review. *Pastoralism, 11*, 11,19. Retrieved from https://doi.org/10.1186/s13570-021-00201-9

Mganga Kevin, M. N. (2013, October). 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 value for livestock. *Grass and Forage Science, 70*(1), 161-167. doi:https://doi.org/10.1111/gfs.12089

Moiko. S., B. C. (2019). *Land use transformation in Kajiado County: imlication for climate change.* Kenya Markets Trust.

Mumina Shibia, W. M. (2021). *Kenya Climate Smart Agricultural Project component two performance evaluation indicators survey report volume two: the livestock value chain.* Kenya Agricultural and Livestock Research Organisation (KALRO). Retrieved from https://www.kalro.org/emimi/sites/default/files/Rhodes%20grass%20x%20Tozi%20factsheet.pdf

Mutwedu, V. M. (2020). *Fodder production manual for extension staff and farmers in South Kivu and Tanganyika Provinces of the Democratic Republic of the Congo* (Vol. ILRI Manual 37). Nairobi, Kenya: ILRI.

Mworia, J. K., Kinyamario, J. I., & John, E. A. (2008a). Impact of the invader Ipomoea hildebrandtii on grass biomass, nitrogen mineralisation and determinants of its seedling establishment in Kajiado, Kenya. *African Journal of Range & Forage Science*.

Mworia, J. K., Kinyamario, J. I., & John, E. A. (2008b). Traditional strategies used by pastoralists to cope with la nina induced drought in Kajiado, Kenya. *African Journal of Environmental Science and Technology., 2*, 10-14.

Nangole, L. F. (2013). *Livestock Feed Production and Marketing in Central and and North Rift Valley Regions of Kenya.* ILRI.

National Weather Services. (2008). *Drought Public Fact Sheet.* Retrieved from ttps://www.nws.noaa.gov/om/csd/graphics/content/outreach/brochures/DroughtPublic2.pdf

Nderi, O. (2016). Current status of fodder production, conservation and marketing in the arid and semi-arid lands of Tharaka Nithi County, Kenya. . *African Journal of Agricultural Research.*, 11. 2337-2347. 10.5897/AJAR2016.11162. .

NDMA. (2017). *National Drought Managment Authority Strategi Plan 2018-2022.* GoK, NDMA. Retrieved from https://www.ndma.go.ke/index.php/resource-center/policy-documents/send/44-policy-documents/5617-strategic-plan-2018-2022

NDMA. (2022). *Drought monitoring and early warning bulletin* . National Drought Management Authority.

NEMA-KENYA. (2015). *Kenya, Second National Communication to the Climate Change.* National Environmental Managment Authority (NEMA-KENYA).

NEPAD. (2003). *Comprehensive Africa Agriculture Development Programme (CAADP).* Retrieved from https://www.nepad.org/comprehensive-africa-agriculture-development-programme-caadp

Newspaper, S. (2020). *Balala orders removal of camp after wildebeest blocked from crossing Mara River*. Retrieved from https://www.standardmedia.co.ke/nairobi/article/2001385815/balala-orders-removal-of-camp-after-wildebeest-blocked-from-crossing-mara-river

Niamir-Fuller, M. K. (2012). Co-existence of wildlife and pastoralism on extensive rangelands: competition or compatibility?. *Pastoralism*, 2,8. Retrieved from https://doi.org/10.1186/2041-7136-2-8

Njenga, J. (2018). *Making and Storing Quality Hay.* Retrieved from https://www.infonet-biovision.org/AnimalHealth/Hay-Making-Mechanisation

Nyariki D.M., A. D. (2019). The value of pastoralism in Kenya: Application of total economic value approach. *Pastoralism, 9,9*, 4,5. doi:https://doi.org/10.1186/s13570-019-0144-x

OCHA. (2022). *Horn of Africa Drought: Regional Humanitarian Overview & Call To Action.* Nairobi: OCHA. Retrieved from https://reliefweb.int/report/ethiopia/horn-africa-drought-regional-humanitarian-overview-call-action-published-4-july-2022

Ogillo B. P., K. B. (2017). *Hay Making and Storage for Livestock Production in Arid and and Semi-Arid Areas.* Nairobi. Retrieved from KALRO: https://www.kalro.org/asal-aprp/sites/default/files/Feed_conservation_in_ASALs_final-2.pdf

Omondi Enos O, O. G. (2015). Livelihood and Food Security Situation among In-migrant and Non-Migrant Communities in Kajiado County, Kenya. *International journal of innovative research & development, Vol 4* (13), 236-246.

Opiyo, M. S. (2011). The influence of water availability on pastoralist's resource use in Mwingi and Kitui Districts in eastern Kenya. *Journal of Human Ecology*, 48. doi:10.1080/09709274.2011.11906389

Oscar Koech, S. K. (2021). *Pasture Production and Conservation Training Manual.* University of Nairobi.

Ouma, O. E. (2017). Analysis of Fodder Production and Marketing in the Rangelands of Southern Kenya. *University of Nairobi Digital Repository, 5171*, 78-80. Retrieved from http://erepository.uonbi.ac.ke/bitstream/handle/11295/101466/Omollo%2CErick%20O_Analysis%20of%20Fodder%20Production%20and%20Marketing%20in%20the%20Rangelands%20of%20Southern%20Kenya.pdf?sequence=1&isAllowed=y

Pan American Health Organization. (2021). A Practical Guide Cost Benefit Analysis. In P. A. Organization, *A practical guide for hospital administrators, health disaster coordinators, health facility designers, engineers and maintenance staff to achieve Smart Health Facilities by conserving resources, cutting costs, increasing efficiency in operations and red* (p. Section IV CBA methodology). Retrieved from Pan America Health Organization: https://www.paho.org/disasters/dmdocuments/SHT_CostBenefitAnalysis.pdf

Panel, M. M. (2018.). *Water-Wise: Smart Irrigation Strategies for Africa, Dakar, Senegal: International Food Policy Research Institute (IFPRI) and Malabo Montpellier Panel.* Dakar: Malabo Montpellier Panel. 2018. .

https://www.mamopanel.org/media/uploads/files/Water-Wise_Smart_Irrigatio. Retrieved from https://www.mamopanel.org/media/uploads/files/Water-Wise_Smart_Irrigation_Strategies_for_Africa.pdf

Pascual, U. B. (2017). Valuing nature's contributions to people: The IPBES approach. . *Current Opinion in Environmental Sustainability, 26,* , 7-16. doi:doi: 10.1016/j.cosust.2016.12.0

Pierre Bonte, J. G. (2019). *Herders, Warriors, and Traders.* New York: Francis & Taylor.

Prevention Consortium. (2008). *From Risk to Resileince: A Cost Benerfit Analysis Methodology.*

R.Carter, M., & Janzen, S. A. (2012). *Coping with Drought: Assessing the Impacts of Livestock Insurance in Kenya.* University of Califonia.

Rajesh Kumar Singh, H. M. (2012). An overview of sustainability assessment methodologies. *Ecological Indicators*, 281-299.

Research and Markets. (2021). *Sudan Alfalfa Hay Market - Growth, Trends, and Forecast (2020 - 2025).* Retrieved from Research and Markets: https://www.researchandmarkets.com/reports/5011947/sudan-alfalfa-hay-market-growth-trends-and

Roberto Rudari, S. C. (2018). *Kenya Disaster Risk Profile.*

Rojas-Downing, M. M. (2017). Climate change and livestock: impacts, adaptation, and mitigation. *Climate Risk Management*, 145-163. doi:10.1016/j.crm.2017.02.001

Sala, O. Y. (2017). Rangeland Ecosystem Services: Nature's Supply and Humans' Demand . In: Briske, D. (eds) , Cham. https://doi.org/10.1007/978-. *Rangeland Systems. Springer Series on Environmental Management. Springer*. Retrieved from https://doi.org/10.1007/978-

Sayre, N. R. (2013). Earth Stewardship of rangelands: Coping with ecological, economic, and political marginality. *Frontiers in Ecology and the Environment*, 348–354.

Seo, N. R. (2009). Adapting to climate change mosaically: an analysis of African livestock management by agro-ecological zones. *Berkeley Electronic Journal of Economic Analysis and Policy*.

Sharma, P. V. (2012). Sha Climate change and carbon sequestration in dryland soils . *Resource Management for Sustainable Agriculture*, 140–164. Retrieved from https://doi.org/10.5772/52103.

Smith, J. (2019). Livestock nutrition: Meeting the dietary needs of animals. *Journal of Animal Science and Technology, 61(2)*, 73-78.

Suzanne van Dijk, A. W. (2018). *The potential for commercial hay production in Kenya*. CGIAR.

T, N. (2016). *Kenya: Country situation assessment working paper - research for climate resilient futures.* Pathways to Resilience in Semi-arid Economies

(PRISE) project. Retrieved from https://prise.odi.org/research/kenya-country-situation-assessment/

T.F. Bernardes, J. D. (2018). Silage review: Unique challenges of silages made in hot and cold regions. *Journal of Dairy Science, Volume 101*(5), 4001-4019. doi:https://doi.org/10.3168/jds.2017-13703

Teague Richard, K. U. (2020). Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services. *Frontiers in Sustainable Food Systems, 4*, 2. doi:10.3389/fsufs.2020.534187

The Joanna Briggs Institute. (2015). *Joanna Briggs Institute Reviewers' Manual: 2015 edition / Supplement.* The Joanna Briggs Institute.

The Northern Rangelands Trust. (2019). *The Northern Rangelands Trust Rangelands Strategy 2019-2022.*

Turner, M. S. (2019). Livestock mobility in sub-Saharan Africa: A critical review. *Pastoralism*, 9-13. Retrieved from https://doi.org/10.1186/s13570-019-0150-z

Uddin Md E., K. E. (2020). Review: Impact of Food and Climate Change on Pastoral Industries. *Frontiers in Sustainable Food Systems*, 4. doi:10.3389/fsufs.2020.543403

UNDRR. (2015). *Sendai Framework for Disaster Risk Reduction 2015 - 2030.* UNDRR.

UNDRR. (2019). *Global Assessment Report (GAR).* United Nation Disaster Risk Reduction.

UNFCCC . (2017). *Opportunities and options for integrating the climate change adaption with the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction 2015-2030.* UNFCCC.

UNFCCC. (2011). *Assessing the costs and benefits of adaption options - An overview ofapproaches.* Bonn: UNFCCC.

United Nations. (1992). *Convention on Biological Diversity.* Retrieved from https://www.cbd.int/convention/

University of Oregon State. (2022). *Forage Information system*. Retrieved from https://forages.oregonstate.edu/nfgc/eo/onlineforagecurriculum/instructormaterials/availabletopics/grazing/types

Valence Bwana Mutwedu, G. J. (2020). *Fodder production manual for extension staff and farmers in South Kivu and Tanganyika provinces of the Democratic Republic of the Congo.* ILRI. Nairobi: ILRI.

Van Dijk S, W. A. (2018). *The potential for commercial hay production in Kenya.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)., CCAFS Info Note. Wageningen, the Netherlands: . Research on Climate Change, Agriculture and Food Security (CGIAR).

Vangimalla Reddy, V. A. (2017). *Managing Stranded Assets and Protecting Food Value Chains from Natural Disasters.* ERIA.

Wairore, J. N. (2015). Benefits Derived from Rehabilitating a Degraded Semi-Arid Rangeland in Private Enclosures in West Pokot County, Kenya.

World Bank. (2015a). *Kenya Agriculture Sector Risk Assessment.*

World Bank. (2015b). *Kenya Livestock Insurance Program.* Retrieved from Financial Protection Forum/ publications: https://www.financialprotectionforum.org/publication/kenya-livestock-insurance-program-klip

World Initiative for Sustaniable Pastoralism . (2008). *Sustainable Pastoralism – Moving forward with appropriate policies.* World Initiative for Sustaniable Pastoralism .

World Resource Institute. (2003). *World Resources: 2002-2004.*

9.0 APPENDICES

Data collecting Questionnaire: (abridged version)

Name of Study: Assessing the effectiveness of climate-smart drought risk reduction strategies in livestock sector in Kajiado County

SECTION 1: BIODATA

Hay farmer biodata

Name	**Sub County**	**Ward /Division**	**Village**	**Date of Interview**	**Questionnaire Number**
				___/___/___	

Animal biodata

No	**Type of Livestock kept *(Circle the number on the first column)***	**Types of Breeds *(Choose from the List below)***	**Herd Size (Numbers now)**	**No. of females**	**No. of calves, kids, foals etc**	**Males as Ratio Breeding: castrated**
1	Cattle					
2	Goats					
3	Sheep					
4	Donkey					
5	Chicken					
6	Bees					
7	Camels					
8.	Dogs					
9.	Cats					
10	Other (Specify) ________________					

SECTION 2: ANIMAL FEEDING METHODS

How do you feed your animals during normal months?
(Tick all applicable answers)

	Number of Animals				
Sources of Feed	**Dairy Cattle**	**Beef cattle**	**Sheep & Goats**	**Poultry (Kiyengi)**	**Poultry (exotic)**
Commercial feeds					
Grazing on Own or Free communal					
Grazing on Rented Land					
Hay – own grown					
Hay - bought					
Other types of Forage (maize, tree leaves,					

legumes)					

What are the Prices of Feeding Methods?

Sources of Feed	Unit	Price per Unit
Commercial feeds	50kgs bag	
Grazing on Own or Free communal	number of animals per acre	
Grazing on Rented Land	number of animals per acre/per day	
Hay – own grown	per Bales (15-17kgs)	
Hay - bought	per Bales (15-17kgs)	
Other types of Forage (maize, tree leaves, legumes)	per Kgs	

SECTION 3: IMPACT OF DROUGHTS ON LIVESTOCK WELFARE

MIGRATION

What costs did you incur during the migration?

Item	Unit Type	Unit Cost (KES)	No. of Workers	No. of Animals	No. of days	No. of Bags	Total Costs (KES)
Permanent Herders	monthly rate			N/A		N/A	
Temporary Herders	daily rate			N/A		N/A	
Security	Daily rate			N/A		N/A	
Movement Permits	rate		N/A		N/A	N/A	
Grazing Permits	rate		N/A			N/A	
Rent of Grazing Land	Daily Rate		N/A			N/A	
Water for animals	per day		N/A			N/A	
Commercial Feed	per 50kg bag		N/A	N/A	N/A		
Veterinary Fees	lumpsum	N/A	N/A	N/A	N/A	N/A	
Other Costs	Total/ lump Sum	N/A	N/A	N/A	N/A	N/A	

SECTION 4: HAY PRODUCTION

4.1 How many acres do you grow Hay? ____________________

4.2 What method do you use to grow your hay?

Hay Growing Method	Tick all the relevant
Clearing Bushes and Trees	
Letting indigenous grass already on land grow	

Fencing has growing area	
Rotational Grazing	
Planting improved hay seed varieties	

4.3 Cost of Planting the Hay

Activity	**Unit Type**	**Unit Cost (KES)**	**No. of Units**	**Total Costs**
Labour Costs				
Clearing bushes and Trees	per person per day			
	per tree			
	per acre			
Tractor Ploughing	per day			
	per acre			
Manual Digging	per person per day			
	per person per acre			
Planting improved varieties	per person per day			
	per person per acre			
Weeding	per person per day			
	per person per acre			
Fertilizer/ Manure application	per person per day			
	per person per acre			
Permanent Staff	monthly salary			
Temporary Staff for hay	daily salary			

4.5 Annual Hay Bales harvest

Tick your Bale weight 15kgs _____ 17Kgs _______

	Number of Bales Harvested					
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Manual Harvest						
Commercial Harvest						
	Number of Bales Sold					
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Manual Harvest						
Commercial Harvest						