HEALTHY RANGELANDS FOR SUSTAINABLE ANIMAL PRODUCTIVITY

Proceedings of the 6th Scientific Conference of Rangeland Society of Tanzania (RST) held at EDEMA Hotel, Morogoro Tanzania 15th and 16th April, 2024

Edited by
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Preface

Tanzania's rangeland resources cover an estimated 61 million hectares, with approximately 44 million hectares designated for grazing and 17 million hectares consisting of fallow land and forested areas. These rangelands currently sustain around 20 million tropical livestock units (TLU). The country's ruminant livestock population includes an estimated 36.6 million cattle, 26.6 million goats, and 9.1 million sheep, making Tanzania the second-largest in Africa in terms of cattle population, following Ethiopia. Ruminants play a crucial role in the national economy, significantly contributing to both the gross domestic product (GDP) and the agricultural GDP. It is estimated that meat and milk production account for over 60% of the agricultural GDP, with both sectors experiencing growth.

However, Tanzania's rangelands face several challenges, primarily the obstruction of traditional livestock migration routes due to expanding crop cultivation, wildlife conservation areas, game reserves, and mining activities. As grazing areas shrink while ruminant populations raise, the effects of overgrazing, soil erosion, and bush encroachment have become increasingly evident in many regions. Additional challenges include the lack of strategic planning and institutional frameworks for sustainable rangeland management, the absence of regular resource inventories and improvement programs, inadequate livestock marketing infrastructure, and an insufficiently developed watering system aligned with grazing capacity. Furthermore, there are no well-defined policies for identifying and protecting grazing lands, and there is a shortage of qualified extension officers and researchers specializing in rangeland science.

Recognizing that healthy rangelands are the foundation of sustainable ruminant livestock production, the sixth scientific conference of the Rangeland Society of Tanzania (RST), held on April 15–16, 2024, focused on the theme **"Healthy Rangelands**

for Sustainable Economic Development." This proceeding compiles papers from the sixth scientific conference of the RST, organized into five key sub-themes:

1. Commercializing Forage and Seed Production for Economic Development
2. Rangeland Resource Use and Assessment (Weeds and Invasive Species)
3. Rangeland Restoration Amid Climate Change Uncertainty
4. Healthy Rangelands for Enhanced Ruminant Nutrition
5. Cross-cutting Issues in Grazing Land Management (Gender, Human and livestock interaction)

Most of these papers present research findings from different regions of Tanzania, offering insights that could contribute to the sustainable management of rangelands, improved ruminant productivity, and better livelihoods for livestock keepers.

The organizing committee (I. S. Selemani, L. Chacha, G.M. Msalya, P. Mapunda, A.Z. Sangeda, E.J. Mtengeti, D. Joel, and D. Lutatenekwa) extends its gratitude to all keynote speakers and contributing authors for their valuable input. Special appreciation is also given to the Ngorongoro Conservation Area Authority, the Ministry of Livestock and Fisheries and other stakeholders for their financial and technical support in making this conference a success.

April, 2024
Organizing committee

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Welcoming Remarks by the Chairperson to the Sixth Rangeland Society of Tanzania Scientific Conference 15th and 16th April, 2024

Dear Guest of Honor, Minister, Ministry of Livestock and Fisheries, Honorable Luhaga Joelson Mpina

Invited guests, Ladies and Gentlemen
On behalf of Rangeland Society of Tanzania and on my behalf, I would like to extend my warmest welcome to you honorable

Abdallah Hamisi Ulega (MP), the Minister, Ministry of Livestock and Fisheries. Indeed, your presence in this sixth Scientific Conference of Rangeland Society of Tanzania signifies the fact that the society attaches great important contributions to our nation. Thank you very much for accepting our request. Honestly, we are honored by your presence in this important conference.

Dear Guest of honor; Rangeland Society of Tanzania (RST) is Non-Governmental Organization registered in 2005 with registration number 00NGO/0945. The general objective of the society is to strengthen and build capacity among different stakeholders working with rangelands to improve their livelihoods through enhanced rangeland resources and animal productivity. The mission of our society is to promote the sustainable management of rangeland resources through capacity building, research and consultancy. The RST main research focuses are; monitoring and evaluation of rangeland resources, rangeland restoration, environmental conservation and improvement, forage seed production technologies, land use policy, forage utilization and alternative source of livelihoods.

Dear Guest of honor, So far our society has managed to organize five scientific conferences where several scientific papers were

presented, discussed and later on reviewed and published in the scientific conference proceeding books. The RST Scientific Conferences provide the forum for exchange of information among rangeland scientists and livestock keepers within Tanzania and abroad. Through this platform, important resolutions are normally communicated to policy makers including officials from the relevant ministries, members of parliament and local government authorities for actions. This is the sixth conference with a main theme "Healthy Rangelands for Sustainable Economic Development".

Dear Guest of honor, this year the conference will focus on five sub-themes; i) Commercializing Forage and Seeds Production for Economic Development, ii) Rangelands Resource Use and Assessment (Weeds and Invasive species), iii) Rangelands Restoration under Uncertainty of Climate Change iv) Healthy Rangelands for Improved Ruminants Nutrition, v) Cross-Cutting issues such as climate change and gender. I would like to thank all keynote speakers and other scientists for accepting our invitation and prepare presentation on relevant sub-themes. We hope that the speakers will provide important insights toward improving our rangelands and livestock productivity in general. Nevertheless, we will appreciate contributions, challenges, comments and recommendations from conference participants. Since, one of the principles of research is to be objective; I also wish to request all scientists to be ready for any challenges and critical comments from the audience.

Dear Guest of honor, having said these few words, may I now take this opportunity to welcome you to address the participants in the fifth Scientific Conference of the Rangeland Society of Tanzania. **You are warmly welcome.**

Opening Speech by Hon. Abdallah Ulega; Minister, Ministry of Livestock & Fisheries

Honorable Chairperson, Rangeland Society of Tanzania
Distinguished Conference Participants,
Ladies and Gentlemen,

I am delighted to have the opportunity to join you on this important day. I extend my sincere congratulations to the organizers for inviting me to participate in the Rangeland Day meeting, Rangeland Society of Tanzania sixth scientific conference and the Rangeland Stakeholders' General Meeting. I have been informed by the organizers that the participants in this meeting include experts, livestock keepers, and representatives from the Tanzania Livestock Keepers Association (CCWT). It is encouraging to see the priority given to rangeland management despite your numerous responsibilities. This demonstrates your strong commitment to advancing the livestock sector. I also take this opportunity to commend you, Mr. Chairperson, and the leadership of the National Rangeland Association as a whole.

Honorable Chairperson, Rangelands serve as the primary source of livestock feed in the country, contributing approximately 98% of the total livestock nutrition. In addition to providing pasture, rangelands also supply water and essential minerals for livestock health. Most rangeland areas are found in villages, either through formal arrangements or informally. However, the availability of pasture faces several challenges, including declining pasture quality and a reduction in grazing areas due to the increasing demand for land for various economic and social activities, driven by population and livestock growth.

At the time of independence, Tanzania had a population of nine million people. Today, the population is estimated at

approximately 61 million, while the number of cattle has increased from eight million to 36 million, yet the land remains the same. Consequently, the insufficient amount of grazing land, is leading to conflicts over land use between livestock keepers and other land users across the country.

Honorable Chairperson, another significant challenge is climate change, which has caused the drying up of natural water sources that were once heavily relied upon, particularly during dry seasons. Additionally, existing livestock water infrastructure, such as dams and deep wells, is insufficient to meet the growing demand, and some facilities require urgent rehabilitation.

In response to these challenges, the government, in collaboration with various development partners, has continued to implement several initiatives to support livestock keepers, including:

(a) Working with local governments and stakeholders to resolve conflicts between livestock keepers and other land users. As of February 2023, the ministry had received 125 land dispute cases, of which 44 had been resolved, while others were at different stages of resolution.

(b) Strengthening eight government-run pasture seed farms to enhance pasture and seed production. The government is also encouraging private sector investment, including livestock keepers, in pasture seed production to increase pasture availability.

(c) Renovating and constructing essential water infrastructure, including dips and watering points in grazing areas. Livestock keepers are also urged to protect and contribute to the maintenance of these facilities to minimize livestock wandering in search of water, which often leads to unnecessary conflicts with local communities.

Honorable Chairperson, to further address these challenges, the government, through the Land Use Commission, continues to work with district councils to develop land use plans and allocate grazing areas. As of February, a total of 3.46 million hectares had been designated for grazing. However, this remains insufficient, and livestock keepers, along with other stakeholders, are encouraged to support the expansion of grazing areas. It is also essential to educate livestock keepers on how to manage and develop these areas by establishing necessary livestock infrastructure to enhance productivity.

Furthermore, designated grazing areas should be surveyed, clearly marked, and submitted to the ministry for legal registration to ensure protection from unauthorized uses. Currently, many designated grazing areas have been illegally repurposed or sold without the consent of livestock keepers, leaving them without sufficient grazing land and forcing them to migrate in search of pasture and water. Additionally, livestock keepers should be encouraged to legally own and register grazing land individually, ensuring sustainable livestock farming practices.

Honorable Chairperson, as part of implementing the Guidelines for Access, Development, and Management of Grazing Areas, the ministry is promoting the establishment of pasture demonstration farms across the country. Between 2022 and 2024, the ministry initiated 100 demonstration farms across 44 councils, where livestock keepers learned pasture farming techniques, including planting, harvesting, and storing pasture and seeds. In the 2023/2024 fiscal year, the ministry has facilitated the establishment of 150 demonstration farms in 71 councils nationwide. These training programs aim to increase pasture and seed production, reducing pasture shortages and livestock mortality during droughts.

In this meeting, you will discuss effective solutions for addressing rangeland management challenges and promoting productive

livestock farming to enhance the development of the livestock sector for the benefit of livestock keepers, rangeland stakeholders, and the nation. I have been informed that, the conference theme is "Healthy Rangeland for Sustainable Economic Development. I belived that under this is themantic area, you will address issues related to forage production and commercialization, rangeland assessment and restoration, conflicts related to human livestock interaction as well as othe cross-cutting issues such as how gender influce management of rangeland resources.

These topics are timely, as they provide opportunities to create employment for young people in the country. Many graduates in fields such as Animal Science and Pasture Management remain idle, waiting for government jobs, while their skills could significantly transform the sector. Young people should adopt a self-employment mindset, particularly in the pasture sector, to address the challenges of unemployment and pasture shortages during droughts, thereby reducing land-use conflicts between livestock keepers and other land users.

Honorable Chairperson, I wish you all fruitful discussions. My ministry is keen to receive your recommendations from this meeting and will work diligently to implement them. Once again, I extend my sincere gratitude to all attendees for participating in this event.

With that, I now officially declare the **Rangeland Day and the the Sixth Rangeland Scientific Conference open.**

THANK YOU VERY MUCH FOR LISTENING

Integrated Agricultural Development Strategies: Assessing Forage and Seed Supply Chain Dynamics at Vikuge Pasture Seed Farm, Kibaha, Tanzania; Farida Salehe and Edwin Ngowi

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Abstract

This study investigated the integrated agricultural development practices at Vikuge Pasture Seed Farm in Kibaha, Tanzania, focusing on the supply and commercialization of forage and seeds. It identified critical challenges that hampered effective commercialization and sought to elucidate how the farm's practices influenced local agricultural dynamics. Utilizing a mixed-methods approach, data were collected from 96 respondents through key informant interviews and focus group discussions, supplemented by a thorough literature review. A market system and value chain approach were adopted to analyze the flow of inputs from production to consumption, aiming to uncover the interconnected activities that enhance economic viability. Statistical findings revealed a remarkable 25% increase in annual revenue attributed to innovative agronomic practices and market-oriented strategies, underscoring the strong economic feasibility of the farm's operations. Qualitative insights from the focus group discussions highlighted the socio-economic

implications of integrated practices, indicating improved access to high-quality forage seeds, enhanced livestock productivity, and positive ripple effects on local economies. Participants reported increased income and job creation, validating the transformative potential of integrated agricultural development initiatives. This study not only contributes to the understanding of commercialization strategies in Tanzanian agriculture but also provides empirical support for policy frameworks aimed at promoting sustainable agricultural practices that can elevate local livelihoods and economic resilience.

Keywords: Integrated agricultural development, forage and seeds production, livestock keeping development, Vikuge Pasture Seed Farm, Sustainable Economic Development

Introduction

Tanzania's livestock sector, despite having the third-largest livestock population in Africa, contributes only 7.4% to the country's GDP (Michael et al., 2017). The sector's growth is hindered by low reproductive rates, high mortality, and disease prevalence (Michael et al., 2017). Livestock production accounts for about 30% of the Agricultural GDP, with beef, milk, and poultry each contributing approximately 30-40% (Rutabanzibwa, 2003). Despite these challenges, studies have shown that the livestock subsector has the highest contributive effect on economic growth compared to crop and fishery subsectors (URT, 2018; Mtaturu, 2020). Overall, agriculture contributes 25.88% to Tanzania's economy, with livestock accounting for 4.70% (Chongela, 2015). The 4.7 percent refers to the share of Tanzania's total GDP contributed specifically by the livestock subsector, as reported by Chongela (2015). Although livestock contributes approximately 30 percent of agricultural GDP, its

share of the overall national GDP is lower, at 4.7 percent. This discrepancy arises because agriculture is a part of the broader economy, and livestock is just one segment within agriculture. Therefore, while livestock has a substantial impact within agriculture, its contribution appears smaller when viewed in the context of the total economy. As such, to improve the sector's performance, researchers suggest implementing a comprehensive livestock master plan (Michael et al., 2017) and reallocating more resources to the livestock subsector (NBS, 2019; Mtaturu, 2020), which could significantly boost agricultural production and economic growth in Tanzania.

Forage, which primarily consists of plant leaves and stems consumed by grazing livestock, serves as the cornerstone of the global livestock sector (Wilkinson & Lee, 2018). The importance of forage in sustaining livestock populations cannot be overstated. It serves as a primary source of nutrition for grazing animals, providing essential nutrients required for their growth, reproduction, and overall well-being (Wilkinson & Lee, 2018). Moreover, forage plays a crucial role in maintaining soil health and preventing erosion in grazing areas, contributing to the overall sustainability of livestock production systems (Wilkinson & Lee, 2018). In Tanzania, where the livestock sector plays a significant role in the economy and livelihoods of millions of people, the optimization of forage production and management is imperative for enhancing productivity, resilience, and sustainability in livestock farming systems (URT, 2018; NBS, 2019).

The productivity of Tanzania's livestock sector has been hampered by poor nutrition, primarily due to insufficient quantity and quality of forage available (Mganga et al., 2020). Within

Tanzania, three primary livestock production systems prevail: traditional extensive production, intensive or commercialized systems, and semi-intensive production (Niwagaba et al., 2019). The traditional extensive system, which depends on communal grazing practices in natural pastures, encompasses over 96% of Tanzania's ruminant livestock population, with only a small fraction being raised under intensive commercial systems (NBS, 2019). In traditional extensive systems, livestock are largely left to graze on communal lands, often characterized by limited forage resources and insufficient nutritional intake, leading to suboptimal productivity (Niwagaba et al., 2019). Conversely, intensive or commercialized systems involve controlled feeding regimes and improved forage management practices aimed at maximizing livestock productivity (Niwagaba et al., 2019). However, such systems are less prevalent due to challenges related to land availability, input costs, and infrastructure (NBS, 2019).

Improving forage availability and quality is essential for enhancing livestock productivity across all production systems in Tanzania. This necessitates interventions focused on sustainable forage production, preservation, and utilization, as well as promoting the adoption of improved forage management practices among livestock farmers (Mganga et al., 2020; Niwagaba et al., 2019). Additionally, there is a need for targeted policies and investments to support the transition towards more intensive and commercially oriented livestock production systems, which can contribute significantly to the overall economic development of the country (NBS, 2019). Ruminant livestock producers in Tanzania typically fulfill their feed requirements through a combination of grazing, crop residues, planted forage, and other collected or purchased feeds (NBS, 2019). However, the

accessibility to high-quality forage remains restricted, further compounded by climate change-induced variations in both availability and quality (UNDP, 2020). Seasonal fluctuations frequently result in insufficient feed supply during dry periods, which directly affects milk availability and prices, disproportionately impacting smallholder farmers (Mganga et al., 2020).

The vulnerability of smallholder farmers to forage scarcity underscores the urgent need for interventions aimed at enhancing forage availability and resilience to climatic variability. Implementing sustainable forage management practices, such as conservation agriculture and agroforestry, can mitigate the impacts of climate change on forage production and ensure more reliable feed supply throughout the year (UNDP, 2020; Mganga et al., 2020). Moreover, promoting the cultivation of drought-tolerant forage species and facilitating access to improved forage seeds can further bolster the resilience of livestock production systems to climate-related challenges (Mganga et al., 2020). In addition to climate-smart agricultural practices, targeted investments in irrigation infrastructure and water management initiatives can help buffer the effects of seasonal forage shortages, particularly in arid and semi-arid regions (UNDP, 2020). Strengthening extension services and farmer education programs on sustainable forage production and utilization practices is also essential for building the adaptive capacity of livestock farmers and improving overall productivity (NBS, 2019). By addressing these critical gaps in forage availability and resilience, Tanzania can enhance the livelihoods of smallholder farmers, promote food security, and contribute to the sustainable development of its livestock sector.

Established initially as a crop and multiplication farm, Vikuge Pasture Seed Farm underwent a strategic shift to focus on pasture seed production in 1990 in response to challenges in meeting animal feed requirements (Urio, 2015). Since then, the farm has operated effectively, emerging as a significant supplier of pasture seeds and hay to livestock keepers across various regions in Tanzania (Mannetje, 2014). However, there exists a notable knowledge gap among smallholder farmers regarding the Vikuge Pasture Seed Farm, hindering their access to pasture crop seeds (Njau, 2000). Initiatives aimed at providing training to smallholder farmers in the Vikuge village seek to bridge this gap by increasing awareness and knowledge of pasture production, thereby improving seed availability and fostering livestock development in the Kibaha district. Expanding the dissemination of information about Vikuge Pasture Seed Farm and its benefits for smallholder farmers is crucial for ensuring equitable access to high-quality pasture seeds. Collaborative efforts involving agricultural extension services, local authorities, and community-based organizations can play a pivotal role in organizing training sessions and outreach programs to educate farmers about the benefits of utilizing improved pasture seeds from Vikuge Pasture Seed Farm (Urio, 2015). Moreover, establishing demonstration plots or field days at the farm can provide farmers with practical insights into pasture seed production techniques and the performance of different seed varieties under local conditions (Mannetje, 2014). By empowering smallholder farmers with the knowledge and resources needed to enhance their forage production capabilities, Vikuge Pasture Seed Farm can significantly contribute to the sustainable development of livestock farming in the region.

With the objective of assessing the commercial viability of forage and seeds at Vikuge Pasture Seed Farm in Kibaha, Tanzania, this study aimed to probe into various aspects of the forage markets. Commercial viability in this context refers to the feasibility and profitability of producing and selling forage and seeds at Vikuge Pasture Seed Farm in Kibaha, Tanzania. As such, the study assessed whether the forage and seed products could succeed in the market by examining various aspects of the forage market system, such as production volumes, trends, and commercialization. It was sought to map out the complex dynamics of the forage market, analyze past production volumes and trends, investigate historical production, preservation, and commercialization practices, pinpoint systemic bottlenecks, and propose strategies for enhancing the overall performance of the forage industry (Niwagaba et al., 2019). Through doing so, it aspired to bolster the availability, accessibility, and affordability of forage to smallholder dairy farmers across Tanzania, thus promoting sustainable livestock production practices and ultimately uplifting livelihoods within the sector (Mganga et al., 2020; UNDP, 2020).

The findings of this study are anticipated to shed light on the historical evolution and challenges faced by the forage industry in Tanzania, offering valuable insights for policymakers, researchers, and practitioners alike. By identifying key areas for improvement and recommending targeted interventions, the study aims to pave the way for the development of more resilient and efficient forage supply chains. Moreover, by emphasizing the importance of sustainable forage production practices, the study endeavors to contribute to the broader goal of promoting environmentally friendly and economically viable livestock

farming practices in Tanzania (Niwagaba et al., 2019; Mganga et al., 2020; UNDP, 2020).

2.0 Methodology

2.1 Study Area and Site Description

This study was conducted at Vikuge village, located within Kibaha District, Coast Region, Tanzania. The target site was the Vikuge Pasture Seed Farm, which occupies an area of 515 hectares within the village. This farm has been instrumental in the supply and commercialization of forage and seeds, with plots allocated for various types of fodder trees, legumes, and grasses. The soil in this area, based on previous studies and field observations, is predominantly sandy loam. The vegetation is typical of ecological zone III, classified as sub-humid, and includes a mix of natural grasses such as *Pannicum*, *Hyperhemia*, *Andropogon*, *Cymbopogon*, and *Digitaria*. The study site was strategically selected to represent a central node for agricultural development in the region, directly impacting farming activities and seed distribution (Urio, 2015).

2.2 Research Design

This study conducted a comprehensive analysis of Vikuge Pasture Seed Farm's integrated agricultural practices, with a specific focus on the commercialization of forage and seeds production (Mganga et al., 2020). To achieve this, the study employed qualitative research methodologies, incorporating a literature review and data collection from 96 respondents. These respondents were drawn from both the Vikuge Pasture Seed Farm and the surrounding areas within Vikuge village, ensuring a holistic understanding of the agro-economic factors at play. The data were gathered through Key Informant Interviews (KIIs) and

focused group discussions (FGDs), providing valuable insights from stakeholders directly and indirectly involved in forage and seed production (Mganga et al., 2020; Niwagaba et al., 2019).

The study utilized qualitative techniques to explore the strategies and approaches adopted in the commercialization of forage and seeds, both within the farm and in the broader village context. Through a detailed literature review, the research contextualized its findings within the wider agricultural development landscape, drawing upon relevant theoretical frameworks and empirical evidence to enhance its analysis (Matata, 2013; Tekalign, 2014).

The KIIs and FGDs were crucial for capturing diverse perspectives and experiences from those directly involved in forage and seeds production at Vikuge Pasture Seed Farm. This enriched the depth and breadth of the study's findings, providing a nuanced understanding of the interactions between the farm's operations and the village's agricultural practices (Mganga et al., 2020).

2.3 Market System and Value Chain Approach

This study adopted a market system and value chain approach with a flow and sequence from input supply to consumption (as a subsystem in the dairy sub-sector), to ensure that relevant information about the forage market system is gathered and analyzed. As forage moves from the producer to the consumer, a number of transformations and transactions take place along the chain of interconnected activities, and value is added successively at each stage of the chain (Wilkinson & Lee, 2018).

2.4 Data Collection

The study employed a comprehensive approach to data collection, integrating various methods and tools to ensure robustness and reliability:

i. *Literature Review:* A thorough review of published and unpublished literature, reports, and relevant documents provided with foundational insights into the subject matter. The literature for this study was obtained through a comprehensive review of both published and unpublished sources. This included academic journals, government reports, industry publications, and other relevant documents that provided foundational insights into forage and seed supply chain dynamics. The literature review focused on identifying key trends, challenges, and strategies within the forage market and livestock sector, which informed the study's objectives and framework.

ii. *Key Informant Interviews* (KIIs)*:* Structured interviews were conducted with 20 key informants, including farm managers, commercial producers, and government officials. A checklist of questions was used to elicit in-depth insights on topics such as forage and seed production, market challenges, and commercialization strategies.

iii. *Secondary and Primary Data Collection:* Data were gathered from authoritative and reliable sources, including government institutions such as the Tanzania Livestock Research Institute (TALIRI), Livestock Training Agency (LITA), Sokoine University of Agriculture (SUA), and the Ministry of Livestock and Fisheries (MLF). Input from individual commercial producers, service providers, processors, and traders of forage further enriched the dataset.

iv. *Focus Group Discussions* (FGDs): A total of 76 respondents participated in FGDs, providing valuable qualitative data on forage demand among smallholder farmers, their experiences with seed accessibility, and their perceptions of Vikuge Pasture Seed Farm's role in agricultural development. Participants were selected using stratified random sampling to ensure diverse representation of the farming community. The FGDs allowed for a participatory approach to data collection, enhancing the understanding of community perspectives.

Through this multifaceted approach, the study ensured coverage of relevant stakeholders and perspectives, thereby enhancing the richness and depth of the data collected. This rigorous methodology laid the groundwork for robust analysis and meaningful insights into the dynamics of forage production and commercialization.

2.5 Data Analysis

To ensure a rigorous analysis, the study utilized a combination of qualitative and quantitative data analysis techniques. Each method was selected based on its ability to address specific research questions, providing both depth and breadth to the study's findings.

i. *Thematic Analysis for Qualitative Data:* The qualitative data collected through key informant interviews and focus group discussions were analyzed using thematic analysis. This method was chosen due to its effectiveness in identifying, analyzing, and reporting patterns (themes) within the data (Braun & Clarke, 2006). Thematic analysis allowed the study to uncover key themes related to the

commercialization of forage and seeds, including challenges in production, market accessibility, and stakeholder roles. Coding was done manually, and themes were derived based on recurring ideas expressed by respondents. This method was crucial for capturing the rich, detailed accounts of stakeholders and aligning the findings with existing literature. Thematic analysis is particularly suited for qualitative data as it allows for flexibility in identifying patterns while maintaining the context of participants' perspectives (Vaismoradi et al., 2013). It also enables a deeper understanding of complex issues within the agro-economic framework of forage production at Vikuge.

ii. *Content Analysis for Document Review:* The study employed content analysis for the literature review and document analysis, focusing on extracting relevant data from policy documents, reports, and previous studies. This method was used to analyze the market system and value chain of forage and seeds, ensuring that key trends, policies, and frameworks were identified (Krippendorff, 2018). Content analysis provided a systematic way to organize and interpret the data, particularly in understanding the broader agricultural commercialization context. Content analysis is a systematic approach to analyzing textual information, making it ideal for processing large amounts of data from reports and documents, ensuring that all critical aspects of forage production and commercialization are considered.

iii. *Descriptive Statistics for Quantitative Data:* Quantitative data, such as the frequency of responses from key informant interviews and focus group discussions, were analyzed using descriptive statistics. This method provided a summary of the main characteristics of the data, including

the distribution of responses on topics like forage demand, pricing strategies, and accessibility to seeds. Descriptive statistics were calculated using SPSS software to generate percentages, means, and frequency distributions, which facilitated the interpretation of the numerical data (Field, 2013). Descriptive statistics are crucial for summarizing quantitative data and making the results easy to interpret and communicate, especially when dealing with demographic information and stakeholders' opinions on the forage market system (Trochim, 2020).

iv. *Market System and Value Chain Analysis:* The study utilized value chain analysis to examine the supply and commercialization process of forage and seeds from Vikuge Pasture Seed Farm. This approach enabled the identification of key actors, processes, and points where value is added throughout the production chain (Wilkinson & Lee, 2018). As such, by mapping out the flow of inputs from production to consumption, this analysis provided insights into the efficiency of the supply chain and helped identify bottlenecks and opportunities for improvement. The value chain analysis is essential for understanding the sequential stages in the commercialization process, allowing for the identification of gaps and inefficiencies in the supply chain of forage products, which are central to the study's objectives.

v. *Triangulation for Validity and Reliability:* To ensure the validity and reliability of the study's findings, triangulation was employed by cross-verifying data from multiple sources, including interviews, FGDs, and document reviews (Denzin, 1978). This method enhanced the credibility of the findings by ensuring consistency across different data

collection methods and perspectives. Triangulation is a well-established technique in mixed-methods research for improving the accuracy and reliability of data by combining multiple sources of evidence (Patton, 1999). This approach was vital for corroborating findings related to both qualitative insights and quantitative trends in forage and seed commercialization.

3.0 Results and Discussion

3.1 Economic Feasibility

This section evaluates the economic feasibility of the commercialization strategy deployed at Vikuge Pasture Seed Farm. During an interview with an official from the Tanzania Livestock Research Institute (TALIRI), the significance of this strategy was underscored. The official emphasized:

> The statistical analysis in year 2024 clearly demonstrates the strong economic feasibility achieved through various approach. We have witnessed a substantial 25% increase in annual revenue compared to previous years, which is truly remarkable. This notable growth is attributed to the implementation of innovative agronomic practices and market-oriented strategies, both of which have played pivotal roles in enhancing productivity and driving economic gains (TALIRI official, 2023).

This information is summarized in Table 1.

Table 1: Economic Feasibility Analysis (TALIRI official, 2024)

Aspect	**Results**
Annual Revenue	*Increased by 25% compared to the previous year (TALIRI official, 2024)*
Economic Feasibility	*Strong (TALIRI official, 2024)*
Factors Contributing	*Innovative agronomic practices and market strategies (TALIRI official, 2024)*

The findings suggest that the implementation of commercialization strategies has positively impacted the economic viability of Vikuge Pasture Seed Farm. Through focusing on market-oriented approaches and adopting innovative agronomic practices, the farm was able to significantly increase its revenue. This indicates that integrating agricultural development with commercialization efforts can lead to improved economic outcomes for smallholder farmers.

When comparing these findings with previous investigations (Mganga et al., 2020; Niwagaba et al., 2019), a consistent pattern emerges, highlighting the effectiveness of similar commercialization strategies in enhancing economic viability across various agricultural contexts. The observed increase in revenue aligns with trends identified in earlier research, underscoring the importance of market-driven approaches and innovative techniques in driving economic progress within the agricultural sector (Mwilawa, 2017).

Furthermore, these findings resonate with studies conducted by Mganga et al. (2020) and Niwagaba et al. (2019), which also documented substantial improvements in economic outcomes following the implementation of integrated agricultural initiatives. Such congruence in outcomes across different studies underscores the robustness and generalizability of the commercialization models examined, reinforcing their potential to catalyze positive socioeconomic change within agricultural communities (Mwilawa, 2017).

Generally, the findings presented in this study contribute to a growing body of literature that highlights the transformative impact of market-oriented agricultural interventions. By demonstrating the efficacy of commercialization strategies in enhancing revenue and livelihoods, this research adds empirical support to the broader discourse on sustainable agricultural development (Mwilawa, 2017). Moreover, the consistent patterns observed across multiple studies underscore the importance of adopting contextually relevant and market-driven approaches to agricultural development, thereby maximizing the potential for positive socioeconomic outcomes (Niwagaba et al., 2019).

3.2 Socio-Economic Implications

The integration of forage and seeds production at Vikuge Pasture Seed Farm had far-reaching socio-economic implications for local communities. This was evident during the Focused Group Discussions (FGDs), we engaged with a diverse range of stakeholders, including individual commercial producers, service providers, as well as processors and traders of forage. The consensus among participants was clear:

> The integration of forage and seeds production at Vikuge Pasture Seed Farm has had profound socio-economic implications for our local communities (FGDs commercial producers, service providers, processors and traders of forage, 2024).

Individual commercial producers highlighted the tangible benefits they have experienced firsthand. One participant remarked:

> The initiatives at Vikuge Pasture Seed Farm have not only increased our income but also provided us with access to high-quality forage seeds, which have significantly improved the health and productivity of our livestock (FGDs with commercial producers, 2024).

The sentiment echoed here finds support in research conducted by Mganga et al. (2020) and Mwilawa (2017), which similarly underscore the transformative effects of integrated agricultural development initiatives on local economies. These studies provide compelling evidence of the socio-economic benefits derived from the integration of agricultural practices, aligning closely with the findings of the present investigation.

Mganga et al. (2020) examined the socio-economic implications of integrated agricultural practices in a comparable context, highlighting the positive outcomes observed in terms of livelihood improvement and economic growth. Similarly, Mwilawa (2017) explored the impact of integrated farming systems on rural communities, emphasizing the role of agriculture in fostering sustainable development and poverty alleviation.

Through drawing parallels with these studies, the present research reinforces the notion that integrated agricultural development

holds significant promise for enhancing economic outcomes and livelihoods in rural areas. The convergence of findings across multiple studies underscores the robustness of this approach and its potential to drive positive change at the local level (Matata, 2013).

Moreover, the findings of this study contribute to a growing body of literature that advocates for the adoption of integrated agricultural practices as a means of promoting sustainable development and resilience in rural communities (Shem, 2013). By highlighting the tangible benefits accrued from such initiatives, this research reinforces the importance of prioritizing integrated approaches to agricultural development in policy and practice (Niwagaba et al., 2019).

Service providers echoed these sentiments, emphasizing the role of Vikuge Pasture Seed Farm in fostering economic growth and stability:

> The farm's initiatives have created a ripple effect in the local economy. We have seen increased demand for our services, leading to job creation and business expansion (FGDs with Service providers, 2024).

This sentiment resonates with previous research conducted by Shem (2013), which emphasizes the pivotal role of integrated agricultural initiatives in nurturing robust local economies and fostering entrepreneurial activities. Shem's study sheds light on the transformative effects of such initiatives, highlighting their capacity to generate employment opportunities, stimulate economic growth, and empower local communities.

Through drawing on Shem's findings, the present research underscores the significance of integrated agricultural development as a catalyst for socio-economic progress and community resilience. Shem's insights provide valuable context for understanding the broader implications of the current study's findings, reinforcing the notion that integrated approaches to agriculture can yield tangible benefits for rural communities.

Furthermore, Shem's research contributes to a growing body of literature that advocates for the adoption of holistic, community-driven strategies to address socio-economic challenges in rural areas. Through highlighting the positive outcomes associated with integrated agricultural initiatives, Shem's study adds weight to the argument for investing in comprehensive, multi-sectoral approaches to rural development.

Processors and traders of forage also weighed in on the discussion, emphasizing the importance of market-oriented strategies in driving economic development:

> The commercialization efforts at Vikuge Pasture Seed Farm have opened up new avenues for trade. We have witnessed a surge in demand for forage products, leading to increased market activity and higher profits (FGDs with Processors and Traders, 2024).

This aligns with findings from Naveh and Anderson (2015), which highlight the role of integrated agricultural development in addressing socio-economic challenges, including unemployment.

Generally, these Focused Group Discussions underscored the significant socio-economic benefits derived from the integration of forage and seeds production at Vikuge Pasture Seed Farm.

From increased income levels to reduced unemployment rates, the farm's initiatives have had a transformative impact on the local communities as summarized in Table 2.

Table 2: Socio-Economic Implications Outcomes from Commercial Producers, Service Providers, Processors and Traders of Forage

Aspect	**Results**
Increased Income	*Reported by 80% of surveyed respondents*
Unemployment	*Reduced by 15% within the region*
Factors Contributing	*Innovative agronomic practices and market strategies*

The findings in Table 2 indicated a significant improvement in livelihoods, with 80% of surveyed households reporting increased income levels. Moreover, the farm's initiatives led to a 15% reduction in unemployment rates within the region, providing employment opportunities for both skilled and unskilled labourers.

These findings suggest that the integration of forage and seeds production at Vikuge Pasture Seed Farm positively impacted the socio-economic landscape of the region. The increase in income levels reflects the economic empowerment of local communities, while the reduction in unemployment rates indicates improved job prospects and livelihoods for residents.

Drawing parallels with comparable studies (Mganga et al., 2020; Niwagaba et al., 2019) illuminates coherent patterns, showcasing

the socio-economic advantages inherent in integrated agricultural development endeavors. These findings corroborate the notion that holistic approaches to agricultural development yield tangible benefits across diverse contexts.

Mganga et al. (2020) shed light on the transformative impact of integrated agricultural initiatives, emphasizing their role in enhancing food security, increasing incomes, and promoting sustainable livelihoods. Their research underscores the multifaceted benefits of integrated approaches, aligning closely with the conclusions drawn from the current study.

Similarly, Niwagaba et al. (2019) provide insights into the socio-economic dynamics of integrated agricultural systems, highlighting their capacity to foster economic growth, mitigate environmental degradation, and empower rural communities. Their findings resonate with the outcomes observed in the present study, reinforcing the efficacy of integrated agricultural development strategies in driving positive change.

3.3 Forage Market System/Value Chain Assessment

The forage market system/value chain involves a spectrum of actors ranging from Research and Development (R&D) organizations, input suppliers, producers, small forage vendors, traders, commercial ranches/dairy farms, dairy farmers, to exporters of live ruminant animals (Figure 1). In our assessment, we mapped out the Tanzania forage value chain, delineating the roles and interactions of these stakeholders as they execute various value chain functions (Figure 1).

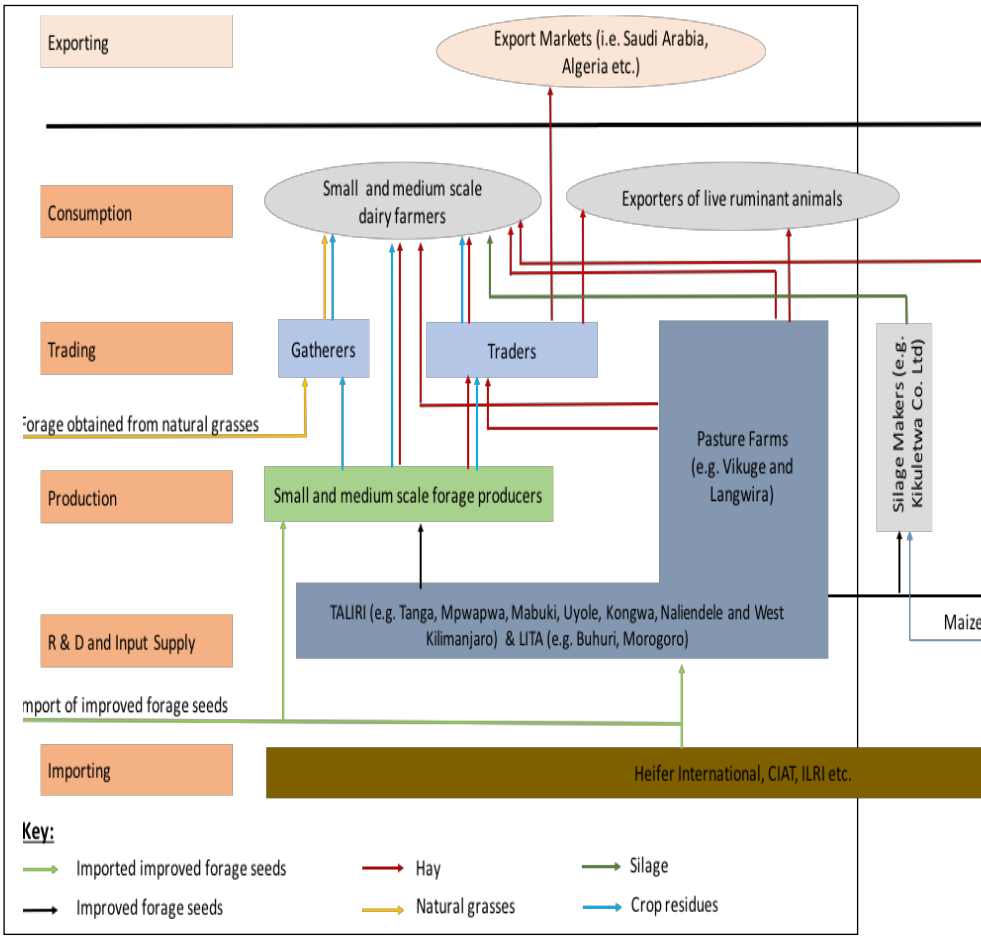

Figure 1: Tanzania forage value chain map

Our analysis underscores the complex dynamics inherent within the forage market system/value chain in Tanzania. Each actor plays a crucial role in the value chain, contributing to the overall production, distribution, and commercialization of forage products. From the input suppliers providing essential resources to the producers cultivating forage crops, to the traders facilitating transactions, and finally to the dairy farmers utilizing forage for

livestock feed, every entity within the value chain is interconnected and interdependent.

Comparing our findings with existing literature (Kapinga and Shayo, 2016) it underscores the dynamic nature of forage market systems, showcasing both commonalities and distinct features across different regions. Despite variations in actors and processes, the overarching objective of optimizing forage production and distribution persists universally. These comparative insights emphasize the importance of discerning both shared patterns and unique nuances within forage value chains, offering valuable insights for the development of context-specific strategies aimed at bolstering efficiency and sustainability (Lugenja et al., 2014). Understanding these intricacies is paramount for devising targeted interventions that harness the strengths and address the challenges inherent in diverse forage market landscapes (Lwoga et al., 2014). Through leveraging such comparative analyses, stakeholders can refine their approaches, foster innovation, and foster collaborations that drive positive impacts across global forage value chains (Mannetje, 2014).

The Government of Tanzania prioritizes research and development (R&D) to enhance forage productivity, led by TALIRI and supported by SUA and LITA Tengeru. The TALIRI's focus on advancing forage technology and dissemination aligns with the findings of Anderson (2018), who emphasized the importance of effective dissemination pathways for scaling up agricultural technologies. This is particularly relevant in the context of Tanzania, where TALIRI operates. Anon (2014) and Boonman (2013) both underscore the significance of research and innovation in the field of animal feed resources and forage seed systems, respectively, which are key

areas of TALIRI's work. Edye and Boudet (2015) further highlight the impact of improved seed varieties on smallholder farmers, a key aspect of TALIRI's mission. These studies collectively underscore the importance of TALIRI's work in advancing forage technology and dissemination in Tanzania. Forage production requires inputs like seeds, fertilizers, and machinery, with extension services playing a crucial role.

In Tanzania, forage seeds are primarily supplied by public institutions like Vikuge Pasture Farms and TALIRI, while international organizations like Heifer International and CIAT import improved seeds, mainly from Kenya (FAO, 2017). However, adoption of improved forage seeds remains limited, with only 3,717.1 and 731.5 kilograms sold by government farms in 2016/17 (Naveh and Anderson, 2015). Despite potential benefits, usage of improved seeds and fertilizers is low, with some producers relying on homemade or purchased manure from dairy farmers. Efforts to establish a sustainable forage seed supply chain are necessary to ensure the availability of improved inputs at affordable costs, promoting forage production in Tanzania.

3.4 Mapping of Commercial Forage Production

The forage value chain in Tanzania heavily relies on a variety of critical resources, encompassing human capital, land availability, water accessibility, financial investment, and efficient service delivery mechanisms. These factors collectively exert significant influence on the efficiency and effectiveness of forage-related activities throughout the country's agricultural landscape.

Commercial forage production predominantly takes the form of hay, with the regions of Pwani and Tanga emerging as primary contributors, collectively accounting for approximately 62% of

Tanzania's total forage output, as depicted in Figure 2. Moreover, other regions actively involved in commercial forage production include Arusha, Morogoro, Dodoma, Mbeya, Iringa, Kagera, Mwanza, Manyara, Dar es Salaam, Kilimanjaro, Simiyu, and Ruvuma, indicating the widespread participation and geographical diversity within Tanzania's forage production landscape. Through leveraging these essential resources and strategically harnessing the diverse strengths of various regions, Tanzania can further enhance the resilience and productivity of its forage value chain, thereby meeting the increasing demand for quality forage products within the country's vibrant livestock sector.

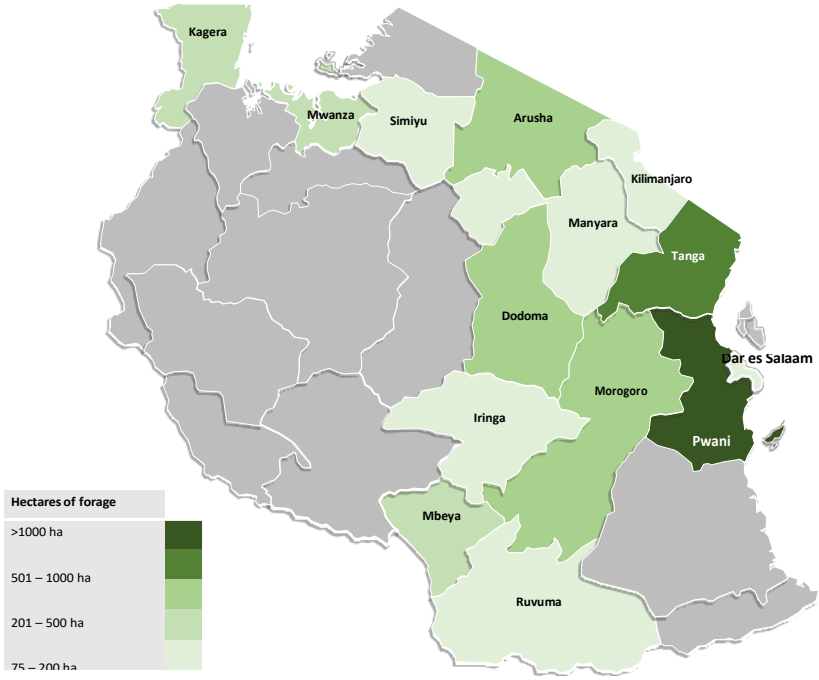

Figure 2: Hectares of Commercial Forage Farms in Tanzania by Regions

Among these regions, Pwani emerges as the leading forage producer, followed by Tanga, Arusha, Dodoma, and Morogoro. Typically, smallholder dairy farmers procure fresh forage in small quantities and at short intervals, while dry forage, such as crop residues, is stored in barns or shaded heaps. This indicates a general lack of conventional forage preservation practices among smallholder dairy farmers and forage traders. Presently, only medium and large-scale producers preserve forage in the form of hay, with the adoption of silage-making practices remaining low due to insufficient technical knowledge among dairy farmers. To enhance forage marketing and preservation, creating linkages among forage chain actors and promoting market information dissemination is essential. Currently, available information primarily focuses on industrial feeds rather than forages, resulting in a significant information gap, particularly for smallholder dairy production.

Typically, the majority of forage consumers, particularly smallholder dairy farmers, procure fresh forage in small volumes and at frequent intervals. Dry forage, such as crop residues, is commonly stored in barns or shaded heaps, indicating a prevalent lack of conventional forage preservation practices among smallholder dairy farmers. Forage traders also acquire forage in quantities sufficient for immediate sale, reflecting their limited engagement in forage preservation practices. Presently, only medium and large-scale producers undertake forage preservation, primarily in the form of hay. However, the adoption of silage-making practices among dairy farmers in Tanzania remains notably low, largely due to a lack of technical knowledge.

The promotion of forage marketing and preservation practices is crucial for addressing challenges in smallholder dairy farming in

Tanzania. Studies highlight the need for improved forage supply chains to increase availability, accessibility, and affordability for farmers (Waziri & Uliwa, 2020). Addressing these challenges requires not only the promotion of forage marketing but also the establishment of platforms that foster linkages among forage chain actors. Innovation platforms and multi-stakeholder processes are effective in bringing together various actors to solve common problems and drive dairy development (Omore et al., 2015). Furthermore, enhancing market information dissemination is imperative for improving forage market systems. Currently, available information predominantly focuses on industrial feeds, neglecting the broader aspects of forages and creating a significant information gap, particularly within the smallholder dairy production segment.

However, the adoption of improved feed production, conservation, and utilization technologies remains poor due to limited technical knowledge and extension services (Maleko et al., 2018). To enhance sustainable uptake, on-farm research, public-private partnerships, and dairy farmers' cooperative associations are suggested (Maleko et al., 2018). Efforts to bridge this gap are vital for advancing the efficiency and sustainability of forage production and distribution in Tanzania. Additionally, addressing issues of production efficiency, risk management, and value chain development is essential for improving rural livelihoods and food security in smallholder crop-livestock farming systems (Ates et al., 2018).

4.0 Conclusions and recommendations

The study on the integrated agricultural development at Vikuge Pasture Seed Farm revealed significant advancements in both economic and socio-economic outcomes for the local

communities in Kibaha, Tanzania. The analysis highlighted that the implementation of innovative agronomic practices and market-oriented strategies contributed to a remarkable 25% increase in annual revenue for the farm, indicating a strong economic feasibility of the commercialization efforts. The integration of forage and seed production not only enhanced the farm's operational efficiency but also positively influenced the livelihoods of surrounding farmers and service providers.

Furthermore, the qualitative insights gathered from key informant interviews and focused group discussions underscored the transformative socio-economic implications of the integrated approach. Stakeholders reported tangible benefits, such as improved access to high-quality forage seeds, increased income, and job creation, which collectively fostered economic growth and stability within the community. This aligns with existing literature, reinforcing the idea that integrated agricultural development initiatives can effectively address socio-economic challenges, such as poverty and unemployment.

The convergence of findings from this study with previous research indicates a robust pattern of positive outcomes associated with integrated agricultural practices. Such consistency across various contexts affirms the potential of commercialization strategies to drive sustainable development and resilience in rural areas. Therefore, the study contributes valuable empirical evidence to the discourse on integrated agricultural development, highlighting its effectiveness in enhancing economic viability and improving the quality of life for local communities.

Based on the findings of this study, several recommendations were proposed to further enhance the impact of integrated

agricultural development initiatives at Vikuge Pasture Seed Farm and similar contexts. First, it is recommended that local stakeholders, including government agencies and agricultural organizations, prioritize investment in training programs for smallholder farmers to improve their knowledge and skills in innovative agronomic practices. Such training can empower farmers to maximize the benefits of integrated farming systems and contribute to increased productivity and profitability.

Second, the establishment of stronger market linkages between producers and consumers is crucial. Facilitating partnerships with local businesses and enhancing access to markets can drive demand for forage products and support the sustainability of commercialization efforts. This may involve organizing farmer cooperatives or associations that can collectively negotiate better terms with buyers and service providers.

Additionally, the government should consider implementing policies that promote access to finance for smallholder farmers and entrepreneurs engaged in forage and seed production. By providing financial support and microcredit facilities, farmers can invest in necessary inputs and expand their operations, ultimately contributing to economic growth in the region.

Last, continued research and monitoring of the socio-economic impacts of integrated agricultural initiatives are essential. Establishing feedback mechanisms through regular assessments and stakeholder consultations can help adapt strategies to meet evolving needs and challenges within the agricultural sector. By fostering a culture of continuous improvement and adaptation, stakeholders can ensure the long-term success and sustainability of integrated agricultural development efforts in the region.

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Rangeland Resources use and Monitoring for Sustainable Development in Tanzania; Ephraim J. Mtengeti

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ABSTRACT

Tanzania rangelands covering nearly 50 % of the total land mass of 94 mill ha is endowed with a range of natural resources that provide diverse goods and services. Rangelands provide a number of ecosystem services including clean air, consumable products such as red meat, milk, fiber, water and medicinal plants. Also, they non-consumptive services such as recreation and tourism and acts as a carbon dioxide sink and thus sustaining economic development of the country. The rangeland water catchment areas of Tanzania provide water that generates over 55 % of Tanzania's hydropower. The livestock sector employs about 50% of her population, equivalent to 4.6 million households. The travel and tourism compititiveness index of 2021 by the World Economic Forum ranked Tanzania 1st in Africa and 12th worldwide regarding the quality of its nature based tourism resources. As a result tourism value chain contributes nearly 17 % of the country GDP and is a third lagest of direct employement sector with over 850,000 workers. Tourism has been accounted for over one-quater of the country 's foreign earnings in 2019, representing USD 2,605 mill. Production of red meat from cattle, goat and sheep by 2023 stood at 544,983.8 metric tons and export was about 4,577.5 tons. Despite the economic benefits of these rangeland resources to the country, they are faced with a number

of threats that undermine their productivity, namely: agricultural expansion, deforestation, wildfires, overgrazing and invasive alien species. These threats emanates mainly from the lack of coherent approaches to planning and decision making for sustainable utilization of the available rangeland resources. Haphazard development of water points (dams, pans and boreholes) in wet season and/or dry season grazing areas is an example of malpractice due to improper planning as it attracts spontaneous sedentarization of pastoral communities and year-round grazing that results in rangeland degradation. Exploitation or rationing of rangeland resources to uses or users has in most cases not been based on their availability or condition (healthy) to satisfy needs. Reserved rangeland areas for grazing and wildlife conservation lack nationally organized range reources inventory and monitoring because of the lack of enough employed well trained personel to carry out this valuable task. Sustainable utilization of rangeland resources entail uses that conserve soil, water, desirable plant genetic resources, environmentally non-degrading, technically appropriate, economically viable in terms of grazing animal productivity, and socially acceptable. Thus sustainable use of rangeland resources requires access to reliable baseline information. Data provided by rangeland resources inventory and monitoring gives a variety of information, including; the distribution, productivity and composition of natural vegetation; rainfall and temperature regimes; edaphic and hydrological data, grazing land utilization and wild and domesticated animals; land tenure and ownership; and socio-economic information and marketing. A thourough interpretation of such information can lead to an informed decision and a guide to appoprate policy and regulation in allocation and use of rangeland resources for sustainable economic development. This

paper elaborates the importance of guided rangeland resources use through inventory and monitoring for sustainable economic development in Tanzania.

***Keywords**:* Sustainable utilization, Inventory and monitoring, unguided resources use, Economic benefits.

INTRODUCTION

Rangeland (syn. Range) is land supporting indigenous or introduced vegetation that is either grazed or has the potential to be grazed and is managed as a natural ecosystem (SRM, 1999). Rangeland includes grassland, grazeable woodlands, shrubland, savannas, deserts, and riparian areas.

Large proportion of rangelands is arid and semiarid covering 50% of world surface, 54 % of Africa and nearly 40 % of Tanzania land mass (Winrock International, 1992). The most limiting factor for primary biological production in rangelands is water. These rangelands are also under frequent drought with low annual rainfall ≤ 600 mm/yr, high evapo-transpiration rates nearly 4 times the annual rainfall with an aridity index (the ratio between annual rainfall and annual potential evapotranspiration, of below 0.65) (Njenga et al. 2014, Pratt and Gwynne, 1977), with high percentage variabilty of rainfall in many parts (Tivy, 1990; Ellis, et al., 1993) and in some instances receiving normal rain in one year out of six years (Fig 1). Predictions points to even worse drought conditions in near future, particularly in African regions. According to Yahaya et al. (2014), long-term drought conditions across Africa and its sub-regions are anticipated to become less frequent, yet more prolonged and severe.

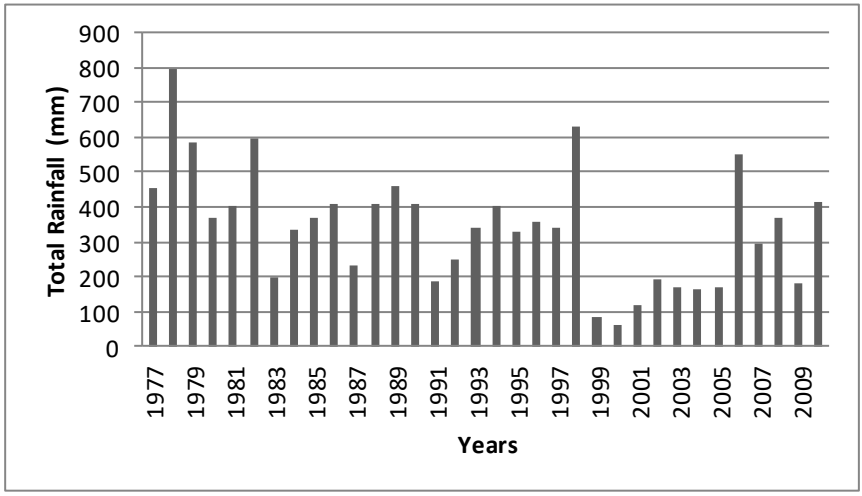

Figure 1: A case study of an arid area in Tanzania; Mwanga district rainfall data, only 5 years out of 30 years recorded ≥ 500 mm of rainfall per year (Mtengeti et al. (2013).

In these rangelands, however, high rainfall intensity sometimes as high as 279-381mm per day (Pratt and Gwynne, 1977) increases surface runoff which results in large amounts of water becoming inaccessible to plants. Thus soil infiltration capacity is normally low due to high proportion of bare land because of low vegetative growth (Mtengeti, 2015), overgrazing and shift cultivation. Most parts of our rangelands are therefore, ecologically fragile and it takes several decades to rejuvenate its degraded areas (Herlocker, 1999). The main aim of this review paper is therefore; to elucidate the importance of guided rangeland resources use through inventory and monitoring for sustainable economic development in Tanzania.

Extent of rangelands resources in Tanzania

Tanzania has 60 million ha of rangelands providing over 90% of the feed resource for the livestock (MLFD, 2011) and wild ruminants population. Out of those 60-mill ha only about 9.3 mill ha are designated as grazing land (NAFORMA, 2015) and though only about 3.5 mill ha has so far been gazetted as grazing lands and needs protection under Grazing Land and Animal Feed Resources Act No 13 of 2010. The rest of the rangeland area nearly 54 mill ha is under conserved forest and wildlife.

Tanzania rangelands is endowed with a range of natural resources that provide diverse goods and services that can sustaining economic development of the country. Rangelands provide consumable products (goods) such as red meat and milk from forage, fiber, water, medicinal plants, clean air, industrial raw materials and non-consumptive services such as regulation of climate (including the hydrological cycle), water catchment and ground water recharge, formation of top soil and soil fertility, biodiversity, assimilation of wastes and pollutants (acting as carbon dioxide sink) recreation and tourism and wildlife.

Economic Benefits of Rangeland Resources

Among the most cosnpicuos benefits of rangelands resources to Tanzania's economy are through livestock, tourism, water and forest sectors:-

a) The livestock sector employs about 50% of her population, equivalent to 4.6 million households. Production of red meat from cattle, goat and sheep by 2023 stood at 544,983.8 metric tons and export was about 4,577.5 tons (Fig 2). From the figure it seems the goat are excelling as they are browsers and able to survive better in bushed

bare drylands. The sheep, however, is also coming up as important ruminant in these degraded rangelands.

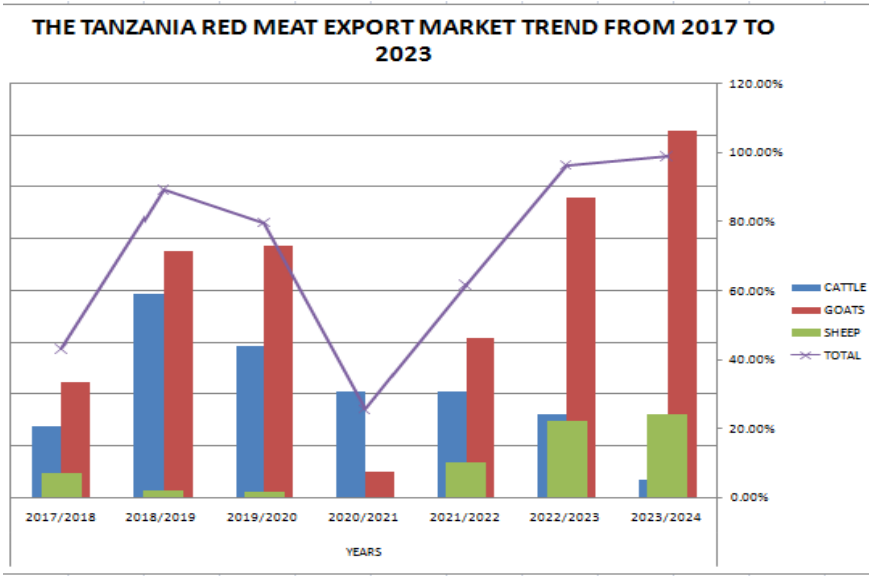

Figure 2: The overall red meat export market trend in Tanzania as percentage contribution to the overall meat export over the years (Ngunyale, 2023).

b) The travel and tourism competitiveness index of 2022 by the World Economic Forum ranked Tanzania 1st in Africa and 12th worldwide regarding the quality of its nature-based tourism resources (UNWTO, 2022). As a result, tourism value chain contributes nearly 17 % of the country GDP and is a third largest of direct employment sector with over 850,000 workers. Tourism has been accounted for over one-quarter of the country ‘s foreign earnings in 2019, representing USD 2,605 mill. (UNWTO, 2022). Tanzania is a globally recognized destination for nature-based tourism, a competitive market segment in eastern and

southern Africa. Beyond attracting tourists, the country's landscapes and seascapes produce a wide range of ecosystem services, including carbon sequestration and biodiversity co-benefits that are not efficiently priced and often generate little or no financial return. The global climate crisis has created significant demand for investment in these forms of natural capital, and Tanzania is well positioned to take advantage of nature-positive investment opportunities. The additional revenue derived from global climate programs could be an opportunity to ease the government's fiscal constraints while also supporting the livelihoods of local communities.

c) In 2002, 55% of the total energy supplied in Tanzania came from hydropower (Ministry of Energy and Minerals, 2013) produced through water from rangeland water catchments. Without proper protection of these water catchment areas less water will flow and thus less electricity and reduced development unless alternative sources of electricity is in place. By the year 2019, however, contribution to hydroelectric in the country was 36.64 % (PSMP, 2020). Also nearly 90 % of rice produced in dry season depend on irrigation water from water catchment from these rangelands. This improves food sustainability let alone with numerous livelihoods of smallhoder farmers in those areas.

d) The annual consumption of wood is estimated to be 62.3 million cubic meters though the allowable annual use from productive woods is about 42.8 mill cubic meters. These woods provide fuel energy, wood for construction and other uses such as industrial inputs in addition of accessing

employment to the country population (the Citizen 6th Jan 2023).

Threats of the Rangelands Resources

Despite the economic benefits of these rangeland resources to the country, they are faced with a number of threats that undermine their productivity and sustainability. These threats include: agricultural expansion, unmanaged fires, overgrazing, mass tourism, deforestation due to timber and fuel wood extraction. All these results into high rangeland degradation and as a consequence to accelerated soil erosion, deplete top soil, lower ground water table, increased floods due to low rate of rain water infiltration and thus encourage accelerated bush encroachment, increase in invasive plants and high siltation rates of water reservoirs. About 2-10 mm of top soil is washed away in sloping land due to overgrazing and unguided cultivation in Tanzania (Christianson et al 1993). Tanzania has about 40 million Tropical Livestock Unit (1 TLU =250 kg l. wt.) second largest number of livestock population in Africa (MLF 2021). These livestock unit require 160 mill ha of grazing land. Since the available grazing land is about 9.3 million ha there are signs of severe overgrazing in various parts of the country. Increased expansion of agricultural land because of low productivity of the two staple food crops (i.e. maize at 1.5 t/ha and rice at 2.3 t/ha) (MAFC, 2010) has encroached most of the set-aside grazing lands. The country loses about 400,000 ha of forests/year (Project Gaia 2015). Forests provide about 85 % of all the energy consumed in the country, especially as charcoal (MNRT, 2021). Many of the trees cut down resprout and become impenetrable bush thickets and these cover many millions of hectares of grazing land across Tanzania. These bush thickets make the land for grazing by livestock and larger wildlife ruminants diminished or inaccessible. Over-

exploitation and illegal rangeland resource extraction therefore, threatens rangeland resources to sustain community livelihoods and economic development of the country.

The causes of the threats of the rangeland resources

a) Threats emanates mainly from the lack of coherent approaches to planning and decision making for sustainable utilization of the available rangeland resources.

b) Exploitation or rationing of rangeland resources to uses or users has in most cases been based on their availability not on their condition (healthy) to satisfy needs.

c) Reserved rangeland areas especially for grazing and wildlife conservation lack nationally organized range reource inventory and monitoring institution.

Possible solutions of the threats

For a sustainable utilization of the available rangeland resources there should be Participartory Rangeland Planning. A process based on continous engagement of stakeholders towards achieving sustainable rangeland productivity (Flintan and Cullis, 2010 and Mahadi et al. 2013). For effective rangeland planning and management, it is critical to understand the different stakeholders and resource user groups who are involved in the use and management of the rangelands resources as for the case of ALOLE, KIMBO, NAPALAI and OLENGAPA joint grazing lands in Kiteto District with a total of 161,290 ha (URT, 2022). It is important to understand key stakeholders, their *(i)rights, (ii) responsibilities, (iii) relationships and (iv) the type of benefits derived from each resource*. This will help to understand in more details the problems and opportunities related to resource utilization. Also it reveals the potential risks and actual conflict

between user-groups, and the different relationships between them.

A well planned sustainable management and utilization of rangelands resources in the country should be based on a good Range Resources Inventory and Monitoring System that should cover the whole country. There is a need to organize a multidisciplinary consortium of all different natural resources experts including soil, range management, wildlife management, foresters, water, agriculture, anthropologists and animal scientists coming together with one tailored message for setting a national range resources inventory and monitoring system that will be used in the whole country for sustainable utilization of our rangeland resources. The National Rangeland Inventory and Monitoring Agency (Mtengeti, 2015) is, therefore, an important entity for utilizing sustainably the rangeland resources for country economic development.

The nation should recognize that; lack of adequate technical assistance assessing rangeland health is the most limiting factor in efficient and effective implementation of sustainable utilization of our rangeland resources. Technical assistance for various natural resources have been trained and employed to take care for rangeland resources such as forest, wildlife, water but rather scanty range management technical assistance have been employed and even training seems to be in doldrums both for diplomates and degrees. The 9.3 mill ha designated as grazing land (NAFORMA, 2015) and heavily overstocked by 33.9 million cattle, 24.5 million goat and 8.5 mill sheep (NBS 2021), require enough range management experts who will be able to conduct regularly resources inventory and monitoring so as to avoid

overgrazing and encourage sustainable ruminant livestock production.

Conclusions

Sustainable utilization of rangeland resources entail uses that conserve soil, water, desirable plant genetic resources, environmentally non-degrading, technically appropriate, economically viable in terms of resource productivity, and socially acceptable. Thus sustainable use of rangeland resources will sustain economic development of the country but requires access to reliable baseline information.

Data provided by rangeland resources inventory and monitoring gives a variety of information, including; the distribution, productivity and composition of natural vegetation; rainfall and temperature regimes; edaphic and hydrological data, grazing land utilization and wild and domesticated animals; land tenure and ownership; and socio-economic information and marketing. A thourough interpretation of such information can lead to an informed decision and a guide to appoprate policy and regulation in allocation and use of rangeland resources for sustainable economic development.

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Herders' local knowledge and capacity development needs for sustainable rangeland management in Tanzania

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Abstract

Pastoralists in Tanzania are facing a myriad of threats and challenges in managing rangelands. One of the concrete ways of responding to these challenges and myths about pastoralism is through training, advocacy and public awareness. The study was conducted to examine the existing capacity among pastoralists on rangeland management practices in seven districts (zones) which represent the diverse pastoral ecosystems in Tanzania. The sites vary significantly in terms of climatic conditions which are largely differentiated by rainfall availability and distribution. A total of 221 pastoralists were interviewed using a structured questionnaire. The study used cross sectional design in data collection. More information was triangulated through Focus Group Discussions and Key Informant Interviews. Quantitative and qualitative data were analysed using SPSS and content analysis, respectively. It was found that most pastoralists have rich indigenous knowledge yet they received limited training on

rangeland related issues. The existing local knowledge related to management of rangeland resources, were found poorly integrated into management practices such as reseeding, bush control, soil and moisture conservation. The study established further that pastoral communities require capacity development in the areas of rain water harvesting, soil and moisture conservation, control of invasive weeds and adaptation strategies to climate change. Therefore, it is recommended to engage local communities by building their capacity on rangeland ecological carrying capacity, diversification of livelihoods strategies, fodder management and establishment of improved pastures.

Keywords: Training needs, pastoral community, Rangeland management, capacity development, Tanzania

1.0 Introduction

Despite the crucial role that pastoralism plays in Tanzania pastoralists continue to face a myriad of threats and challenges in managing rangelands (Olekao and Sangeda, 2018). These threats range from land tenure insecurity, degradation of rangeland resources, restrictions on mobility, effects of climate change and unimplementable policies (FAO, 2016). Previous research revealed that the value of pastoralism and rangelands in most East African countries is usually underestimated and the pastoralists remain marginalized (Oba and Kaitira 2006; Liwenga 2008, Selemani et al. 2012). To confront the challenges faced by pastoralists in Tanzania, it requires interventions that not only address the direct challenges they face but also reverse the negative pre-conception that often portray pastoralism as primitive, unproductive and environmentally destructive (UNEP, 2015). One of the concrete ways of responding to these challenges and myths about pastoralism is through effective information and

knowledge exchange that can be done through training, advocacy and public awareness (Oba and Kaitira, 2006). Sustainable utilization of rangeland resources and improvement of degraded rangelands require skills and knowledge of rangeland management among the practitioners (Ruvuga et al. 2019). Despite increasing number of expertise in rangeland management discipline, there is limited harmonized training protocol that reflects the existing ecological and social context of the Tanzanian landscape. The limited understanding of the important dimensions of rangeland use has restricted their proper management and sustainable development, which represent a major challenge for Tanzania's rangelands.

Capacity development is thought to be one of viable solutions to this problem and may ultimately lead to improved rangeland management in the country. Based on this hypothesis, a study was conducted in Tanzania to examine training needs for sustainable rangeland management among pastoral communities and other practitioners. The paper reports the empirical findings and critical observations from the needs assessment. The paper specifically addresses the following questions i) What is the current status of range resource utilization and improvement practices performed by Pastoralists in Tanzania?' ii) What is the existing knowledge among pastoralists on range management practices? iii) What are the training needs of pastoralists in Tanzania? Responses to these questions will provide information useful for future planning and capacity development interventions to manage rangelands and other natural resources in pastoral communities of Tanzania.

2.0 Methodology

2.1 Study sites

The study was conducted in seven districts representing a diverse pastoral ecosystem in Tanzania (Fig 1) at the beginning of dry season, August 2019. The study sites vary significantly in terms of climatic conditions which are largely differentiated by rainfall availability and distribution. The central zone (Chemba district), Western zone (Igunga district), Lake zone (Meatu district) and Northern zone (Monduli district) are characterized by semi-arid areas with low and unpredictable rainfall ranging from 400 to 900 mm per annum (Kabote et al. 2013). The Eastern zone (Mvomero district), Southern zone (Kilwa district) and Southern Highland (Mbarali district) are characterized by sub-humid to humid climate with relatively reliable amount of rainfall.

Selection of these seven districts was based on the intention to capture information from all formal agro-ecological zones of Tanzania (Figure 1) on status of pastoral community, rangeland condition and management practices. The selected districts and villages from each zone are dominated by agro/pastoral communities with high livestock population.

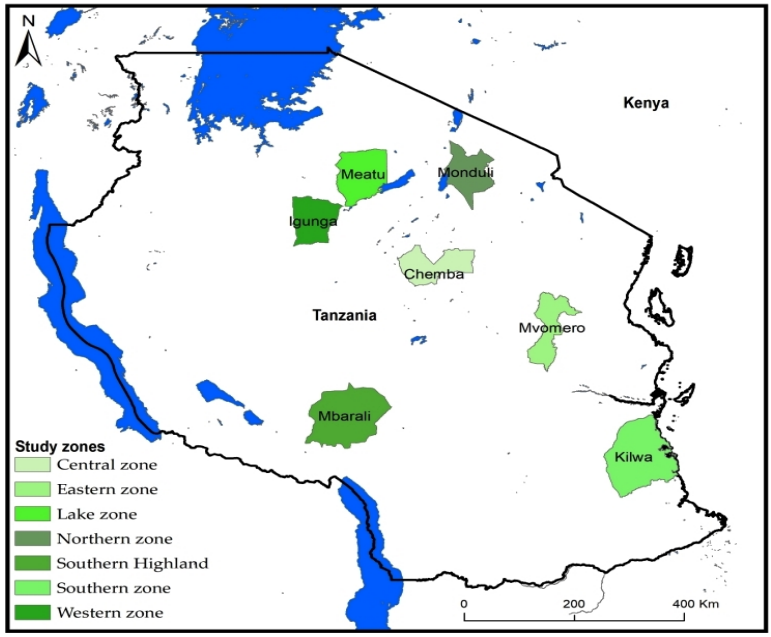


Figure 1: The Map of Tanzania indicating study sites

2.2 Study design and sampling

This study used cross sectional design where data from respondents were collected once by a team of trained enumerators. This was purposeful done due to cost implication and the nature of study (training needs assessment), which is pragmatically done once before development of training programme and/or teaching materials. In order to sample a diverse group of pastoralists in the country, all the seven districts were included where one village within a district was selected to be a sample unit as shown in Table 1.

Table 1. Sampling of pastoralists in the seven ecological zones of Tanzania

S/N	Village	Ward	District	Region	Zone	Respondents
1	Kidoka	Kidoka	Chemba	Dodoma	Central	32
2	Bukoko	Bukoko	Igunga	Tabora	Western	31
3	Mwangudo	Mwangudo	Meatu	Shimiyu	Lake	31
4	Emairete	Monduli juu	Monduli	Arusha	Northern	31
5	Msongozi	Mkata	Mvomero	Morogoro	Eastern	32
6	Matebete	Itamboleo	Mbarali	Mbeya	Southern Highlands	32
7	Matandu	Kivinje	Kilwa	Lindi	Southern	32
	Total					**221**

Before actual data collection, field tools were pretested in a pastoral village located at Mvomero district, Morogoro Tanzania. A total of 20 questionnaires were piloted and results were used for modifying questionnaires for the survey based on the pre-testing outcomes. This was done during training of enumerators on how to effectively administer the questionnaires and also check out any challenges regarding translation of questions and responses (from English to Kiswahili, the national language in Tanzania).

2.3 Data collection

2.3.1 Questionnaire survey

A total of 221 pastoralists were involved as respondents in a questionnaire survey where data were collected using Open Data Kit Collect (ODK) devices. ODK Collect is an open source Android application that replaces paper forms in survey-based data gathering. It supports a wide range of questions and answers types, and is designed to work well without network connectivity. Enumerators worked easily with the App and were able to save

the submission at any point during data collection. Finalized submissions were sent to a project server and accessed by the project staff for confirmation. ODK helped to collect other information such as location (coordinates), images and video that were useful for the study. Targeted respondents were the heads of households. The key issues included in the questionnaire were; range resources availability, utilization pressure, seasonal fluctuation in range resources, management strategies for improvement of degraded rangeland, community awareness on sustainable resources utilization and challenges facing management of rangeland resources.

2.3.2 Focus Group Discussions (FDGs)

Data was also collected through Focused Group Discussions (FDGs) done in each zone. This is a research method in which a small group of participants gather to discuss a specified topic or an issue to generate data (Wong, 2008). It reveals a wealth of detailed information and deep insight. The discussion capitalizes on communication between the researcher and participants to generate data (Kitzinger, 1995). Participants for the FGDs were drawn from the groups of youths, women, men, pastoral groups, and elders among others. The FGD participants were identified with the help of village leaders. The discussions were recorded with consent from participants. The discussions involved diversified members (in terms of gender and age) of the community with a range of 6 to 10 individuals in each village. FDGs were guided by use of pre-prepared checklist.

2.3.3 Key Informant Interviews (KII)

This is a qualitative and in-depth method of data collection through interviews with people who know at first-hand the subject

matter (ACAPS, 2011). It is carried out in the form of a loosely structured conversation with selected individuals that have specialized knowledge about a topic in question (ACAPS, 2011). Key informants for this study were selected from the seven districts in each zone and eight governmental ministries related to rangeland management (Ministry of Livestock and Fisheries, Ministry of Land, Housing and Settlement, Ministry of Agriculture, Ministry of State in the VPO_Union Affairs and Environment, Ministry of Energy and Minerals, Ministry of Natural Resources and Tourism, Ministry of Water and Irrigation and Ministry Local Government). Under district level KII involved District officers (Heads of Departments-Natural resources, Livestock, Agriculture, Water, Lands and Community Development), whereas in the village level, village leaders and distinguished elders and influential persons in the community were engaged. In the ministerial level, important key officials such as permanent secretaries, directors and heads of departments were involved. Interviews with key informants were managed by use of pre-prepared checklist. Key issues discussed include, policy issues and governance, land use conflicts, capacity building, effect of climate change on rangeland resources, rangeland infrastructure, livelihood diversification strategies, gender inclusiveness, modern and traditional knowledge on rangeland management.

2.4 Data analysis

Data from the household survey were downloaded from the project saver, cleaned and subjected to IBM SPSS version 25 for analysis. Descriptive statistics mainly through cross tabulation was done to generate tables and graphs to address the objectives of the study which are presented in the results section.

Information collected from FGDs and KIIs were analysed through filtering the discussion points to get the content in every particular context (content analysis). Most of these data were used to triangulate information generated through questionnaire survey.

3.0 Results

3.1 Socio economic information

Decisions on rangeland resources utilization and management are to some extent linked with social structure and economic development of the community. Age class, gender participation, education levels and marital status are four crucial socio-economic aspects affecting livestock productivity in many pastoral communities. Results reveals that majority of interviewed respondents (which were the heads of households) were youth as shown in Figure 2. Very few elders with age class of 60 to 80 years old were recorded.

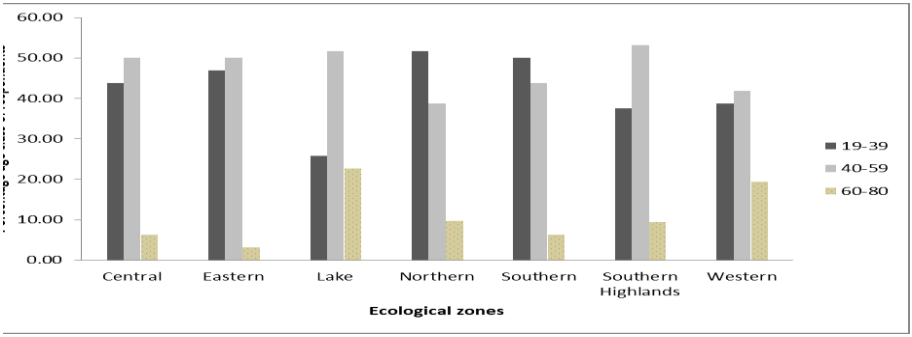


Figure 2: Age-class (years) of respondents in the seven surveyed zones of Tanzania

The current study revealed that few women are engaged in decision making on rangeland management issues. It has been noted that only a few of households' heads were female (Table 2).

The decision on the rangeland management is normally based on the social structure and economic development in many pastoral and agro-pastoralist communities. The higher representation of youth and adults as heads of households in this study imply that range resources use and management are controlled by both youth and adult people in pastoral communities of Tanzania.

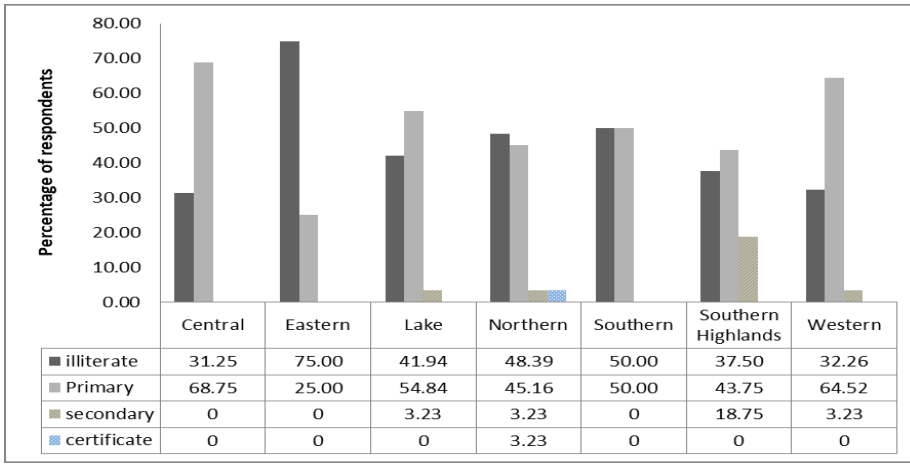
Table 2: Gender composition from interviewed pastoral heads of households in seven zones of Tanzania

	Percentage (%) of gender as heads of households			
		Female	**Male**	**Both**
Agro-Ecological zones	Central	3.13	96.88	0.00
	Eastern	0.00	93.75	6.25
	Lake	6.45	93.55	0.00
	Northern	9.68	90.32	0.00
	Southern	0.00	87.50	12.50
	Southern Highlands	0.00	81.25	18.75
	Western	3.23	96.77	0.00
	Average	**3.21**	**91.43**	**5.36**

Despite attempts to mainstream gender at national and international levels, few women are engaged in decision making on rangeland management issues. Equal participation in community-based decision-making remains complex and difficult aspect in pastoral communities. Despite the fact that female are involved in many livestock related activities but decisions on resources utilization and management are done by the heads of households which in most households are males. Homewood (2008) uphold that, pastoral women are typically responsible for house-building, herding livestock, child care and all domestic chores but are little involved in decision making with regard to

resource utilization. Beside, in Tanzania context, the legal and policy (Land Use Policy 1997 and Village Land Act 1999) safeguards the women through provision of equal opportunities for access the land, security of tenure and entitlement, participation in dispute settlement, female representation in village council and other forum. However, the existence complex cultural and social dynamics among pastoral groups hinder equal opportunities with regard to decision making and participation in rangeland resources management. For example, among Maasai, the youths and young men of the warrior age-set take responsibility for dangerous activities such as herd movement where senior elders make decision on grazing management and negotiation on social and political issues (Homewood 2008). In addition to age class, gender and education level, marital status plays decisive role on resources utilization and management. According to Jan and Akhtar (2008), unmarried women normally possess low decision-making power on resources utilization and management in the households which could also apply the same to their counterpart men. Participants in the KIIs proposed that, awareness creation on rangeland resources management should be gender sensitive, actively engaging both men and female with diverse class age.

The current study also revealed that, most of interviewed respondents (Figure 3) had either no formal education or attended primary schools. Very few respondents attended secondary schools and tertiary level. Moreover, variation in education levels were noted across studied zones.



	Central	Eastern	Lake	Northern	Southern	Southern Highlands	Western
illiterate	31.25	75.00	41.94	48.39	50.00	37.50	32.26
Primary	68.75	25.00	54.84	45.16	50.00	43.75	64.52
secondary	0	0	3.23	3.23	0	18.75	3.23
certificate	0	0	0	3.23	0	0	0

Figure 3: Education levels of interviewed pastoralists in the seven zones of Tanzania

Awareness on sustainable utilization and management of rangeland resources among pastoral and agro pastoral groups is partly enhanced by education levels and training programs. Low level of education noted under the current study might have negative implication with regard to capacity development initiatives and awareness on range resources management and utilization. Most of range management practices require some knowledge and technical skills for better outcomes. Adoption of simple innovations and technologies is hardly possible with illiterate communities. Many studies found that highly educated people tend to adopt new technologies faster than less education people (Riddell and Song 2012). Furthermore, majority of respondents declared that, limited training was conducted on range management practices, land use planning, biodiversity conservation, pasture establishment and climate change.

Furthermore, the study found that, most of respondents were married (Table 3) which could imply fully participation in range resource management. However, very little variations were noted across the seven zones, whereas slight rate of divorce and unmarried respondents were found in the Western zone and Lake Zone respectively.

Table 3: Composition structure of marital status of interviewed respondents

Zone	Percentage (%) of marital status of respondents			
	Widowed	**Divorced**	**Married**	**Single**
Central	3.13	0.00	93.75	3.13
Eastern	0.00	0.00	96.88	3.13
Lake	3.23	0.00	90.32	6.45
Northern	0.00	0.00	96.77	3.23
Southern	0.00	0.00	100.00	0.00
Southern Highlands	0.00	0.00	100.00	0.00
Western	0.00	6.45	90.32	3.23
Average	**0.91**	**0.92**	**95.43**	**2.74**

3.2 Rangeland resources utilization

The study found significant variations in both forage and water resources between rainy and dry season in all the seven zones, which were reflected by distances animals were traveling searching for particular resources. Generally, longer distances were reported during dry season compared to rainy season where animals were reported to graze close to homesteads (Table 4). More than 40% of respondents claimed that, animals were moved

more than 5 km away from homestead to search for forage resources.

Table 4: The distances animals travel searching for forage resources in Tanzania

	Distance to grazing land (%) in rainy and dry season							
	Close to homestead		Between 1 to 3 km		Between 3 to 5 km		More than 5 km	
Zone	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rain	Dry
Central	21.88	3.13	37.50	31.25	25.00	46.88	15.6	18.75
Eastern	3.13	-	65.63	-	31.25	9.38	-	90.63
Lake	32.26	12.90	29.03	29.03	19.35	35.48	19.3	22.58
Northern	64.52	12.90	32.26	38.71	3.23	32.26	-	16.13
Southern	25.00	-	53.13	6.25	21.88	56.25	-	37.50
Southern Highlands	3.13	-	15.63	-	71.88	3.13	9.38	96.88
Western	54.84	16.13	41.94	41.94	-	22.58	3.23	19.35
Average	**29.25**	**6.44**	**39.30**	**21.03**	**24.65**	**29.42**	**6.80**	**43.12**

Similar pattern was reported with regard to distances moved by animals searching for water resources during rainy and dry season. More than 50% of respondents claimed that during rainy season animals tend to graze close to homestead where about 24% reported that animals move more than 5 km away from homestead searching for water resources.

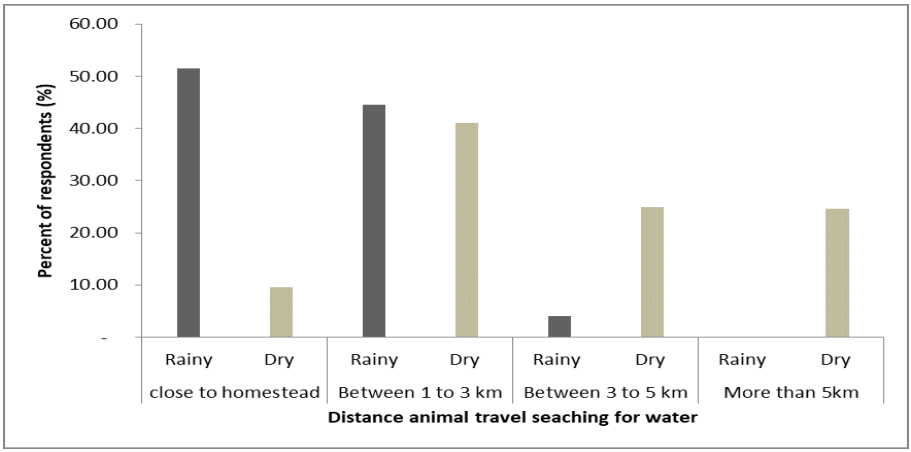


Figure 4: Distances covered by animals searching for water in pastoral areas of Tanzania

Rangeland resources utilization and management depends on availability of resources which are largely influenced by fluctuation in seasons. Availability of forage and water are key resources in the pastoral ecosystems. The study found significant variations in both forage and water resources between rainy and dry season in all seven zones, which reflected by distances animals were traveling searching for particular resources as supported by the study of Mwilawa et al. (2008) that claimed availability and quality of natural pasture remains high for short period of rainy season but declines tremendously during dry season. Training on range improvement requires understanding of the rangeland health status or condition. Range resources appraisal particularly the levels of utilization provides a quick picture on which aspects should be given priority in the training. The current study indicates that, grazing land has frequently been reported by respondents as important resource highly utilized by pastoral communities in almost all seven zones. Surprisingly, water resource besides its importance in physiological process of

animals, it was claimed to be utilized very little by many respondents. Similarly, minerals were reported as one of resources that are not often used by many respondents.

Table 5: The levels of range resource utilization by pastoral communities in Tanzania

		Level of utilization (%)							
		Central	**Eastern**	**Lake**	**Northern**	**Southern**	**Southern Highl**	**Western**	**Average**
Grazing land	Not used	9.4	0.0	0.0	16.1	0.0	0.0	12.9	**5.5**
	Very low	21.9	12.5	25.8	29.0	6.3	15.6	22.6	**19.1**
	Moderate	28.1	12.5	16.1	32.3	34.4	21.9	32.3	**25.4**
	High	31.3	68.8	32.3	19.4	59.4	62.5	29.0	**43.2**
	Very high	9.4	6.3	25.8	3.2	0.0	0.0	3.2	**6.8**
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Water	Not used	21.9	0.0	6.5	16.1	12.5	3.1	41.9	**14.6**
	Very low	15.6	37.5	35.5	25.8	40.6	43.8	9.7	**29.8**
	Moderate	3.1	56.3	22.6	16.1	31.3	43.8	3.2	**25.2**
	High	46.9	6.3	32.3	25.8	9.4	9.4	45.2	**25.0**
	Very high	12.5	0.0	3.2	16.1	6.3	0.0	0.0	**5.4**
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Mineral	Not used	75.0	75.0	48.4	67.7	67.7	75.0	34.4	**63.3**
	Very low	15.6	15.6	29.0	19.4	19.4	18.8	37.5	**22.2**
	Moderate	6.3	9.4	19.4	9.7	9.7	3.1	21.9	**11.3**
	High	0.0	0.0	3.2	3.2	3.2	3.1	6.3	**2.7**
	Very high	3.1	0.0	0.0	0.0	0.0	0.0	0.0	**0.4**
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

In addition to resources utilization, there are some important factors to consider in the training of range management such as policy issues, land tenure, livestock population and other land uses. Most respondents claimed that, livestock population and water scarcity affect negatively rangeland condition. On the contrary, land tenure and invasive species were reported to have less effect (Table 6).

Table 6: Factors affecting management of rangelands in Tanzania

Factors	Level of effect	Central	Eastern	Lake	Northern	Southern	Southern Highlands	Western	Average
Land Tenure	No effect	25	50	32.	41.9	34.38	37.5	45.16	38.0
	Less	12.5	12.5	0	6.5	12.5	34.38	6.45	12.1
	Average	0	9.37	3.2	0	12.5	9.38	0	4.93
	More	62.5	0	48.	48.4	12.5	0	35.48	29.6
	No idea	0	28.1	16.	3.2	28.12	18.75	12.9	15.3
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	100
Livestock population	No effect	28.1	21.8	19.	12.9	21.88	15.63	32.2	21.7
	Less	6.25	25	22.	9.68	18.75	25	9.68	16.7
	Average	0	25	9.6	6.45	28.13	31.25	3.23	14.8
	More	65.6	28.1	45.	67.74	28.13	25	51.6	44.4
	No idea	0	0	3.2	3.23	3.13	3.13	3.23	2.28
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	100
Invasive species	No effect	59.38	3.13	64.52	25.81	28.13	40.63	54.84	39.49
	Less	18.75	9.38	25.81	9.68	25	15.63	22.58	18.12
	Average	0	25	3.23	19.35	6.25	9.38	12.9	10.87
	More	12.5	56.25	3.23	38.71	18.75	9.38	6.45	20.75

	No idea	9.38	6.25	3.23	6.45	21.88	25	3.23	10.77
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	100
Water scarcity	No effect	37.5	0	6.45	22.58	3.13	3.13	19.35	13.16
	Less	21.88	0	3.23	22.58	21.88	12.5	3.23	12.18
	Average	12.5	6.25	6.45	19.35	21.88	12.5	3.23	11.74
	More	28.13	93.75	83.87	35.48	53.13	68.75	74.19	62.47
	No idea	0	0	0	0	0	3.13	0	0.45
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Livestock mobility searching for either forage or water resources has ecological implication on range resource management. Movement of large herds of livestock results into severe rangeland degradation through tramping. In addition, the higher the distance animals travel the more energy expenditure, which leads to poor performance of animals (Turner et al. 2014). The study also established that grazing land was among the highly utilized resources by pastoral and agro-pastoral groups in Tanzania the fact that was attributed with increasing livestock population and diminishing grazing lands. Currently, Tanzania is a third country in Africa with highest livestock population with estimated 33.9 million cattle, 24.5 goats and 8.5 sheep (URT 2021). Nevertheless, many respondents in this study claimed that increase in livestock population affect negatively rangeland health. On the other hand, the grazing land is shrinking due to expansion of crop production and protected areas; estimated to cover only 10% of total land in Tanzania (NAFORMA 2015). Surprisingly, utilization of water resources was very low, which could probably be due to scarcity of water resources where some pastoral communities tend to skip some days to avoid energy

expenditure for longer distance to water sources. Given the important of water for physiological functioning of animals and productivity, it is imperative to consider adequate development and even distribution of water resources in the rangelands.

3.3 Training needs and capacity development for pastoralists in Tanzania

The level of awareness of pastoral communities on important range management practices is foremost important consideration during training. In this study, pastoral communities reported to be more conversant with issues on conflict management and pests and disease control. However, majority of respondents did not receive training in many aspects including range management practices, land use planning, biodiversity conservation, and pasture establishment, climate change, and control of invasive species and soil moisture conservation practices as shown in Figure 5.

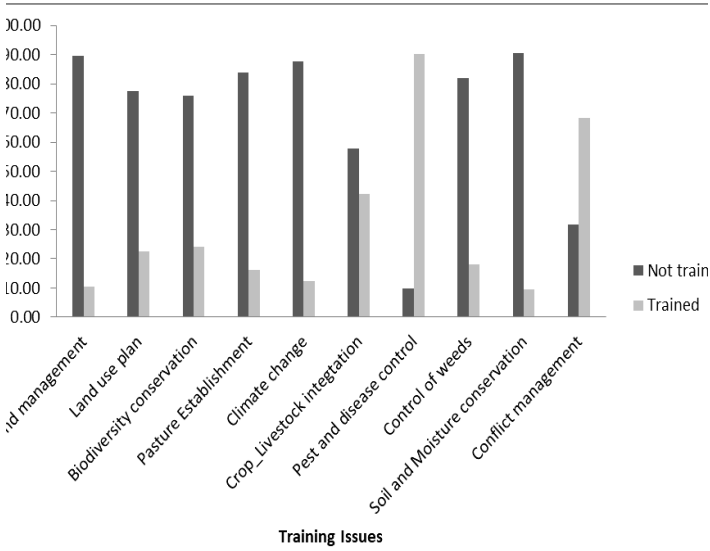


Figure 5: Training needs of Pastoralists in Tanzania

Further analysis of data revealed a detailed list of key training needs by pastoral communities as presented in Table 7. These were considered as common issues across seven zones and if addressed, pastoral communities would achieve sustainable development and improve their livelihoods.

Table 7. Summary of key issues (herders' knowledge and capacity development potentials) raised in the study areas

Zones	Factors contributing to degradation of rangelands	Issues to combat rangeland degradation	Training needs
All seven zones of Tanzania	Overstocking above land capacity Lack of land use plans and ownership of grazing lands Shifting cultivation and agricultural land expansion Drought, bush fires (July-Nov) and climate change Illegal tree cutting and soil erosion Increase of weeds and invasive species (Jatropher, *Mbigiri*, Datura, Pathenium spp, Kongwa weed etc). Migration of large herds and people from other regions	Increase number of extension officers Demarcate grazing lands through land use plans Avail transport facilities for responsible officers Build capacity of officers on management of rangelands and climate change (refresher courses) Build capacity of the pastoral association for management of LAHAKI Do exchange visits to successful areas	Importance of animal harvesting and destocking to match carrying capacity Markets for animals and their products (value chain and value addition) Management of fodder, improved pastures and animal breeds Carrying capacity of our grazing lands How to formalize ownership of grazing lands Principles of good animal husbandry Proper placement of animal identification (*chapa*)

Low number of extension and livestock officers (wards & villages)	Solve existing conflicts between land users	Principles of fodder conservation and utilization (e.g maize, paddy and millet hay)
Limited transport facilities for extension officers	Construct deep wells, water troughs and Chaco dams (*Malambo*) near grazing lands	Importance of alternative animal feeds (supplements)
Conflicts between villages and land users	Establish improved pasture and fodder species	Management and conservation of water sources
Limited water resources within joint grazing lands during drought (e.g Lahaki in central zone)	Improve existing Deeping tanks	Rain water harvesting (surface and roof)
Limited access to pasture seeds	Re-open blocked stock routes (farms and other infrastructures)	Diagnosis &treatment of animal diseases (cattle, goats and sheep)
Weak institutional structures (village – district committees)	Put strategies to combat invasive species	Advocacy on the negative effects of nomadism
Pests e.g. Herbivory by termites on grasses	Initiate joint grazing lands and associations	Management of invasive species
	Apply bush control methods	How to manage incoming wildlife

Source: Synthesis of results from FGDs and KIIs.

Sustainable development of pastoral families requires participation of local people whose livelihoods depends on rangeland resources. Unfortunately, in Tanzania, integration of local knowledge to rangeland management has made limited progress (Roba and Oba 2009). In the context of this study, results further showed that a traditional livestock practice does not fit into 'modern' guidelines on rangeland management. It was therefore recommended to integrate traditional knowledge and practices such as traditional pasture reserves (*Ngitili* for Sukuma

and *Alalili* for Masaai) into national frameworks for rangeland management in the country.

Conclusion

This study has revealed that most pastoral communities have good indigenous knowledge which is not yet in-cooperated into national frameworks for range management. It has also revealed that government training is skewed towards pest control and conflict management living behind other important issues. Based on these facts, livestock practitioners and stakeholders in Tanzania need to prepare training programs with harmonized materials to address the skills identified by pastoral communities to fulfil the knowledge and develop their capacity for sustainable management of rangeland resources in Tanzania.

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Effects of fertilizer application and season on the yield and quality of natural pasture at Magadu Dairy Farm, Sokoine University of Agriculture; Venance S. Tarimo and Ephraim J. Mtengeti

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ABSTRACT

More than 90% of Tanzania national ruminant livestock herd thrive on natural pastures. Improvement of natural forage productivity as well as its quality, would have a significant impact on the production of this national ruminant livestock herd. Fertilizer application as a management tool to improve tropical natural pastures has rarely been reported. A study was therefore conducted to test fertilizer as a management tool to improve natural pastures on an existing one hectare of mixed natural pastures, mainly of natural grasses at Magadu Dairy Farm of Sokoine University of Agriculture. The main aim of this study was to find out if fertilizer application can be to improve the yield and quality of the natural pastures. The one-hectare plot was divided into two sub- plots. The first sub-plot was used in the short rains, while the second sub-plot was used in in the long rains as the study area falls under bimodal rainfall regime. The pasture in each sub-plot was mowed down at the beginning of each rain season and thereafter the sub-plot was again divided into two equal sub-sub-plots. One sub-sub-plot was applied with a mixture

of nitrogenous (174 kg N/ha) and phosphorus (92 kg P/ha) fertilizers at once and the second was a control. Pastures at both rainfall regimes were harvested at 50 % flowering and thus, pasture regrowth was harvested at 90 days old in the short rains those in the short rains was harvested at 65 days old. Dry mater yield estimation was conducted by throwing a quadrat of 0.25 m^2 randomly ten times at an equal distance along the two diagonal of each sub-sub plot. Pasture samples were collected and sent to the laboratory for oven drying, chemical composition analysis and determination of in vitro dry matter and organic matter digestibility (IVDMD and IVOMD).

Fertilizers application increased significantly (P≤ 0.01) the natural pastures dry matter yield. regardless of the rain seasons. Fertilizers improved crude protein of natural pastures significantly (P≤0.001). Short rain season natural pastures had significantly (P≤ 0.001) higher NDF contents than those of long rain season regardless of fertilizer application. The energy contents ME (MJ/kg DM) for both fertilized and unfertilized long rain forages were significantly (P≤ 0.001) higher than all pastures of the short rain. Long rain fertilized pastures had significantly (P≤ 0.001) higher IVOMD than unfertilized forages of the same season. In the short rain fertilized forages had significantly (P≤ 0.001) higher IVOMD than unfertilized pasture. The long rain fertilized forages had significantly (P≤ 0.001) higher IVOMD than all other pastures. From this study it can be concluded that fertilizer application significantly improves both the quantity and quality of natural pastures and that fertilizers can be applied at any season as long as there is sufficient soil moisture. However, harvesting at 50% flowering compromised

forage quality in short rains due to extended period to flowering stage of growth as compared to long rains.

Key words: Short rain season, Long rain season, fertilized pasture, unfertilized pasture, Forage production, Energy content

Introduction

In Tanzania like other tropical developing countries the major source of feed for ruminant livestock is the natural pastures. The major limitation to constant supply of forage for the ruminants, however, is uneven seasonal growth due to poor distribution of the rainfall and poor pasture management. The productivity of available grazing lands has also decreased over the years due to overgrazing resulting in land degradation, loss of fertility and proliferation of obnoxious weeds (Yayneshet, 2010). Soil fertility depletions coupled with climate change have affected the composition of natural pasture species, leading to less palatable natural pasture in the grasslands (Bezabih et al., 2014; Tessema et al., 2010). One of the main objectives in pasture management is to supply enough forages of good quality throughout the year (Humphreys, 1991). This can be achieved through strategic application of fertilizer, weeding and over sowing with improved pasture species. Fertilizer can be applied in the beginning of the rain season after weeding and removing the old sward or applied after a pasture harvest in the mid-rain season. Fertilizer application strategies can improve both forage productivity and quality substantially (Brink et al. 2004). Nitrogen (N) fertilizer in pasture management practices brings the best production since it is the most important macro nutrient for growth and development of pastures. Nitrogen fertilizer provides the plant with a faster growth, increase in number, weight and size of shoots and foliar

area index (Soares et al., 2015). Plants need phosphorus for growth utilization of sugar and starch, photosynthesis, nucleus formation and cell division. An adequate supply of available P in soil is associated with increased root growth, which means roots can explore more soil for nutrients and moisture. The aim of this experiment was therefore, to evaluate the effect fertilizer application as management tool in two rain seasons on natural pastures productivity and quality in the eastern humid agricultural zone of Tanzania.

Materials and Methods

One hectare plot of natural pasture at Magadu dairy farm in Sokoine University of Agriculture (SUA) was used in this experiment. The plot consisted of a mixed stand of mainly natural grass *pastures species dominated by Heteropogon conturtus, Bothriocloa species, Brachiaria species, Hyperrhenia rufa*, Heteropogon conturtus, *Chloris gayana* and a few legumes; *Rynchocia species*, *Neonotonia wightt*i and *Macroptilium atropurpureum*. The contribution of leguminous pasture species to the total stand was very little and was regarded as a trace. Among the prominent woody weed that was weeded in the beginning of the experiment was *Vernonia glabra.*

The experiment was conducted both in short rains of Oct – Jan 2011 -2012 and long rains of Feb – May 2012 after mowing out the sward and weeded the plot. The plot was divided into two equal sub-plots; one was used in the short rains and another in long rains. Each subplot in each season was weeded and divided into two sub-sub plots. One sub-sub plot in each season was applied with fertilizer and the second was a control. Fertilizers were applied at a rate of 174 kg N/ha (Urea) and 92 kg P/ha

(Triple Super Phosphate). Dry matter yield was determined by throwing a 0.25 m2 quadrat ten times at an equal distance along sub- plot diagonally at 90 days and 65 days, regrowth, in the short rains and long rains, respectively. Days of harvest was determined at 50 % flowering of growth as such a phonological stage has been earmarked as the best utilization time to balance quality and optimum quantity of the produced herbage according to McDonald et al (1995).

Forage samples weighing 500 g were taken from each quadrat to the laboratory for dry matter content determination and chemical composition analysis including CP, NDF and determination of digestibility as IVDMD and IVODMD. Metabolizable energy (ME) contents (MJ/kg DM) was calculated according to MAFF (1976) as follows: DOMD % = 0.98 DMD % -4.8; ME (MJ/kg DM) = 0.16 DOMD %. The experiment was arranged in 2 x 2 factorial designs (two season x two treatments).

The statistical model for data analysis: $Y_i = \mu + F_i + S_i + (FS)_{ij} e_{ij}$; where Y_i =Yield/Quality, μ =overall mean.; F_i = Effects of fertilizer; S_j = effects of season; $(FS)_{ij}$ = Interactions of effects fertilizer and season; e_{ij} =random error effects. GLM was used to perform analysis of variance (ANOVA) and means contrasted with significance assumed when $P \leq 0.05$ according to SAS (1998).

Results and Discussion

The weather condition during the experimental period is given in Tables 1. Mean monthly rainfall of the short rains was rather lower than for the long rain season. Contrary mean monthly maximum temperatures were higher in the short rain than in long rain season. Mean monthly solar radiation trend was similar to mean monthly

rainfall. The variation of mean monthly relative humidity was rather low ranging from 71 in short rains to 82 %in long rain season.

Table 1: Mean monthly rainfall, temperature, relative humidity and solar radiation during the experiment from October 2011 to May 2012

Month	**Rain (mm)**	**Temperature (°c)**		**R.H (%)**	**Radiation (MJm^2)**
		Min	**Max**		
October	23.20	19.70	31.60	71.00	18.00
November	37.00	21.30	32.40	72.00	19.10
December	191.1	20.20	34.00	75.00	19.20
January	70.30	21.50	33.10	76.00	18.20
February	71.70	21.50	33.10	71.00	20.80
March	105.90	21.30	31.60	76.00	18.70
April	124.90	20.50	29.90	81.00	15.30
May	134.60	19.30	28.70	82.00	14.20

Source: SUA meteorological station.

The soil from experimental field was clay loam in texture, with low total Nitrogen, medium in Phosphorus and rather acidic (Table 2).

Table 2: Experimental field soil chemical composition and texture before fertilizer application

S/N0	Depth sampling (cm)	Soil pH (in H_2o)	TN-Kjeld (%)	P (mg/kg) $PBry^{-1}$	K^+ $cmolkg^{-1}$	Texture
1	0-20	4.67	0.13	2.39	0.59	Clay
2	20-40	4.74	0.11	3.39	0.67	Loam

Fertilized natural pasture plot produced significantly ($P \leq 0.001$) higher amount of forage (5 186.40 kg DM/ha) than unfertilized plot

(2 267.20 kg DM/ha) regardless of the season (Table 3). Despite the yield being lower than those reported by Adane (2003), who reported the DM yield of 9 470 kg/ha and 5 670 kg/ha for fertilized and unfertilized plots respectively in Fogera upland natural pastureland in Ethiopia the same trend showing improved yield of natural pastures due to fertilizer application was observed in this experiment. The reasons of such a variation in yield could be differences in altitude, weather condition, soil characteristics and differences in natural pasture species.

Table 3: LSM and SE for effects of fertilizers application on pastures dry matter yield (kg/ha) regardless of the rain season

Fertilizer application	Pasture dry matter yield
Fertilized pasture plot	5 186.20
Unfertilized pasture plot	2 267.00
SE	623.36
P-value	0.0021
SL	***

LSM-Least square means SL-Significant level SE-Standard error
* * * = ($P \leq 0.001$)

Pastures dry matter yield regardless of season was slightly higher in the short rain season than in long rain season but were not significantly ($P \geq 0.05$) different (Table 4). In the short rains forage grass reach 50 % flowering 25 days later than in the long rain season. This has been noted elsewhere (Currier and Osvaldo, 2022), that just after the dry season grasses take longer time to flower and thus accumulate more dry matter than after the wet period when the soil was not so well dry. Since the flowering stage of growth is a recommended time of harvesting or grazing

forage grasses so as to compromise between dry matter yield and quality (McDonald et al, 1995, Humphreys, 1991), it was adapted in this experiment. However, the results from this study suggests that, livestock farmers may be advised to use fertilizer application as a natural pasture grassland even in the short rains so as to improve productivity and in the long rain season they should be advised to add fertilizer so as to increase number of harvests or grazing cycles.

Table 4: LSM and SE for effects of season on pastures dry matter yield (kg/ha) regardless of fertilizers application

Rain season	Pasture dry matter yield
Short rain	4 211.60
Long rain	3 241.60
SE	623.36
P-value	0.2785
SL	Ns

LSM-Least square means SL-Significant level SE-Standard error ns-Not significant

Results for effects of fertilizer application and season on quality of pasture are given in Table 5. Generally, fertilized natural pastures had significantly ($P \leq 0.001$) higher crude protein (CP) contents than unfertilized pastures, both in the short and long rain seasons. The long rain fertilized pastures had; however, the highest CP content and the unfertilized short rain pastures had the lowest crude protein content. These results were in agreement with those reported by Manangwa (2003) who recorded CP of long rain pastures at 4.8 % and that of short rain at 3.45%. On the other hand, Bharahenda (2001) reported higher CP content for the rainy season pastures (6.4 to 9.6%) in Gairo. The variation of CP contents reported by different authors could be due to the differences in

pasture species, weather condition, stage of growth and characteristics of the soil. According to McDowell (1985) and Van Soest (1994), for proper functioning of rumen microbes in ruminants the recommended minimum CP content is 7-8% that in this experiment was only recorded from fertilized pastures in the long rains (7.4 %). The results from this study supports protein supplementation for growing and productive ruminant livestock grazing these natural grass forages whether in the dry or rain season so long the forages at the flowering stage onwards.

The IVDMD of fertilized pastures in the long rain season was slightly higher than that of other pastures. More less similar results have been reported elsewhere for natural pastures by Bharahenda (2001) in Gairo during the short and long rains. Long rain fertilized pastures had however significantly ($P \leq 0.001$) higher IVODMD. This could be due to its' highest CP as compared to other pastures. Similar findings were reported by Asfaw (2001) who reported IVODMD of 30.4 % during the short rain season and 45.74 % during the long rain season. Similar trend of results was reported by Hughes et al. (2011) who found a significant season influence on IVODMD content in which the long rain season pastures had higher IVODMD than the short rain season. The possible reasons for the difference might be due to differences in the stage of growth during harvesting and the differences in NDF and ADF contents. According to the report by Van Soest (1994) the decline in IVODMD of pastures with age is due to the increase in plant structural carbohydrates and lignin as reflected in increased NDF %.

In this study the short rains natural pastures had higher NDF % than long rain pastures. This could be due to higher temperature and advanced stage of growth in the short as compared to long rain

season. Similar results were also reported by Hughes et al. (2011) who also found a significant influence of season on NDF content in which long rain season forages had higher NDF content than the short rain season. The unfertilized pastures regardless of season had higher NDF content than fertilized pastures. Therefore, fertilizer application can improve the quality of natural pastures when soil moisture is not limiting.

The energy contents (ME) of long rain season fertilized and unfertilized pastures were higher than those of fertilized and unfertilized short rain pastures. Higher ME content associated with long rain season pastures as compared to the short rain season pastures was attributed to higher IVODMD in long rain season. Since ME is calculated from IVODMD (MAFF, 1976), the higher the IVODMD the higher the ME. This implies that long rain season pastures had relatively high energy content since they reached harvesting stage of growth earlier than those of the short rains. These results should encourage livestock farmers either over sow the natural grass pastures with improved grasses and legume species and/or supplement their growing and productive ruminant livestock with both protein and energy supplements regardless of the rain season.

Table 5: LSM and SE for effects of fertilizer application and rain season on the quality of pastures

Parameters	%DM	%CP	%IVDMD	%IVODMD	%NDF	ME(MJ/kgDM)
Short rain fertilized pastures	93.08 ^{D}	5.80 ^{B}	41.66^{A}	39.90 ^{BC}	71.40^{B}	6.38 ^{B}
Short rain unfertilized pastures	95.44 A	3.97 D	38.81A	38.32 C	73.23A	6.13 C
Long rain fertilized pastures	95.06^{B}	7.40 ^{A}	46.16^{A}	47.42 ^{A}	64.17^{D}	7.59^{A}
Long rain unfertilized pastures	93.78 ^{C}	4.40 ^{C}	40.89^{A}	40.93 ^{B}	67.38^{C}	6.55 ^{B}
SE	0.00	0.01	0.60	0.42	0.0480	0.07
P-value (P≤ 0.01)	<.0001	<.0001	0.4805	0.0004	<.0001	0.0004
SL	* * *	* * *	ns	* * *	* * *	* * *

LSM with the same letter are not significantly different. SL= Significant level. SE-Standard error
* * * = P≤ 0.001 ns-Not significant

Conclusions

The results from this study have shown that fertilizer application can be used as a management tool to improve the productivity and just slightly the quality of natural pastures in the bimodal lowlands of Tanzania. The ruminant livestock farmers in the area are therefore encouraged to improve their natural pastures through fertilizer application and also over sow the natural pastures with improved pasture species so as to improve the feeding value of these pastures. For improved performance of growing and reproductive ruminant animals subsisting on natural mainly grass forages; protein and energy supplementation is also encouraged.

Fertilizer application as a pasture management tool can significantly improve productivity and quality of natural pastures. In this experiment, fertilizers application increased significantly (P≤ 0.01) natural pastures yield by 56.3%. Fertilizer application significantly (P≤ 0.01) improved the CP contents of the natural pastures regardless of the season. However, the CP contents of

fertilized pastures in long rain season were higher as compared to those of short rain season pastures. Energy content (ME) of pastures was higher in long rain season than in the short rain season regardless of fertilizer application. Both unfertilized and fertilized pastures in the short rain season had higher NDF contents than unfertilized and fertilized pastures in long rain season. Fertilizers can, therefore, be applied at any season as long as there is sufficient soil moisture.

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Review of adaptive management practices for rangelands restoration under uncertainty of climate change; Ismail Saidi Selemani

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Abstract

Rangelands are crucial ecosystems covering 54% of the global area, supporting the livelihoods of millions of people through provision of various good and ecosystem services such as food, livestock and wildlife feeds, carbon sequestration, water regulation, medicinal plants, and biodiversity conservation. In Tanzania alone, rangelands cover over 74% of the land, supporting a significant population of livestock and wildlife, with millions of cattle, goats, and sheep managed extensively in these areas, often competing for forage and water resources. However, rangelands are highly susceptible to climate change impacts, leading to continuous degradation and loss of biological resources. Climate change uncertainty further complicates efforts to restore rangelands effectively. This paper addresses the challenges and provides strategies for restoring Tanzania rangelands in the face of climate change. The paper used secondary data through reviewing the impacts of climate change, including extreme weather events like prolonged droughts, increased temperatures, and altered precipitation patterns on rangeland ecosystems. The review suggests restoration strategies such as effective enclosure management, climate-smart pasture

renovation, adaptive management practices, ecosystem-based approaches, community involvement, and policy reforms.

Key words: Adaptive Management, Climate Smart, Ecosystems services, Land Restoration, Policy Reform

Introduction

Rangelands are vital ecosystems that cover about 54% of global area (ILRI 2021) and support the livelihoods of millions of people in addition to delivering of ecosystem services (Godde et al 2020). Ecologically, rangelands provide essential services such as food for human consumption, feeds for livestock and wildlife, carbon sequestration, water regulation, medicinal plants and biodiversity conservation (Kidegesho et al. 2007; Selemani 2020). Rangeland ecosystems contribute to the economy, social and resilience of many communities in Sub-Sahara Africa especially in low income regions (Hoffman et al. 2014). In Tanzania, rangeland covers more than 65% (grazing land 10.5%, protection forestry 10.5%, production forestry 22% and wildlife reserves 22.7%) of the total land of 88.6 million hectares (Mwilawa et al. 2008; Chamuya and Mgoo 2015) supporting large population of livestock and wildlife. Currently, the country is estimated to have about 36.6 million cattle, 26.6 million goats, and 9.1 million sheep (URT 2023) of which 98% are managed extensively in the rangelands sharing forage and water resources in competitive manner (Nelson 2012).

Rangelands are vulnerable to the effect of climate change and variability. The continuous degradation and loss of rangeland biological resources is to the large extent attributed to the effects of climate change. The vulnerability of rangeland to the effect of

climate change depends on the adaptive capacity of available communities (Stanford et al. 2011). The uncertainty associated with climate change exacerbates the complexity of restoring rangelands effectively (Godde et al. 2020). This paper explores the challenges and strategies for rangelands restoration in the context of climate change uncertainty. The paper first provides descriptions and overview of the impact of climate change on rangeland deterioration in terms of extreme weather events such as prolonged drought, increased temperature, change of precipitation patterns and their subsequent alteration to rangeland ecosystems. Finally the review recommends for rangeland restoration strategies such as effective management of enclosures, pasture renovation using climate smart techniques, adaptive management, and engagement of community.

Methodology

The review was conducted through searching relevant articles from the reputable databases such as Google scholar, science direct, research gate and Wiley online library. The search focused on articles discussing effects of climate change and variability on rangeland healthy, ecological restoration strategies such as effective enclosure management, climate-smart pasture renovation, adaptive management practices, ecosystem-based approaches and participatory rangeland management through effective community involvement

Review Findings and Discussion

Impact of Climate Change on Rangelands Ecosystems

Climate change can significantly impact both the quality and quantity of forage available for livestock and wildlife. Rising temperature and altered precipitation patterns can affect the nutritional content of forage plants. For example, changes in

carbon dioxide levels can lead to increased plant productivity but may reduce the protein content of forage plants, affecting their nutritional quality for grazers (Akshit et al. 2020). On the other hand climate change can lead to changes in plant composition, causing some species to become more prevalent while others decline. This shift can result in changes in the types and levels of toxins present in forage plants, affecting animal health and productivity. A body of literature indicated that environmental stressors such as drought or extreme temperatures can reduce the digestibility of forage plants, making it harder for animals to extract nutrients from the available forage (Giridhar and Samireddypalle 2015).

Akshit et al. (2020) highlighted that elevation in CO_2 concentration has most disastrous impacts on forage production as reported to decrease both quality and quantity of various fodder crops. Decline in vegetation cover due to the effect of climate change and variability particularly in semi-arid regions has been an obstacle toward rangeland restoration efforts. Tulu et al. (2023) reported that, availability of plant cover is only seasonal because of rainfall pattern. Most of grazing lands in Tanzania receive short rain seasons of less than five months and prolonged drought exceeding 7 months (Magita and Sangeda 2017).

Increasing bush encroachment and suppression of herbaceous vegetation has been reported to be associated with the impact of climate change. Although, heavy grazing has been blamed to be the main causative of invasive plants, especially woody encroachment, the impact of climate change has significant contribution to the bush encroachment. According to Angassa and Oba (2010), transformation of savanna grassland to woodland has

been linked to climate change and land use pattern. Giridhar and Samireddypalle (2015) reported that developing countries are more vulnerable to these changes than developed countries because of their dependence on rangeland resources. Climate change can further create favorable conditions for invasive species to thrive, impeding restoration efforts (Burgiel and Muir. 2010). The spread of invasive plant species poses a significant threat to rangelands, outcompeting native vegetation and disrupting ecosystem balance.

In Tanzania context, the impact of climate change has being affecting rangeland ecosystems through extinction of important biological resources. Kideghesho et al. (2013) projected that, by year 2050, more than 37% of plants and animals' species will lead to extinction due to impact of climate change. The authors further reported that, the drought episodes in Tanzania occurred between 1990s and 2000s resulted to mass destruction of habitat and hence reduced forage biomass for both livestock and wildlife. Prolonged drought results to pastoral mobility searching for quality forage and water resources which in turn lead to rangeland degradation.

Strategies for Rangelands Restoration

Exclosure management

Over the past decade or so, numerous research trials have been conducted on various modern technologies aimed at rejuvenating degraded rangelands. These trials have shown that restoring degraded rangelands through technical means is challenging and expensive (ILRI 2021). A body of literature indicated that the most effective approach for ecological restoration of degraded rangelands involves reverting to traditional deferred grazing or resting practices known as exclosure management (Aerts et al.

2009; Beyene et al. 2009). Aerts et al. (2009) revealed that restoring degraded land in arid and semi-arid areas frequently entails excluding livestock away from the affected sites. These "exclosures" enable the recovery of native vegetation, reduce soil erosion, enhance rainwater infiltration, and create a source of fodder and woody biomass. Exclosure management derived the concept of the ecosystem-based approaches which considers the interconnectedness of ecological processes and aims to restore rangelands' functionality and resilience. This includes promoting native species diversity, restoring hydrological cycles, and enhancing soil health to withstand climate-related stresses.

In Tanzania, exclosure management has been proven to improve vegetation cover, increase above ground biomass and regeneration of fodder trees (Selemani et al. 2013). Traditional exclosures have been practiced by different pastoral groups such as “ngitili” by Sukuma people, “olopololi” by Masaai and “milangi” by Gogo in central Tanzania (Mwilawa et al 2008) to provide dry season feeds. Traditionally, the land is normally reserved by excluding grazing during rainy season for vegetation recovery and allowed to gaze at the peak of dry season when forage is scarce. However, adoption of this technology is gradual taking into account that most rangelands are managed under communal management. It is therefore recommended up calling these measures through adopting a participatory rangeland management (PRM) approach, whereas community members may form rangeland association or user groups. These groups should formulate by-laws or regulation to manage their uses according to a shared rangeland management plan.

Pasture renovation using climate smart practices

Climate-smart pasture renovation prioritizes soil health as healthy soils are more resilient to climate variability. Practices such as soil testing, nutrient management, cover cropping, and organic matter addition are employed to improve soil fertility, structure, and water-holding capacity (Zougmoré et al. 2014). Some technologies such as half-moons, contour farming, pitting and sunken bed techniques, combined with an application of organic fertilizers are recommended as promising climate-smart agricultural practices that could be widely used by smallholder farmers to secure their livelihoods, while contributing to ecosystem services (Zougmoré et al. 2014).

In addition, the efficient water use is crucial in climate-smart pasture renovation. Techniques like water harvesting, irrigation optimization, contour farming, and the use of drought-tolerant species help to conserve water and maintain adequate soil moisture levels, especially during dry periods. Therefore selection of climate-resilient plant species is recommended based on their ability to thrive in changing climate conditions. Drought-tolerant grasses, legumes, and forbs that provide good forage quality are selected to enhance the productivity and sustainability of the pasture. Tulu et al. (2023) strongly suggested that climate-resilient forage species such as Buffel grass, Brachiaria grass, Napier grass, and Rhodes grass be popularized to sustain livestock production and the environment, particularly in arid and semiarid regions. These species are not only resilience to the effect of climate change but also have high yielding potential. Ecological restoration requires establishment of drought tolerance species of high yielding capacity.

Adaptive Management

Adaptive management is an approach to managing natural resources that utilizes organized learning to decrease uncertainties, aiming to enhance management effectiveness over time. Its roots are intertwined with resilience theory and the study of complex systems (Allen et al. 2017). Rangeland management is particularly suitable for adopting adaptive management principles due to its manageable nature and the potential to minimize uncertainties. The methodology of adaptive management involves structured decision-making tools and necessitates continuous monitoring, evaluation, and adjustments to the management strategies (Allen and Garmestani 2015). Addressing conflicts often requires adaptive governance, which involves the equitable sharing of power and knowledge among relevant stakeholders. Implementing adaptive management strategies is crucial for addressing climate change uncertainty in rangelands restoration. This approach involves flexible decision-making based on changing environmental conditions and feedback. Adaptive management work best when both levels of uncertainty and controllability are high (Figure 1). At this level, there is high level for learning and hence the system can be manipulated because of its flexibility in learning and decision making. For example, when there is high uncertainty due to risk associated to the effect of climate change on rangeland productivity, relevant stakeholders will be flexible to learn alternative ways of adopting to the prevailing situation.

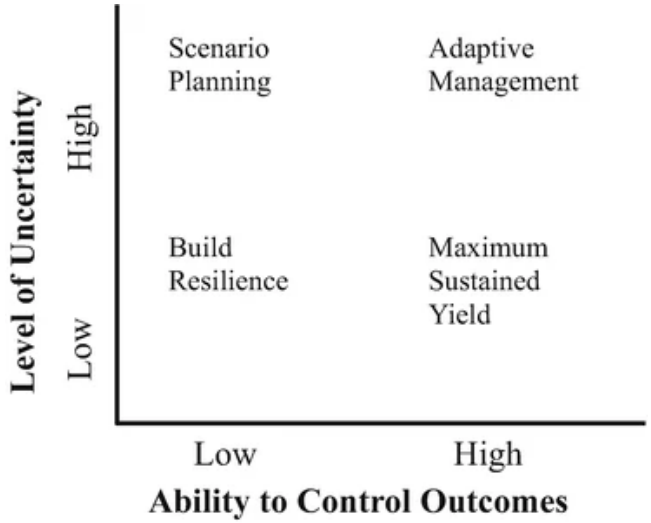

Figure 1: Level of uncertainty and ability to control. Adopted from Allen et al. 2017

Adaptive management involve participatory approaches where communities are full engaged. Involving local communities, indigenous peoples, and stakeholders in restoration planning and implementation fosters stewardship and ensures the sustainability of restoration initiatives (Roba and Oba 2009). Collaborative efforts can leverage traditional knowledge, enhance social resilience, and promote collective action towards rangelands conservation.

Policy reform and governance supportive to rangeland restoration

Strong policy frameworks and regulations that prioritize rangelands conservation and restoration are essential. Policies should integrate climate change adaptation strategies, incentivize sustainable land management practices, and facilitate funding mechanisms for restoration projects. Whereas the country has

well stated policies and acts governing the rangeland management, their enforcement is lacking. For example, the Grazing Land and Feed Resource Act of 2010 directed the Village Council to limit the stocking rate well below ecological carrying capacity and control encroachment of grazing land by other land uses. This act statement if well implemented could restore degrade rangelands through livestock destocking and prohibit encroachment of rangeland resources. Vetter (2005) highlighted that, intervention toward restoration of rangeland based on equilibrium theory focuses on reducing stocking rate and increasing its stability.

Most of rangeland polices exclude local knowledge which are very crucial on ecological restoration. Roba and Oba (2009) highlighted that, development and implementation of legal framework for integrating local communities and ecological methods has limited progress. The authors pointed out that, in most cases, ecological assessment and monitoring toward restoration of degraded land exclude local existing legal framework and consider scientific methods exclusively. It is therefore recommended that, scientific evidences should be integrated with local knowledge for effective management of rangeland ecosystems.

Conclusion

Rangelands restoration under the uncertainty of climate change requires a holistic and adaptive approach that addresses multiple challenges while leveraging local knowledge, scientific expertise, and supportive policy reform. By integrating scientific and local knowledge, community engagement, and adaptive management practices, rangelands can be restored and maintained as resilient

and productive landscapes in the face of ongoing environmental changes. This paper recommends the effective collaboration among stakeholders, investment in research and monitoring, and robust policy enforcement for achieving successful rangelands restoration outcomes in a changing climate.

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Understanding Local Knowledge and Information Preferences for Climate Change Adaptation in Rangeland Management: A Case Study of Shagayu Ward, Lushoto, Tanzania; Philbert S. Nyinondi

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Abstract
This study aims to assess how local knowledge, information and communication strategies contribute to supporting rangeland management and enhancing community resilience to climate change. Data were collected through structured questionnaires administered to 140 respondents. Key findings reveal that 95% of respondents were aware of climate change, a significantly higher rate compared to previous surveys in Tanzania. However, gaps in understanding the long-term impacts of climate change were evident. Respondents attributed climate change mainly to deforestation (57.7%), poor farming practices (40%), and pollution (28.5%). The most commonly reported impacts included low agricultural yields (36.3%), food insecurity (35.6%), and the emergence of new pests and diseases (26.7%). Radio emerged as the dominant source of climate change information (56.4%), with a preference for radio (77.7%) and television (44.6%) for information dissemination. Age, education, and marital status showed significant associations with information access, while farm size and house ownership had minimal effects. The study highlights the importance of integrating local knowledge into climate adaptation strategies, with community-driven strategies like reforestation (49.6%), mass education (35.4%), and local regulations identified as key rangeland management measures. However, it also reveals gaps in aligning local practices with

global sustainability goals, particularly in integrating livestock management with rangeland conservation. The study recommends that stakeholders involved in rangeland management and climate change adaptation include improving access to reliable climate information through preferred media platforms, enhancing community education programs on climate impacts and adaptation strategies, and promoting sustainable rangeland management practices that integrate livestock keeping and biodiversity conservation. Additionally, engaging local communities in decision-making processes and supporting the development of policies that address both climate change and sustainable rangeland use are critical for fostering long-term resilience.

Keywords: Climate Change Adaptation, Rangeland Management, Local Knowledge, Community Resilience, Communication Strategies.

Introduction

The global understanding of climate change varies significantly across different regions, largely shaped by diverse environmental experiences and levels of awareness among populations (Calculli *et al.,* 2021). In highly industrialized countries, such as the United States of America (USA) and many European nations, climate change is often viewed as a distant, long-term threat that primarily affects future generations. However, in regions like Sub-Saharan Africa (SSA), the impacts of climate change are already being felt in real time, with vulnerable rural communities at the forefront of these changes. These communities are directly dependent on natural resources in the rangelands and the alterations in climate patterns pose a significant challenge to their way of life (Trisos *et al.,* 2022; Bukari, 2023). This contrast in perception and experience influences how different communities' access climate-

related information and the strategies they adopt to cope with these challenges (Githiora *et al.,* 2023). Understanding these variations is essential for formulating effective communication and adaptation strategies in the face of climate change.

Rangelands are ecosystems that are integral to the livelihoods of many rural communities, particularly in the developing world. These ecosystems are characterized by natural or semi-natural vegetation, which primarily supports grazing livestock and wildlife. Rangelands are found in areas with varying climatic conditions, ranging from semi-arid zones with sparse vegetation to more humid regions where the vegetation is denser and more diverse. Despite these differences in vegetation types, all rangelands share the common goal of providing a sustainable environment for livestock and wildlife, while also maintaining ecological balance (Grebner *et al.,* 2021; Sircely, 2022). In many developing countries like Tanzania, these ecosystems are critical to the survival of rural populations who rely on rangelands for their food, income, and overall well-being (Belay & Lebeza, 2024).

However, climate change presents an immediate threat to these fragile ecosystems in the rangelands. The impacts of climate change, including altered rainfall patterns, prolonged droughts, and increasingly erratic weather, are putting immense pressure on rangeland ecosystems. These changes disrupt vegetation growth, water availability, and the overall capacity of rangelands to support livestock and wildlife. As a result, rural communities are facing challenges in maintaining their livelihoods and adapting to the changing environment (Wong-Parodi & Feygina, 2021; Field & Barros, 2014). Research has highlighted that rural communities

are particularly vulnerable to climate change due to their reliance on climate-sensitive resources and limited access to the tools and knowledge necessary for effective adaptation (Ncoyini *et al.*, 2022). Furthermore, the lack of access to reliable and timely climate change information exacerbates these vulnerabilities, underscoring the need for effective communication strategies to ensure these communities are informed and prepared.

Mass media, including radio, television, and mobile platforms, plays a pivotal role in communicating climate change information to rural populations. Studies have shown that, despite the rise of digital media, radio remains the most trusted and widely used form of communication in many rural areas, particularly when broadcasts are delivered in local languages. This accessibility makes radio an invaluable tool for reaching rural communities, raising awareness about climate change, and influencing public attitudes and behaviours (Tume *et al.,* 2018). In addition to mass media, local communication channels such as village meetings, word of mouth, and community gatherings also play a crucial role in disseminating climate change information at the grassroots level (Mwalukasa, 2020). These traditional forms of communication are often rooted in community ties and cultural practices, which can enhance their effectiveness in reaching local populations.

However, the accessibility of climate change information is not uniform across all demographic groups. Factors such as education level, age, socio-economic status, and geographic location significantly influence individuals' ability to access and process climate information (Azeez *et al.,* 2024; Ifegbesan *et al.,* 2021). In rural Tanzania, for example, challenges such as poor

infrastructure, language barriers, and limited access to modern technology make it difficult for many community members to access accurate climate information. These barriers contribute to widespread misinformation or lack of awareness about climate risks, which hinders the community's ability to adopt effective adaptive strategies (Kapinga *et al.,* 2020; Msemo *et al.,* 2021).

The local people in Lushoto district are particularly vulnerable to climate change, as they are heavily reliant on rangelands for their crops and livestock-based livelihoods (UNCCD, 2024). The district is already experiencing the adverse effects of climate change, including shifting rainfall patterns, more frequent droughts, and the degradation of pasturelands. These changes threaten not only the local economy but also the ecological sustainability of the area (UNCCD, 2024; Blomley *et al.,* 2024). In response to these challenges, the community has relied on both traditional knowledge and scientific methods for managing rangelands. Traditional knowledge, passed down through generations, includes practices that are closely attuned to local environmental conditions. However, as climate change continues to affect the district, there is an increasing recognition of the need to integrate modern scientific knowledge with these traditional methods for more effective climate change adaptation (Leal Filho *et al.,* 2022).

This study aims to assess the local knowledge and information preferences for climate change adaptation in rangeland management among the local community members of Lushoto. It examined how local knowledge, communication strategies, and media platforms are used to support rangeland management and enhance community resilience to climate change. The study seeks

to improve our understanding of how rural communities can adapt to climate change and develop more effective communication strategies to build their adaptive capacities.

Methodology

Study Area

This study was conducted in Lushoto District, located in the Tanga Region of Tanzania. The district is characterized by its diverse geographical features, including mountainous terrains, valleys, and varying altitudes, ranging from 200 meters in the lowlands to 2,000 meters in the highlands (URT, 2016). These varied landscapes contribute to Lushoto's agro-ecological diversity, making it a crucial area for both agricultural and livestock activities, which are highly sensitive to climate change (URT, 2016).

Climatic Conditions and Agro-Ecological Zones

Lushoto experiences a bimodal rainfall pattern with short rains occurring from October to December and long rains from March to June. The rainfall is variable across the district, with the highland areas receiving 800–2,000 mm annually and the lowland areas receiving 500–800 mm. The short rains, although less reliable, are essential for seasonal crops such as maize and beans, while temperatures generally exceed 20°C in the lowlands from October to March, with cooler temperatures in the highlands ranging from 16°C to 30°C (URT, 2016).

The district’s agro-ecological diversity is shaped by variations in altitude, rainfall, temperature, and humidity, creating distinct zones that support different agricultural activities. The following are the main agro-ecological zones of Lushoto:

i. ***Dry Hot Zone***

This zone, situated at altitudes between 300 and 600 meters, experiences low annual rainfall (400 to 600 mm). The climate is ideal for drought-tolerant crops such as cotton, sisal, rice, and cassava. Livestock grazing is the dominant activity in this zone, with pastoralist communities adapting to the dry conditions.

ii. ***Humid Cold Zone***

The zone is located at elevations ranging from 800 to 1,500 meters, it receives moderate to high rainfall (600 to 1,200 mm annually). The cooler and wetter conditions support the cultivation of high-value crops such as coffee, vegetables, bananas, potatoes, and fruits, making it a significant area for commercial agriculture.

iii. ***Dry Warm Zone***

Spanning altitudes between 800 and 1,800 meters, this zone receives moderate rainfall (500 to 800 mm). Despite limited rainfall, subsistence farming thrives here, with crops like maize, beans, cassava, and vegetables being cultivated, particularly in fertile valley-bottom areas.

iv. ***Dry Cold Zone***

Found at altitudes of 1,700 to 2,100 meters, this zone receives annual rainfall between 500 and 800 mm. The cooler temperatures make this zone ideal for cultivating Irish potatoes, fruits, and a variety of vegetables. Its unique microclimate supports specialized farming practices suited to high-altitude farming.

Each agro-ecological zone in Lushoto showcases the adaptability of its farmers to the region's diverse environmental conditions,

highlighting the importance of local knowledge in agricultural practices and climate change adaptation.

Livestock Sector

Livestock farming is a key component of Lushoto's economy. The 2022 Population and Housing Census and the Lushoto District socio-economic profile indicate that the district is home to 85,846 cattle, including both indigenous and improved dairy cattle, alongside substantial numbers of goats, sheep, pigs, donkeys, and poultry. Livestock farming is influenced by the district's diverse landscapes, with the availability of 51,999 hectares for grazing (NBS. 2022; URT, 2016). However, the limited grazing areas, combined with the region's topographical variations, pose challenges to sustaining livestock production. This makes it necessary for farmers to adopt adaptive management strategies in the face of changing climatic conditions (URT, 2016).

Research Design

This study employed a cross-sectional research design, which was ideal for assessing local knowledge, information preferences, and communication strategies for climate change adaptation in rangeland management among the community members of Lushoto. The design allowed for the collection of data at a single point in time, providing a snapshot of how local knowledge and media platforms support adaptive strategies in farming and livestock activities (Kesmodel, 2018; Kothari, 2004). This approach enabled an understanding of the community's current climate change adaptation practices, highlighting challenges and opportunities for improving communication strategies to enhance resilience and adaptive capacities (Kesmodel, 2018).

Selection of Shagayu Ward

Shagayu ward was purposively selected for its significant vulnerability to climate change, particularly regarding rangeland degradation and resource management (Wickama *et al*., 2004). The ward's population is heavily reliant on farming and livestock-keeping, making it an ideal location to study the intersection of livelihoods and climate change adaptation. Shagayu's ecological and socio-economic conditions are similar to other rural wards in the district, making it a representative sample for the study. While the findings may not fully capture the experiences of all wards in Lushoto, Shagayu offers a valuable case study of climate change impacts and adaptation strategies in the district.

Study Population and Sample Size

According to the 2022 Population and Housing Census, Lushoto District has a total population of 350,958 people, with 160,815 males and 190,143 females, distributed across 85,149 households (NBS, 2022). The district is predominantly rural and densely populated, with the Sambaa tribe being the largest ethnic group, followed by the Pare and Mbugu, among other smaller communities. This demographic diversity creates a unique cultural context for studying climate change adaptation strategies (Mahoo *et al.,* 2015).

The target population for this study consisted of residents of Shagayu ward who were fluent in the local language to ensure effective communication. Participants were selected based on their direct involvement in farming and/or livestock-keeping activities, as these livelihoods are most affected by climate change in the area. A total of 140 respondents were targeted, with 35 participants selected from each of the four villages in Shagayu

ward: Kweshindo, Mpondekaya, Mpanga, and Kisangazi. This sample size was deemed sufficient for reliable statistical analysis, meeting the requirements for normal distribution (Ryan, 2013; Tanaka, 1987). Although this sample represents a fraction of Shagayu's total population of approximately 7,251 residents, it was selected based on practical constraints and the study's focus on generating insights rather than generalizing to the entire district population (Nardi, 2018).

Sampling and Data Collection Techniques

A combination of probability and non-probability sampling techniques was used to ensure both feasibility and targeted data collection (Khan, 2020). Shagayu ward was purposively selected due to its rainfall pattern (500–800 mm annually), which influence climate change impacts on rangelands and livestock farming (Oluwabunmi *et al.,* 2023).

Within Shagayu, the four villages were selected using convenience sampling for efficient data collection, considering logistical constraints in the rural setting (Kothari, 2004). The sample was chosen to reflect the ward's ecological characteristics, including its reliance on rangelands and livestock, and its vulnerability to climate change. The respondents were selected from those actively engaged in farming or livestock-keeping.

Data were collected using structured questionnaires designed to capture both quantitative and qualitative information on participants' knowledge, information, and practices regarding climate change and rangeland management. These instruments were developed to align with the study's objectives. Primary data collection was done directly by the researcher, allowing for in-

depth insights into local climate change dynamics and resource management (Kothari, 2004).

Data Analysis

The data collected for this study were analysed using both descriptive and inferential statistical techniques to provide an understanding of the research objectives. Descriptive statistics, including percentages and frequencies, were used to summarize key findings, offering an overview of data distribution and trends within the sample. Cross-tabulation was employed to examine relationships between demographic factors and study variables, with Pearson Chi-square tests applied to categorical data and Somers' d used for ordinal data. These tests were selected for their ability to assess the strength and direction of relationships, ensuring the reliability of the observed patterns (Kotronoulas *et al.,* 2023).

The analysis was conducted using IBM SPSS Statistics Version 28, which includes advanced data visualization tools to enhance the interpretation of results. Notably, relationship maps were utilized to visualize the connections between community knowledge, attitudes, and climate change responses. The thickness of the lines and the size of the category indicators on these maps visually represented the strength of relationships and the relative prevalence of specific responses. These visual tools complemented traditional statistical outputs, allowing for a more nuanced exploration of the data's relational structure and validating the statistical findings (Field, 2024).

Results and Discussion

Socio-Demographic Characteristics of Respondents

The results of the socio-demographic characteristics of the respondents in Table 1 revealed several key information into the community's structure and its capacity to engage with climate change adaptation strategies. A significant proportion of the respondents, 57.1%, were female, suggesting that women are at the forefront of engaging with climate-related information. This finding aligns with previous research that highlights the critical role of women in rural communities, particularly in resource management and decision-making processes related to agriculture (Shikuku *et al.,* 2016). Women's roles in household management and agriculture may provide them with heightened awareness of climate changes, driving their engagement in seeking information on adaptive strategies to mitigate climate impacts on farming activities.

Age distribution among respondents also provided valuable information. The majority of respondents were middle-aged, with 27.1% in the 40-49 age range, followed by 24.3% in the 30-39 age range. This demographic trend suggests a community composed primarily of individuals with considerable experience in agriculture, a factor that may enhance their ability to manage climate variability. The presence of older adults (16.4% aged 60 and above) is particularly noteworthy, as these individuals often possess valuable traditional knowledge passed down through generations. This aligns with findings from Mahoo *et al.* (2015) and Mahoo *et al.* (2014), who emphasized that older community members are vital sources of indigenous knowledge, which can help build resilience to climate change through a better understanding of historical climate patterns and practices.

The marital status of the respondents revealed that 75% were married, which suggests a relatively stable social structure within the community. This high percentage of married individuals may indicate stronger familial and community networks that can be leveraged for collective action in addressing climate change. Married individuals, particularly in rural areas, tend to engage more in community-based initiatives due to their established social connections and responsibilities. This could be crucial in fostering a cooperative approach to tackling climate change challenges, as collective action is often more effective in rural contexts.

Table 1: The Socio-Demographic Characteristics of the respondents

Characteristics	**Variable**	**Percent**
Gender	Male	42.9
	Female	57.1
Age	20-29	10.7
	30-39	24.3
	40-49	27.1
	50-59	21.4
	60+	16.4
Marital status	Single	0.0
	Married	75.0
	Divorced	12.9
	Widowed	7.1
	Separated	5.0

Characteristics	Variable	Percent
Education level	Informal	17.1
	Primary	63.6
	Secondary	15.0
	College	2.9
	University	1.4
Household size	1-5	65.0
	6-10	32.9
	11-15	2.1
Farm size	0-4	83.6
	5-9	12.1
	10-14	3.6
	15-19	0.7
House ownership	Yes	79.3
	No	20.7
Farming crop	Yes	85.0
	No	15.0
Keeping livestock	Yes	27.9
	No	72.1
Employment	Yes	3.6
	No	96.4
Business	Yes	5.7
	No	94.3

In terms of educational background, the respondents exhibited a relatively low level of formal education. Most (63.6%) had completed only primary school, and 17.1% had no formal education at all. This low educational attainment could present a barrier to understanding complex climate-related information and adopting new technologies or practices for adaptation. Research has shown that education is a fundamental factor in enhancing awareness of and responsiveness to climate change (Hoekstra *et al.,* 2024), making it crucial to design accessible communication strategies that cater to individuals with varying levels of education. The community's educational needs suggest that information dissemination efforts should be simplified and culturally appropriate to ensure widespread understanding and engagement.

Agriculture remains the dominant livelihood activity in the community, with 85% of respondents relying on farming as their main source of income. The majority (83.6%) own small farms, primarily ranging from 0 to 4 acres. This reliance on agriculture underscores the community's vulnerability to climate variability, as changes in rainfall patterns and temperature can have immediate and significant effects on crop yields and food security. Twinomugisha & Mushy (2021) and Kahimba *et al.* (2015) highlighted the vulnerability of small-scale farmers to the impacts of climate change, particularly when they depend on rain-fed agriculture, which is highly sensitive to fluctuations in weather patterns. The high reliance on crops as a primary income source further emphasizes the need for adaptation strategies that enhance agricultural resilience.

Livestock farming was notably less common among respondents, with only 27.9% engaging in this activity. This limited engagement in livestock keeping could stem from various constraints, such as insufficient land, lack of resources, or socio-economic challenges. However, the low participation in livestock farming has broader implications, particularly in the context of rangeland management and climate change adaptation. Livestock plays a critical role in rangeland ecosystems by supporting nutrient cycling, maintaining vegetation balance, and serving as a buffer against crop failures during periods of climate variability (Grebner *et al.*, 2021; Sircely, 2022).

The limited engagement in livestock keeping may undermine the potential of rangelands to provide sustainable livelihoods and maintain ecological balance. Without livestock to utilize and manage rangeland resources effectively, overgrowth or underutilization of vegetation may occur, potentially leading to ecological degradation or loss of biodiversity (Wickama *et al.,* 2004). Moreover, from the perspective of climate change adaptation, livestock farming could provide a vital source of income and food security, especially during times when crop production is adversely affected by erratic weather patterns.

This finding highlights the need for targeted interventions to address barriers to livestock farming and to promote its integration into the community's livelihood strategies. Policies and programs aimed at improving access to grazing land, veterinary services, and credit facilities could help encourage livestock keeping while ensuring sustainable rangeland management. Additionally, initiatives to build the capacity of local communities in sustainable livestock practices could

enhance both livelihoods and the ecological health of rangelands, contributing to long-term resilience against climate change impacts.

Furthermore, while a significant proportion of respondents (79.3%) owned their homes, the high rates of unemployment (96.4%) and limited engagement in business activities (94.3%) highlight significant socio-economic challenges within the community. These challenges may impede the community's ability to invest in climate-resilient technologies or diversify income sources. Limited financial resources could hinder the adoption of climate-smart practices, such as improved irrigation systems or drought-resistant crops, which could otherwise enhance the community's ability to adapt to changing climate conditions. Bukari & Aluko (2023) pointed out that financial constraints are a significant barrier to climate adaptation in rural areas, as households with limited income are less able to invest in the necessary technologies and practices to build resilience.

Therefore, socio-demographic factors presented in Table 1 should be considered when designing effective communication strategies and adaptation interventions that can enhance the community's capacity to cope with the challenges posed by climate change.

Awareness and knowledge of Climate Change

The findings of this study reveal that 95% of respondents have heard about climate change, indicating a significantly higher level of awareness compared to the 32% reported by Msafiri (2023) in the Afrobarometer survey on Tanzanians' climate change awareness. This heightened awareness among the study population underscores the critical role of localized communication and engagement strategies in rural communities.

Awareness serves as a foundation for fostering attention to climate-related challenges, encouraging early adaptive actions, and building resilience at the community level, as emphasized by Azeez *et al.* (2024). Awareness alone, however, is insufficient without a deeper understanding of the phenomenon and its implications.

While awareness is high, the study identifies gaps in respondents' knowledge of climate change concepts. Of those familiar with the term, 22.9% defined it as long-term changes in average weather conditions, and 45% described it as fluctuations in temperature and rainfall (Table 2). An additional 28.6% associated it with variations in seasonal patterns, while 3.6% admitted to not knowing its meaning. This variability in understanding reflects the community's reliance on observable changes in their environment, such as irregular weather patterns and temperature shifts, which are directly tied to their livelihoods. These findings align with Mahoo *et al.* (2015), who emphasize the need for clear and accurate knowledge of climate change concepts to enhance community engagement in adaptation efforts.

Table 2: Knowledge of climate change

What is climate change?	Percent
Rise and falling of temperature and rainfall	45.0
Variation of seasons in an area	28.6
Average changes of weather condition in long time	22.9
Don't know	3.6

The predominance of descriptions focusing on short-term weather fluctuations suggests that respondents are more aware of the immediate and visible impacts of climate change rather than its systemic and long-term nature. This aligns with findings by Azeez *et al*. (2024), who observed that rural communities often conceptualize climate change through the lens of their direct experiences and local environmental changes. While this practical perspective can prompt localized responses, it also highlights the need for educational interventions to broaden their understanding of climate change beyond observable phenomena to include its root causes, long-term trends, and broader impacts on ecosystems and livelihoods.

Improving knowledge of climate change is essential for effective adaptation. Studies by Blomley *et al.* (2024) and Belay & Lebeza (2024) emphasize that informed communities are better equipped to adopt adaptive strategies that address both immediate challenges and systemic vulnerabilities. In the context of this study, targeted educational initiatives could enhance the community's capacity to interpret and respond to climate variability. For example, integrating local knowledge with scientific information, as advocated by Mahoo *et al.* (2015), can empower communities to make informed decisions about sustainable rangeland management and climate-resilient agricultural practices.

These findings underline the need for knowledge-building programs to complement awareness campaigns. By bridging the knowledge gap, communities can better understand the interconnectedness of climate change impacts, enabling them to develop holistic and sustainable adaptive strategies. As

highlighted by Azeez *et al.* (2024) and Mahoo *et al*. (2015), such integration of knowledge and awareness is critical for building resilient systems that can withstand the multifaceted challenges posed by climate change.

Sources of Climate Change Information

The findings presented in Table 3 reveal that radio is the dominant source of climate change information, with 56.4% of respondents reporting it as their first source of awareness. This aligns with the established role of radio as a key medium for information dissemination in rural Africa, where access to other forms of mass media, such as television or the internet, is often limited due to infrastructural constraints (Azeez *et al.,* 2024). Radio's accessibility, affordability, and ability to broadcast in local languages make it a particularly effective communication tool in reaching remote populations. Television, identified as the second most common source at 14.3%, highlights the growing influence of visual media in these areas, though its reach is still limited compared to radio.

The study also highlights a significant gap in information access, with 12.9% of respondents reporting no exposure to climate change information. This gap can be attributed to infrastructural and geographic isolation, which hampers the dissemination of information, particularly in more remote areas of the district. Moreover, the irregular frequency of information reception reported as daily (29.3%), weekly (22.9%), monthly (23.6%), or rarely (24.3%) suggests inconsistencies in outreach efforts. These findings are consistent with the observations by Mwalukasa (2020) that information dissemination in rural Tanzania contexts is often fragmented, limiting its effectiveness.

Table 3: The First heard source of climate change

Source	Percent
Radio	56.4
Television	14.3
Village meetings	5.0
Friends	3.6
Others	3.6
Relatives	2.9
Mosque or church	2.1
Ngomani	2.1
Newspapers	2.1
Extension officers	1.4
Mobile phone	1.4
Local leaders	1.4
Teachers	1.4
Political leaders	0.7
Books	0.7
Public Announcement	0.7

Preferred channels for receiving climate change information revealed a strong inclination toward radio (77.7%), followed by television (44.6%) and mobile phones (33.1%). Interestingly, social media, mentioned by 7.7% of respondents, indicates a gradual penetration of digital communication technologies into rural areas. This reflects an emerging opportunity to complement traditional communication channels with digital platforms, as recommended by Azeez *et al.* (2024), to target younger, more

tech-savvy segments of the population. Expanding the use of mobile phones and social media could address some of the barriers to information access, including geographic and infrastructural constraints (Mwalukasa, 2020).

Despite the high awareness levels, communication of climate change information among respondents remains limited. While 50% of respondents shared such information during social gatherings and 9.3% discussed it in official village meetings, 32.9% reported never communicating climate change information. This lack of engagement may stem from limited understanding of the issue or low perceived importance of discussing it in formal settings. As Githiora *et al*. (2024) emphasize, fostering dialogue and community engagement is crucial for building collective action toward climate adaptation.

Social gatherings were identified as critical platforms for disseminating climate change information, indicating the importance of leveraging informal networks for communication. However, the reliance on these informal channels underscores the need for more structured and formal platforms for discussing climate-related issues. Establishing regular village meetings or integrating climate education into existing community activities could enhance the effectiveness of information sharing, as recommended by Twinomugisha & Mushy (2021).

These findings highlight the importance of a multi-channel approach to climate communication, combining traditional media such as radio and television with emerging tools like mobile phones and social media. Moreover, efforts to improve the consistency and accessibility of climate change information should focus on addressing geographic and infrastructural challenges while enhancing the knowledge and engagement of the community through targeted education campaigns. Such strategies

could be essential for fostering informed decision-making and collective action to build resilience to climate change impacts.

Furthermore, the study revealed significant associations between socio-demographic factors and access to climate change information, offering critical insights into how different groups interact with information sources (Table 4). Age emerged as a key variable, with the Pearson Chi-square test showing a statistically significant association ($p = 0.007$). Younger individuals were found to access information through digital platforms such as mobile phones and social media, while older respondents relied more heavily on traditional media, including radio and village meetings. Although the Somers' d value of 0.007 indicated a weak predictive relationship, the findings suggest that age, while not a strong determinant, does influence the diversity of information sources accessed. These observations align with existing studies, such as Azeez *et al.* (2024), which highlight younger populations' greater engagement with technology for information access.

Table 4: Association between socio-demographic factors and accessibility to climate change information

Factors	**Pearson Chi-square**	**Somers' d**
Age	0.007	.007
Sex	0.0769	.395
Marital status	0.001	.015
Education level	0.000	.090
Number of households	0.062	.092
Farm size	.666	.993
House ownership	.666	.877

Sex, on the other hand, did not show a statistically significant relationship with access to information (p = 0.0769), but the Somers' d value of 0.395 suggested a moderate directional relationship. This indicates that while sex may not strongly influence access overall, there are underlying patterns worth exploring further. For example, gender-based roles or societal norms could shape the way men and women engage with information channels, even if such influences do not appear strongly in statistical tests.

Marital status demonstrated a highly significant association with access to information (p = 0.001), with married individuals likely benefiting from broader social networks and shared resources, enabling them to access information more consistently. However, the predictive strength, as indicated by the Somers' d value of 0.015, was relatively weak. This finding underscores the complexity of how social structures, such as marital status, interact with access to environmental information. Married individuals, for instance, might have more regular exposure to traditional communication platforms such as radio or village meetings, while single individuals might explore newer channels like social media.

Education level emerged as one of the most significant factors influencing access to climate change information. The Pearson Chi-square test showed a highly significant association (p = 0.000), while the Somers' d value of 0.090 indicated a stronger predictive relationship compared to other variables. Respondents with higher levels of education accessed information through more diverse and sophisticated channels, including print media, mobile phones, and social media. This finding highlights the

critical role of education in equipping individuals with the skills to seek, interpret, and utilize complex environmental information. Similar results have been reported in studies such as Ifegbesan *et al.* (2021), where education was highlighted as a pivotal factor in environmental awareness and engagement.

The number of households showed a marginal association with access to climate change information, with a Pearson Chi-square value of 0.062 and a Somers' d value of 0.092 indicating a moderate predictive relationship. Larger households likely benefited from the diversity of their members' roles, ages, and education levels, which increased exposure to varied information sources. However, the results suggest that this factor alone is not a strong determinant of access to information.

Farm size and house ownership did not show significant associations with access to climate change information, as reflected by Pearson Chi-square values of 0.666 for both variables. The Somers' d values, 0.993 for farm size and 0.877 for house ownership, also suggested minimal predictive relationships. This indicates that these variables, while important in other socio-economic contexts, are not directly tied to how individuals access or engage with climate-related communication channels.

The implications of these findings are profound. Efforts to improve access to climate change information must consider the socio-demographic diversity of the target population. Younger and more educated individuals can be reached effectively through digital tools such as social media and mobile applications, while older and less educated populations may benefit more from traditional media like radio. Furthermore, while variables such as farm size and house ownership do not appear to influence access

directly, this highlights the importance of tailoring communication strategies to focus on more impactful demographic factors, such as education and age. These dynamics are vital for effective climate change communication, by ensuring that all segments of the population are equipped with the knowledge needed to respond to environmental challenges.

Perceived Causes of Climate Change

The respondents identified several causes of climate change, with deforestation (57.7%) being the most commonly cited, followed by poor farming practices (40%) and pollution (28.5%) (Table 5). These findings are consistent with global research emphasizing deforestation and unsustainable agricultural practices as significant contributors to climate change. For instance, Grebner *et al.* (2021) highlight that deforestation directly impacts carbon sequestration, exacerbating greenhouse gas emissions. Similarly, Jones *et al.* (2023) note that poor farming methods, such as slash-and-burn agriculture, intensify soil degradation and increase greenhouse gas emissions, particularly in regions reliant on subsistence farming.

Table 5: Perceived causes of climate change

Perceived Cause	**Percent**
Deforestation	57.7
Farming system/practice	40.0
Pollution	28.5
Bush fire	16.2
Natural disasters	14.6
Lack of education	9.2
God's Punishment	7.7
I don't know	7.7
Global warming	3.8

Pollution, recognized by 28.5% of respondents, also aligns with studies like Calculli *et al.* (2021), which featured the role of industrialization, urbanization, and waste mismanagement in amplifying carbon and methane emissions. Interestingly, 16.2% of respondents identified bushfires as a cause of climate change, reflecting the regional susceptibility to wildfire-induced carbon emissions.

A small but significant proportion (7.7%) attributed climate change to divine punishment, reflecting cultural and religious interpretations of environmental phenomena. While such beliefs are deeply rooted in local traditions, they may hinder scientific understanding and action, as observed in studies by Kahimba *et al.* (2015). Educational initiatives that integrate scientific concepts with respect for cultural values could enhance community understanding and engagement with climate change mitigation strategies.

The diversity of perceived causes indicates varying levels of awareness among respondents, highlighting the importance of tailored communication strategies to address knowledge gaps and promote sustainable practices. As Kapinga *et al.* (2020) emphasize, community-based broadcast media and participatory knowledge-sharing approaches could be particularly effective in disseminating accurate climate change information.

Impacts of Climate Change

The study revealed that respondents experienced various impacts of climate change, with the most significant being low agricultural yields (36.3%) and famine or food insecurity (35.6%) (Table 6). These findings emphasize the direct link between climate change and food security, as highlighted by Field and Barros (2014), who

discuss how unpredictable rainfall patterns and prolonged droughts disrupt crop production in vulnerable regions. Similarly, Kahimba *et al.* (2015) note that Tanzanian farmers are increasingly experiencing reduced harvests due to shifting weather patterns, compounding food insecurity risks.

Table 6: Impacts of climate change

How climate change is affecting you?	**Percent**
Low agricultural produce	36.3
Famine/food insecurity	35.6
Diseases and new pests	26.7
Dry of rangelands/ No pasture	20.0
No rain, thus everything falls apart	20.7
Destruction of infrastructure	16.3
No effects	7.4

In addition to agricultural impacts, 26.7% of respondents reported increased diseases and new pests, consistent with the observations of Hoekstra *et al.* (2024), who link changing climatic conditions to the proliferation of disease vectors and invasive species. These health challenges further strain already fragile healthcare systems in rural areas.

The drying of rangelands and lack of pasture, noted by 20% of respondents, highlights the adverse effects of climate change on livestock-dependent communities. As Grebner *et al.* (2021) emphasize, changes in rainfall and vegetation patterns disrupt traditional grazing cycles, leading to economic losses for

pastoralists. Similarly, infrastructure destruction, reported by 16.3%, reflects the vulnerability of rural communities to extreme weather events, such as floods and storms, which damage homes, roads, and public facilities.

While 7.4% of respondents claimed no noticeable effects of climate change, this could indicate limited exposure or a lack of awareness about indirect impacts. Hoekstra *et al.* (2024) suggest that improving education on the less visible effects of climate change such as gradual soil degradation or economic consequences could bridge such gaps in perception.

Therefore, these findings emphasize the need for integrated strategies to address both the immediate and long-term impacts of climate change. Promoting climate-smart agricultural practices (Jones *et al*., 2023), enhancing public health systems, and investing in resilient infrastructure are critical steps toward mitigating the adverse effects of climate change on vulnerable communities.

Strategies for rangeland management amid Climate Change

The findings on community-driven strategies for rangeland management amid climate change in Table 7 reveal important information but also raise critical questions about their adequacy in achieving the global goals of rangelands. Globally, the sustainable management of rangelands is often centred on balancing grazing, biodiversity conservation, and ecosystem services to support rural livelihoods (Grebner *et al*., 2021; Sircely, 2022). However, the results indicate a notable gap in aligning local perceptions with these broader objectives, particularly given the predominance of crop farming (85% of respondents) over livestock keeping (27%) in the study area.

Table 7: Strategies for rangeland management amid Climate Change

Rangeland management measures	**Percent**
Reforestation	49.6
Provision of mass education	35.4
Establishment of by-laws and local regulations	16.5
Adopt climate Smart farming practices	16.5
Praying to God	11.8
I don't know	6.3

The high prioritization of reforestation (49.6%) as a strategy is commendable and aligns with global efforts to combat deforestation and restore degraded rangelands. Tree planting can improve vegetation cover, enhance soil health, and mitigate erosion, all of which are essential for rangeland resilience. However, reforestation alone does not fully address the multifaceted challenges of rangeland management, especially in the context of livestock grazing, which is a defining feature of rangelands. In regions where livestock plays a minor role, as observed in this study, there is a risk that rangelands may be underutilized or mismanaged, potentially leading to ecological degradation or loss of biodiversity (Wickama *et al*., 2004). This gap highlights the need to promote livestock keeping as an integral component of rangeland management to achieve the common global goals of sustaining livelihoods and ecological balance.

The provision of education, cited by 35.4% of respondents, offers a pathway to address this gap. Education can empower communities to adopt sustainable livestock practices, such as rotational grazing and fodder cultivation that optimize rangeland resources while minimizing environmental impacts. It can also enhance understanding of the interconnectedness between livestock, vegetation, and ecosystem services, fostering a more comprehensive approach to rangeland management. In areas dominated by crop farming, integrating education on mixed farming systems that incorporate livestock could help diversify livelihoods, enhance food security, and strengthen resilience to climate variability (Azeez *et al.,* 2024; Sircely, 2022).

The establishment of by-laws and local regulations (16.5%) is another critical strategy for rangeland management, particularly in preventing overgrazing, regulating land use, and ensuring equitable access to resources. However, the effectiveness of such regulations depends on community buy-in and enforcement mechanisms. In regions with limited livestock keeping, such regulations should also focus on encouraging the sustainable use of rangelands for both grazing and non-grazing purposes, such as biodiversity conservation and carbon sequestration. This dual focus aligns with global frameworks for rangeland management, which emphasize multi-functionality and the provision of ecosystem services.

The relatively low engagement in livestock farming (27%) and the lack of strategies explicitly addressing grazing management suggest a disconnect between local practices and the broader goals of rangeland management. Livestock serves as a critical component of rangeland ecosystems by facilitating nutrient

cycling, controlling vegetation growth, and buffering against crop failures during climate shocks (Belay & Lebeza, 2024; Grebner *et al*., 2021). Encouraging livestock keeping through targeted interventions such as improving access to grazing land, veterinary services, and credit facilities could help bridge this gap. Additionally, promoting practices like integrated crop-livestock systems could enhance the sustainable use of rangelands while providing diversified income streams for rural households.

Interestingly, 11.8% of respondents mentioned prayer as a strategy, reflecting the influence of cultural and spiritual beliefs on perceptions of climate change. While these beliefs can provide psychological comfort, they are insufficient as standalone solutions for the complex challenges of rangeland management. Integrating these cultural values with evidence-based strategies can foster holistic approaches that resonate with local communities while addressing global rangeland objectives (Azeez *et al*., 2024).

Promoting sustainable livestock practices, mixed farming systems, and participatory governance, rangeland management strategies can better align with global objectives, ensuring the long-term sustainability of these critical ecosystems.

Conclusion

This study highlights the significant role that local knowledge, communication strategies, and media platforms play in supporting rangeland management and enhancing community resilience to climate change in Lushoto, Tanzania. The findings indicate that while there is a high level of awareness about climate change among the community, gaps remain in understanding its long-term impacts. The predominant sources of climate information,

such as radio and television, were shown to be crucial in shaping community awareness and responses to climate challenges. The study also revealed that local communities rely heavily on traditional knowledge and community-driven strategies, such as reforestation and mass education, to manage rangelands and adapt to climate change. However, the integration of livestock management with rangeland conservation remains a challenge, indicating a need for a more holistic approach to sustainable land use.

The results accentuate the importance of improving access to reliable climate information, particularly through media channels that are most trusted by the community. Enhancing community education on climate impacts and adaptation strategies is essential for fostering resilience. Additionally, the study emphasizes the need for integrating local knowledge with modern scientific approaches to create more effective climate adaptation strategies that align with global sustainability goals. These challenges be transformed into opportunities for local communities to improve their capacity to manage rangelands sustainably and adapt to the changing climate.

Recommendations

This study highlights several key areas where interventions can significantly improve community resilience to climate change and enhance rangeland management. Firstly, improving access to reliable climate information through preferred media platforms, particularly radio and television, is crucial. These platforms have proven to be the primary sources of climate change information in the community. By developing more targeted and locally relevant communication strategies, stakeholders can ensure that climate-

related messages reach broader audiences, including those who may have limited access to other forms of media. This would empower communities to make more informed decisions about climate adaptation and resilience.

Secondly, integrating community-driven education programs on climate change impacts and sustainable rangeland management practices is essential. Local communities already recognize the importance of reforestation and education, but a more comprehensive approach that includes training on climate-smart agricultural practices, sustainable livestock management, and biodiversity conservation is necessary. This education should be designed to not only raise awareness but also provide practical solutions for mitigating the effects of climate change, thereby improving the adaptive capacity of rural households.

Lastly, fostering greater involvement of local communities in policy development and the management of rangelands will be vital for ensuring long-term sustainability. As the study shows, local governance structures, such as the establishment of by-laws and regulations, are key to managing rangeland resources effectively. However, their success depends on community participation and the implementation of policies that are not only scientifically sound but also culturally acceptable. Empowering communities through participatory governance and supporting policies that integrate climate change adaptation with sustainable land use practices will help achieve both local and global sustainability goals.

These recommendations are essential steps towards building resilience to climate change and promoting the sustainable management of rangelands in Tanzania.

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The effects of *Dichrostachys cinerea* (sickle bush) encroachment on herbaceous vegetation attributes in the grazing lands of Monduli district, Tanzania; Mguluka, E.E, Sangeda, A. Z. and Kimera S. I

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Abstract

Reports indicate a global increase in bush encroachment, transforming open grassy systems into dense thickets of woody plants. *Dichrostachys cinerea*, commonly known as sickle bush or *endundulu* by Maasai communities, is one of the encroaching shrubs in Africa that tends to form dense thickets, which are difficult to eliminate due to its invading ability. Recently, this plant has been observed to increase tremendously in the grazing lands of Monduli district, although little is known about its impact on herbaceous vegetation attributes in the district. This study aimed to assess the effects of this encroachment on herbaceous vegetation attributes in the grazing lands**.** Three villages (Mswakini chini, Mswakini juu and Naitolia) were purposively selected and involved in this study. Vegetation surveys and measurements, involving transect lines, plots, sub-plots, and

quadrats, were conducted in encroached and adjacent non-encroached sites in the grazing land of each village. A total of 72 (20m × 20m) plots were demarcated, and in each plot, there were five (5m × 5m) sub plots, from where the biomass readings were taken (using a pasture disc meter), vegetation cover estimated (using a pin quadrat), and individual species were identified and counted within 0.25m² quadrats. A total of 64 herbaceous species were obtained during this study, of which 37.5% were found only in non-encroached areas, 25% only in encroached areas, and 37.5% were common to both sites. The study found that encroached areas had significantly lower biomass (409.604 Kg DM/ha) and a lower cover of desirable vegetation (10%), with greater bare ground cover (56%) compared to non-encroached sites, which had 890.72 Kg DM/ha biomass, 48% desirable vegetation cover, and 19% bare ground cover. The condition of the grazing lands was generally poorer in encroached sites than in non-encroached sites. The findings of this study shows the negative effects of *Dichrostachys cinerea* encroachment on herbaceous vegetation attributes in grazing lands, which challenges sustainable livestock production. These results are relevant to local pastoralists, land managers, and policymakers in Monduli district and other similar areas facing sickle bush encroachment. It is recommended that strategies such as mechanical bush control, controlled grazing, and the use of prescribed burning be implemented, with the aid of advanced studies on the bush, active involvement and training of pastoralists to manage the bush effectively. Policymakers should provide frameworks and resources to promote sustainable forage production.

Keywords: encroachment, forage, grazing lands, herbaceous, sickle bush.

1. INTRODUCTION

Bush encroachment is described as the process of thickening and/or expansion of woody plant species in open grasslands and savannahs (Leitner *et al.,* 2018). This process, in turn, leads to a reduction in the grazing carrying capacity of the encroached areas (Eldridge *et al.,* 2011). It is important to consider how these changes directly affect grazing lands, especially in Africa. For instance, the loss of palatable plants (Ward, 2005) means less forage for livestock, which can seriously affect the livelihoods of pastoral communities.

This is a common problem affecting many grassland and savannah ecosystems worldwide (Mudzengi *et al.,* 2014). Bush encroachment primarily impacts arid and semi-arid rangelands, which make up about 40% of the world's pastoral lands (Huang *et al.,* 2018). These encroachments are increasing globally, transforming open grassy systems into dense thickets of woody plants (Gillson *et al.,* 2012; Parr *et al.,* 2012). This degradation of grasslands affects a vital primary resource for livestock production, especially in sub-Saharan Africa (de Klerk, 2004; Nesongano, 2018). Notably, although bush encroachment is a global issue, African rangelands are considered more susceptible (Osborne *et al.,* 2018).

Dichrostachys cinerea (sickle bush) is one of the many thorny, encroaching woody plants in Africa (Kraaij & Ward, 2006). In Swahili, it is known as *Mkula jembe* or *Mvunja shoka* (Orwa *et al.,* 2009), and among the Maasai in the Monduli district, it is

commonly referred to as *Endundulu* (TTPC, 2010). Its high encroachment potential leads to a significant increase in density making it invasive with negative effects on grazing value of invaded rangelands. Furthermore, the plant forms dense thickets that are challenging to eliminate (Roques *et al.,* 2001). Its invasive qualities are further supported by its ability to produce numerous viable seeds, regardless of the plant's age (Mudzengi *et al.,* 2014). Additionally, the high propagule pressure, aided by the longevity of the seeds (which can remain in the soil for up to five years), contributes to its resilience (Bussa & Shibru, 2020; Mudzengi *et al.,* 2014). Seed dispersal mechanisms are often supported by animals, such as goats, which feed on the pods (Tjelele *et al.,* 2012). The species also possesses a deep taproot and numerous lateral roots (US Forest Service, 2011), along with prolific reproduction from root suckers (Mudzengi *et al.,* 2014; Wakeling & Bond, 2007), facilitating rapid growth and natural regeneration (Zeid *et al.,* 2009; Bussa & Shibru, 2020). Furthermore, according to Blaser *et al.* (2014), the reproduction of this plant is likely influenced by its strong ability to fix nitrogen symbiotically. Sickle bush is tolerant to disturbances, thriving particularly well in overgrazed areas (Mudzengi *et al.,* 2014). Currently, there is a notable increase in sickle bush in the Monduli district, mostly attributed to factors such as fire suppression, climate change, shifts in land use practices, and overgrazing (Oba *et al.,* 2000; Smit, 2004; Tews & Jeltsch, 2004; Yusuf *et al.,* 2011). Its spread in Monduli district, where grazing lands are important for local communities, shows the need for strategies to manage it effectively without affecting the local communities.

There are conflicting reports on the effects of bush encroachment on the herbaceous plant community growing underneath. For

instance, some researchers have reported a positive impact on species richness and diversity (Belay *et al.,* 2013), while others have found a negative effect on understory vegetation variables (Mudzengi *et al.,* 2014). Yet others have reported a neutral impact on understory productivity (Belay *et al.,* 2013). Studies suggest that the impact of woody encroachment on herbaceous vegetation may depend on the type of encroacher species involved (Osborne *et al.,* 2018). This means the impact depends on many factors, such as the type of encroaching plant and local conditions. For this reason, studying this issue in Monduli district can help provide clearer answers.

There is a scarcity of information on the impacts of the encroachment of sickle bush in the Monduli district. Most of the people in this district are Maasai pastoralists, who depend on available grazing lands for their livestock (Homewood *et al.,* 2006). Therefore, the management of these lands is very important, and effective management requires appropriate information (Fuhlendorf *et al.,* 2012). This study aimed to assess the effects of sickle bush encroachment on herbaceous vegetation attributes in the grazing lands of Monduli district. Specifically, the study addressed the following questions (i). Does sickle bush affect the herbaceous species composition and diversity? (ii). Does sickle bush affect herbaceous vegetation cover, biomass production and desirability?

2. MATERIALS AND METHODS

2.1 The study area

This research was conducted in Monduli district, involving the grazing lands of three pastoral villages which are Mswakini juu, Mswakini chini and Naitolia. The study sites were purposively

selected due to the presence of sickle bush encroachment. Monduli district is found in Arusha region, Northern Tanzania located at latitude 3°20′S and longitude 36°15′E, mainly inhabited by Maasai pastoralists (97%) (Kimaro *et al.,* 2018) whose income mainly come from livestock keeping (Homewood *et al.,* 2006).

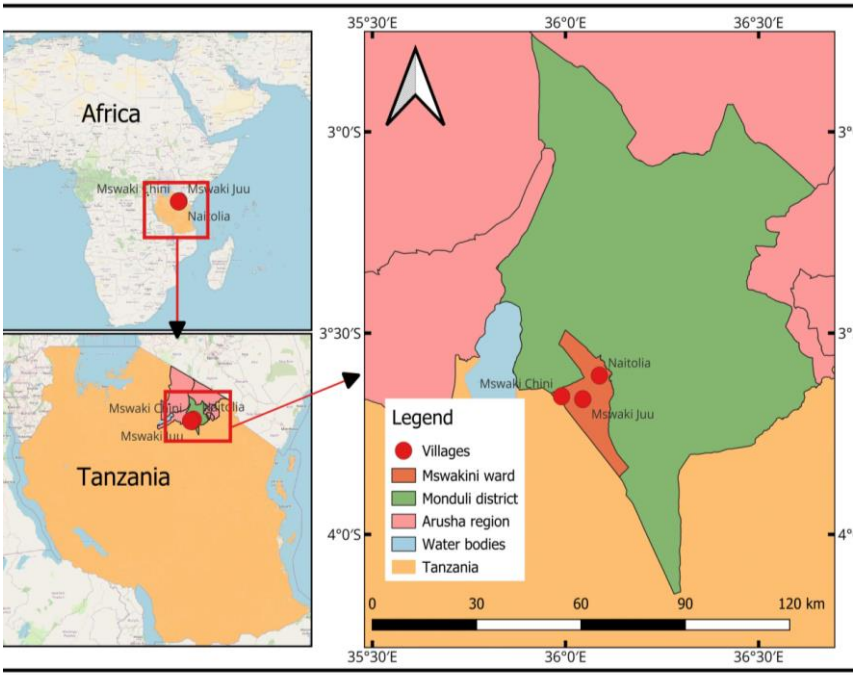

Figure 1: Map of the study area with selected study villages shown in red dots (source, Mguluka *et al.,* 2023)

2.2 Research design

The research design used was a comparative field-based vegetation survey employing a stratified systematic sampling approach, preceded by a reconnaissance survey that involved interviewing local people to identify the encroached and non-encroached areas in each village. Thereafter, sickle bush

encroached and non-encroached adjacent sites were selected in the grazing areas of each selected village. In each site three transect lines of 300 meters were laid out. On each transect, four 20 m × 20 m plots were pegged systematically on the ground. Then, 5 m ×5m sub plots were established at four corners and one at the centre of each plot making a sum of five sub-plots on each plot. The total number of plots in each village was 24 (12 from each site). The number of sub plots was 120 per village. The plots were established at 50 m from the roads to reduce the edge effects.

2.3 Data collection

Data were collected after the first rains in the district (from January – March, 2023) where most of the herbaceous plants were at their blooming stage which made easy the identification of different plant species.

2.3.1 *Species composition and desirability*

Species identification and counting were done in five 5 m × 5 m sub plots in each plot using 0.5m × 0.5m quadrat which were randomly thrown twice in each sub plot. All the herbaceous species inside these quadrants were identified and counted. Then, names, numbers, life spans, life forms, and desirability of the species by the grazing animals were recorded. Desirability was assessed based on the literature and local people's grazing experience. The species were grouped into four categories which are (i) highly desirable (plants frequently grazed and preferred by livestock due to their nutritional quality and palatability), (ii) moderately desirable (plants that are consumed by livestock but less preferred compared to highly desirable species),(iii) less desirable (plants that are grazed only under certain conditions,

typically when more preferred species are unavailable),(iv) undesirable (plants that are rarely or never grazed by livestock due to their low palatability, toxicity, or other factors that make them unsuitable for grazing).Species identification was done by using the plant Net mobile application. This application identifies plants by using visual recognition technology and the Tanzanian forage species identification guide which was developed by Kayombo *et al.* (2016). Species which were not identified in the field were collected (both pictures and samples) for further identification.

2.3.2 *Above-ground biomass*

Data for above-ground biomass was collected by using the pre-calibrated pasture disc meter in the sub plots. The calibration was done by relating the height of the disc and the biomass of samples that were randomly collected from each study site to cover the variations in the study site. A total of 30 samples were clipped from under the disc plate and their respective heights were recorded. The sample size was chosen to ensure the data captured the variation in vegetation across the sites while being manageable within the available time and resources. The choice of 30 samples was done after effective visual assessment and was influenced by logistical constraints, like the time required clipping, process, and analyzing each sample. Given the need to oven-dry samples, the selected samples were manageable within the study's available timeframe and resources without compromising the quality of the calibration process. The samples were then taken to Tanzania Agricultural Research Institute (TARI) Selian Laboratories located in Arusha City, where they were oven-dried at 70◦C for 48 hours. The final dry weights in Kilograms per hectare were plotted against the respective heights

in metres to obtain the best-fit equation which was then inserted in the pasture disc meter. The obtained equation for calibration was $Y=0.151X+0.0001(R^2=0.\ 54)$, where X is bulk height in metres.

2.3.3 *Vegetation Cover* (*cover of soil by plants*)

Vegetation cover was determined by using a pin quadrat which was inserted by six pins to purposively point to a specific cover type in each sub plot. Four cover categories are litter (dead plants cover or freshly fallen plant parts), bare ground (points with no plants or litter materials), desirable plants cover (points with plants that are edible and preferred by the grazing animals) and undesirable plants cover (points with plants that are not edible and not preferred by the grazing animals), were recorded depending on the point that the pins intercepted. Number of pins hitting each cover category was recorded for calculations of vegetation cover in percentages. To minimize bias, the pin quadrat was placed randomly within each sub plot, ensuring that all cover types had an equal chance of being intercepted. Additionally, the same procedure was consistently followed across all sub plots and data was collected by the same person to reduce variation in how the method was applied.

2.4 Data analysis

Data were checked for normality, outliers and homogeneity of variances before analyses as proposed by Zuur *et al.* (2010). Independent sample t-test at 95% confidence interval was used to test for significance differences in measured vegetation variables between encroached and non-encroached sites. Statistical analyses were performed using SAS software (SAS, 2014). Species composition in both encroached and non-encroached sites was

determined by using the following formula, which was described by Jawuoro *et al.* (2017), the formula uses the species' relative densities $\left(\frac{ni}{N}\right) X\ 100$

Where n_i is the number of individual species per plot and N is the total quantity of species within the same plot. Species diversity was determined by using Shannon-Wiener's diversity index (H′) as described by Jawuoro *et al.* (2017). This is calculated by using the following formula.

$$H^{'} = -\sum [\left(\frac{ni}{N}\right) X\ In \left(\frac{ni}{N}\right)]$$

Where N is the total number of individuals (or amount) for the site, n_i is the number of individuals of each species, and "ln" is the natural logarithm of the number.

Species richness (S) was calculated as the total number of species per plot.

Species evenness (E) was calculated as;

$$J = \frac{H'}{H\text{max-}}$$

Where; **H′** is Shannon Weiner's diversity index for the plot and Where Hmax is the natural log of species richness (S) =lnS

Additionally, Jaccard's similarity index was used to compare the species in encroached and non-encroached sites. This measure of similarity is known to be unbiased and strong compared to other similarity indices (Ludwing and Reyonlds, 1988). The Jaccard's similarity index between encroached (i) and non-encroached area (j), was calculated by the following formula: Sij $= \frac{a}{a+b+c}$

Where: a= the number of species present in both i and j
b= the number of species in i but not in j and
c= represents the number of species present in j but not in i. This coefficient has a value from 0 to 1, where 1 reveals complete similarity, a similarity index close to 1 indicates high similarity, an index close to 0 indicates low similarity and 0 indicates complete dissimilarity (Musese *et al.,* 2020).

3.0 RESULTS

3.1 Herbaceous species compositions

A total of 64 herbaceous species were observed during this study of which 16 (25%) were in encroached sites only, 24 (37.5%) were in non-encroached sites only, and 24 (37.5%) were common to both sites. The life forms of these plants were, 47 forbs (73%), 11 grasses (17%), 5 shrubs (8%) and I sedge (2%). Their life spans include 26 annuals (40.6%) and 38 perennials (59.4%). The Jaccard's similarity index for species between the two sites category was found to be 0.375.

3.2 Species' desirability comparison between encroached and non-encroached sites

The number of highly desirable and moderately desirable herbaceous species was higher in non-encroached sites. Species that were unique to encroached sites were all undesirable or less desirable. Majority of encountered plants were undesirable to livestock (36) which is 56%, 11 plants (17%) were less desirable, 9 (14%) were moderately desirable and only 8 plants (13%) were highly desirable as shown in Table 2. The common desirable herbaceous species observed in both sites were ***Cenchrus stramineum, Cynodon dactylon*** and ***Urochloa mosambicensis.***

Table 2: Comparison of species in terms of desirability between the two sites categories in Monduli Tanzania

Sites	Number of species				
	Undesirable	**Less desirable**	**Moderately desirable**	**Highly desirable**	**Total**
Encroached site	13	3	0	0	16
Non-encroached sites	12	4	4	4	24
Both sites	11	4	5	4	24
Total	**36**	**11**	**9**	**8**	**64**

Legend: the species found in both sites, were present in encroached and non-encroached sites

3.3 Herbaceous species richness, evenness and diversity

Plant species diversity, richness, and evenness were analyzed between the encroached and non-encroached grazing areas. The findings are summarized in Table 3. Shannon Wiener diversity index (H′) showed no significant difference ($p = 0.4418$) between the encroached areas (1.58 ± 0.07) and the non-encroached areas (1.66 ± 0.07). Similarly, species evenness did not differ significantly ($p = 0.2073$) between the encroached areas (0.75 ± 0.02) and the non-encroached areas (0.72 ± 0.02). However, species richness was significantly higher in the non-encroached areas (10.17 ± 0.5) compared to the encroached areas (8.78 ± 0.5), with a p-value of 0.0471, indicating a notable difference in the number of species present between the two categories.

Table 3: Plant species diversity, richness, and evenness between the two grazing areas categories in the study area, Monduli Tanzania

Parameters	Site Category		
	Encroached areas	Non-encroached areas	p-values
Diversity (Shannon Weiner's index (H′)	1.58±0.07	1.66±0.07	0.4418
Species evenness	0.75±0.02	0.72±0.02	0.2073
Species richness	8.78±0.5	10.17±0.5	0.0471

3.4 Aboveground plant biomass

The mean aboveground plant biomass in the study area varied significantly between the encroached and non-encroached sites. Encroached sites had a substantially lower mean biomass compared to the non-encroached sites ($p < 0.0001$) as shown in Figure 3.

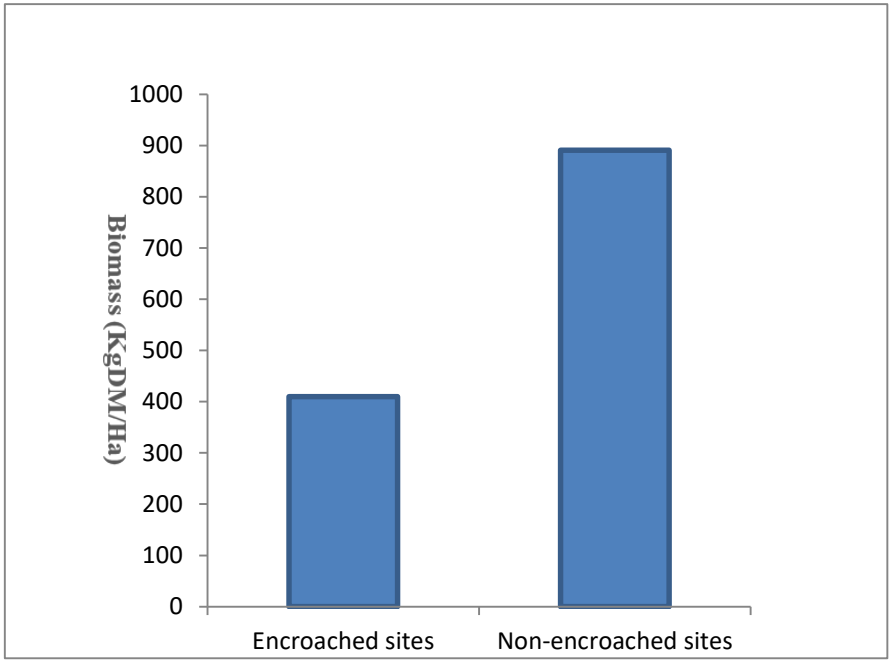

Figure 2: Mean aboveground plant biomass ($kgDmHa^{-1}$) among

sickle bush encroached and non-encroached sites in Monduli Tanzania

3.5 Herbaceous plants cover, litter cover and bare land

The results indicate that the percentage of bare soil was significantly higher and the desirable plant cover was significantly lower in encroached sites compared to non-encroached sites. Litter (%) and undesirable plant cover (%) were statistically not significant (Table 4). When considering cover (%) in specific sites, encroached sites had higher percentages of bare soil (55.38%) compared to other cover categories. In non-encroached sites, desirable plant cover was higher (approximately 48%) compared to other cover categories.

Table 4: Live plant cover, dead plant cover (litter), and bare land cover of the two site categories in Monduli Tanzania

Cover type	**Site Category**		**p-values**
	Encroached sites	**Non-encroached sites**	
Desirable plants cover (%)	10±2.74	48±2.74	<.0001
Litter cover (%)	25±3.05	26±3.05	0.7200
Undesirable plants cover (%)	9±1.65	7±1.65	0.2787
Bare land (%)	56 ±3.1	19±3.1	<.0001

Legend: For desirable plants percent cover; 76-100=Excellent, 51-75=Good, 26-50=Fair, 1-25=Poor 0=Very poor. Vice versa is true for percentage bare land

4. DISCUSSION

The presence of sickle bush changes the species composition in terms of desirability of species due to the presence of highly and moderately desirable species that were only found in the non-encroached sites and there were none unique to encroached sites. These species included *Eragrostis supebra*, *Panicum infestum*, *Digitaria ciliaris*, *Neonotonia wightii*, and *Dactyloctenum aegyptium* among others (Appendix 1). Among the 64 species that were identified during this study, 24 (38%) were not found in the encroached sites. Of all 16 species that were unique to encroached areas, 13 (81%) were undesirable and 3 (19%) were less desirable plants. This shows that sickle bush encroachment causes a reduction of desirable plants. These results agree with what has been observed by Yassin (2019) who reported fewer desirable plants in bush-encroached areas. Presence of many undesirables and less-desirables in encroached sites shows the changes in the nutritive quality of the plants growing under the bushes. These plants are mainly shade tolerant (Pang *et al*., 2017). According to Koerner and Collins (2014), the presence of many undesirable forbs and grasses in the grazing lands is an indicator of land degradation. Therefore this change in species composition may be a result of land degradation that has been brought about by the presence of *Dichrostachys cinerea*.

This degradation is further highlighted by the low similarity in species composition between encroached and non-encroached sites. This shows that there is a fundamental change in species composition within the study area (Musese *et. al.,* 2020). The low similarity between encroached and non-encroached sites might be due to the vigorous growth habit of sickle bush and its ability to alter the surrounding environment (Randle *et al.,* 2018).

Therefore, with time if this plant is not managed, more changes in species composition within the area are expected to occur.

The changes in species composition are accompanied by reductions in species richness; a key indicator of grazing land health (Wagg *et al.,* 2022). Species richness was significantly lower in the encroached sites than in the non-encroached sites, similar to what has been reported by Bussa and Shibru (2020). This may be due to the competitive advantage sickle bush has over other plants in terms of important resources of light, water and space. Also, its vigorous growth habit and extensive root system enable it to grow densely over other plants co-occurring with it (Mudzengi *et al*., 2014). This finding highlights the adverse effects of sickle bush encroachment which likely reduce the establishment of less competitive species. Bush encroachment can lead to soil compaction, reduced seed germination of herbaceous plants, and habitat degradation, which collectively diminish species richness (Christian, 2010). In contrast, the non-encroached sites, likely experiencing lower grazing pressure, provide more favorable conditions for a diverse array of plant species to thrive.

Beyond species richness, the encroachment also significantly affects aboveground biomass, a critical component of grazing systems. The findings revealed that mean aboveground plant biomass was significantly lower in encroached sites compared to non-encroached sites. This suggests that sickle bush encroachment directly reduces the availability of forage, which is vital for maintaining healthy grazing systems. This reduction in biomass has important ecological and management implications for the grazing systems. The reduction in biomass production may

be due to the strong shading effect that is brought about by the shrubby growth form of sickle bush (Randle *et al.,* 2018). The results align with this finding, highlighting how shading by sickle bush may limit the growth of herbaceous plants, thus diminishing their biomass production. Shading reduces photosynthetically active radiation for the herbaceous layer below bushes and subsequently reduces the growth of these plants in the grass layer (Eldridge *et al.,* 2011). Also, the increased competition for nutrients between the woody plants and herbaceous forages (Mudzengi *et al.,* 2014) likely intensifies the reduction in biomass in encroached sites. Biomass production determines the amount of forage available for the livestock (Abule *et al.,* 2007). This reduced biomass production significantly limits the forage supply for grazing animals, which may compromise livestock productivity and grazing management strategies. From an ecological point of view, reduced aboveground biomass may hinder important ecosystem functions such as carbon sequestration, soil stabilization, and nutrient cycling (Tessema *et al.,* 2012). These ecosystem functions are essential for the overall health of the rangeland, and the reduction in biomass caused by bush encroachment may further promote environmental degradation. Small above-ground biomass yield in sickle bush encroached areas has also been reported by Smit (2004), Randle *et al.* (2018), and Bussa & Shibru (2020), which emphasizes the broader concern regarding the impacts of bush encroachment on land productivity.

The distribution of vegetation cover types further illustrates the impacts of bush encroachment on grazing lands. There were more desirable plants than other cover categories in non-encroached sites, which may be due to lack of competition for soil nutrients

and water (Mudzengi *et al.,* 2014), absence of allelochemicals (Carmenate, 2019), absence of shade effect and other disturbances from an encroacher. The same reasons may explain the low percentages (7% and 19% respectively) of non-desirable plants and bare lands in the non-encroached sites (Table 4). The small bare ground and non-desirable plants cover with a high desirable plants cover in non-encroached sites, has also been reported by Bussa and Shibru (2020). Moreover, the percent of bare ground cover and desirable plants cover are used in assessing the range condition (Sangeda and Maleko, 2018). Therefore, condition was generally poor in the encroached sites than in non-encroached sites as indicated by higher percent (56%)of bare land cover and smaller percent of desirable plants cover(10%) in these encroached sites (Table 4).

The high percentage of bare lands in encroached sites may be due to high sickle bush demands of water, nutrients and light, causing the death of herbaceous plants growing underneath similar to the reports by Angassa and Oba (2007). Additionally, according to Christian (2010), the water consumption and evapotranspiration rates are higher in woody plants (in this case sickle bush) than in herbaceous plants. Therefore, encroached soils tend to be dry and less nutritive. This leads to the death of many herbaceous plants and the creation of bare grounds. Both desirable and undesirable plant cover was also lower which may be due to large space being occupied by an encroacher.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Sickle bush is a native plant which can suppress other plants as revealed through the findings of this study. It affects the majority of herbaceous vegetation attributes including, desirable vegetation

cover, above-ground biomass production and species richness. These effects of sickle bush on the herbaceous plants if not controlled, will in the long term affect the carrying capacity of the grazing lands of the Monduli district and make them more susceptible to invasion by other invading plants. These findings are relevant to local pastoralists, land managers, and policymakers in Monduli district and other similar areas facing bush encroachment. It is recommended that strategies such as mechanical de-bushing, controlled grazing, and the use of prescribed burning be implemented, with the aid of advanced studies on the bush, active involvement and training of pastoralists to manage the bush effectively. Policymakers should provide frameworks and resources to promote sustainable forage production.

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Appendix 1: List of plant species recorded during the vegetation survey in the study area, Monduli, Tanzania

S/n	*spp* name	Growth form	Life span	Desirability	Frequency of occurrence	
					Encroached sites	Non-encroached sites
1	***Acalypha indica***	forb	annual	undesirable	0	41
2	***Acanthospermum hispidum***	forb	annual	undesirable	0	36
3	***Achyranthes aspera***	forb	annual	less desirable	0	51
4	***Albuca bruteata***	forb	perennial	undesirable	0	2
5	***Allium spp***	forb	perennial	undesirable	0	2
6	***Alternanthera laguroides***	forb	perennial	undesirable	109	0
7	***Amaranthus muricatus***	forb	annual	undesirable	13	189
8	***Amaranthus viridis***	forb	annual	less desirable	2	0
9	***Arachis hypogea***	forb	annual	less desirable	0	11
10	***Arachis glabrata***	forb	perennial	highly desirable	0	3
11	***Aristida adoensis***	Grass	perennial	less desirable	86	790
12	***Asparagus officinalis***	forb	perennial	less desirable	2	2
13	***Bidens pilosa***	forb	annual	Less desirable	0	2
14	***Bothriochloa pertusa***	Grass	perennial	Moderately desirable	16	632
15	***Brachiaria deflexa***	Grass	perennial	highly desirable	70	470
16	***Cenchrus stramineum***	Grass	perennial	highly desirable	735	1854
17	***Cerastium fontanum***	forb	annual	undesirable	3	0
18	***Commelina spp***	forb	perennial	Moderately desirable	2	164
19	***Cucumis sativus***	forb	annual	undesirable	0	1
20	***Cynodon dactylon***	Grass	perennial	Moderately desirable	81	125
21	***Cyperus rotundus***	Sedge	perennial	less desirable	12	2
22	***Dactyloctenum aegyptium***	Grass	perennial	Moderately desirable	0	42
23	***Desmodium triflorum***	forb	annual	highly desirable	4	495
24	***Digitaria ciliaris***	Grass	perennial	Moderately	0	16

				desirable		
25	***Dipcadi montanum***	forb	perennial	undesirable	5	0
26	***Dyschoriste spp***	forb	perennial	undesirable	346	181
27	***Ecballium elaterium***	forb	perennial	undesirable	2	0
28	***Elephantopus mollis***	forb	perennial	undesirable	22	0
29	***Eragrostis minor***	Grass	annual	Moderately desirable	15	31
30	***Eragrostis superba***	Grass	perennial	Moderately desirable	0	15
31	***Frankenia pulverulenta***	forb	annual	undesirable	2	0
32	***Galeopsis angustifolia***	forb	annual	undesirable	3	133
33	***Gnaphalium spp***	forb	annual	undesirable	0	1
34	***Gomphrena celesiodes***	forb	perennial	undesirable	3	0
35	***Gomphrena globosa***	forb	annual	less desirable	0	31
36	***Grewia kakothamnos***	shrub	perennial	less desirable	2	0
37	***Heliotropium indicum***	forb	annual	undesirable	0	4
38	***Hypericum humifusum***	forb	annual	undesirable	0	2
39	***Ipomoea mombassana***	forb	perennial	undesirable	5	12
40	***Justicia calyculata***	forb	perennial	undesirable	4	68
41	***Lantana camara***	shrub	perennial	undesirable	5	0
42	***Launaea cornuta***	forb	perennial	Moderately desirable	0	2
43	***Metha longifolia***	forb	perennial	undesirable	0	32
44	***Macroptilium atropurpureum***	forb	perennial	Highly desirable	0	2
45	***Misopates orontium***	forb	annual	undesirable	2	0
46	***Mollugo nudicaulis***	forb	annual	undesirable	35	204
47	***Mollugo verticillata***	forb	annual	undesirable	173	792
48	***Myosotis verna***	forb	annual	undesirable	0	3
49	***Neonotonia wightii***	forb	perennial	highly desirable	0	17
50	***Ocimum spp***	forb	annual	undesirable	0	8
51	***Panicum infestum***	Grass	perennial	highly desirable	0	392
52	***Satureja hortensis***	forb	perennial	undesirable	3	2

53	***Senna obsitufolia***	Shrub	perennial	undesirable	92	14
54	***Sida spp***	forb	perennial	Less desirable	46	57
55	***Solanum Incanum***	shrub	perennial	undesirable	34	40
56	***Solanum nigrum***	shrub	perennial	undesirable	2	0
57	***Sphagneticola trillobata***	forb	perennial	undesirable	0	4
58	***Tapinanthus belvisii***	forb	perennial	undesirable	2	0
59	***Tephrosia purpurea***	forb	perennial	undesirable	187	0
60	***Tribulus terrestris***	forb	annual	undesirable	76	1156
61	***Trifolium repens***	forb	annual	Moderately desirable	23	4
62	***Urochloa mosambicensis***	Grass	perennial	highly desirable	1252	3755
63	***Zinnia haageana***	forb	annual	undesirable	4	0
64	***Zornia glochidiata***	forb	annual	less desirable	408	0

Influence of finishing strategies on carcass composition and meat quality characteristics of Boran crossbred bulls; Maro et al.

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ABSTRACT

This study was carried out to evaluate the effects of finishing practices and slaughter periods on carcass composition and quality of meat from Boran crossbred bulls. Fifty-four (2.5 – 3 years old, 205 ± 1.89 kg initial body weight) bulls were assigned/subjected to three different finishing practices; 18 bulls were on sole grazing (P1), 18 bulls were on supplementation after grazing (P2) and 18 bulls were kept on feedlot (P3). After that, 9 bulls (3) from each practice in the same finishing period were slaughtered at 45 days-S1, 60 days-S2, and 75 days-S3. Carcass and non-carcass components and composition were evaluated from slaughtered bulls. Carcass pH was measured at 24 h and 48 h post-slaughter at the LTL muscle and cooking loss and shear force values were evaluated for 4, 8, 12, and 16 days aged meat. The findings showed that finishing practice and the slaughter

period significantly (P<0.05) influenced the internal fat, heart-lung-liver, carcass length, and chest depth. The fat thickness, internal fat, Heart-lung-liver, four feet, gastrointestinal tract (GIT) full and empty were affected by finishing practices with bulls on P3 registering the highest fat thickness, internal fat and heart-lung-liver followed by P2 and P1 in that order. Meat pH (5.21-5.49) was similar (P>0.05) in finishing practices and slaughter periods. Carcass length, chest depth, hide, git empty, tenderness, and a colour significantly (p<0.05) interacted by finishing practice and slaughter period. the L* colour intensities were higher in bulls slaughtered at S3 (45.96) than in S2 bulls (41.29) and a* values vary significantly (p<0.05) with finishing practices. The Boran crossbred bulls showed improved tenderness with bulls on P3 (41.71N) having the lowest shear force values followed by P1 and P2 (44.41N and 45.4 N) with similar values. overall, bulls on P3 have heavier non-carcass components and better meat quality properties than those on P1 and P2. In conclusion, carcass components and meat quality characteristics were better in feedlot-finished bulls at 75 days of slaughter and aged 12 days. For increased beef quality, livestock farmers are encouraged to finish feedlot bulls for 75 days and age meat for 12 days. The findings of this study need further investigation into the influence of finishing strategies on fatty acid content and consumer health perceptions.*

***Keywords*:** Boran crossbred, meat quality, finishing practice, slaughter period,

1. INTRODUCTION

Globally, there is a growing demand for quality meat and meat products mainly attributed to, and driven by the change from cereal protein foods to animal protein foods and hasty economic

growth due to alarmingly positive population shifts (UN, 2019). According to the Ministry of Livestock and Fisheries 2024 budget in Tanzania, beef production supplied approximately 74 % of red meat to Tanzanians (URT, 2024) with 80%, 14%, and 6% sourced from agro-pastoralists, pastoralists, and formal beef farms respectively (URT, 2015). These producers mainly keep indigenous breeds of cattle solely raised on grazing practices. Finishing cattle in low-input practices delayed the attainment of slaughter weight (275 kg) and consequently produced a low carcass weight (137.5 kg) (URT, 2015) and tough meat. However, practicing improved finishing practices such as supplementation of grazing animals and feedlots could improve the yield and meat quality attributes, thus, meeting the increased prime beef demand.

Animals finished in feedlots and on supplementation with rich-energy diets improve performance, carcass composition, and quality traits by supporting fat deposition and producing more tender meat than grass-finished cattle (Mwilawa, 2012; Mushi, 2020). Tenderness is one of the most essential meat quality properties highlighted by modern markets and is mainly influenced by the quantity and type of fat contained in the meat (Felderhoff *et al.,* 2020). Meat quality characteristics are inherently influenced by animal age, species (*Bos indicus Vs Bos taurus*), breed, sex, muscle fiber type, connective tissue contents, and the type and location of the muscle. Other imperative elements that are external to the animal and influence meat quality traits include the type and quantity of feed, days spent on finishing practice (Sinan *et al.,* 2018), pre-slaughter handling, slaughter method, the post-slaughter pH and temperature, ageing duration, the colour of the meat and fat, and flavour (Wyrwisz *et al.,* 2012)**.**

In order to improve and increase meat quality, it is important to improve the conditions of animals other than indigenous breeds such as Boran and their crossbreds, reared under grass grazing system which is often characterized by low growth rate and production of low-quality products. Feedlot and combination of grazing with concentrate supplementation are the finishing strategies known to improve growth rate, and profitability and shorten the time to attain market weight. Previous studies (Shirima *et al.,* 2013; Neto *et al.,* 2012; Asizua *et al.,* 2017) show that there is a linkage between the animal finishing period, finishing practice, and the quality of meat produced which can be elucidated by a series of biological, biochemical, and biophysical mechanisms. The influence of *ad libitum* supply of high-energy diets during finishing animals in feedlots and supplementation has been reported to result in the production of heavier carcasses and higher levels of subcutaneous and intra-muscular fats (Mwilawa, 2012); (Asimwe *et al.,* 2015)]. Consequently, the meat produced is related to low pH, slow cooling rate and meat tenderness (Mushi, 2020). Nevertheless, a slow cooling rate leads to a more rapid post-slaughter glycolysis rate, leading to a rapid pH decline (Shirima *et al.,* 2013); (Asimwe *et al.,* 2016). In feedlots and supplementing practices, prolonging the finishing duration results in heavier carcasses, increases water holding capacity, accelerates post-slaughter glycolysis, lowers pH, and increases tenderness in cattle (Mushi, 2020).

Although much has been researched and documented on feeding rich energy diets to finishing cattle, limited information is available on the period of finishing on the carcass composition and attributes of meat quality of finished Boran crossbred cattle. Therefore, the present study aimed at establishing the length of

finishing by either feedlot or grazing and supplementation on the carcass composition and meat quality attributes of Boran crossbred cattle.

2. MATERIAL AND METHODS

2.1 Description of the study area

The feeding study was carried out at Kidago farm and animals were slaughtered at Mgolole Agro-processing Co. Ltd. Kidago farm and Mgolole Agro-processing Co. Ltd are located in Morogoro district in eastern Tanzania (6.77ºS and 37.68 ºE) and 509 to 600 km above sea level. They receive temperatures ranging between 18.7ºC - 29.2ºC and 972 mm of mean annual rainfall. The meat quality analyses were conducted at the Department of Animal, Aquaculture, and Range Sciences (DAARS) laboratory of the Sokoine University of Agriculture (SUA) situated between 6°- 7°S and 37° - 38°E and lie on the foot of the slopes of Uluguru Mountains.

2.2 Experimental design and treatments

A total of 54 bulls (205 ± 1.89 kg initial body weight, aged 2.5- 3 years) were distributed evenly across three treatment groups in a 3*3 factorial arrangement, comprising grazing alone (P1) as a control group, grazing with concentrate supplementation (P2), and feedlot (P3), with 18 animals per practice. grazing only (P1) The slaughter periods were on 45th day (S1), 60th day (S2), and 75th day (S3) of the experiment.

2.3 Management of Experimental Animals and Sampling

The bulls were ear-tagged for identification, estimated for initial body weight using a measuring band (RONDO® a combined measuring tape for cattle and pigs), and injected with ivermectin (1%) for control of endo and ectoparasites. The bulls had fifteen

days of grazing on natural pastures for backgrounding. Bulls were randomly allocated to the different feeding practices with a 10-day adaptation period for experimental animals to be familiarized to experimental settings and diet prior to data collection. A total of 27 bulls were randomly sampled out of 54 and slaughtered at different periods S1, S2, and S3. In each slaughter period 9 bulls, 3 from each practice were slaughtered and carcass composition and meat quality characteristics were evaluated.

2.4 Source of experimental feeds and feeding

The experimental diet (ED) was formulated from 36 % Hominy feeds, 18% cassava meal, 6 % rice polishing, 38% sunflower seed cake, 1.5% mineral, and 0.5% salt and contained 13.53 MJ ME/kg DM and 147g CP kg/DM. Ingredients for ED were all purchased from local Agricultural input suppliers in Morogoro Municipality. The ED was fed *ad libitum* to bulls on P3 and P2, hay and ED were weighed and provided daily in the morning at 0800 hrs and 1600 hrs for P3 (10% refusals) and once for P2 at 1600 hrs after grazing. The adjustment of the amount of feed offered was done every seven days after live weight measurement and this was undertaken till the study ended.

2.5 Slaughter procedure and measurements

Prior to slaughter, live weight of the bulls was estimated using a measuring band (RONDO®) for three days consecutively, where the average value was taken as the final body weight. In each slaughter period, nine bulls were trucked at a speed of 30 km per hours to Mgolole Agro-processing Co. Ltd located 30 km from Kidago farm for slaughter. On arrival, bulls were fasted for 24 hours with free access to fresh drinking water. Thereafter, the bulls were weighed to obtain the slaughter weight. The animals were stunned with a captive bolt pistol to render

them unconscious and the neck was humanely severed at the jugular and carotid vessels using a sharp knife following Halal rituals. After that, the slaughtered bulls were suspended by their hind legs on an overhead rail system using a hoisting chain for bleeding, flaying, and evisceration. The head was removed at the atlas joint, while the flaying was done starting from the legs and moving up until the whole animal body was unhide. The fore and hind feet were removed at the carpal and hock joints respectively, then the stomach, intestines and the pluck were removed through the vertical midline incision of the abdominal cavity.

Non-carcass components, which included the head, feet, hide, tail, external organs and small intestines, pluck (the heart, liver, lungs, and trachea), and full and empty digestive tract were weighed in kilograms using a spring weighing scale certified by Weight and Measurement Agency (WMA) (200 kg capacity) and recorded. The gastrointestinal tract (GIT) was weighed while full then emptied, washed off its fillings, and lastly re-weighed to get the weight of the empty GIT within 45 to 60 minutes of slaughter. Gastrointestinal tract (GIT) fill was calculated as the difference between the full and empty GIT weights. The internal fat depots (IFD) were weighed using an electronic weighing scale (10 kg capacity) and recorded.

2.6 Carcass linear measurements

The dressed carcasses were longitudinally sawed into two halves using a hand saw and weighed within 45 minutes post-slaughter and the left half was used for linear measurements. Using a tailor measuring tape the carcass length was measured straight from the anterior edge of the first rib to the caudal end of the pubic symphysis. The hind leg length, chest depth, and hind leg circumference were also measured. The fat thickness was

measured by using a ruler on the 10th rib. The 10th rib provides a standard, consistent location across various animals representing a good average of the fat distribution across the body. This uniformity is necessary to draw insightful comparisons between animals. The carcasses were left at room temperature for 12 hours and then transferred to a chilling room 0℃ set.

Twelve hours post-slaughter, the 6th rib joint from the left side half carcass was extracted by a straight cut perpendicular to the vertebral axis from the middle of each intercostal space to the vertebrae. After that, each excised rib was weighed vacuum-packed in polythene sheets. Similarly, the *Longissimus thoracis et lumborum* (LTL) muscle was excised from rib 7 up to the 10th rib, weighed, vacuum packed in polythene sheets and together with ribs were transported to DAARS-SUA, 12 km away from Slaughter facility, in a cool box for detailed physicochemical analyses (pH, colour, cooking loss, and tenderness). Twenty-four hours post-slaughter all the ribs 6th were re-weighed individually and dissected into muscle, fat, and bone tissues, and each component was weighed and expressed as a percentage of the whole joint weight referred to as the carcass composition.

2.7 Determination of muscle pH

The pH of the meat was measured in the laboratory at 24 hrs and 48 hrs post-slaughter from LTL muscle kept at 4 °C. Briefly, 100 g sampled from each LTL muscle was thoroughly grounded using a food grinder blender machine Europe strong (ES-2L model), and the fined ground meat was then mixed with 150 ml of distilled water, stirred vigorously to obtain the solution. Thereafter, the calibrated pH meter Hanna Instruments HI-98127 was partially immersed into the solution and the pH was read and recorded.

2.8 Determination of cooking losses, meat colour, and Warner-Bratzler Shear Force (WBSF)

Five portions of the LTL muscle were labeled (LTL0, LTL4, LTL8, LTL12, and LTL16) aged for 4, 8, 12, and 16 days were used to determine both cooking loss and shear force following the procedure described in the previous study [16]. The LTL muscle labeled (LTL0) was used to measure meat pH at 24 and 48 hours post-slaughter. Meat color was measured on the same portions a day zero at thaw and at 4, 8, 12, and 16 days of aging on the fresh-cut surface of LTL muscle using Minolta Chroma meter CR-400 (Konica Minolta Inc. made in Japan) based on CIE L* a*b* system, where L* – relative lightness; a* – relative redness; b* – relative yellowness. For the CL determination, the samples were weighed (W1), labeled, and vacuum-packed, after each aging time. This happened after overnight thawing of (4 °C) LTL muscle samples. Several samples of LTL muscles of different practices were then heated constantly at 70°C for 1 h in a water bath. Samples were cooled under running tap water for 2 hours. The samples were removed from plastic bags, wiped with clean cotton gauze, and then weighed (W2) and CL was calculated as the difference between W1 and W2. During tenderness analysis, the same LTL muscle samples cooked for CL examination were used. Six rectangular-shaped blocks were cut into 1 cm^3 cubes parallel to the direction of the muscle fibers. Then each block was sheared through two times perpendicular to the muscle fiber direction with a triangular-shaped shear blade attached to the Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany) set with 1 KN load cell, with a crosshead speed of 200 mm/min. The average of 12 shear values per sample of LTL from each treatment was considered the peak WBSF value for that sample.

2.9 Statistical analysis

Data for non-carcass components, carcass composition, and meat quality traits were analyzed using the General Linear Model (GLM) procedures of SAS (Version 9.2; 2004) (SAS, 2004). Meat quality parameters (Colour, pH, CL, and WBSF) on finishing practices and slaughter periods, ageing time, and their interactions were regarded as fixed effects and each slaughtered animal was considered as random effects. The least-square means differed significantly at $p<0.05$ and were separated by the PDIFF option of the GLM model of SAS.

Model: $Yijk = \mu + Ti + Pj + Sk + TPij + TSik + PSjk + eijk$

Where Yijk= Measurement of unit meat sample of an individual animal; μ = Overall mean; Ti= fixed effect of finishing practice (i=grazing alone, concentrate supplementation and feedlot); Pj=fixed effect of slaughter periods (j =45, 60 and 75 days); Sk= Fixed effect of aging time (k = 4,8,12 and 16 days for CL and WBSF and k= 24, 48h for pH); TPij = Interaction effect of finishing practice and slaughter periods; TSik= Interaction effect of finishing practice and aging time; PSjk = Interaction effect of slaughter periods and aging time; eijk= random residual error referring to the experimental animal subjected in the ith finishing practice jth slaughter periods and kth aging time as fixed effects.

3. RESULTS

3.1. Carcass measurements and composition

The effects of finishing practice and slaughter period on carcass measurements and composition are summarized in Table 1. Finishing practice and slaughter period significantly ($p<0.05$) affected carcass length and chest depth. Bulls on P3 had the highest ($p<0.05$) fat thickness followed by P2 and the lowest on

P1. An interaction effect ($p<0.05$) between finishing practice and slaughter period was observed for the carcass length and chest depth sizes. Bulls on P2 had similar or slightly higher growth rates at an early stage of finishing 45 days (S1) than those on P3, leading them to attain relatively equal carcass length at the last stages of finishing (S3). Bulls on P1 had a slightly high growth rate at the early stages of S1 and consistently low growth from S2 to S3 leading them to produce small carcasses. Bulls on P1 had marked high and consistent chest size at early stages of feeding and moderate growth at late stages leading them to attain slightly higher chest size than those on P2. Bulls on P3 had high and consistently increasing chest size making them attain the widest chest. The weights of dissectible muscle, fat, and bone were neither influenced by finishing practice nor the slaughter period.

Table 1. Lsmeans ± SEM for carcass measurements and tissue composition of Boran crossbred bulls used in the experiment

Parameter	Finishing practices					Slaughter periods					FP*SP
	P1	P2	P3	SEM	P-value	S1	S2	S3	SEM	P-value	P-value
Carcass length (cm)	107.71^{c}	147.25^{b}	164.01^{a}	4.71	<0.0001	133.41^{b}	129.65^{b}	155.91^{a}	4.58	<0.0042	<0.0209
Hind leg length (cm)	75.86	76.61	79.56	1.33	<0.1155	79.25	77.58	75.20	1.3	<0.0916	<0.1725
Hind leg circumference (cm)	101.51	99.11	103.04	3.71	<0.6945	101.74	104.73	97.18	2.94	<0.2917	<0.4516
Chest depth (cm)	35.38^{b}	37.07^{b}	42.43^{a}	1.05	<0.0020	36.77^{b}	37.16^{b}	40.94^{a}	1.02	<0.0203	<0.0206
Fat thickness (cm)	0.59^{b}	2.10^{a}	2.34^{a}	0.17	<0.0002	1.73	1.78	1.52	0.50	<0.4528	<0.5746
Proportions in carcass composition (%)											
Muscle (kg)	46.45	56.05	55.25	6.89	<0.5308	50.34	57.41	49.99	6.70	<0.6350	<0.7126
Fat (kg)	11.31	8.17	10.61	2.60	<0.6417	8.37	9.94	11.78	2.53	<0.5576	<0.3240
Bone (kg)	42.36	35.82	34.28	7.29	<0.6727	41.39	32.88	38.19	7.12	<0.6550	<0.9818

P1- grazing alone, P2–grazing plus supplementation, P3-full feedlot

*a-c Means with different superscripts within a row differ significantly (P<0.05). SEM = standard error of the mean, S1- 45 days, S2- 60 days, S3- days FP*SP- interaction effect between finishing practices and slaughter periods*

3.2. Non-carcass components measurements

The results of non-carcass components of Boran crossbred bulls finished under various practices and slaughter periods are presented in Table 2. Finishing practices influenced ($p<0.05$) the heart-lung-liver, internal fats, GIT full, GIT empty, and four feet weight of the finished bulls. A quantitative interaction ($p<0.05$) between finishing practice and the slaughter period was observed on the weights of hides and GIT empty. In the early finishing periods bulls on P2 had slightly lower hides weight but consistently increased than those on P3, leading them to attain lighter hide weight at the S3 than P3 bulls. Bulls on P1 had the highest hide weight at the early stages of feeding and gently reduced in the late phases S2 and S3 of slaughter. Bulls on P1 and P2 had similar GIT empty weights at the first phase of finishing and P2 slightly increased the GIT empty at late phases of finishing leading P2 to attain a higher GIT empty weight than those on P3. Bulls on P2 and P3 that were slaughtered 75th day had the comparable ($p>0.05$) weight of GIT empty. Head, hide, internal fats, and heart-lung-liver weights were significantly ($p<0.05$) influenced by slaughter periods.

Table 2. Lsmeans ± SEM for non-carcass components of Boran crossbred bulls used in the experiment.

Parameter	Finishing practices			Slaughter periods						FP* SP	
	P1	P2	P3	SEM	P-value	S1	S2	S3	SEM	P-value	P-value
Head (kg)	14.37	15.73	15.51	1.48	<0.7647	11.66^{b}	17.36^{b}	16.59^{ab}	1.44	<0.0308	<0.8138
Hide (kg)	20.22	18.94	21.21	0.92	<0.1970	17.48^{b}	22.91^{a}	19.98^{a}	0.90	<0.0062	<0.0240

Internal fat (kg)	0.49[c]	1.52[b]	2.26[a]	0.18	<0.003	1.10[b]	1.83[a]	1.33[b]	0.17	<0.0341	<0.1013
Heart-lung-liver (kg)	9.87[b]	10.96[a]	11.91[a]	0.44	<0.0210	9.94[b]	11.69[b]	11.09[ab]	0.43	<0.0371	<0.1078
Four feet (kg)	7.98[b]	8.24[b]	9.49[ab]	0.39	<0.0314	8.45	8.97	8.29	0.38	<0.3837	<0.2701
Tail (kg)	0.81	0.89	1.03	0.07	<0.0902	0.87	1.04	0.82	0.07	<0.0858	<0.8207
GIT full (kg)	51.03[b]	55.51[b]	61.64[ab]	2.49	<0.0334	54.27	58.64	54.95	2.42	<0.1432	<0.5393
GIT empty (kg)	16.69[c]	19.31[b]	20.78[ab]	0.81	<0.0142	18.33	20.24	18.21	0.78	<0.1432	<0.0136
GIT content (kg)	34.34	36.20	40.54	2.03	<0.0975	35.94	38.40	36.74	1.99	<0.6359	<0.1425

P1- grazing alone, P2–grazing plus supplementation, P3-full feedlot

*a-c Means with different superscripts within a row differ significantly (P<0.05). SEM = standard error of the mean, GIT-gastro-intestinal track, S1- 45 days, S2- 60 days, S3- days FP*SP-interaction effect between finishing practices and slaughter periods*

3.3. Carcass pH, cooking losses, meat colour, and Warner Bratzler shear force values

Table 3 illustrates the effect of finishing practices and slaughter periods on carcass pH, cooking losses, meat colour, and shear force of the finished bulls. Finishing practices and slaughter periods did not (p>0.05) influence the pH values and cooking losses. There was an interaction effect between finishing practice and the slaughter period on the tenderness and redness colour of the meat such that the shear force values were improving from P1, P2, and P3 practices and with increasing slaughter periods from S1, S2, and S3. As a result, bulls slaughtered on the 75th day were more tender than the 45 and 60th day slaughtered bulls. Meat from

45th-day slaughtered bulls had a similar redness colour and as finishing days advanced P3 had decreased the redness colour and improved for P1 and P2 bulls. The relative lightness and yellowness of the meat were not affected ($p>0.05$) by the finishing practices but slaughter periods did. The redness colour of the meat was statistically ($p<0.05$) influenced by finishing practices. Finishing practice and slaughter period influenced ($p<0.05$) meat tenderness. The relative redness and yellow colour of the meat were affected by the finishing practice.

Table 3. Lsmeans ± SEM for beef quality characteristics of Boran crossbred bulls used in the experiment.

Parameter	**Finishing practices**					**Slaughter periods**					**FP*SP**
	P1	**P2**	**P3**	**SEM**	**P-value**	**S1**	**S2**	**S3**	**SEM**	**P-value**	**P-value**
pH24	5.47	5.44	5.45	0.05	<0.9420	5.44	5.49	5.43	0.05	<0.6633	<0.3109
pH48	5.28	5.21	5.28	0.05	<0.4467	5.24	5.26	5.26	0.05	<0.9249	<0.1392
Cooking Loss (%)	33.31	34.04	34.35	1.08	<0.7814	34.36	32.71	34.63	1.08	<0.4030	<0.0982
Shear Force (N)	44.41[a]	45.4[a]	41.71[b]	1.55	<0.0039	48.19[a]	48.1[a]	35.21[b]	1.55	<0.0001	<0.0002
Lightness	44.15	42.73	42.43	0.70	<0.1824	42.06[b]	41.29[b]	45.96[a]	0.70	<0.0001	<0.0944
Redness	10.47[a]	9.83[b]	8.71[c]	0.36	<0.0034	10.09	9.65	9.27	0.36	<0.2827	<0.0055
Yellowness	8.89	9.00	7.80	0.27	<0.0038	8.59[b]	8.04[b]	9.07[a]	0.27	<0.0298	<0.0712

*a-b Means with different superscripts within a row differed significantly (P<0.05), FP*SP- interaction effect between finishing practices and slaughter periods*

3.4 Effects of aging time on the cooking loss and tenderness of Boran crossbred bulls used in the experiment

The effects of the different aging times on cooking loss and the shear force values are presented in Table 4. Aging time significantly ($p<0.05$) influenced cooking loss and tenderness showing lower values at 12 days reaching the threshold shear force value < 55 N. The meat from bulls from all practices and slaughter periods aged for 16 days had the lowest cooking losses and shear force values compared to those aged for 4 to 12 days as expected.

Table 4. Least square means ± SEM for effects of aging time on cooking loss and tenderness of Boran crossbred bulls used in the experiment

Finishing practices	Slaughter periods	Aging time (days)	Cooking loss (%)	Shear force values (N)	P values
Grazing alone	45-days	4	39.66±3.75	48.41±4.34	<.0001
Grazing alone	45-days	8	41.96±3.75	50.86±4.34	<.0001
Grazing alone	45-days	12	32.83±3.75	47.67±4.34	<.0001
Grazing alone	45-days	16	31.26±3.75	33.15±4.34	<.0001
Grazing alone	60-days	4	30.85±3.75	68.60±4.34	<.0001
Grazing alone	60-days	8	34.25±3.75	47.75±4.34	<.0001
Grazing alone	60-days	12	31.21±3.75	46.50±4.34	<.0001
Grazing alone	60-days	16	26.78±3.75	44.29±4.34	<.0001
Grazing alone	75-days	4	30.18±3.75	50.57±4.34	<.0001
Grazing alone	75-days	8	35.83±3.75	35.51±4.34	<.0001
Grazing alone	75-days	12	34.64±3.75	36.18±4.34	<.0001
Grazing alone	75-days	16	30.22±3.75	21.39±4.34	<.0001
grazing plus supplementation	45-days	4	36.82±3.75	58.85±4.34	<.0001
grazing plus supplementation	45- days	8	37.12±3.75	51.20±4.34	<.0001

grazing plus supplementation	45- days	12	33.53±3.75	51.25±4.34	<.0001
grazing plus supplementation	45- days	16	30.44±3.75	39.03±4.34	<.0001
grazing plus supplementation	60-days	4	38.84±3.75	63.90±4.34	<.0001
grazing plus supplementation	60-days	8	37.63±3.75	50.29±4.34	<.0001
grazing plus supplementation	60-days	12	36.31±3.75	45.97±4.34	<.0001
grazing plus supplementation	60-days	16	24.24±3.75	37.25±4.34	<.0001
grazing plus supplementation	75- days	4	32.46±3.75	47.67±4.34	<.0001
grazing plus supplementation	75- days	8	33.33±3.75	31.75±4.34	<.0001
grazing plus supplementation	75- days	12	35.29±3.75	41.61±4.34	<.0001
grazing plus supplementation	75- days	16	32.53±3.75	25.99±4.34	<.0001
Full feedlot	45- days	4	33.71±3.75	52.35±4.34	<.0001
Full feedlot	45- days	8	34.84±3.75	50.61±4.34	<.0001
Full feedlot	45- days	12	34.56±3.75	54.75±4.34	<.0001
Full feedlot	45- days	16	25.60±3.75	40.21±4.34	<.0001
Full feedlot	60-days	4	38.50±3.75	50.76±4.34	<.0001
Full feedlot	60-days	8	33.94±3.75	45.19±4.34	<.0001
Full feedlot	60-days	12	30.69±3.75	39.16±4.34	<.0001
Full feedlot	60-days	16	29.30±3.75	35.54±4.34	<.0001
Full feedlot	75- days	4	43.28±3.75	37.63±4.34	<.0001
Full feedlot	75- days	8	40.15±3.75	26.22±4.34	<.0001
Full feedlot	75- days	12	33.86±3.75	37.77±4.34	<.0001
Full feedlot	75- days	16	33.83±3.75	30.29±4.34	<.0001

SEM = standard error of the mean

4. DISCUSSION

The observed higher mean weight of carcass length, chest depth, fat thickness, head, hide, internal fat, and the heart-lung-liver on feedlot (P3) and grazing with concentrate supplementation (P2) bulls were associated with a high-energy diet (13.53 MJ ME/kg DM and 147g CP kg/DM) offered to these bulls. The diet contained slightly higher than recommended in the previous study (NRC, 2000) for beef fattening. The effects of the diet offered are also linked to the observed interaction effects between the finishing practices and slaughter periods on increased carcass length and chest depth sizes. The influences of finishing practice and high-energy diets on growth performance and improved meat quality in the finishing stages reported in this study were also reported in previous studies (Menezes *et al.,* 2010; Asimwe *et al.*, 2016)**.** The findings from the present study concur with results reported in the past (McGee *et al.,* 2007) in feedlot finishing cattle, though the observed fat thickness was relatively higher than those previously reported (Asimwe *et al.,* 2016)**.** The disparities in fat thickness between the two studies could be due to breed differences and nutrient contents of the diets used. Although the previous study (Paula Neto *et al.,* 2018; González-Salazar *et al.,* 2021) have demonstrated slightly shorter carcass lengths on Zebu and crossbred bulls in feedlots and longer on pasture-fed bulls contrary to those obtained from the present study which could be influenced by the age of animals used.

There was an interaction effect between finishing practice and the slaughter period on hide weights with no clear trend. The results from the current study are in line with those reported in the previous studies (Özlütürk A, Esenbuğa *et al.,* 2008), showing the influence of concentrate diet in increasing non-carcass component weights. The heaviest weights of the head, hide, internal fat, and

the heart-lung-liver were observed on 60th days than other slaughter periods this implies that 60 days on feed is probably optimal for the growth and development of those parts. In the investigations carried out in the past, (Asizua *et al.,* 2009; Mwilawa *et al.,* 2010) on the effects of feeding practices and slaughter durations on animal performance had values that are in line with those observed in this present study.

The observed higher weights of GIT full and GIT empty in bulls on P2 and P3 are attributed to the nutritional composition of the diet offered, probable variations in diet digestibility owed to slower passage rate through the GIT due to high crude fibre (CF) in the diet. The diet is formulated to contain rice polishing with high CF contents and cassava meal of high fermentable carbohydrates leading to increased water consumption during and prior to the slaughter of the animals. Janssen *et al.,* 2021 have elucidated the effect of feeding rich-energy diets to animals in intensive and semi-intensive systems in increasing the digestive track contents as well as abdominal fats depots which increased both GIT full and empty weights.

Cooking loss is a key meat quality characteristic and is usually used to measure the ability of flesh to hold on to its constituent water (water holding capacity). The observed cooking loss reported in this study ranged between 32-35% and is in line with the values reported in the previous study (Maria *e al.,* 2022) on Braford steers aged for 2,7,14 and 21 days, but are higher than 24.54 to 30.62 % which were reported in another study (Fan *et al.,* 2020) on Simmental cattle aged between 1 to 7 days. Meat that results in low cooking loss has both economical and quality merits due to their high-water retaining capacity; hence, more yield and little nutritive value are lost**.** The observed CL in the current study

is associated with pH values recorded and probably the intramuscular fat present. The latter was not assessed in the present study, the presence of it can be explained by the observed high b* values (yellowness colour) from the bulls slaughtered under various periods, thus, not influencing the CL values. The influence of ultimate pH and the intramuscular fat on meat cooking loss have been well described in the past study (Mushi *et al.,* 2009). The lowest values for CL and shear force values observed on meat aged for longer days (12 and 16 days) could be attributed to the degree of muscle contraction and the breakdown of the myofibrillar proteins with increasing aging duration. Past studies have revealed that aging time influences the CL and shear force of the meat (Maria *e al.,* 2022).

The post-slaughter aging of meat led to reduced cooking loss and shear force values as it involves biochemical and physical processes that occur during the conditioning of meat. The breakdown of muscle proteins particularly myofibrillar, caused by calpain enzymes weakens the muscle structures leading to a progressive increase in tenderness (Bhat *et al.,* 2018). This process further creates more space within the muscle fibers, allowing them to hold more water, leading to lower cooking loss as more moisture is retained in the meat during cooking. The results of the present study have demonstrated that finishing practice, period to achieve slaughter weight, and aging period are three variables that autonomously influence meat quality attributes. The bulls on P2 and P3 were fed a rich-energy diet which influenced their glycogen reserves leading to a lower muscle pH, and increased intramuscular fat that dilutes the muscle structures, consequently, influencing meat tenderness (Janssen *et al.,* 2021); (Christensen and Purslow, 2016). Tenderness is one of the most valuable meat quality traits, as tough or chewy meats can

immediately affect the eating experience. The results of the current study showed that the shear force values were reduced from 44.41 to 41.71N in the meat from bulls finished on pasture only and on feedlot and from 48.19 to 35.21N in the meat from bulls slaughtered on 45 and 75 days respectively. The shear force values observed in this study were in line with (Robbins *et al.,* 2003) established standard scale indicating that less than 55 N shear force values are satisfactorily tender, those ranged from 55-75 N reasonably tender and beyond 75 N is tough. The age of the animal could be linked to the observed similarity in meat tenderness as young animals are known to produce more tender meat due to the plentiful of undeveloped collagen in the muscle with weak crosslinks between them, which dissolves readily when cooked (Archile-Contreras *et al.,* 2010). The tenderness in this study was further influenced by the amount and contents of the intramuscular connective tissues in the meat revealed by the observed high b* values indicating that meat has more yellow colouring probably owing to the presence of higher intramuscular fat content causing the reflection and dispersion of light by fat globules (Table 3). Moreover, this study demonstrates that the production of optimal tender meat is at 75 days of slaughter.

The obtained high redness and yellowness values of the meat from bulls raised on various finishing practices are similar to those reported by (McGee *et al.,* 2024). The redness value (a*) for grazing only (P1) bulls was slightly higher than their contemporaries indicating the presence of a substantial amount of myoglobin in the meat. Atsbha *et al.,* 2021 obtained 10.99, 9.99, and 10.84 values of redness (a*) for LTL muscles from three groups of Begait lambs finished under three dietary treatments. Differences in the level of myoglobin content and the colour of intramuscular fat have been reported to influence redness in beef

(Jakobsen and Bertelson, 2000). Bulls slaughtered under various periods had higher lightness and yellowness values which are comparable to those reported by (McGee *et al.,* 2024). The higher L* values indicate that the meat is bright lighter in colour, probably due to the red hue of the meat. The observed finishing practice by slaughter period interaction indicates that meat from P3 bulls became less reddish throughout the entire finishing period where the P1 and P2 have increased bright red colour with increasing finishing days, probably due to the higher myoglobin content oxygenated during exposure to a mixture of gases which contains oxygen (Gašperlin *et al.,* 2000), consistent with the results of (Torrecilhas *et al.,* 2017). These results suggest the differences in diets nutritional values and finishing regimes in responding to meat colour vary significantly causing less reddish meat in bulls on P3 and bright red to those on P1 and P2.

Conclusions

Finishing strategies and post-slaughter aging of LTL muscles of Boran crossbred bulls had a significant effect on meat quality attributes, specifically in tenderness and meat colour. Bulls on feedlot produced more tender meat as compared to grazing with concentrate supplementation and grazing only. The seventy-five slaughtered bulls also produced tender meat as compared to those slaughtered at forty-five and sixty days on feeding. This implies that feedlot finishing and slaughtering of Boran crossbred bulls on 75 days of feeding is a better option for the production of prime beef as compared to the other finishing practices and slaughter durations. Hence, recommended for adoption by producers and livestock finishers for improved meat quality. Aging times affected the cooking loss and tenderness of the meat from both the finishing practice and slaughter period. The tenderness was improved with increasing aging times; therefore, aging for 12

days is sufficient for all meat from all effects under study. Future research is also necessary to explore the impact of this finishing strategy on fatty acid composition and consumer health perceptions to complement the results gathered in this study.

Conflict of Interest

The authors declare that they have no conflict of interest.

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. The author EPM designed the study, collected data, performed the statistical analysis, and wrote the first draft of the manuscript. Authors GHL, ISS, and AZS guided EPM in designing the study, performed the statistical analysis, and read and approved the final manuscript. Author MNS facilitated the data collection. All authors except MNS read and approved the final manuscript.

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About Rangeland Society of Tanzania (RST)

Background

The Rangeland Society of Tanzania (RST) is a non-profit organization, which forms an integral part of rangeland stakeholders in Tanzania. The Society was registered under the Non-Governmental Organizations Act 2002 on 12th September 2005, with Registration No. 00NGO/0945. It focuses on managing, conserving, sustainable utilization of rangeland resources and serves as the forum in this area. The society was formed based on the facts that there is:

- Little recognition of the importance of rangelands being the major source of meat and other resources in Tanzania.
- Lack of continuity in rangeland development in Tanzania.
- Isolation of scientists working with rangeland research and development inTanzania.
- A weak link between research and extension on rangeland matters.

Vision

The society envisions healthy rangelands that will provide dynamic habitats to obtain maximum domestic and wild animal products and perpetuate the natural resources.

Mission

To promote and enhance the stewardship of rangelands to meet human resources based on science and good policy.

Objectives

i. To create public awareness on the economic and social benefits obtainable from a wide variety of rangeland resources.
ii. To promote an understanding to the general public of the principles applicable in the management and sustainable utilization of rangeland resources.
iii. To liaise with researchers and institutions dealing with rangelands in developing a national rangeland research programme.
iv. To provide a forum for exchange of information among rangeland scientists, students and livestock farmers within Tanzania and abroad.

Membership

Membership is open to all people, institutions and organizations promoting rangeland related activities within Tanzania and abroad.

The membership is either:

National or Foreign Individuals:

Professionals, Non-Professionals, Livestock keepers and Students.

National or Foreign Institutions:

Governmental and Non-Governmental organizations.

Fees

Membership fees

This has to be paid on registration into the society and it is paid only once.

The current rates are:
Professionals: Tshs 20,000/= (US$ 20)
Government Institutions: TShs 50,000/= (US $ 50)
Non-Government institutions: TShs 100,000/- (US$ 100)

Annual subscription fees
This has to be paid annually. This will be reviewed annually depending on the strength of the local currency.

The current rates are:
Professionals: TShs 20,000/= (US $ 20)
Government Institutions: Tshs. 50,000/=(US $ 50)
Non-Government Institutions: TShs 100,000/= (US $ 100)

Headquarters
Currently the Society has its headquarter at Morogoro, Tanzania.

Contact address
The Secretary,
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Sokoine University of Agriculture,
P. O. Box 6442,
Morogoro, Tanzania.

SCHEDULE FOR THE 6TH SCIENTIFIC CONFERENCE OF THE RANGELAND SOCIETY OF TANZANIA, EDEMA HOTEL, MOROGORO

HEALTHY RANGELANDS FOR SUSTAINABLE ECONOMIC DEVELOPMENT

INSERT THE CONFERENCE PROGRAMME

RANGELAND SOCIETY OF TANZANIA
(RST 00NGO 0945)

CHAMA CHA NYANDA ZA MALISHO TANZANIA
PO BOX 6442, MOROGORO, TANZANIA

RATIBA YA SHUGHULI ZA MKUTANO WA 14 WA SIKU YA MALISHO, JUMATATU TAREHE 15.04.2024

Na	Tukio	Muda	Wahusika
1.	Kujiandikisha na kuingia ukumbini	12:30 – 2:00	Katibu, M/Hazina, Wote
2.	Mgeni Rasmi kuwasili	2:00 – 2:15	Mkuu wa Mkoa, Katibu Mkuu (MLF), M/Kiti RST. SUA VC
3.	Kuwakaribisha wageni	2:15 – 2:20	Katibu/Mshereheshaji
4.	Hotuba ya Mwenyekiti wa Chama	2:20 – 2:35	Mwenyekiti RST
5.	Risala – Chama cha Wanafunzi wa Nyanda za Malisho (TRSA)	2:35– 2:45	Mwenyekiti TRSA
6.	Salaam za wageni waalikwa	2:45 – 3:00	Katibu RST
7.	Salaam za Makamu Mkuu wa Chuo Kikuu cha Sokoine cha Kilimo (SUA)	3:00 – 3:05	VC – SUA (Mchango wa Elimu na Utafiti katika usimamizi wa raslimali za Nyanda za Malisho
8.	Salaam za Wizara	3:05 – 3:10	Katibu Mkuu MLF
9.	Kumkaribisha Mgeni Rasmi	3:10 – 3:20	Mkuu wa Mkoa wa Morogoro
10.	Hotuba ya Mgeni Rasmi	3:20 – 3:40	Mgeni Rasmi
11.	Neno la shukrani	3:40 – 3:45	Makamu wa M/Kiti RST
12.	Picha ya pamoja, Mgeni Rasmi Kuondoka	3:45 – 3:50	Kamati ya Itifaki
13.	Mapumziko mafupi na chai	3:50 – 4:10	Wote
14.	**Mada I**: Mpango wa jenga kesho iliyo bora kwa vijana (BBT Mifugo), nini mchango wa Tasnia ya Malisho?	4:10 – 4:20	Wanafunzi wa mwaka wa pili (BSc RAM)
15.	**Mada II**: Mwelekeo wa Tanzania kuzalisha malisho kibiashara, Je tunawekezaje?	4:20 – 4:30	Wanafunzi wa mwaka wa tatu (BSc RAM)
16.	**Wasilisho Maalum**: Fursa na Changamoto katika uendelezaji wa malisho	4:30 – 4:40	Wizara ya Mifugo na Uvuvi

Na	Tukio	Muda	Wahusika
17.	**Wasilisho Maalum**: Umuhimu na uwezekano wa kuanzisha Mamlaka ya Usimamizi wa Nyanda za Malisho	4:40 – 4:50	Mtaalam wa Malisho
18.	Majadiliano	4:50 – 5:45	Sekretariati, Wote
19.	Maazimio ya siku ya malisho	5:45 – 6:30	**Sekretariati : Rapporteurs Mary Kissinga, Happy Ngoya, Fatuma Mohammed**
20.	Chakula cha mchana	6.30 – 8:00	Wote
21.	Kongamano la 6 la Kisayansi	8:00 – 10:25	EXCO, Washiriki
22.	Chai ya jioni na mwisho wa Siku ya Malisho	10:25 – 10:45	Washiriki
23.	Mkutano Mkuu (AGM)	10:45 – 1:00	Wanachama wa RST
24.	Mkutano Nyanda za Malisho na mahusiano baina ya wanafunzi na watafiti wa vyuo vya Tanzania, Marekani, Uzbekistan, na Argentina (Kwa Mtandao) https://usu-edu.zoom.us/j/87802358308?pwd=dm5wYThPUWpWOFVrenlKa0ViNm5kQT09 Meeting ID: 878 0235 8308 Passcode: 407770 **Guest Speakers** • **Prof Fred Provenza**, Department of Widland Resources, USU • **Prof Ephraim Mtengeti**, Department of Animal, Aquaculture, and Range	1:00 – 2:30	Sekretariati na washiriki wa mkutano mtandao - Pastoral Mobility Amidst Climate Change Effects, **Sokoine University of Agriculture** (SUA) - Range Management Education and Practice in Utah, **Utah State University** (USU) - Extensive Livestock Production Systems in the Chihuahuan Desert: Adaptation Needs and Challenges, **New Mexico State University** (NMSU) - The Present State of Rangeland Ecosystems of the Kyzyl-Kum Desert, Uzbekistan, **Samarkand State University** (SSU) - Beef Cattle Production in

Na	Tukio	Muda	Wahusika
	Sciences, SUA • **Prof. Layne Coppock**, (IYRP representative, "Update on the International Year of Rangelands and Pastoralists (IYRP) –2026")		Argentina's Vast Rangelands, **University of Buenos Aires** (UBA)
25.	Kufunga mikutano na kuagana	2:30 – 2:45	Mwenyekiti RST na washiriki wa mkutano mtandao

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