Chapter

Interaction of Grassland Ecosystem with Livelihood and Wildlife Sustainability: Tanzanian Perspectives

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Abstract

In Tanzania, pure grasslands cover is estimated to be 60,381 km^2, about 6.8% of the total land area, and is distributed in different parts. These grasslands are diverse in dominant grass species depending on rainfall, soil type, altitude, and management or grazing system. They support livestock and wildlife distributed in different eco-tomes and habitats of the country. The potential of grasslands for the livelihood of rural people is explicit from the fact that local people depend solely on natural production to satisfy their needs for animal products. Analysis of grazing lands indicated that livestock population, production of meat, and milk from grasslands increased. But the wildlife population, when considered in terms of livestock equivalent units (Large Herbivore Units) showed a declining trend. The contribution of grasslands to the total volume of meat produced in the country showed a declining state, while milk production showed a slight increase. This situation entails a need to evaluate the grasslands of Tanzania to ascertain their potential for supporting people's livestock, wildlife, and livelihood. This study concluded that more research is needed to establish the possibility of grasslands to keep large numbers of grazing herbivores for sustainable livestock and wildlife production.

Keywords: grass species, grazing, livestock, Serengeti, Ugalla ecosystem, wildlife

1. Introduction

Grasslands are areas where the vegetation is dominated by grasses (Graminae species) and other herbaceous (non-woody) plants, having shrub or tree canopy cover not exceeding 2% (**Figure 1**) [1, 2]. Grasslands provide feed resources for grazing animals that include livestock and wildlife [3]. In addition, grasslands

provide essential ecosystem services that include water catchments, biodiversity reserves, and socio-cultural and recreational needs [4, 5]. Grasslands are found in every continent and comprise 26% of the world's total land area and 80% of agricultural land and represent a wide variety of ecosystems [6].

In Sub-Saharan Africa, Angola, Benin, Botswana, Burkina Faso, Central African Republic, Cote d'Ivoire, Ethiopia, Ghana, Guinea, Kenya, Madagascar, Mozambique, Nigeria, Senegal, Somalia, South Africa, Tanzania, Zambia, and Zimbabwe have more than 100,000 km^2 of grassland [6]. According to Sulla-Menashe and Friedl [7] Moderate Resolution Imaging Spectroradiometer (MODIS) 2019 Land cover product (MCD12Q1) and International Geosphere-Biosphere Programme (IGBP) vegetation cover classes, the grasslands dominated by herbaceous annuals (<2 m) in Tanzania cover 385,427 km^2 which are distributed in different parts of the country.

Climate conditions and human activities affect the productivity of grasslands in Tanzania in terms of Net Primary Production (NPP) [8]. The general pattern of NPP in Tanzania shows a decreasing trend in the northeast-southwest, while the most significant decrease in NPP mainly occurred in the northeast [8, 9]. On the other hand, it predicted that the mean NPP values in the western, eastern, and central parts would increase by 2050 [8, 9]. Therefore, it implies an increase in the population of grazing animals with a consequential impact on people's livelihood in these areas. Thus, the prediction poses a need to establish baseline information on the capacity of grasslands to support livestock and wildlife with consequent effects on people's livelihood.

It is certain that grasslands provide numerous services and are central to the livelihoods and economies of many people in the country. Therefore, it is imperative to understand the current situation to develop strategies for sustaining this important biome. Therefore, this study was conducted to depict the importance of grasslands in Tanzania, their sustainability challenges, and how to keep productive grasslands in Tanzania.

Figure 1.
Typical grassland of Serengeti ecosystem in Northern Tanzania.

2. Methodology

2.1 Study area

This study covers all regions of Tanzania mainland as shown in the map (**Figure 2**).

2.2 Data collection and analysis

A systematic review of the scientific literature to obtain information on the grasslands of Tanzania was conducted using guidelines outlined by researchers [10, 11]. The study was done using various search engines, including Google Scholar, to establish the body of knowledge concerning the subject. The process involved a pre-defined search protocol using filters for keywords to audit search relevance and applicability [10]. The authors used experience from research conducted in Serengeti and Ugalla ecosystems and the eastern Tanzania grasslands to supplement the information obtained from the literature. The R software version 3.5.0 was used for data visualization with the ggplot2 package and analysis for correlation of human, wildlife populations and human-wildlife conflicts.

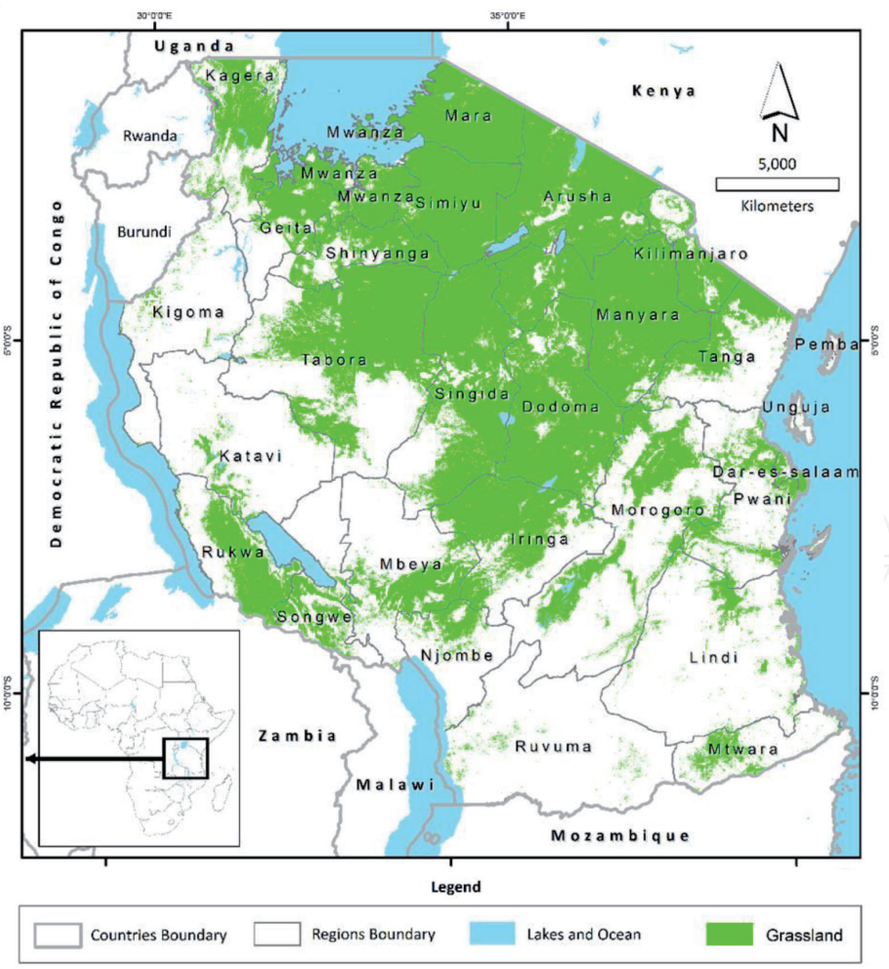

Figure 2.
Distribution of grasslands in Tanzania mainland (source: Tanzania Wildlife Research Institute GIS unit 2021).

3. Findings

Findings explained in this section combine ideas extracted from various sources of literature and authors' comprehensive understanding of the grasslands of Tanzania accrued by research experience.

3.1 Characteristics of Tanzania's grasslands

Grasslands are very diverse and widely distributed in Tanzania, with a range of dominant species depending on rainfall patterns, soil type, altitude, and management or grazing system. *Themeda triandra* is one of the most widespread grass species in Tanzania, and it is the dominant grassland type in central and northern Tanzania [9, 12]. However, the species is very variable and shows wide adaptation to growth in both the highlands and the lowlands. Themeda, Bothriochloa, Brachiaria, Sporobolus, Digitaria, and Heteropogon mixtures are common in the open dry areas such as the Serengeti plains (**Figure 3**).

Short tufted ecotypes of Themeda triandra are found at high altitudes and taller, more woody types are located in the open lowlands [9]. The dominant grass species in the drylands of central Tanzania include Cenchrus, Aristida, and Heteropogon. These grasses normally grow in association, and the establishment pattern of herbaceous plants is generally determined by the environment and soil texture [13]. Hyparrhenia, Hyperthelia, and *Pennisetum polystachyon* tall grass are common in the miombo woodlands of western Tanzania. The miombo forest is a vital vegetation type covering the southern two-thirds of Tanzania [14].

Pennisetum grasslands are classified into two types: high altitude grasslands of *Pennisetum clandestinum* and savannah grasslands of *Pennisetum mezianum* and *Pennisetum purpureum* [9, 15]. *P. clandestinum* is a prostrate stoloniferous perennial grass that is widely distributed in high altitudes (1400 m to over 3000 m.a.s.l *P. purpureum* is a tall, erect, vigorous perennial species that grows in damp grasslands and forest areas up to 2400 m.a.s.l.). At the same time, *Pennisetum mezianum* occurs in soils with impeded drainage heavy clay soil (Kavana, personal observation). *Panicum maximum* is a common grass in the eastern part of Tanzania and it is often associated with Bothriochloa in abandoned sisal farms in the coastal areas (Kavana, personal observation). The Panicum-Hyparrhenia is recognized as a region along the Coast

Figure 3.
Mixed plant species in open wooded grassland of western Serengeti, Tanzania.

northwards from Tanzania, Kenya, and finally into Somalia [15]. *P. maximum* is more typical grass of shady places in the foothills of Mountain ranges up to 2000 m.a.s.l. and is a pioneer grass that comes in after clearing and cultivating the lowland forest [15]. The Sporobolus-dominated grasslands usually exist on seasonally dry alkaline soils and are not destroyed by fire [16]. Therefore, grassland habitats provide valuable pastures in semi-arid areas of Tanzania where *Sporobolus pyramidalis*, *S. marginatus*, *S. ioclados* and *S. cordofanus* sometimes occur in association. *S. consimilis* and *S. spicatus* association occurs as a mosaic along the lakeshore for example along Lake Burunge in northern Tanzania [16].

In southern miombo woodlands of Tanzania, *T. triandra* is a dominant grass and widespread and occurs at different topographic positions [17]. On deeper Plateau soils tall grasses of *Hyperthelia dissoluta* and *Andropogon gayanus* of about 2 m dominate. On hill slopes, *Hyparrhenia newtonii* and *Andropogon schirensis* with a height of about 1.2–1.4 m is very frequently present. On leached soils grasses are mostly 0.6–0.8 m, *Aristida adscensionis* is primarily dominant [17].

In the western miombo woodlands of Tanzania, there are extensive, continuous woodlands interspersed with seasonally inundated grasslands known as "mbuga" in the Kiswahili language (**Figure 4**).

According to an unpublished report by Kavana and Kakengi [18] they observed that common grasses in seasonally flooded plains include *Cynodon dactylon, C. articularis, C. cyperoides, C. difformis, C. dives, C. esculantus, C. involucratus, Cyperus papyrus, C. rotundus, Phragmates mauritianus, Pennisetum purpureum, Sporobolus spp, Echinochloa pyramidalis* and *Oryza longistaminata* (**Figure 5**).

In settlement areas where miombo woodlands are cleared for agricultural and grazing lands, the common grasses include *Panicum maximum, P. repens, Panicum trichocladum, P. trichocladum, Pennisetum polystachyon, P. polystachyon, Rhynchelytrum repens, Setaria homonyma, S. sphacelata, Sporobolus africanus, S. fimbriatus, S. ioclados, Sporobolus pyramidalis, S. sanguineus, Urochloa decumbents* and *U. echinolaenoides* (**Figure 6**).

Some characteristic mosaic grassland occurs proximal to Lake Rukwa where dominant grass species stand a change with soil alkalinity progressing towards the lake [19]. Cymbopogon begins in less alkaline soil (pH 7.5–8.5) followed by Hyparrhenia, Chloris, Cynodon, *Sporobolus robustus*, Echinochloa, Cyperus, Diplachne, and *Sporobolus spicatus* at pH 9.5–11 [19]. Therefore, Tanzania is diverse and influenced by climatic conditions, soil, and anthropogenic activities [8].

Figure 4.
Typical characteristics of grassland in Ugalla ecosystem assessed by researchers from Tanzania Wildlife Research Institute.

Figure 5.
Seasonally flooded grassland plains of Western Serengeti were assessed by researchers from Tanzania Wildlife Research Institution.

Figure 6.
Robust Pennisetum polystachyon and Rhynchelytrum repens in agricultural land, western Tanzania.

3.2 Importance of grasslands for grazing animals

Grasslands can be classified as natural and improved grasslands. Natural grasslands are dominated by native grass species mixtures that occur naturally, while improved grasslands are developed by seeding and vegetative propagation of selected grass species [20]. Grasses form a basal diet for both livestock and wildlife animals that make livestock production in the traditional sector and the most protected areas for wildlife to rely on [21]. This situation leads to Livestock-wildlife competition that operates through two sets of processes within the social-ecological systems and economic processes that influence Livestock and wildlife-based enterprises as sources of income for people and the nation, respectively [20]. The authors considered that ecological processes affect the relative efficiencies of livestock and wildlife species in utilizing grasslands' feed and water resources. As a result, the contribution of livestock enterprises to people's livelihood generally exceeds the contribution of wildlife conservation to the livelihood of people within the same area [22]. Further studies show that economic processes result typically in agricultural returns to outcompete wildlife returns and the patchwork of land use within rangelands intensifies towards

croplands and fragmented rangelands [22, 23]. This scenario corroborates observations made in the grasslands of Tanzania, as shown in **Figure 7**.

Population trends in **Figure 7** indicate that livestock increased continuously from 1995, possibly due to an increase in demand for livestock products that resulted from the increase in the human population. It has been reported that there is a close relationship between increases in cattle and growth in the human population that result from the need for livestock products to cater to the growing human population [26]. However, livestock in grasslands increases typically at the expense of wildlife [26]. Many studies show that markets, technology, and infrastructure development, the position of a rangeland/grassland on its production possibility frontier (PPF), changes with agricultural production becoming specialized, driving down the possibilities for wildlife production [27–31]. The overall population trend of grazers in the grasslands of Tanzania indicates a steady increase in the population [32]. This implies an increase in grazing pressure in grasslands that entails the need for close monitoring of the grasslands of Tanzania for sustainable livestock and wildlife production [8].

Frequent and severe droughts in many parts of Tanzania are being felt with their associated consequences on food production and water scarcity, leading to food shortages and insecurity, water scarcity, hunger, and it provides poor forage for animals [33]. Prolonged drought is a significant driver of grassland ecosystems and is likely to lead to increased wildfires and loss of wetland habitats that are critical habitats for migratory bird species and species migration and habitat shifts [34]. An increase in temperatures, reduced rainfall, and drought is already being observed in some regions of Tanzania [35]. In particular, the northern part of Tanzania-central Serengeti grassland is projected to become even drier in this century [36]. In wetter areas, forests are likely to encroach on existing grasslands. In contrast, deserts are projected to expand in extent and move upward in elevation in increasingly arid areas, causing "desertification" of arid grassland ecosystems. Such a process will greatly affect the productivity of the grasslands ecosystem, impacting animal welfare [35, 36].

3.2.1 Natural grasslands

Survival of wildlife in protected areas and livestock production in the traditional sector in Tanzania rely on grasslands dominated by native grass species. The native grass species provide a basal diet for both wildlife and livestock herbivores. Native

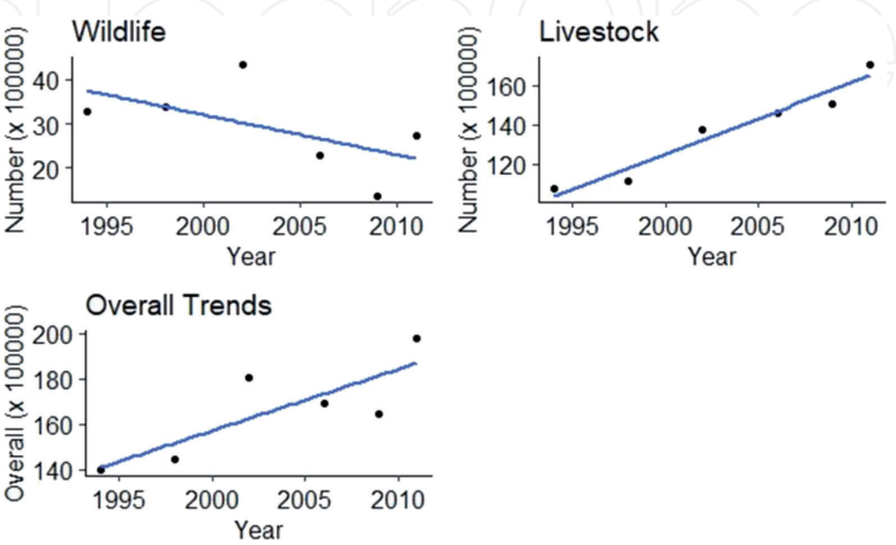

Figure 7.
Large Herbivore Units (LHU) population for livestock and wildlife in grasslands of Tanzania (source: Authors' computation based on TZFAOSTAT_data [24, 25]).

grass species inherently vary in biomass and nutrient contents they supply to the grazing animals. This compels wildlife and livestock to select certain grass species when grazing to meet their energy and nutrient requirements [37]. For a grass species to be consumed by grazing animals, it must belong to edible plant species (i.e., not harmful). Among edible plant species, some species are highly desirable, desirable, and less desirable. Plant species that are not edible are termed undesirable plants in terms of grazing animals' feeding value [37]. The natural grasslands of Tanzania are mainly composed of desirable and highly desirable grass species (**Figure 8**). This composition supports the survival of large numbers of grazing wildlife and livestock in the country.

Nutritive value of grasses in natural grasslands vitiates in quality rapidly across months within a year (**Figure 9**). This makes it rather difficult for natural grassland to support the high productivity of grazing animals throughout the year. High grazing animal production and products follow periods of high quantity and quality of grasses in grasslands [39]. In other words, there is natural synchronization of the reproduction cycle such that most of the calving occurs during periods of high quantity and quality of grasses in natural grasslands [39].

3.2.2 Improved grasslands

Improved grasslands in Tanzania are classified according to usages, such as pasture production farms for haymaking and grazing farms for dairy production. These farms are seeded with improved grass species: *Chloris gayana*, *Cenchrus ciliaris*, *Pennisetum purpureum*, *Panicum maximum*, *Setaria sphacelata*, *Tripsacum laxum* and improved varieties of Brachiaria species. In some cases, leguminous species are over-sowed in grass farms to improve the quality of hay. Common leguminous species mixed with grass include *Desmodium uncinatum*, *Centrosema pubescens*, *Macroptilium atropurpureum*, *Stylosanthes guianensis*, *S. guianensis*, *Pueraria phaseoloides*, *Clitoria ternatea* and *Calopogonium mucunoides*.

A considerable amount of work for improved grassland was carried out in Tanzania at Kongwa Pasture Research Centre with large-scale sowing of *C. ciliaris* under large-scale management [40–42]. Material initially selected in Tanzania was much more widespread use outside the country: common cultivars of tropical

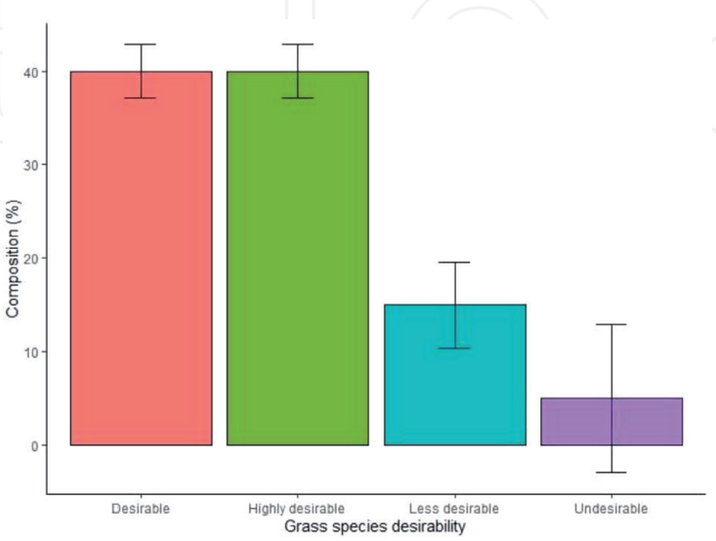

Figure 8
The desirability of grass species in western Serengeti natural grassland. Source: Authors' computation based on Kavana et al. [38].

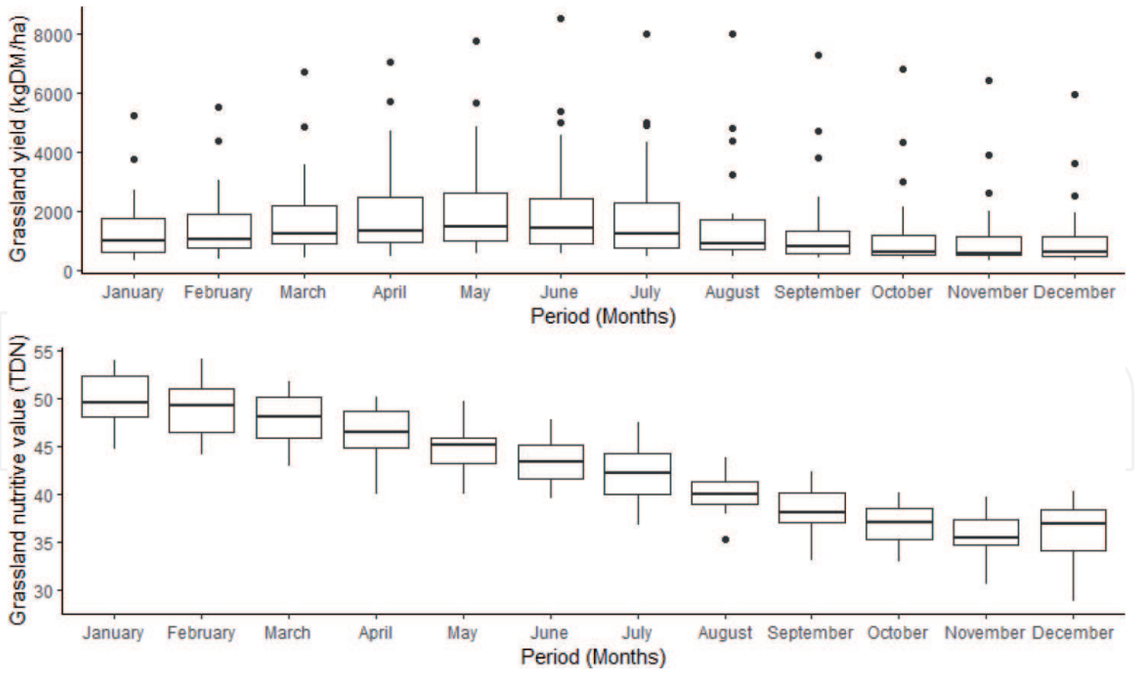

Figure 9.
Quantity and quality of grasses in Ugalla ecosystem's natural grasslands. Source: Authors computation from unpublished research data.

pasture plants developed from Tanzanian material in Australia include *C. ciliaris* "Biloela", *C. gayana* 'Callide' and *Neonotonia wightii* 'Clarence' [43]. Mixing grasses with legumes is considered to increase dry matter production of grass. The highest dry matter yield of *C. ciliaris* was observed in a mixture with *Phaseolus atropurpureus*, *S. guianensis* and *C. pubescens* [44].

3.3 Contribution of grasslands to the livelihood of rural communities

A direct result of the contribution of grassland to the livelihood of people and the national economy in Tanzania is that local people rely mainly on grassland for the production of livestock products. The trend of meat production from grasslands (**Figure 10**) shows that meat production increased at a decreasing rate, and the value of meat produced from grasslands increased progressively. This indicates that livestock keeping in grasslands is a lucrative business that contributes to rural people's economy. However, the contribution of meat produced from grassland to the total meat produced by grazing livestock showed a declining trend. This could be attributed to the decline in the potential of Tanzania's grassland of Tanzania to support large herds of grazing animals. The potential of grasslands to support grazing animals is affected by environmental fluctuations and increased human activities [45, 46]. Human population increase resulted in the expansion of cultivated land at the expense of grassland, and the need for animal products led to the keeping of large herds of livestock [26]. This situation causes shrinkage of grassland and overgrazing, reducing grassland's potential to support grazing animals in the country.

Grasslands contribute more than 60% of milk produced in Tanzania, and the value of milk produced increased steadily (**Figure 11**), contributing more than 2500 billion TZS to people's economy. However, the contribution of grassland to the total milk produced in Tanzania has been slightly increasing year after year [47]. This might be caused by improvement in urban dairy farming and probably deterioration of grasslands in terms of quantity and quality of feed resources availability in communal grasslands that need to be evaluated.

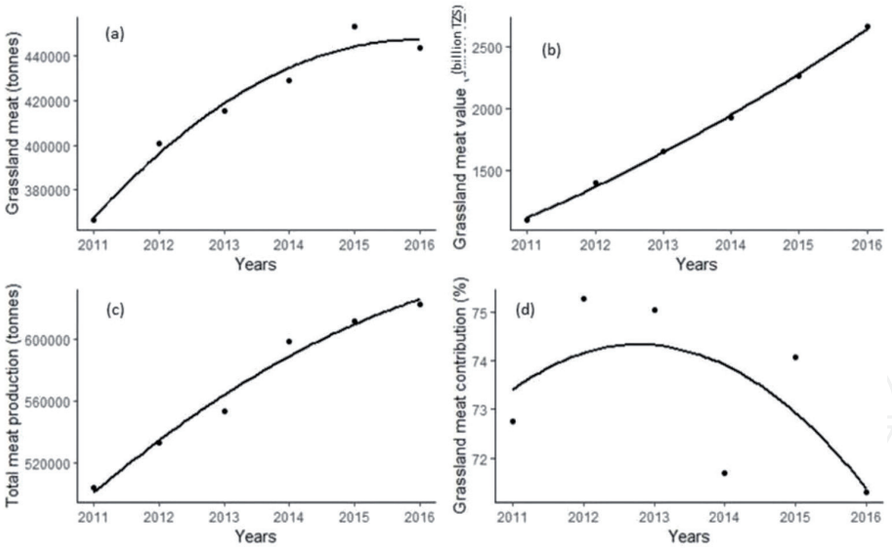

Figure 10.
Quantity and value of meat produced from grasslands and other places of Tanzania. Source: Authors' computation based on livestock and fisheries basic data and Tanzania in figures 2016 documents.

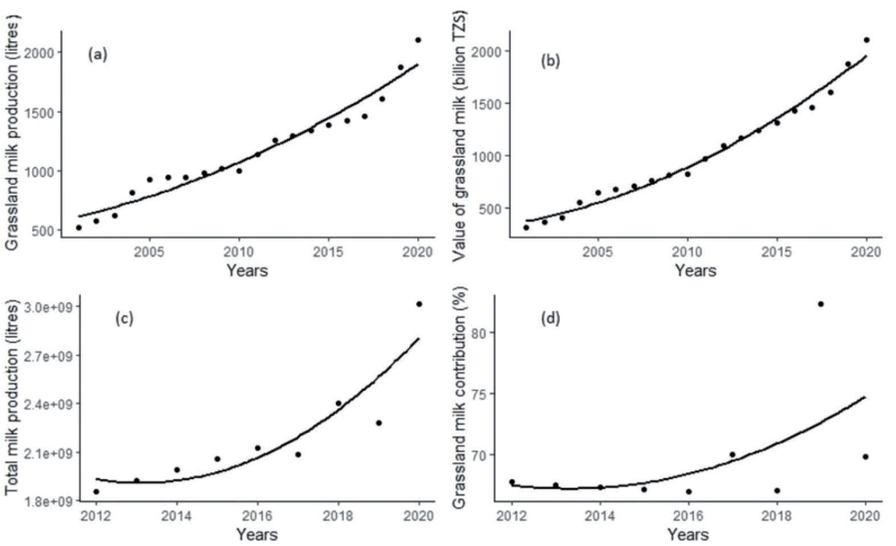

Figure 11.
Contribution of grassland to milk production and economy of people in Tanzania. Source: Authors' computation based on Tanzania in figures document [47].

3.4 Challenges on the sustainability of grasslands

Agriculture poses a significant challenge for the sustainability of grasslands in Tanzania. Current agriculture production is hinged on the expansion of mono-cropping farms to increase food production for the growing human population. In many cases, the expansion of crop farms is done at the expense of grasslands. Land clearing and cultivation for crop production re-structure and disrupts a previously stabilized grassland ecosystem. The disturbed ecosystem due to cultivation immediately begins succession where annual grasses and forbs adapted to bare land conditions and disturbed soil invade the site and become established. This situation results in changes in plant species composition of the grassland.

Grasslands are the main grazing areas for livestock where most of the grazing lands in the country are communally managed. Poor livestock grazing management results in soil compaction due to the effects of animal trampling, leading to poor water infiltration. Removal of plants due to many grazing livestock in communal

lands causes bare land (**Figure 12**). In combination with poor water, infiltration causes surface water runoff during the rainy season that erodes soil.

Soil erosion of bare land during the rainy season removes top fertile soil resulting in low soil fertility. Poor soil fertility causes the establishment of a limited number of plant species resulting in low plant composition on grassland. Low plant species composition leads to low above-ground biomass production that causes an insufficient feed resource base for grazing animals.

A high number of grazing animals in a shrinking grassland with an insufficient feed resource base in terms of quantity and quality results in high utilization pressure by grazing animals. High grazing pressure exerted on highly desirable and desirable grass decreases the potential of grassland to support grazing animals.

Effects of climate change on the grasslands of Tanzania could be manifested in relation to the variability of temperature and precipitation [8]. Climate change projections indicate that western parts of the country, central, north, Lake Victoria basin, eastern parts of Lake Nyasa, south-western and north-eastern highlands are projected to feature increased minimum temperature [48]. An increase in temperature is associated with an increase in the photosynthetic rate of plants under optimum soil moisture. Projections of precipitation indicate that Coastal regions, parts of north-eastern highlands, northern areas, western and southern parts of the Lake Victoria basin will experience an increase in annual rainfall. This implies that most of the grasslands of Tanzania are expected to increase Net Primary Production (NPP) of grass biomass. Therefore, the main limitations for the sustainability of most grasslands of Tanzania will be extensive crop cultivation and livestock population grazing.

3.5 Way forward to sustain grasslands

An increase in the human population triggers a need for food sufficiency that stimulates cultivation of land and livestock keeping which is based on the availability of land. This shows that in many cases increase in the human population in rural areas results in the expansion of cultivated land to cater to food demand. However, this scenario occurs when land is available for expansion of crop farms but changes to intensive cultivation when land is scarce.

Figure 12.
Bare land due to overgrazing and trampling in the grassland of western Serengeti.

Changing from extensive crop cultivation to intensive cultivation and reducing grazing pressure is inevitable for the sustainability of grasslands in Tanzania because the land is a fixed commodity. Intensive cultivation will be achieved by increasing production in the same land units by increasing agricultural inputs and technology. Reducing grazing pressure in grasslands will be achieved by either reducing the number of grazing animals per unit of land or reducing the duration of grazing on grassland units.

Determinants of the holistic direction that agro-pastoralism is developing in Tanzania are still not clearly understood. A combined model including economic, social, ecological components and wildlife conservation is needed to enable predictions about the future of agro-pastoralism in areas that are adjacent to protected areas.

4. Conclusions

Our review details the significance of grasslands in Tanzania. Grasslands of Tanzania are diverse, and their diversity is influenced by both climatic, soils, and topographic variations across Tanzania. They support an enormously larger number of livestock and wildlife populations.

Grasslands of Tanzania show a big potential to support people's livelihood through meat and milk production, but its contribution is declining. However, such ecosystems experience overgrazing, conversion to agricultural lands, frequent annual fires, and climate change.

Evaluation of the grasslands of Tanzania is worthwhile to establish baseline information or trends that will be used for comparison in long-term monitoring of grasslands condition. This can only be achieved if proper land use plans are put in place, especially in all rural settings and improved management systems that operate at different regimes across Tanzania.

Evaluation of the grasslands of Tanzania is inevitable to establish baseline information for comparison in long-term monitoring of grasslands condition. However, we can only achieve this if proper land use plans are implemented, especially in rural settings.

Conflict of interest

The authors proclaim no conflict of interest.

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