INTL J TROP DRYLANDS
Volume 7, Number 2, December 2023
Pages: 83-101
E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t070204

Review: Rangeland management in Tanzania: Opportunities, challenges, and prospects for sustainability

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Manuscript received: 25 August 2023 Revision accepted: 24 November 2023.

Abstract. *Muzzo BI, Maleko DD, Thacker E, Provenza FD. 2023. Review: Rangeland management in Tanzania: Opportunities, challenges, and prospects for sustainability. Intl J Trop Drylands 7: 83-101.* Rangelands in Tanzania play a crucial role in supporting local livelihoods and the country's economic development. However, their long-term sustainability is threatened. This review paper identifies challenges and explores opportunities to ensure their continued sustainability. Opportunities include implementing dedicated policies and regulations, using expertise in range science, leveraging technological advancements, investment land for opening private ranches, ample bushes and shrub resources for small ruminants, and high market demand for milk and meat from ruminants. Major challenges include insufficient technology and limited technical know-how, low and erratic rains leading to dry season pasture scarcity, infectious diseases, and the spread of invasive species. Other challenges include conflicting interests from other land users that have led to the massive conversion of communal rangelands to croplands, areas to protect wildlife, and human settlements. These challenges can be addressed by policy enforcement, strengthening pastoral organizations, fostering the growth of experts in climate-adapted forage breeding, and embracing advanced technology. Active involvement of local communities in decision-making processes and facilitating rangeland restoration can ensure the sustainable management of rangelands in Tanzania. Another promising avenue is the strategic use of locally adapted livestock species to control invasive plants, complemented by governmental enforcement of a grading system for meat and establishing a price-based quality meat market. Incorporating these prospects into rangeland management strategies can enhance the ecological sustainability and resilience of rangelands while supporting local livelihoods. Future research should focus on evaluating and implementing these strategies to promote sustainable rangeland management practices in Tanzania and elsewhere with similar environment.

Keywords: Invasive species, nomadism, rangeland improvement, shrubs and bushes, Tanzania

INTRODUCTION

Rangelands are extensive natural landscapes, covering approximately 40-50% of the Earth's terrestrial surface (Robinson et al. 2019). These landscapes include grasslands, shrublands, savannahs, woodlands, deserts, tundra, and riparian and wetland areas. The lands are unsuitable for cultivation activities but revegetated naturally or artificially and managed like native vegetation. The predominant vegetation in rangelands are grasses, forbs, shrubs, and fodder trees, proving suitable forage for wildlife and livestock species through grazing or browsing. Rangelands play a significant role in environmental, economic, and cultural functions supporting millions of people worldwide (Bremer et al. 2021). In Tanzania, rangelands which receive an annual rainfall of less than 700 mm, are mostly allocated in the country's Central and Northern regions (Figure 1). They provide several ecosystem services, including habitat for wild flora and fauna, carbon sequestration, and catchments for watersheds. They also provide forage for ruminant livestock production systems. Tanzania has 35.3 million cattle, 25.6 million goats, and 8.8 million sheep, mostly raised in rangelands (URT 2022). According to the NAFORMA (2015), grazing and wildlife areas cover 10.5% and 22% of the Tanzanian mainland, respectively. This provides an estimated 9,923,414 ha for grazing and 20,791,914 ha for wildlife, with nearly half of these areas managed as private or protected areas and ranches, while the remaining acreage is village or public land (Figure 2). Tanzanian livestock production is sustained by rangelands dominated by native pastures, contributing 7.4% of the national GDP (Nandonde et al. 2017). Most communal lands are dominated by miombo woodlands that receive less than 700 mm of precipitation per year (Ruvuga et al. 2021), followed by grassland (800-1200 mm), forest grassland, and gallery forest (1,200 to 2,000 mm) and thick bush lands (600 to 800 mm). The major Tanzanian rangeland products and services are potable water for human use, irrigation for forage crops for livestock, and various products such as meat, milk, wool, leather, and medicinal plants.

In 2022, the Tanzanian government formally incorporated communal rangelands into land regulations as a method for empowering the people to make proper use of existing resources. Kamwenda (2002) suggested that closely tracking resource utilization by village guards (*sungusungu*) and village assemblies (*dagashida*) in the north-western semi-arid regions of Tanzania could protect resources. However, these areas are degraded, and some cannot support grazing because of seasonal variations in the quantity and quality of forages (Selemani 2014). Rotational grazing systems are often used to promote recovery of diverse plant richness (Muzzo and Provenza 2018; Harmel et al. 2021). However, Tanzania's population is 61.7 million (NBS 2022), with an estimated annual average growth rate of 3.1% since 2012. This has led to the conversion of rangelands into settlements and croplands (Table 1) to increase food security. Although Participatory Rangeland Management (PRM) projects have been implemented in some regions of Tanzania, management practices remain less adaptable, and benefits from common properties are not equally distributed, and as Flintan (2012) noted, common property decisions are often made irrationally due to self-interest. Numerous practices can enhance Tanzanian rangeland management. In their studies, Rainsford et al. (2021) and Rego et al. (2021) emphasized the significant contribution of fire to ecosystem health, highlighting the importance of accurate timing in the application of prescribed burning to effectively manage undesirable rangeland plants that can hinder livestock productivity. Fire and herbivory are ecological processes that drive the heterogeneity of rangelands. Fires clear away dead vegetation, promote fast regrowth of fire-tolerant plant species (e.g., *Themeda triandra* grass and *Acacia nilotica* fodder tree), and create more open spaces (Lamont et al. 2019). The intensity and frequency of fires influence the type and structure of vegetation in a given area (Fernandez-Garcia et al. 2020), while excessive fires lead to massive death of plant communities. Grazing by herbivores affects the composition and structure of plant communities (Lindén et al. 2021). Different species of herbivores may selectively graze specific plant species, which can impact the overall vegetation composition (Pauler et al. 2020). When fire and herbivory occur in the same spatial and temporal scales, they create heterogeneity that can attract wildlife and livestock to recently burned patches (Fuhlendorf et al. 2009). Pyric herbivory or patch-burning strategic practice can not only enhance livestock production and benefit wildlife but also increase heterogeneity, which in turn increases biodiversity, enhancing ecosystem services (Allred et al. 2014; Scasta et al. 2016; Scasta et al. 2023). In a changing climate associated with extended drought and variable rainfall, improved pasture and irrigated farm pastureland are essential for maintaining annual livestock production (Ndesanjo and Theodory 2021). Feed conservation, crop residue, hay, and lopping practices offer alternative strategies to sustain livestock productivity during dry seasons (Muzzo and Provenza 2018).

In conclusion, proper range management practices will help sustain ecosystems and biodiversity, which can help reduce soil erosion, increase vegetation cover, and increase water infiltration, eventually increasing water flow into the soil, streams, and reservoirs. Conversely, a growing Tanzanian population is increasing demands for water, food, and other rangeland resources. Tanzanian rangelands support unique wildlife species important for tourism and recreation. The future of these multi-benefits from Tanzanian rangelands is uncertain due to global climate change and variability. Therefore, this review paper explores the challenges and opportunities within Tanzanian rangelands and fills some gaps in prospects for their sustainability.

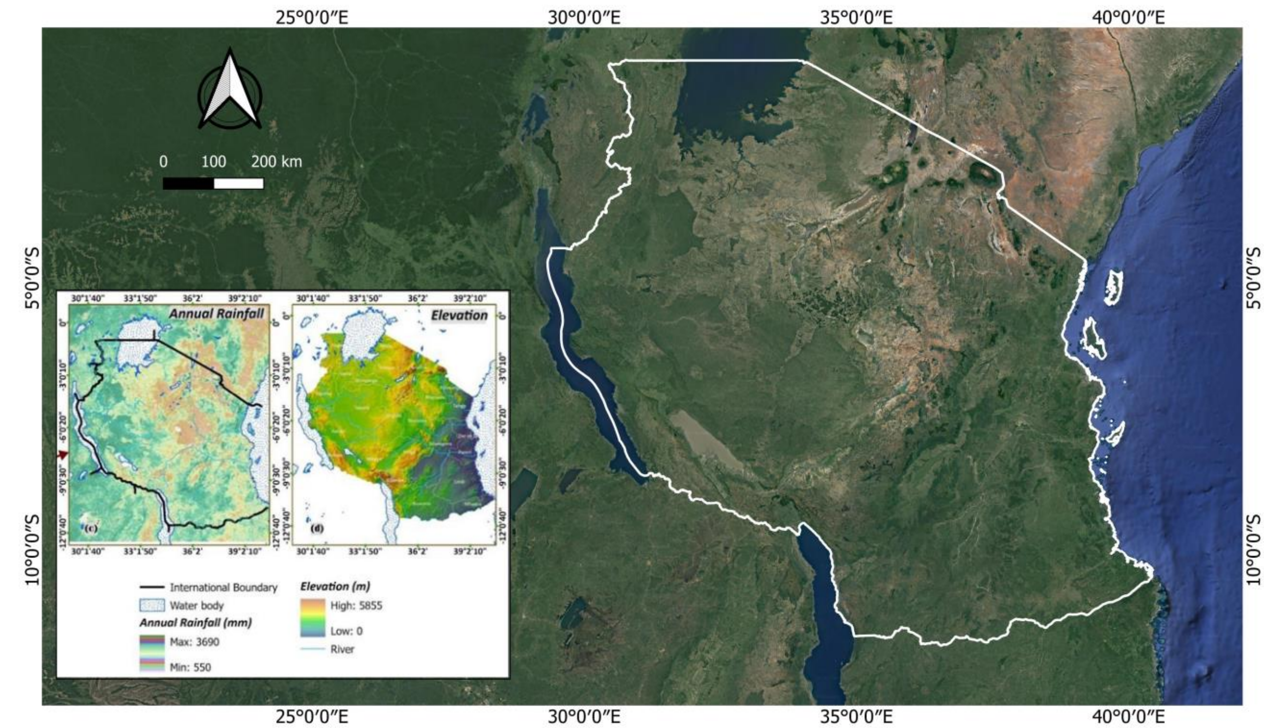

Figure 1. A map showing the location of Tanzania

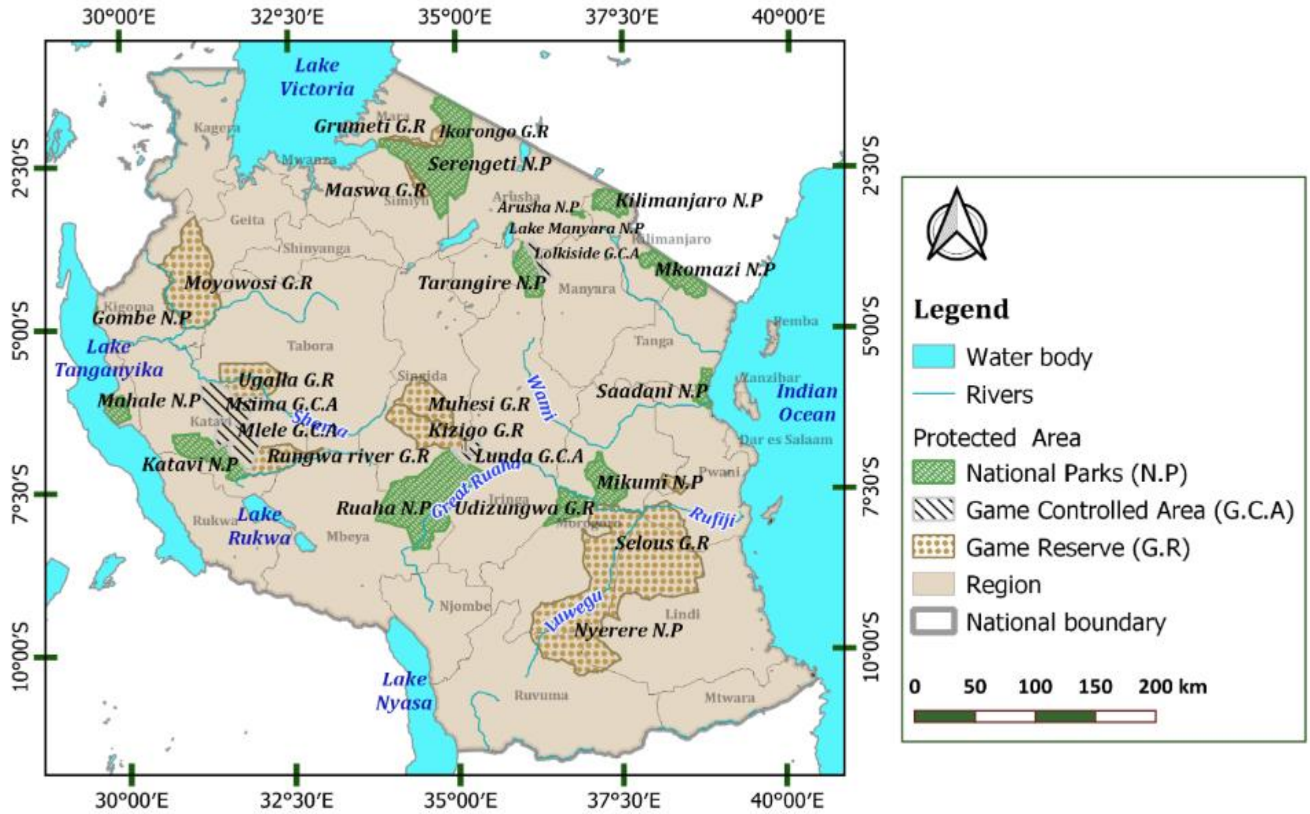

Figure 2. Map of Tanzania showing the distribution of different wildlife protected areas in the rangelands

Table 1. Land use area and rate of change in cover classification according to Nzunda and Midtgaard (2019)

Cover class and land use	Area (ha)[a]		Total changed area 2010–1995 (ha)	Changed area per year (ha/yr)	2010 Area as a percentage of 1995 area	% Annual rate of change [b]
	1995	2010				
Bushland	17,372,207	12,666,025	-4,706,182	-313,745	72.90	-2.10
Cultivation	9,764,073	31,967,393	22,203,320	1,480,221	327.40	7.90
Grassland	20,606,711	6,056,976	-14,549,735	-969,982	29.40	-8.20
Forest	38,097,662	33,296,651	-4,801,010	-320,067	87.40	-0.90
Cover and other land uses	1,715,590	3,569,198	1,853,608	123,574	208.00	4.90

Note: The 2010 land cover map did not include 514,594 ha of unclassified area, and rate annual changes was calculated according to Puyravaud (2003)

OPPORTUNITIES FOR PROPER MANAGEMENT

Availability of experts, institutions for rangeland management and research

Experts in range science, such as graduates from Sokoine University of Agriculture (SUA), the Tanzanian Presidents' Office, Ministry of Agriculture, Livestock, and Fisheries (MLF), Regional Administration, and Local Government Tanzania (PO-RALG), along with institutions like the Tanzania Livestock Research Institute (TALIRI) and Livestock Training Ageny (LITA), and the Rangeland Society of Tanzania (RST) an NGO, can make significant contributions to managing rangelands. Moreover, the Tanzania Wildlife Authority (TAWA) and Tanzania Wildlife Research Institute (TAWIRI) are another key stakeholders in addressing the various challenges of human, wildlife, and livestock interactions in the rangelands. The number of SUA graduates in range management averaged 60 students per academic year from 2011 to 2022. The first B.Sc. Range Management students enrolled in 2008; since 2011, students have continuously graduated, resulting in 664 graduates by 2022 (Figure 3). They possess the knowledge and skills required to sustainably manage rangelands. Regarding gender, between 2011 and 2022, SUA graduated 193 females and 471 males with a B.Sc. in Range Management (Figure 4). This underscores the institution's steadfast commitment to promoting gender diversity in this field, ensuring that Tanzania's livestock keepers benefit from a diverse and well-trained pool of graduates. However, there is a challenge in securing relevant employment for these graduates, as there are limited job opportunities in government rangeland management sections and private companies. This is due to lower government budget allocations, policies, and sectoral prioritization. Additionally, there may be a scarcity of companies specifically dealing with the graduates' specialty. Within MLF and PO-RALG, leading heads of the sector employ range/livestock officers to oversee and facilitate sustainable rangeland management practices. Their roles are instrumental for effectively implementing policies and practices essential for rangeland management. TALIRI operates seven research centers strategically located in seven agro-ecological zones of the Tanzania Mainland. These centers include Kongwa (Dodoma) and TALIRI Mpwapwa, TALIRI Naliendele (Mtwara), TALIRI Mabuki (Mwanza), TALIRI Tanga, TALIRI West Kilimanjaro (Kilimanjaro) and TALIRI Uyole (Mbeya), these centers conduct invaluable research on rangelands in diverse environments, significantly advancing our understanding of rangeland dynamics and serving as vital sources of guidance for sustainable use and conservation. TAWIRI comprises four Research Centers, including Kingupira Wildlife Research Centre (Selous Game Reserve), Njiro Wildlife Research Centre (Njiro in Arusha), Mahale-Gombe Wildlife Research Centre (Gombe National Park), and Serengeti Wildlife Research Centre (Serengeti National Park). These research centers provide invaluable insights into the intricate interplay between wildlife and rangelands. They offer essential research, extension services, and capacity-building initiatives that are fundamental for harmonizing rangeland conservation with wildlife habitat preservation. In addition to these government institutions and academic establishments, the Rangeland Society of Tanzania (RST) unites professionals and experts in range science. This collaborative platform fosters knowledge exchange and advocates adopting sustainable rangeland management practices. Moreover, the active engagement of non-governmental organizations (NGOs) is pivotal in this holistic approach. There are numerous NGOs, both national, such as Tanzania Natural Resources Forum (TNRF), and international, such as The Nature Conservancy (TNC), Wildlife Conservation Society, and International Livestock Research Institute (ILRI), working to promote sustainable rangeland Management in Tanzania. These organizations work in synergy with governmental bodies, academic institutions, and local communities to implement projects and initiatives aimed at rangeland conservation and supporting community livelihoods. Their involvement amplifies the collective impact on the sustainable management of Tanzania.

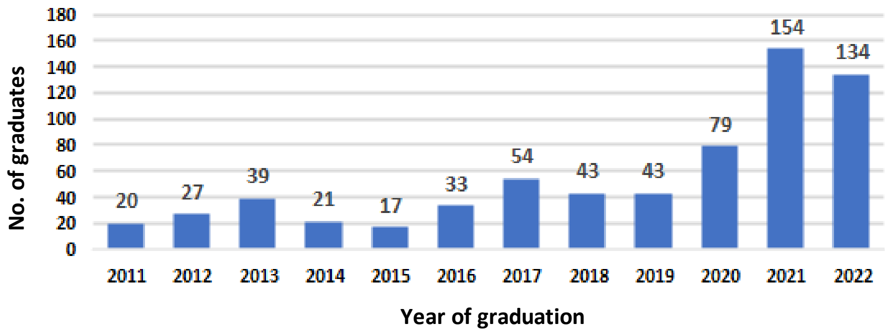

Figure 3. Number of individuals who graduated with B.Sc. Range Management at SUA between year 2011 and 2022 (Source: Sokoine University of Agriculture)

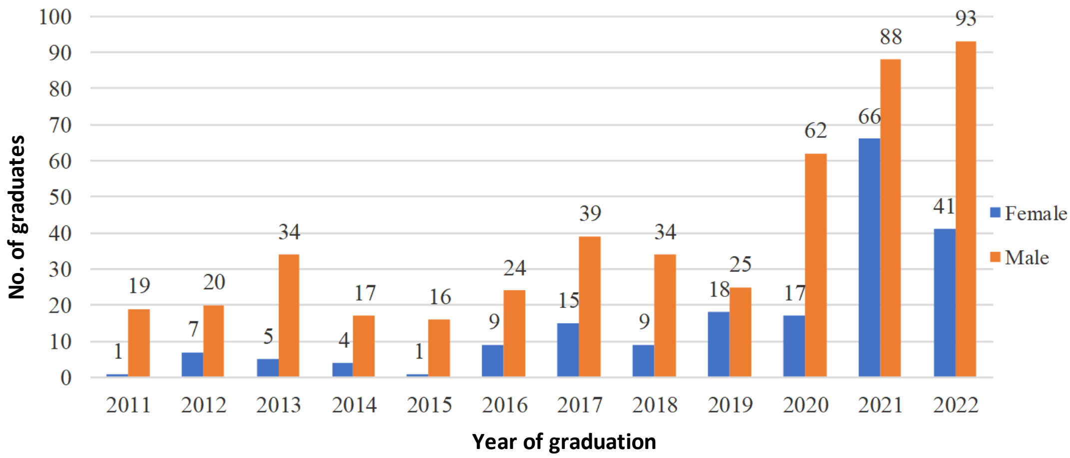

Figure 4. Number of individuals who graduated with B.Sc. Range Management at SUA between 2011 and 2022 by gender (Source: Sokoine University of Agriculture)

Availability of policy and regulations for rangeland management

The Grazing land and Animal Feed Resources Tanzania Act, 2010 (No. 13) provides legal frameworks for managing rangelands in Tanzania. The act promotes community participation in rangeland management, allowing for the involvement of local communities in decision-making processes. That promotes a sense of ownership and responsibility among the communities towards the sustainable management of rangelands. The act also regulates grazing activities, specifying the number of animals that can be grazed on a particular area of rangeland, the duration of grazing periods, and the use of rotational grazing systems. This helps to prevent overgrazing, soil erosion, and degradation of rangelands. In addition, the act promotes the conservation of rangelands and their biodiversity by providing guidelines for demarcating and safeguarding grazing lands. It recognizes the importance of rangelands in supporting wildlife, particularly in areas designated for conservation, while providing guidelines for managing rangelands in in ways that balance the needs of livestock and wildlife. Finally, the act penalizes illegal activities that damage rangelands, such as logging, charcoal production, and mining. This helps to deter illegal activities that can destroy rangelands and their ecosystems.

Technological advancement for range improvement

Tanzania has recently achieved major technological strides in range improvement with the goal of enhancing the management, sustainability, and production of rangelands. Remote sensing technology, such as satellite imagery, is used to monitor and map rangeland conditions, including vegetation cover, soil moisture, and land use changes (Jamali et al. 2023). According to a systematic review by Nzunda and Yusuph (2022), Geographic Information Systems (GIS) are used in rangeland management in Tanzania to analyze and visualize spatial data, assess land use changes, and monitor grazing patterns. GIS is also used to map the distribution of rangeland resources, identify areas of degradation and the potential distribution of invasive alien species (Sutomo et al. 2016). This technology has effectively identified potential areas for sustainable grazing and improved pasture management. Thus, GIS is a useful tool for rangeland managers in Tanzania to make informed decisions and develop effective management plans. Wiethase et al. (2023) found remote sensing and ecological modeling methods were used to investigate degradation of rangelands in Northern Tanzania. By integrating remote sensing and ecological modeling, researchers have identified pathways of degradation in rangelands, assessed the potential for recovery (Donovan and Monaghan 2021). They found degradation was driven by overgrazing, bush encroachment, and soil erosion and that these pathways led to a loss of vegetation cover and soil fertility. However, they also found with proper management practices, such as rotational grazing and bush thinning, rangelands can recover and regain their productivity and ecological functions. In addition, integrated ecological modeling has been employed to map the potential distribution of invasive species under current and future climatic conditions, providing valuable insights for managing *A. nilotica* invasive species in Central-Eastern Indonesia (Sutomo and Van Etten 2017). Mobile-based applications, such as the Tanzania Livestock Market Information System (TL-MIS), provide information on market prices, livestock diseases, and other relevant information to livestock farmers. This helps people make informed decisions on livestock production and marketing. Tanzania has developed and distributed improved pasture seeds, such as *Brachiaria* grass and *Napier* grass, that are more resistant to drought and pests and have higher nutritional value. According to a study by Tenga and Mramba (2015), adopting improved forage varieties has improved livestock production, reduced pressure on natural rangelands, and enhanced soil fertility. For example, the Tanzania shorthorn zebu cattle breed is known for its high disease resistance and adaptability to harsh environmental conditions. According to a study by Yonas (2020), crossbreeding of local and exotic breeds has improved breeds with higher productivity and resilience to the adverse effects of climate change. Water harvesting techniques such as constructing water ponds and dams, are used to store water for livestock and wildlife during the dry season. This helps to reduce pressure on natural water sources and supports the sustainable use of rangelands. Tanzania has also implemented community-based management systems, such as village land use planning and joint forest management, to promote community participation in rangeland management. Collectively, these practices help to ensure the sustainable use of rangelands and reduce conflicts over natural resources.

Investment land for opening private ranches

Achieving the sustainable use and management of rangeland resources in Tanzania requires a multifaceted approach considering ecological, social, and economic factors. The country's rangelands are critical to its economy, providing grazing areas for livestock, which is a key source of income for many rural communities. According to Yanda et al. (2021), private ranching provides an alternative land-use option for rangelands in Tanzania, especially in areas where communal grazing can lead to overgrazing, land degradation, and encroachment. Private ranching can provide incentives for proper land management, as the owners have a financial interest in maintaining the health and productivity of their land in ways that lead to better grazing management, reduced overgrazing, and improved rangeland health. The Mwiba Wildlife Reserve is one example of a successful private ranch in Tanzania. This 125,000-acre reserve was established in 2006 and is managed by the Friedkin Conservation Fund. The reserve provides more diverse habitats for wildlife, such as elephants, lions, and giraffes. It also generates revenue through ecotourism, with visitors paying to stay at the reserve's luxury lodges. Also, the Manyara Ranch Conservancy, spanning 45,000 acres and managed by the African Wildlife Foundation, offers another compelling illustration of private ranching's potential. This conservancy provides a sanctuary for wildlife such as elephants, zebras, and wildebeests and serves as an income source for the local Maasai community through ecotourism and grazing fees. Furthermore, the Makoa Farm, situated in the southern highlands of Tanzania, demonstrates the efficacy of private ranching practices that integrate this ranch supports livestock production and wildlife conservation over approximately 3,707 acres. The farm embraces holistic management principles, incorporating planned grazing, water resource management, and soil conservation to rejuvenate rangeland health. This approach has yielded tangible benefits, including increased livestock production, enhanced soil health, and restoration of previously degraded rangelands.

Availability of ample bush and shrub resources for small ruminants' production

Tanzanian rangelands have a high diversity of plant species, which include a variety of shrubs and woodlands over 33 million ha that provide valuable forage for small ruminants such as goats and sheep (Nzunda and Midtgaard 2019) (Figure 2). These shrubs and woodlands have high nutritional quality and palatability for small ruminants, making them a valuable source of protein, minerals, and vitamins. Browse species such as *Acacia*, *Commiphora*, and *Terminalia* spp contain high levels of crude protein and minerals in their leaves, making them highly preferred by goats and sheep (Kideghesho 2016). Furthermore, the fruit pulp and leaves of *Tamarindus indica* contain secondary compounds with potential medicinal properties, aiding in the treatment of digestive issues and acting as a natural anthelmintic. *Azadirachta indica*, commonly known as neem tree, represents another valuable resource for managing various livestock ailments, particularly external parasites (Landau et al. 2009). Certain *Acacia* shrub species, like *Acacia angustissima*, have condensed tannins that can reduce enteric methane emissions and environmental impacts (Naumann et al. 2018). Moreover, *Acacia* species are renowned as nitrogen-fixing legumes, offering valuable forage for animals and contributing to soil fertility.

The abundance of shrubs in Tanzania's rangelands presents a valuable opportunity for raising small ruminants, allowing them to benefit from a wide range of nutritious forages that benefit their health and human health. The selective grazing behavior of small ruminants, which enables them to target the most nutritious portions of vegetation, maximizes their nutritional intake and growth potential, enhancing the productivity and market value of small ruminants raised in rangelands (Claps et al. 2020). Shrubs within the grazing landscape offer small ruminants access to a more diverse diet, ensuring a balanced intake of nutrients and other health-promoting phytochemicals (Villalba et al. 2019). Goats raised in rangelands exhibit higher body weights and market values than those raised on farm-based diets (Dieters et al. 2021). In turn, the health of humans is promoted by eating meat and dairy products from livestock that consume diverse mixtures of phytochemically rich plants (Provenza et al. 2019; Van Vliet et al. 2021). Tanzanian pastoralists have historically relied on various shrubs as remedies for their animals nutritional and medicinal needs. Further research is needed to identify secondary compounds within the most common shrubs that may benefit animal health and production while reducing environmental impacts and greenhouse gas emissions. Muzzo and Provenza (2018) have proposed exploring ethno-veterinary pharmacopeia and plant usage as alternatives to costly veterinary medications. Thus, incorporating shrubs into the ecosystem can benefit soil health, promote plant growth, and enhance animal and human well-being.

High market demand for milk and meat from rangeland ruminants

The demand for a range of products is a significant driver for managing rangeland areas in Tanzania. According to the Tanzania Livestock Modernization Initiative, the country has an estimated 34 million cattle, which provide a valuable source of meat for the local and export markets (Nandonde et al. 2017). Over the last decade, milk production has increased significantly, but the need for improved breeds and specialized feed has resulted in poor milk yields (CSIRO 2022). In recent years, the milk demand has surged owing to population growth and the economy. This has widenec the gap between the demand and the local milk supply (Blackmore et al. 2022; Maleko 2022). According to MLF's report in 2017, the projected increase in beef meat production by 52% will not meet demands of the expected 71% growth in consumption by 2022, resulting in a 17% deficit (124,778 tons) in beef production and consumption (MLF 2017). Additionally, the Livestock Analysis (LSA) estimates a significant red meat (beef) supply gap of 1.7 million tons by 2031-32 under the business as usual (investment scenario. This suggests that by 2031, the anticipated domestic beef production will only meet 15% of domestic consumption (MLF 2017). The resulting deficit will likely increase meat prices, impacting consumers in Tanzania. This may increase pressures on rangelands and lead to overgrazing, soil erosion, and land degradation, which will decrease productivity, posing a threat to the industry's long-term sustainability. Therefore, managing rangelands sustainably presents an opportunity to improve the productivity and health of the land, thus increasing the supply and market value of range products. Sustainable management practices can improve the quality and quantity of pasture, leading to higher meat yields and better prices for farmers. Rotational grazing, where livestock are moved between pastures to allow for vegetation recovery, can increase the weight gain of livestock, resulting in higher meat yields (Msofe et al. 2019; Munson et al. 2020). Similarly, sustainable management of rangelands can enhance the availability and quality of pasture seeds and milk for sale, thus increasing the industry's profitability.

In addition to livestock, wildlife can become a valuable source of income. Wildlife can add value through utilitarian uses such as hunting or harvesting wild game meat for local use or as part of an ecotourism operation for international markets. However, unregulated hunting practices can lead to exploitation of wildlife, resulting in population declines and loss of biodiversity. When wildlife species have economic value, and their use is regulated, they help promote conservation and provide opportunities for conservation practices. However, caution should be used when creating or supporting wildlife markets; creating wildlife markets can lead to the exploitation of wildlife resources. While some argue that hunting operations have increase conservation efforts in places like Tanzania, others have questioned this approach's effectiveness, ethics, and social considerations (Lindsey et al. 2007). In North America, the elimination of wildlife markets that sold wild game meats is partially credited with reducing the illegal taking of game in the USA in the late 19th and early 20th century (Trefethen 1975). Regulating hunting and harvesting is essential to the long-term sustainability of game species (Trefethen 1975; Thacker et al. 2023). Sustainable hunting practices, such as regulated quotas and regulated hunting seasons, can provide a source of wild game meat for sale while ensuring the long-term conservation of wildlife (Ingram 2020; Ingram et al. 2021). Therefore, there is a need for a coordinated effort among stakeholders, including government agencies, farmers, and local communities, to implement sustainable management practices and meet the marketing demand for a range of products in Tanzania. Sustainable rangeland management practices can improve livestock and wildlife productivity and land health while reducing the industry's environmental impact.

RANGELANDS MANAGEMENT CHALLENGES IN TANZANIA

Limited knowledge of sustainable rangeland management

Limited knowledge and skills in rangeland management in Tanzania has led to degradation and desertification, with significant economic, social, and environmental consequences. Overgrazing, inadequate control of invasive species and unsustainable grazing practices are prevalent issues, resulting in soil fertility loss and declining vegetation cover (Beever et al. 2006; Middleton 2018; Wassie 2020). Increased investment in education and training programs is essential to address this challenge. Capacity-building initiatives should focus on soil and water conservation, range ecology, and livestock management (Cullen et al. 2014). Collaborative efforts involving research institutions, government agencies, and stakeholders can promote innovative approaches like precision livestock management techniques, using GPS tracking, and remote sensing to optimize grazing patterns and reduce overgrazing (Bailey et al. 2021). Other countries have improved rangeland management through technological advancements and research. Satellite technology in Australia aids in mapping rangeland vegetation, facilitating targeted management interventions (Ward et al. 2016). Incorporating indigenous knowledge and practices, such as rotational grazing and controlled burning, can also promote rangeland health and productivity (Finca et al. 2023). Similarly, shepherding practices, as adeptly employed by the Maasai, have been successfully harnessed for enhancing rangeland conditions and reducing predation pressures. By addressing knowledge gaps and applying successful strategies from other countries, Tanzania can improve rangeland management, mitigate degradation, and preserve these valuable resources.

Tanzania's rangelands are a critical resource for the country's economy, supporting livestock production and wildlife conservation and providing vital ecosystem services (URT 2022). Multisectoral competition among agriculture, forestry, mining, urbanization, and wildlife conservation is a significant challenge facing rangeland management in Tanzania (Kivelia 2007; Msoffe 2010; Nuhu 2019; Mahajan et al. 2021; Anthony et al. 2023). These sectors have different objectives and priorities, which can sometimes conflict, leading to unsustainable land use practices that degrade the rangeland ecosystem. For instance, the expansion of agriculture and settlement has resulted in the conversion of Maasailand rangelands to croplands and urban areas, which has led to habitat loss and fragmentation, reducing the carrying capacity of rangelands (Kivelia 2007; Msoffe 2010; Anthony et al. 2023). Similarly, mining activities in the Mara region have led to soil disturbance, land degradation, and water pollution, affecting the quality of rangelands (Matano et al. 2015). Establishing Wildlife Management Areas (WMAs) in Tanzania was intended to involve local communities in wildlife management on village lands and promote wildlife conservation. However, implementing WMAs have yielded the expected socioeconomic benefits due to top-down approaches that overlook the meaningful participation of local communities and led to conflicts and disengagement from local communities. WMAs have been converting community grazing land, leading to conflicts between local communities in the Maasai Steppe and the Eastern Arc Mountains and conservation authorities. Nelson et al. (2016) found that WMAs converted over 160,000 hectares of community grazing land between 2009 and 2014, negatively impacting local communities, particularly pastoralists. Similarly, Moyo et al. (2016) and Kicheleri et al. (2018) reported that establishing a WMA in the Burunge Wildlife Management Area resulted in conflicts between conservation authorities and local pastoralists due to the enclosure of communal grazing lands. Involving local communities in the WMA process and respecting their customary rights and practices is essential for successful conservation and sustainable livelihoods in Tanzania.

The government's budget allocation to rangeland management has been insufficient despite the importance of these lands to the national economy. Eilola et al. (2021) found that funding for rangeland management in Tanzania is limited and often fragmented across different government departments, leading to ineffective management and conservation of these lands. Additionally, a lack of coordination and collaboration among government departments, stakeholders, and communities involved in rangeland management can lead to conflicts over land use and cooperation in implementing conservation and management strategies. For instance, Mairomi and Kimengsi (2021) found limited coordination and communication among government agencies responsible for rangeland management, leading to conflicting policies and ineffective management strategies. The absence of a specific National Rangeland Policy also contributes to the challenges in managing Tanzania's rangelands. While the National Land Use Policy provides guidelines for the sustainable use and management of land, including rangelands, the absence of a dedicated policy makes it difficult to address these lands' unique needs and issues (Robinson et al. 2019). Tanzania's rangelands are not the only ones facing challenges in effective management. For example, despite having a national rangeland policy, Ethiopia has limited implementation of practices due to a lack of funding and weak enforcement mechanisms (Gelan 2014). Similarly, in Nigeria, the government's focus on other sectors, such as oil and gas, has resulted in the neglect of rangelands, leading to their degradation and loss of biodiversity, despite having a national policy on sustainable rangeland management (Leke and Leke 2019; Olayide 2021).

Communal grazing land is state-owned

State-owned communal lands are a key issue in Tanzanian rangeland management. Traditionally, rural communities managed lands communally under customary laws (Yanda and Mung'ong'o 2018). However, state ownership results in conflicts over land use and limited community involvement (Haller 2019; Robinson et al. 2019). This hampers effective strategies and conservation support (John and Kabote 2017). Neglecting customary practices caused conflicts and weakened community cohesion (Sulle and Nelson 2009). This challenge is also evident in other countries like Ethiopia and Kenya. In Ethiopia, converting communal lands into state-owned lands has sparked conflicts and undermined community involvement in land management (Atmadja et al. 2019; Sulle 2021). Similarly, Kenya's nationalization of communal lands has led to conflicts over land use and the neglect of customary land tenure systems (Little 2019). Recognizing and involving local communities in decision-making is essential (Atmadja et al. 2019; Little 2019). The National Land Policy acknowledges customary tenure, but implementation is limited (Biddulph and Hillbom 2020). Addressing state-owned communal lands necessitates a reverence for customary practices, community involvement in decision-making, and the establishment of robust legal and institutional frameworks. Strengthening community participation through capacity building empowers involvement, with transparent land tenure systems reinforcing equitable rights. Inclusive policies harmonizing land use with livelihoods and culturally sensitive conflict resolution mechanisms are vital for promoting effective rangeland management in Tanzania (John and Kabote 2017; Little 2019).

Poor cattle breeds

Effective rangeland management in Tanzania is challenged by the need to improve the performance of local animal breeds. According to Abdurehman (2019), most of Tanzania's livestock are local breeds generally well adapted to the harsh rangeland conditions. However, improving their performance is crucial to enhance rangeland productivity and sustainability. These breeds are often small, have low productivity, and are susceptible to diseases and parasites (Kangalawe et al. 2017). As a result, livestock production is low, and livestock keepers must graze their animals on larger areas of rangelands to meet their needs, leading to overgrazing and degradation of rangelands. Access to improved animal breeds has been challenging in Tanzania (Armson et al. 2020). The government's efforts to introduce improved breeds, such as the Mpwapwa breed, have been limited (Wilson 2021), and the private sector has not invested enough in breeding and distributing improved breeds to livestock keepers in rangeland areas. According to Baker et al. (2015), the lack of access to improved breeds has significantly constrained livestock production in Tanzania, particularly in rangeland areas. Other countries face similar challenges in improving animal breeds in rangeland areas. For instance, in Ethiopia, the low productivity of livestock breeds has been identified as a significant constraint to rangeland management (Ma'alin et al. 2021). Ethiopia has tried introducing improved breeds with higher production and performance than local breeds (Table 2). However, the adoption rates by livestock keepers have been low due to the high cost of purchasing and maintaining improved breeds (Gebreyohanes et al. 2021). Kenya has a long history of importing high-yielding animal breeds, such as Friesian, Ayrshire, Guernsey, and Jersey dairy cattle breeds from Europe and North America (Aliloo et al. 2020). These breeds were introduced to improve milk production and meet the growing demand for dairy products. However, these breeds have negative impacts on rangeland management, as they require more water and forage (Kelio 2022; Oloo et al. 2022) than local breeds, which are adapted to the arid and semi-arid conditions of these rangelands (Mudavadi et al. 2020).

Clearly, the trade-off between exotic and local breeds is a complex issue involving social, economic, and ecological factors. While exotic breeds may have advantages in terms of productivity and marketability, they may not be suitable for all environments because they require more inputs, such as feed and veterinary care. On the other hand, local breeds adapted to local conditions require fewer inputs, making them more sustainable and resilient in the face of environmental and economic shocks (Gerber et al. 2015; Ragkos et al. 2017; Tribaldos 2021). However, people's desire for higher performance and potentially better economic gain has triggered the adoption of exotic breeds (Opiyo et al. 2015; Snaibi and Mezrhab 2020), leading to the loss of local breeds and a decline in genetic diversity. This trend has also resulted in losing traditional knowledge and cultural practices associated with animal husbandry in pastoralist communities (Ayantunde et al. 2007; Njisane et al. 2020; Hailemariam et al. 2021). Crossbreeding with locally adapted and improved breeds can be a viable solution to enhance Tanzanian rangeland productivity and sustainability while preserving genetic diversity and traditional knowledge. Castaño-Sánchez et al. (2023)

conducted a study involving Hispanic heritage cattle (e.g., Criollo) and crossbreeds (Criollo × Angus), comparing them with traditional Angus cattle in the southwestern US. Crossbreed cattle exhibited lower water use, fuel consumption, nitrogen footprint, and production costs regardless of the finishing diet. Crossbreeding can produce offspring with desirable traits such as higher productivity, disease resistance, and adaptability to local conditions. However, crossbreeding has risks, such as unintended consequences on genetic diversity (Kitole and Sesabo 2022) and negative impacts on traditional knowledge and cultural practices. To improve the livelihoods of Tanzanian pastoral communities, local communities must be involved in the decision-making process while carefully evaluating the potential benefits and risks of crossbreeding.

Infectious diseases

Diseases in Tanzania's rangelands, such as East Coast Fever (ECF), Foot-and-Mouth Disease (FMD), Contagious Bovine Pleuropneumonia (CBPP), and Rift Valley Fever (RVF), significantly impacts on livestock productivity and human health. Annual outbreaks of FMD and CBPP across the country lead to losses (Swai et al. 2021), with CBPP outbreaks causing about 55% of cattle deaths in the southern highlands region (Msami et al. 2001). Rift Valley Fever (RVF), an important viral disease affecting ruminants in Tanzania, causes significant economic losses in the livestock industry (Sindato et al. 2011; Olovsson 2019; De Glanville et al. 2022;). Mosquitoes primarily transmit the RVF virus, and outbreaks in Tanzania have been reported since the 1930s, with the most recent outbreaks occurring in 2007 and 2018 resulting in significant human and livestock losses, highlighting the need for effective disease control strategies and interventions (Sindato et al. 2011, 2022). RVF is an emerging and re-emerging disease in Tanzania, with the potential to cause significant impacts. Poor animal husbandry practices, inadequate vaccination, and lack of quarantine measures contribute to disease transmission, and the movement of livestock between regions and countries exacerbates the issue and the spread of diseases in rangeland areas (Sindato et al. 2022). Limited access to veterinary services in remote rangeland areas also hampers effective disease control efforts (Kimaro et al. 2018). Mitigating the effects of these endemic diseases is crucial for ruminant health, farmer livelihoods, and the livestock industry. Disease control strategies should include surveillance, vaccination, and biosecurity measures to prevent disease spread (Sargison 2020). A comprehensive approach is needed to address the challenge of diseases in Tanzania's rangelands, focusing on improved animal husbandry, expanded vaccination and treatment programs, and strengthened veterinary services in remote areas. Community-based animal health programs can enhance disease control measures and access to veterinary services in rural regions (Auty et al. 2021; Enahoro et al. 2021). Additionally, improving surveillance and early warning systems can help detect and control disease outbreaks in rangeland areas. Species Distribution Models (SDMs) can be employed to predict the potential distribution of livestock disease vectors and assess the risk of outbreaks (Lippi et al. 2023), providing valuable insights for proactive disease management and control. Khwarahm (2023) showed how SDMs can also be applied to understand changing species' geographical distribution and abundance patterns, considering dynamic environmental conditions. These models have been used to create high-resolution maps of host distribution, reflecting the baseline risk of disease (Singleton et al. 2023). By using SDM such as MaxEnt (Maximum Entropy Modeling), one can accurately predict species distribution and identify the relevant environmental and bioclimatic determinants of disease risk (Gwaka et al. 2023; Rathore and Sharma 2023; Saputra et al. 2023; Singleton et al. 2023). Additionally, they can consider the temporal dimension, accounting for changes in species distributions over time (Karger et al. 2023). For instance, MaxEnt modeling has been used to estimate and predict zoonotic animal diseases under climate change in China (Cao et al. 2023) and to predict the spatial distribution of vector ticks of Crimean–Congo Haemorrhagic Fever in Iraq (Khwarahm 2023). Therefore, implementing SDMs, especially using MaxEnt in Tanzania rangelands, can contribute to a more effective and informed approach to addressing livestock diseases by predicting disease occurrence and identifying areas at high risk of outbreaks.

Acidic and infertile soils

Tanzania's rangelands face a significant challenge due to acidic and infertile soils. Mdegela et al. (2022) found a significant proportion of Tanzania's rangelands are in areas with soils that are acidic and low in essential nutrients, such as nitrogen and phosphorus. These soils are also susceptible to erosion. The acidic nature of the soil, ranging from pH 5.0-6.5 (Zarekia et al. 2012; Selemani 2015; Mdegela et al. 2022), affects the growth of vegetation, which is a critical resource for livestock production and wildlife conservation. The effect of acid pH on plant biomass production in rangeland was clearly observed in the study conducted by Werner et al. (2016) (Table 3). Poor rangeland management practices, such as overgrazing and deforestation, further compound the challenge, leading to soil erosion and degradation. The problem of acidic or alkaline and infertile soils is not unique to Tanzania's rangelands. For example, in Ethiopia, rangelands located in areas with acidic and low-fertility soils are less productive than those in areas with more fertile soils (Mesfin et al. 2018; Getabalew and Alemneh 2019; Hailu and Mehari 2021; Milisha 2021). In Kenya, soil acidity is a significant problem in rangelands, particularly in areas with high rainfall, which can leach essential nutrients from the soil (Jawuoro et al. 2017; Bolo et al. 2019). In South Africa, many rangelands suffer from highly acidic soils due to years of overgrazing, which affect plant growth and reduces biodiversity (Kotzé et al. 2013; Ntalo et al. 2022). Similarly, in Egypt, rangelands are also affected by highly saline and alkaline soils, which limit vegetation growth and reduces forage availability for livestock (El Shaer and Al Dakheel 2016; Deshesh 2021; Tahir et al. 2022). A multifaceted approach is necessary to address this issue.

Conservation measures like terracing, soil bunds, and agroforestry can reduce erosion and improve fertility. Promoting appropriate soil amendments and fertilizers can address acidity and nutrient deficiencies, improving soil structure and fertility (Horák et al. 2021). Lime and organic matter amendments help raise soil pH and increase nutrient availability (Bossolani et al. 2020). Sustainable land management practices, like rotational grazing, further enhance soil quality and reduce erosion. Therefore, a comprehensive approach that includes soil conservation practices, suitable soil amendments, and sustainable land management strategies is essential to improve Tanzania's rangeland health, productivity, and ecological sustainability.

Alien invasive species

Invasive plants pose a significant challenge to Tanzania's rangelands, impacting native species and reducing productivity. Studies by Ngondya and Munishi (2022) and Muzzo et al. (2023) reveal how invasive weeds decrease plant diversity and constrain ecosystem services. Improper rangeland management practices such as overgrazing and nomadism have also contributed to the spread of invasive plant species, further exacerbating the degradation of rangelands (Leroy et al. 2020). Invasive species, such as *Prosopis juliflora* (mesquite), *Parthenium hysterophorus* (carrot weed), *Astripomoea lachnosperma* (choisy), *Hygrophila auriculata* (marsh barbell), *Trichodesma zeylanicum* (cattle bush) and *Gutenbergia cordifolia* have taken over large areas of rangelands in Tanzania (Adkins et al. 2019). The *P. juliflora* and *Chromolaena odorata* are notable invasive species in Tanzania, negatively affecting rangelands near the Serengeti National Park and reducing forage quality and livestock productivity (Muzzo and Provenza 2018). Similarly, other countries like South Africa, Egypt, and the USA face invasive plant challenges. In South Africa, *Acacia* and *Eucalyptus* species cover over 10% of the land, including rangelands, adversely impacting water resources and biodiversity (O'Connor and van Wilgen 2020). In Egypt, *P. juliflora* reduces rangeland biodiversity and productivity (Dakhil et al. 2021). The USA grapples with invasive plants such as *Bromus tectorum* (cheatgrass), *Taeniatherum caput-medusae* (medusahead), and *Centaurea solstitialis* (yellow star thistle), altering ecosystem functions and hampering livestock production (USDA 2017). Managing invasive plants requires prevention, early detection, and integrated approaches (Van Beek et al. 2017). Ngondya and Munishi (2022) recommend Nature-based Solutions (NbS) like tree planting and promoting native species to control *G. cordifolia.* Integrated Weed Management (IWM) can also restore ecosystem composition and functioning. Effective management of invasive plants improves rangeland productivity and ecological health and provides economic benefits through increased livestock production. Innovative grazing management programs should also be implemented to increase the use of invasive species by livestock.

Climate change and variability

Climate change is a major challenge, increasing temperatures while decreasing the amount of rainfall on rangelands in Tanzania (Figures 5 and 6). Prolonged droughts have become more frequent and severe, resulting in the loss of vegetation cover and reduced productivity of rangelands (Wiethase et al. 2023). The effects of climate change are exacerbated by overgrazing and the continued expansion of human populations, which increase pressure on the limited grazing resources available in rangelands (Louhaichi et al. 2019). As a result, the loss of grazing land has become a major issue for many communities in Tanzania, as they struggle to maintain their livelihoods and feed their livestock (Sangeda and Maleko 2018). The situation is similar in South Africa, where prolonged droughts have led to the loss of grazing land and reduced productivity of rangelands (Vetter et al. 2020). In response, some communities have established community ranches, where grazing land is managed collectively and sustainably to ensure long-term productivity and livelihoods (Hall and Cousins 2013). These ranches are often managed through traditional governance structures that benefit local communities economically through increased livestock production and ecotourism activities (Taylor et al. 2016). Similarly, in Kenya, community ranches have been established to address the challenges of overgrazing, climate change, and the loss of grazing land (Maoncha 2021). These ranches are managed through participatory decision-making processes and often incorporate innovative practices, such as rotational grazing and the restoration of degraded rangelands (Niamir-Fuller 2005). As a result, these community ranches have successfully improved rangeland productivity and ecological health while providing economic benefits to local communities (Kimiti et al. 2018). However, climate change exacerbates other challenges beyond rangeland productivity. For example, it increases the frequency and intensity of wildfires, diseases, and invasive species (IPCC 2014; Gomez-Casanovas et al. 2021). Wildfires have increased in many parts of the world due to climate change, with the total number of large wildfires and the area burned increasing by 4.2% and 2.5% per year on average between 1984 and 2015, respectively (Mueller et al. 2020). Similarly, climate change has contributed to the spread of infectious diseases, such as Lyme disease and West Nile virus, into higher latitudes and altitudes since the 1980s (Semenza and Menne 2009). The rise in temperatures and changing precipitation patterns are creating more favorable conditions for invasive species to thrive, potentially exacerbating ecosystem degradation (IPCC 2014; Turbelin and Catford 2021).

Table 2. Livestock breeds in Tanzania and their performance parameters (Ministry of Livestock and Fisheries 2017)

Species	Breed	Total population	Parameters						
			Parturition rate	**Prolificacy rates**	**Mortality rates**	**Weight adults**	**Dressing %**	**Milk yield**	**Loin Length**
Cattle									
Local breeds	Tanzania Short-Horned Zebu (TSZ)	24,014,360	61%	1.00	2%-20%	260-380 kg	51-53%	270-1,200	250
	Sanga	1,062,440							
	Mpwapwa	800							
	Boran	103,200							
Exotic breeds	Ayrshire	61,920	67%	1.00	2%-10%	350-400kg		155-2,200	305
	Friesian	133,840							
	Jersey	9,536							
	Sahiwal	2,384							
	crossbreeds	411,500							
Total cattle		25,799,980							
Sheep									
Local	East African Blackheaded	1,979,952	1.50	1.20	2-7%	38-40kg	45-47%		
	Tanganyika Long-legged	5,182,627						NA	NA
	Red Maasai	1,522,182							
Exotics	Black Head Persian	15,239	1.60	1.10	2-6%	47-50kg	50%		
Total sheep		8,700,000							
Goats									
Local	Small East African	16,196,201	1.50	1.30	2-20%	38-65%	48%	NA	NA
	Malya	1,984		1.50			50%	90	180
Exotics	Anglo-Nubian	672		1.50	2-12%	49-70%	50%	500	187
	Boer	1,680					53%		
	Norwegian	1,903					50%		
	Saanen	1,680							
	Toggenburg	3,359							
	Crossbreeds	492,521							
Total goats		16,700,00							
Pigs									
local	Local Tanzanian	475,000	2	6.00	2-30%	55-60kg	60%	NA	NA
Exotics	Hampshire	19,000		8-10	2-15%	72-90kg	70%	NA	NA
	Landrace	95,000							
	Large white	133,000							
	Saddleback	38,000							
	Crossbreeds	1,140,000							
Total pigs		1,900,000							
Poultry									
Local	local	42,000,000	Not	Not	8-40%	1.2-1.5kg	80%	NA	NA
Exotics	Layers	12,000,000	Established	Established	2-5%	1.2-1.6kg	85.5%	NA	NA
	Broilers	22,500,000							
Total poultry		76,500,000							

Table 3. Soil pH and forage biomass in different range management systems

Treatment	Plant biomass		Total (kg ha -1)	Composition of grazing material		
	Grazing materials	**Weeds**		**Grasses**	**Leguminous**	**pH**
BR	465.50b	601.70a	1,067.20b	465.30b	0.20b	5.40a
NR	2,664.90a	330.50ab	2,995.30a	2,664.60a	0.30b	4.10b
IH	2,820.50a	204.90b	305.40a	2,690.90a	129.60b	4.00c
IC	1,640.00ab	198.80b	1,838.80ab	1,507.20ab	132.80a	5.00d
CV (%)	50.40	66.70	37.00	50.20	62.00	4.80

Note: NR: Natural rangeland; BR: Burned natural rangeland; IH: Natural rangeland improved with harrowing; IC: Natural rangeland improved with chisel plowing (Werner et al. 2016). Values followed by same letter(s) within a column did not differ significantly at 0.05 level

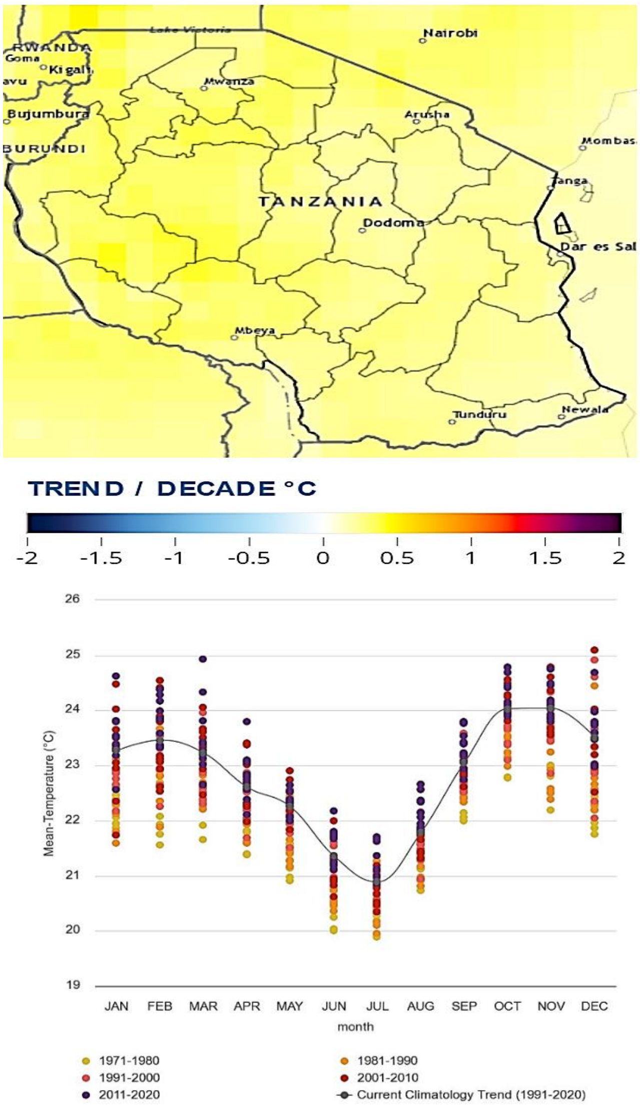

Figure 5. Tanzania mean temperature trend and variability across seasonal cycle per decade 1971-2020 (Source: World Bank group data).

PROSPECTS FOR SUSTAINABILITY OF RANGELANDS IN TANZANIA

Policy enforcement on rangeland resource use and management.

Tanzania has policies and laws governing rangeland resource use and management, such as the Grazing-land and Animal Feed Resources Act of 2010 and the Wildlife Conservation Act of 2009. These legal frameworks ensure the sustainable conservation of rangeland resources, including soils, water, plants, and animals. The Land Act of 1999 recognizes local communities' rights to use and manage land, including rangelands. However, enforcing these laws is challenging, especially at the local level, due to limited capacity and resources. Addressing these challenges and strengthening enforcement mechanisms is vital for sustainable rangeland management in Tanzania.

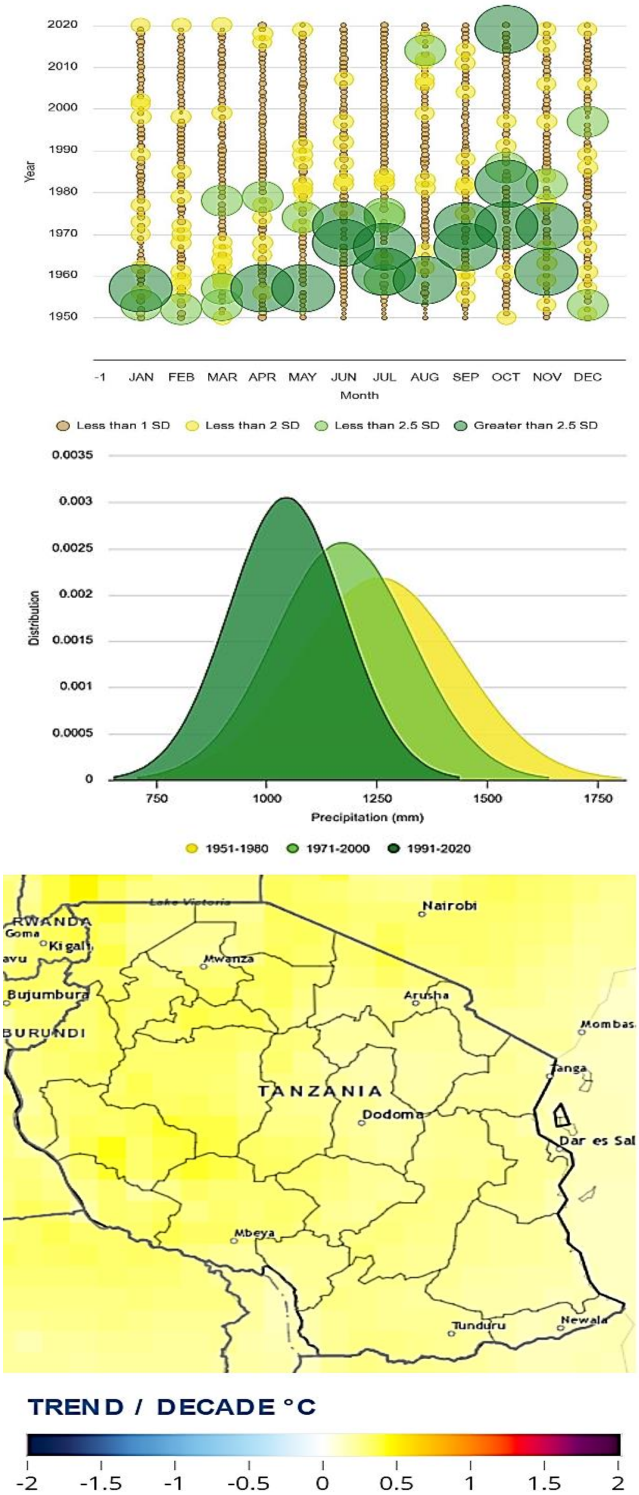

Figure 6. Tanzania's change in precipitation distribution and events intensity from 1971 – 2020 (World Bank group data)

Examples from other countries include Mongolia, where the National Rangeland Health Program, launched in 2003, addresses rangeland degradation through monitoring, training on sustainable grazing practices, and rehabilitation efforts. The Forest Service and Bureau of Land Management manage vast rangelands in the United States using policies like rotational grazing and habitat restoration. These examples highlight the significance of policies and laws in governing rangeland use and management. Effective enforcement, through monitoring and community involvement, is crucial to ensuring the sustainability of rangeland ecosystems.

Pastoral organizations

Forming pastoral organizations in Tanzania promotes sustainable land use practices and community involvement (Nganga et al. 2019). Village-level organizations endorse practices like rotational grazing, preserving rangeland productivity and ecological integrity. They bridge local communities and government agencies, facilitating communication and collaboration in rangeland management. Organizations coordinate rangeland management across villages and stakeholders at district and regional levels. The Tanzania Pastoralist Council (TPC) advocates for policies supporting pastoralists' livelihoods and sustainable land use. TPC collaborates with government agencies and NGOs for participatory rangeland management, ensuring community access to resources. The Forum for Pastoralists in Ethiopia (FPNE) promotes pastoralism and sustainable land use. FPNE influenced a national rangeland management policy supporting pastoralism (Gebeye 2016). The Maasai Mara Wildlife Conservancies Association (MMWCA) manages wildlife conservancies with holistic grazing and wildlife conservation, reducing conflicts and enhancing rangeland productivity (Weldemichel and Lein 2019). Pastoral organizations mobilize resources for research through the Pastoralist Knowledge Hub (PKH), led by the International Livestock Research Institute (ILRI), improving pastoral communities' well-being in East and West Africa (Nganga et al. 2019). Forming pastoral organizations is vital for rangeland management in Tanzania. They promote community-based practices, coordinate efforts, advocate for sustainable policies, mobilize research resources, and support local communities' livelihoods.

Advanced technology in rangeland restoration

Effective rangeland restoration in Tanzania relies on advanced technologies like re-seeding, bush control, remote sensing, mapping, and precision grazing management for sustainability. Strategic re-seeding involves planting resilient seeds in degraded areas to restore vegetation and biodiversity (Fertu et al. 2021). Mapping and remote sensing identify restoration areas and monitor progress through satellite imagery and drone sensors (Rhodes et al. 2022). Targeted re-seeding has been found to positively impact vegetation cover and diversity, improving rangeland health (Fertu et al. 2021). Invasive species control and promoting native vegetation involve various methods, including herbicidal applications, mechanical removal, and biological interventions. Tebuthiuron herbicide has effectively controlled invasive species while facilitating native vegetation regrowth in weed-invaded rangelands, with minimal disruption to ecological balance and cost-effectiveness (Chambers et al. 2021). Thus, making the herbicide a suitable choice for restoration initiatives in countries such as the USA, Canada, and Australia. Combining indigenous knowledge with modern tracking tools can safeguard vital rangeland environments and boost resilience in pastoralist livelihoods. Precision livestock management, exemplified by GPS tracking, prevents overgrazing, minimizing impacts on rangeland ecosystems (Bailey et al. 2021). Maasai shepherd practices, deeply rooted in cultural heritage, provide insights into localized grazing dynamics and animal behavior, merging indigenous wisdom with real-time data through GPS technology (Galvin et al. 2020). This integration enhances pastoralist livelihoods and preserves rangeland ecosystems (McKemey et al. 2020). Expanding climate-adapted forage breeding improves sustainability (Moorby and Fraser 2021). Recruiting more forage plant breeders mitigates climate impacts on livestock production, ensuring food supply and soil health (Gomez-Casanovas et al. 2021). Adopting climate-adapted forages enhances income and livelihoods and incorporates indigenous knowledge (Baker 2013). The fusion of tradition and technology promises a resilient and sustainable future.

Use of locally adapted livestock to utilize and control invasive species.

Strategic utilization of locally adapted livestock species and breeds offers an effective approach to addressing invasive species in Tanzanian rangelands. The Ankole cattle, Small East African goats, Red Maasai sheep, and Short Horn Zebu are notable examples of breeds with evolved capabilities to thrive in rangeland conditions (Sikiru et al. 2023). Ankole cattle have browsing behaviors that make them effective at consuming invasive plants. Small East African goats exhibit resilience and adaptability, allowing them to eat a variety of shrubs, as well as invasive species of grasses and forbs, efficiently. Red Maasai sheep possess grazing and browsing capabilities, selectively consuming invasive plants while preserving native vegetation. Short Horn Zebu cattle have evolved heat and drought tolerance, disease resistance, and efficient foraging abilities, making them adept at utilizing and controlling invasive species. Including these locally adapted livestock species in management strategies provides a scientifically supported approach to mitigate the spread and impact of invasive species in Tanzanian rangelands, leading to improved ecological sustainability and resilience. Further research and appropriate grazing management practices can optimize the effectiveness of this approach.

Enforcing grading system and quality meat market-based price

Implementing a meat grading system, standard prices, and meat inspectors holds potential in managing Tanzanian rangelands. However, the lack of necessary resources and law enforcement hinders the system's implementation outlined in the Meat Industry Act of 2006. Successful meat grading systems in South Africa and Egypt maximize quality meat production and resolve land use conflicts (Muzzo and Provenza 2018). Adapting such practices in Tanzania could boost meat exports and address challenges beef producers face with high input costs and inadequate incentives for quality meat production. Enforcing meat grading systems and setting standard prices based on quality could transform Tanzania's beef industry. Consumers respond positively to quality meat even at higher prices. Short training courses and government certificates are necessary for successful implementation. This system improves beef production, encourages the meat processing industry, increases employment opportunities, and improves living standards. Reducing livestock numbers and optimizing use of pastures can mitigate farmer-pastoral conflicts (Benjaminsen et al. 2009; Neely et al. 2009). By embracing these measures, Tanzania can achieve sustainable rangeland management, economic growth, and improved community livelihoods, but collaboration among government agencies, local communities, researchers, and stakeholders is crucial for success.

Satellite, group, and family ranching initiatives in Tanzania

Tanzania, known for its vast rangelands and diverse landscapes, presents a lucrative investment opportunity in livestock and game farming. The concept of satellite ranches, smaller-scale livestock farming operations near central entities like NARCO, has gained attention in Tanzania. These satellite ranches are strategically designed to complement the objectives and activities of the central entities while addressing the specific needs and opportunities of local livestock keepers. However, the current state of satellite ranches often fails to fully utilize their potential, as they primarily serve as land for livestock keeping rather than integrated components of a comprehensive livestock production strategy. Therefore, to unlock the full potential of satellite ranches, it is crucial to reassess and align the goals of the government and the livestock industry towards profitability and sustainability. Well-established satellite ranches can facilitate structured and sustainable livestock management practices among local communities, optimizing the utilization of rangeland resources. This can be achieved by distributing grazing areas and reducing the risk of overgrazing and land degradation. Additionally, satellite ranches provide knowledge and skill transfer opportunities from central entities, fostering capacity building and enhancing local livestock management and land stewardship capabilities. These ranches also contribute to diversifying the income sources of local communities, potentially including ecotourism, which can enhance financial stability. The proliferation of satellite ranches collectively plays a pivotal role in supporting the growth of Tanzania's vital livestock sector and significantly contributes to its development and sustainability.

Group livestock ranching offers an alternative and accessible approach to sustainable rangeland management, particularly for individual pastoralists with limited resources (Boone et al. 2005; Kerven et al. 2021). By forming collaborative initiatives, pastoralists can pool their livestock herds and resources, share responsibilities, and collectively manage rangelands (Undargaa 2017). This approach reduces the workload for individual members and enables more efficient land management (Hannus and Sauer 2021). Group ranching often attracts support from governmental and non-governmental organizations, providing training, access to veterinary services, and funding for sustainable practices (Pas et al. 2023). Furthermore, collective action enhances the bargaining power of pastoralist groups in markets, leading to better prices for livestock and related products. Moreover, group ranches can implement sustainable practices to reduce environmental impacts, such as overgrazing and land degradation (Zhang et al. 2021). Beyond economic benefits, group ranching fosters community, mutual support, and collaboration among members, contributing to improved livelihoods and the conservation of rangeland ecosystems (Nishi et al. 2023).

Promoting family ranches, exemplified by multi-generational family ranches like the King Ranch in Texas, stands out as a key strategy for enhancing the sustainability of rangeland management (Henderson 2021). These family ranches provide numerous advantages, including multigenerational stewardship, localized expertise in understanding rangeland ecosystems, economic resilience, community integration, and a strong commitment to conservation practices (Grelet et al. 2021). This commitment includes responsible land management techniques like rotational grazing and the preservation of native plant species, contributing to the overall health of rangeland ecosystems. Tanzania supports the establishment of family ranches among pastoralists with substantial herds, often exceeding 200 head of livestock. Like the multi-generational family ranches in the United States that have often been in operation for decades, these family ranches significantly contribute to improved rangeland management, economic stability, and biodiversity preservation (Wilmer et al. 2020; Biggs 2022). The long-term planning views held by multigenerational ranchers in Utah contributed to the ranches implementing more innovative approaches. Their long-term plans included ensuring financial and economic sustainability for future generations (Didier and Brunson 2004). By supporting pastoralist families in transitioning to family ranches and ensuring that these initiatives align with sustainability goals, Tanzania can harness the potential of these ranches to benefit both its people and its vast rangeland ecosystem. Ranch income was a valuable predictor of ranching operations that were innovative (Didier and Brunson 2004). As pastoralists transition to ranching families, they must be able to rely on ranch income to support their families.

In conclusion, satellite, group, and family ranching initiatives offer promising prospects for enhancing the sustainability of Tanzania's renowned and ecologically diverse rangelands. By embracing these initiatives and aligning government policies with sustainability goals, Tanzania can unlock the full potential of its rangelands, ensuring their long-term viability and prosperity. However, the conversion from pastoralism to generational ranching will depend on future generations being able and willing to continue the family operation. In the United States, generational transitions include the transition of capital (often land ownership, equipment, and animals) and knowledge; this can result in a culture of socialization of the heirs to continue the “family tradition”. First generation operations often face high barriers, such as the cost of equipment, animals, land, and knowledge. Therefore, creating family ranch operations will depend on policies and incentives that allow new ranchers to remove barriers to successfully establish satellite operations. This will likely require a combination of culturally relevant educational programs, financial assistance, and the needed capital to create economically sustainable ranching operations that can survive for multiple generations (Inwood 2013).

CONCLUSION AND RECOMMENDATIONS

Sustainable rangeland resource use and management in Tanzania can be achieved by employing a multifaceted approach that considers ecological, social, and economic factors. Strengthening policy enforcement, forming pastoral organizations, advancing technology for rangeland restoration, utilizing locally adapted livestock, and enforcing a grading system and price-based quality meat market are key possibilities to consider. Effective policy enforcement is essential to implement existing laws and regulations governing rangeland resource use and management. Forming pastoral organizations at various levels promotes community-based natural resource management practices and, facilitates stakeholder coordination, and embraces public-private partnerships. Advances in technology offer valuable tools for rangeland restoration, enabling targeted interventions, efficient monitoring, and informed decision-making, leading to enhanced vegetation cover, biodiversity, and overall rangeland health. Utilizing locally adapted livestock breeds is crucial in utilizing and controlling invasive species in Tanzanian rangelands, contributing to ecological sustainability and resilience, and enhancing livelihoods of people. Enforcing a grading system and price-based quality meat market can transform Tanzania's beef industry, incentivizing quality meat production, increasing profitability for beef producers, and improving living standards. By embracing these prospects and implementing them effectively, Tanzania can achieve the sustainable use and management of its rangeland resources, leading to ecological preservation, economic growth, and improved livelihoods for local communities. Collaborative efforts among government agencies, local communities, researchers, and other stakeholders are crucial to ensure the successful implementation of these strategies and secure a prosperous future for Tanzania's rangelands.

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