Chapter

Impact of Agro-pastoralism on Grasslands in Serengeti and Ugalla Ecosystems, Tanzania

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Abstract

This chapter delves into the intricate relationship between agro-pastoralism and grassland ecosystems in Tanzania's Western Serengeti and Ugalla Ecosystems. Despite the acknowledged contribution of agro-pastoralism to rural well-being and economic development, its impact on the delicate balance of grassland ecosystems remains unclear in these crucial Tanzanian landscapes. The chapter aims to illuminate agro-pastoralism's environmental, social, and economic dimensions in these regions. Guided by research questions exploring current conditions, potential solutions, and the path toward sustainable grassland resource utilization, the study employed a systematic literature review and data analysis using R software. Key findings highlight challenges from the progressive expansion of agro-pastoral activities, leading to trade-offs between ecosystem services and productivity. The study identifies agro-pastoral clusters across the area, revealing variations in economic activities and their impact on grassland utilization. Impacts on natural resources, such as soil pH changes, reduced herbaceous biomass, and shifts in plant composition, are discussed. The legal framework related to natural resource conservation in grasslands emphasizes the need for a balanced, ecologically sustainable approach. Efforts to alleviate agro-pastoral impacts, including introducing climate-smart agriculture, are explored. The chapter concludes by emphasizing the importance of integrated, participatory methods for sustainable management in the Serengeti and Ugalla ecosystems. Recommendations include promoting sustainable land use practices, implementing rotational grazing, and enhancing community involvement in decision-making.

Keywords: agro-pastoral activities, grassland ecosystems, grassland utilization, grazing land, herbaceous plants

1. Introduction

Agro-pastoralism has been extensively studied at regional and global scales in relation to environmental processes [1]. However, the effect of agro-pastoralism on grassland ecosystems and the livelihood of people in Tanzania has remained unknown. It is widely acknowledged that agro-pastoralism contributes to the well-being of people in rural areas and the country's economy. On the other hand, little has been done to quantify the contribution of agro-pastoralism to the livelihood of people in Serengeti and Ugalla grassland ecosystems. The present study investigates the impact of agro-pastoralism on herbaceous plants and soil properties in Serengeti and Ugalla grasslands, as well as its contribution to livelihoods.

Grassland covers more than 40% of the Earth's surface [2] and about 6.8% of the land surface of Tanzania [3]. Grassland plays an essential role in ecosystem productivity and biogeochemical processes [4]. Grassland ecosystems have local importance for maintaining biodiversity and food production, influencing ecological processes, water, and climate regulation [5]. Approximately 49.3% of grassland in the world encounters degradation problems [6], and the grasslands of Tanzania are not exceptional in degradation problems. There is a progressive growth in human population and conversion of grasslands to agro-pastoral land [7]. This affects grassland as there can be conflicting goals between agro-pastoralism and the maintenance of grassland ecosystem services. Maximizing the provisioning of services from agro-pastoralism tends to result in a trade-off with plant composition and other ecosystem services. As a result of the non-linear relationships between ecosystem services, such as grassland composition and agro-pastoral productivity, managing them poses challenges [8]. When one service is optimized, other services are reduced or lost (a situation known as 'trade-offs') [8]. As communities continue to transform grassland ecosystems to obtain greater provision of specific services, the demand for more agro-pastoral land may lead to diminishing some grassland services.

1.1 Research questions

i. What is happening in the grasslands of Tanzania?

ii. Is there any solution to the negative impacts caused by anthropogenic activities?

iii. What is the way forward to sustainable utilization of available grassland resources in Tanzania?

1.2 The objective of the chapter

To depict the current situation of grasslands resulting from anthropogenic activities and its future scenario.

2. Methodology

2.1 Study area

The study was conducted in Western Serengeti and the Ugalla ecosystem in Western Tanzania (**Figure 1**). Western Serengeti is home to agri-pastoralists, and the population

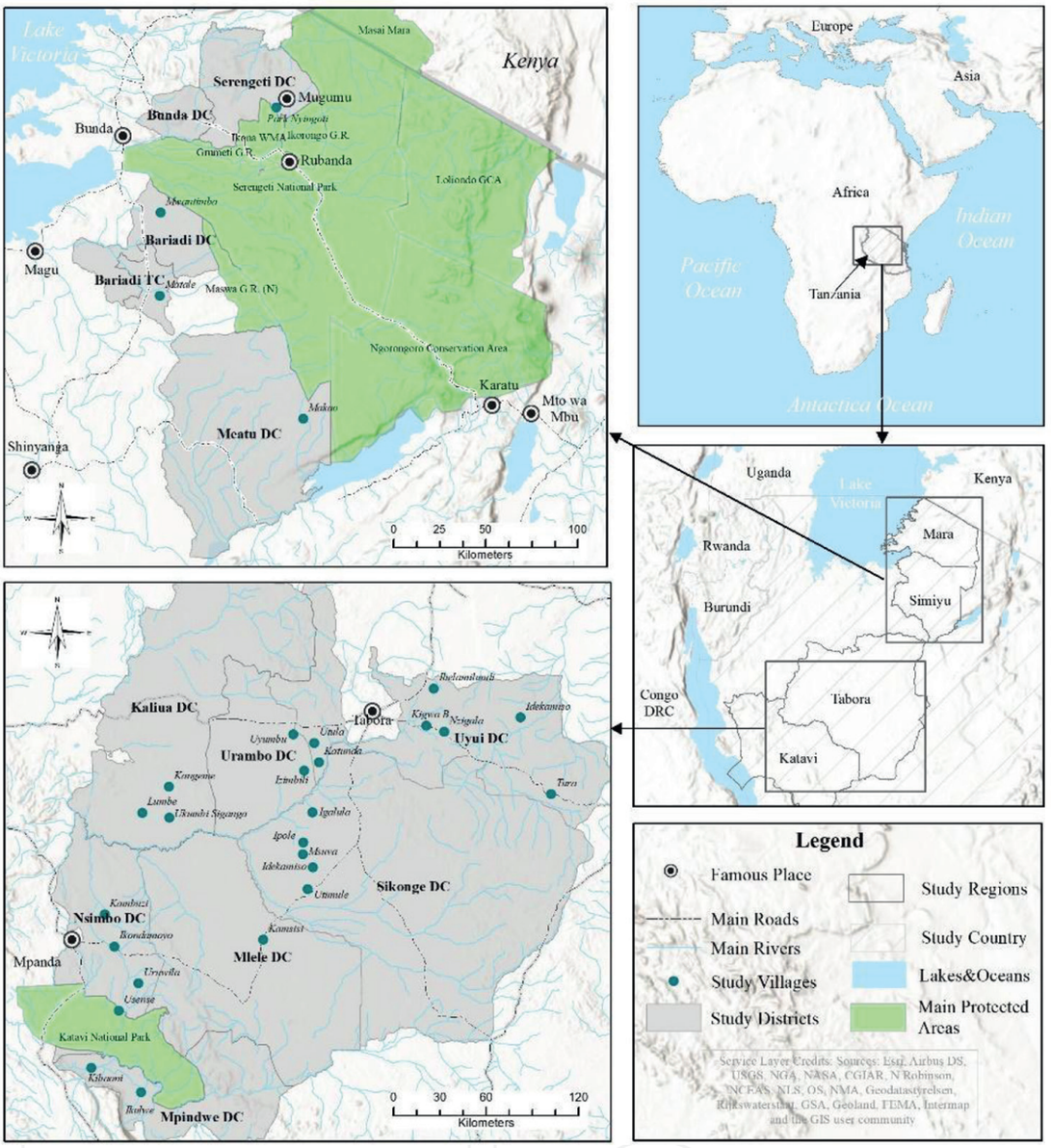

Figure 1.
Location of study sites in Serengeti and Ugalla ecosystems.

growth rate there is higher than in the north, east, and south of the National Park [9]. It is considered to have low suitability for arable agriculture. Although its subsistence economy is primarily based on agro-pastoralism [10], poor delivery of agricultural extension services, and insufficient input supplies limit this activity, which leads to the practice of extensive cropping and livestock keeping in villages that encroach on protected areas [11]. The study was conducted in four districts: Serengeti, Bunda, Meatu, and Bariadi.

Ugalla ecosystem comprises the Tanzania Ramsar site with many important socio-economic and cultural values. Some of the most important include harvesting wetland-related products, including fish, forest products, medicinal plants, honey, and wildlife. Other values of importance to the local communities include flood control, water supply, and dry-season grazing. The human population's subsistence economy in and around the proposed site depends mainly on farming, fishing, hunting, and honey gathering. Although honey gathering and fishing are not normally permitted in game reserves in Tanzania, it has been the practice to permit such activities in

the game reserves in the Ramsar site as these activities predate the establishment of the reserves. Large numbers of fishing and beekeeping camps operate throughout the Ramsar site during the dry season (July to December). Permanent fishing villages are present around some of the lakes, such as Lake Sagara.

The estimated number of cattle is 15–20,000 in the central portion of the wetland and more cattle in the southern parts of the Ramsar site. Groups of nomadic pastoralists also move into the area during the dry season. The traditions of the local people on this site do not allow hunting or capturing of some birds like ground hornbill and animals like bushbuck. The majority of the Ramsar Site is under the direct jurisdiction of government agencies, comprising game reserves of 2.45 million ha, forest reserves of about 650,000 ha, and the balance being district or village land amounting to about 150,000 ha. The Ramsar site is surrounded by forest reserves in certain areas, notably in the northeast and south. In the central and northwest portions, the site is bounded by open or public land or agricultural areas primarily controlled by villages or district authorities. The study was conducted in five districts, including Urambo, Uyui, Kaliua, and Sikonge in the Tabora region and two districts in the Katavi region that include Mpanda (Nsimbo district council) and Mlele (Mlele and Mpindwe district councils).

2.2 Data collection and analysis

A systematic review of the scientific literature on agro-pastoral impact in grasslands was conducted using guidelines outlined by Pullin and Stewart [12] and Inskip and Inskip & Zimmermann [13]. Google Scholar, as well as other search engines, was used to determine the body of knowledge on the subject. To determine relevance and applicability, the search protocol was preceded by predefined filters for keywords [12, 13]. The relationship between agro-pastoral activities and edaphic factors was analyzed using R software version 3.5.0 [14].

2.3 Agro-pastoralism in Tanzania

Agro-pastoralism refers to a livelihood strategy that involves growing of crops and keeping of livestock by the local communities. This kind of livelihood significantly relies on rainfall patterns and the availability of natural pastures. Depending on cattle management types, there are three types of agro-pastoralism practiced in Tanzania. Brandström et al. [15] identified unilocal agro-pastoralism where livestock herds graze in the neighborhood of the homesteads and are taken back to craals every night. Another form of agro-pastrolism is bilocal, where herds graze near homesteads during certain months, but move far away for pasture and water during others. In addition, Brandström et al. [15] identified multilocal agro-pastoralism, in which a small number of cattle is permanently kept at the homesteads while the main herd is far from it throughout the year. In Tanzania, livestock density is highest in agro-pastoral areas around Lake Victoria [15]. This agro-pastoral area uses most of its labour in cultivation, where surplus is used to rear livestock by grazing crop residues. The same strategy is also applied in the agro-pastoral regions of central Tanzania [16]. Data from the 2014–2015 and 2016–2017 annual agriculture censuses [17, 18] show that agro-pastoralism is practiced throughout Tanzania's mainland (**Figure 2**).

Based on the data, the Mwanza region had the highest number of agro-pastoral operators whereas the Dar-es-Salaam region had considerably fewer operators. Further, cluster analysis revealed three main clusters of the regions practicing agro-pastoralism in Tanzania's mainland (**Figure 3**).

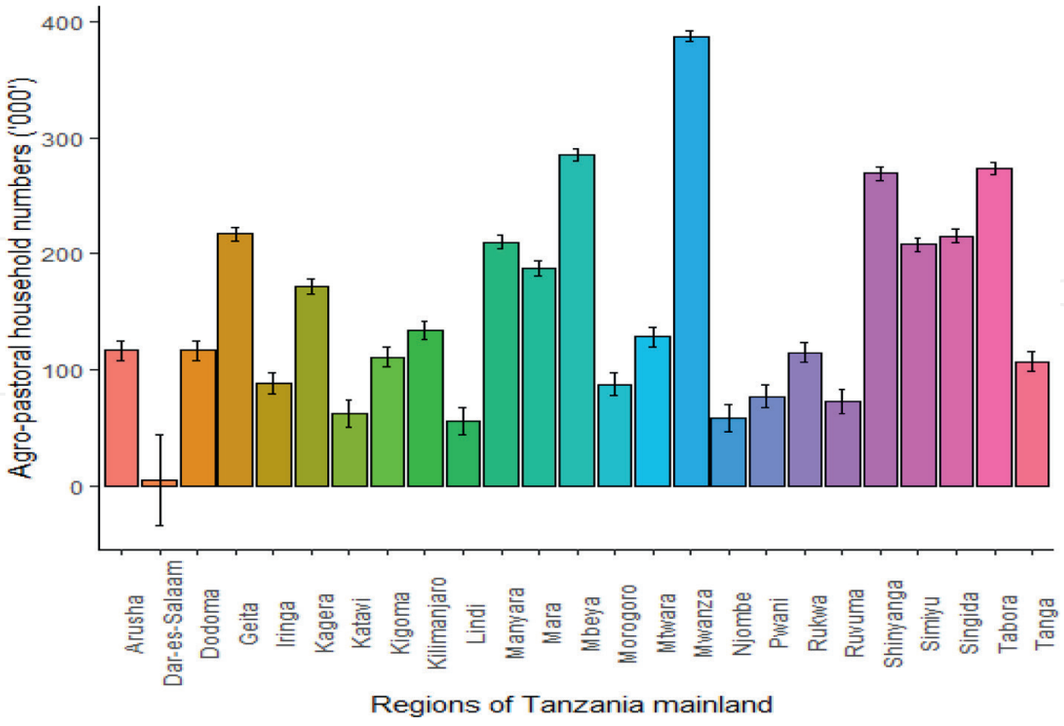

Figure 2.
Average number of agro-pastoral operators in different regions of Tanzania mainland. Source: Authors' synthesis from NBS [17, 18] data.

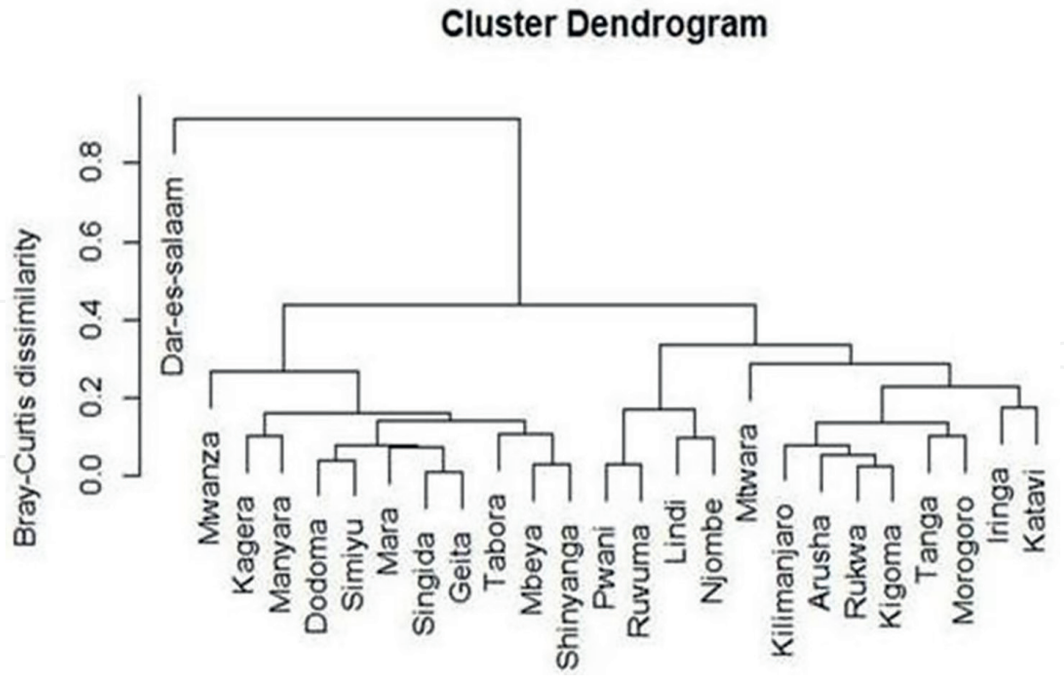

Figure 3.
Regional clusters of agro-pastoral operators in Tanzania's mainland. Source: Authors' analysis from NBS [17, 18] data.

The Dar-es-Salaam region was a distinctive cluster. The other cluster included the regions of Dodoma, Mara, Singida, Mwanza, Kagera, Manyara, Simiyu, Geita, Tabora, Mbeya, and Shinyanga. The final cluster included the regions of Tanga, Morogoro, Lindi, Njombe, Pwani, Kilimanjaro, Arusha, Rukwa, Ruvuma,

Mtwara, Kigoma, Iringa, and Katavi. Additional research into the various clusters revealed that clusters 1 and 3 were dominated by crop farming (**Figure 4**). However, in cluster 1 operators were very few compared to other clusters. The reason for the low involvement of operators in cluster 1 can be associated with its city dwellers who are mainly engaged in salary jobs. Pastoralism activity was lacking in cluster 1, a circumstance implying the absence of land for roaming animals in the city.

In cluster 2, crop farming and agro-pastoralism businesses were fairly evenly distributed. In cluster 2, agro-pastoralism appeared to be a clear and unchangeable decision regarding social and economic life. As a result, the agro-pastoralists in cluster 2 likely descended from a pastoral society that turned to farming as a means of subsistence after suffering cattle losses due to natural disasters. Crop farming alone was the primary source of income in cluster 3. Cluster 3 agro-pastoralists likely arose from farming groups that decided to start raising cattle. Climate change and the requirement to use animals to boost agricultural output to obtain surplus crops in favorable years may drive the shift to livestock husbandry.

Compared to the Agrarian households in clusters 2 and 3, which engaged in crop farming and agro-pastoralism, fewer practiced pastoralism. This suggests that practicing pastoralism in Tanzania is challenging due to the effects of population expansion, climate change, and variability. Climate stress alters the amount, patterns, and distribution of rainfall and lengthens dry spells and droughts that reduce grazing land and water resources, resulting in decreased cattle output [19]. The number of households engaged in pastoralism in clusters 2 and 3 may decline if the country's climate stress persists.

Agro-pastoralism, in general, entails using tools, methods, and knowledge to alter the natural environment to create a variety of goods. Specific agro-pastoral clusters are shaped by the integration of economic activities used in agro-pastoral systems, and variances between these economic activities cause inconsistencies between clusters. Agro-pastoralism has criticism, and there are many diverse varieties that, depending on the economic circumstances of the local community, may place more or less emphasis on agriculture. The social, political, ecological, and geographic context in which these groups are found determines how often there are continual changes and transitions between more farming and more herding across time [20].

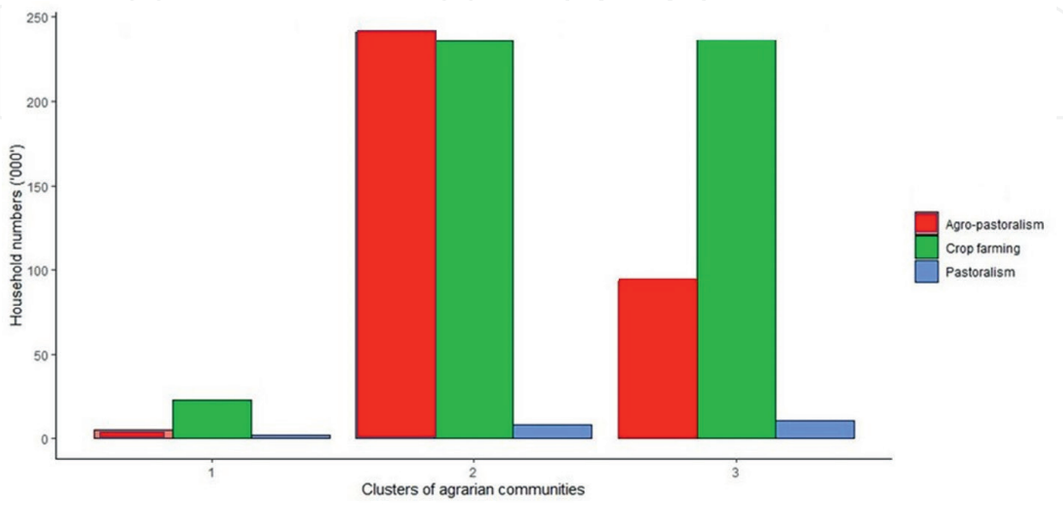

Figure 4.
Distribution of households involved in different agricultural activities among clusters in Tanzania's mainland. Source: Authors' synthesis from NBS [17] data.

2.4 Natural resources available in grasslands

Grasslands in Tanzania are dominated by native plants that include grasses, sedges, herbs, and scattered trees. The dominant plants in western Serengeti include *Themeda triandra* in wildlife grazing areas, *Cynodon dactylon* in livestock grazing areas, and *Chloris pycnothrix* in areas with mixed grazing of livestock and wildlife [21]. Grasslands in the Ugalla ecosystem are dominated by plant species that include *Digitaria macroblephara*, *Setaria pumila,* and *Echnocloa pyramidalis* in protected areas. In contrast, *Pennisetum polystachyon* commonly dominates cultivated land in villages (**Figure 5**).

Common trees in western Serengeti include *Kigelia africana* found along seasonal river banks; *Phoenix reclinate* found along rivers and swamps; *Commiphora Africana* scattered in various places; *Vachellia xanthophloea* found along rivers, swamps, and floodplains; *Vachellia tortilis* found in regular plains and *Vachellia drepanolobium* found in seasonally water-logged soils. Thornless deciduous trees adapted to uni-modal rainfall patterns are common in the Ugalla ecosystem. The common tree species include *Brachystegia augustistipulata*, *Brachystegia boehmii*, *Brachystegia glaberrima*, *Brachystegia glaucescens*, *Brachystegia longifolia*, *Brachystegia spiciformis*, *Brachystegia taxifolia*, *Julbernardia globiflora*, *Julbernardia paniculate*, *Isoberlinia angolensis,* and *Isoberlinia tomentosa*. The dominant genera in this ecosystem include Brachystegia, Julbernadia, Isorberlinia, Markhamia, Grewia, Terminalia, Syzygium, Vachellia, and Combretum [22]. Vegetations available in the grassland ecosystems of Ugalla and Serengeti provide non-timber forest products such as wild fruits, mushrooms, ropes, honey, bamboo, fodder, and brooms. Gathering of non-timber forest products helps local communities to boost their livelihood and households' upkeep. These products are used as food, medicine, and some of them are used for decorations.

2.5 Effect of agro-pastoralism on natural resources

Agro-pastoralism is a predominant livelihood in Serengeti and Ugalla ecosystems, where land and natural pasture are primary natural resources. Livestock moves in the vicinity of the villages and grazes on communal grazing lands, fallow lands, and crop fields after harvest. Studies showed that there is growth in human population and conversion of land to agriculture in agro-pastoral areas of Tanzania [7]. The increase in human population triggered the need for food sufficiency that stimulated cultivation and livestock keeping (**Figure 6**) based on land availability. Competition for

Figure 5.
Plants field assessment in Ugalla and Serengeti ecosystems.

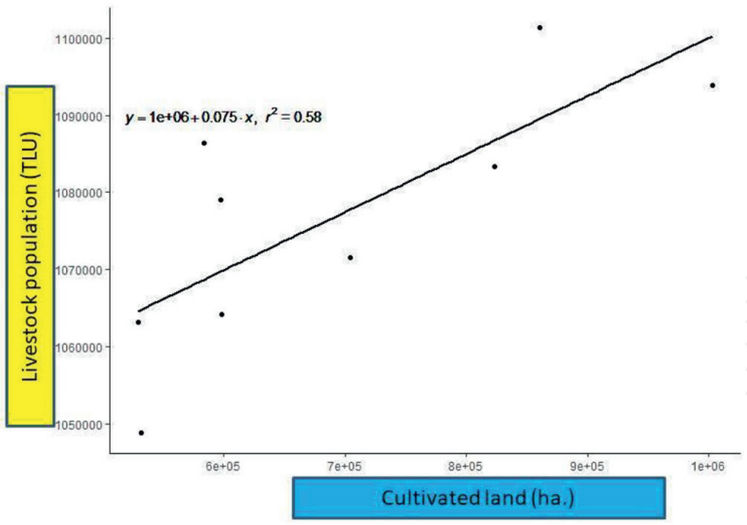

Figure 6.
Relationship between livestock population and land cultivated for crop production. TLU = Tropical Livestock Unit. Source: Authors' synthesis from NBS [17, 18] data.

natural resources, especially land, has become an issue of major concern and cause of conflict worldwide [23].

The change in land use in the upper catchments within ecosystems resulted in higher peak water flow during the rains and lower peak water flow during river drought [24]. Water abstraction levels for consumptive uses are normally highest during the dry season, imparting additional strain on the rivers within ecosystems during critical low water flow. This situation compelled the development of the Tanzania National Water Policy, which requires the protection of reserve flows to enable water availability for basic human needs and sustain ecosystems [25].

Soil is an important component of any ecosystem. It supports life systems by delivering ecosystem goods and services. For instance, the soil is one of the major carbon sinks, and plays roles in water regulation, soil fertility, and food production, which have effects on human well-being [26]. In any biological ecosystem, soil pH greatly influences biogeochemical processes [27]. Soil pH influences varieties of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield [28]. Despite the roles played by soil pH in ecosystems, keeping large numbers of livestock in communal grazing land tends to lower it [29]. For example, Tamartash et al. [30], demonstrated soil acidity to increase with increasing grazing intensity. Nevertheless, low soil pH affects soil microbial activities of decomposing organic carbon, shown by an increase in C:N ratio as the stocking rate increases (**Figure 7B**). Soil pH controlled microbial activity that consequently influenced microbial decomposition of carbon and nitrogen [27]. Therefore, agro-pastoral activities are envisaged to lead to acidification of soil.

Low soil pH (<6) in western Serengeti caused by agro-pastoral activities resulted in low herbaceous standing biomass (< 2000 kgDM/ha) and low herbaceous plant species richness (<5 species/quadrat), as shown in **Figure 6C** and **D**, respectively. Results obtained in western Serengeti concur showed that a soil pH of 6.3 was optimum for standing biomass and species richness of herbaceous vascular plants in miombo woodlands [31].

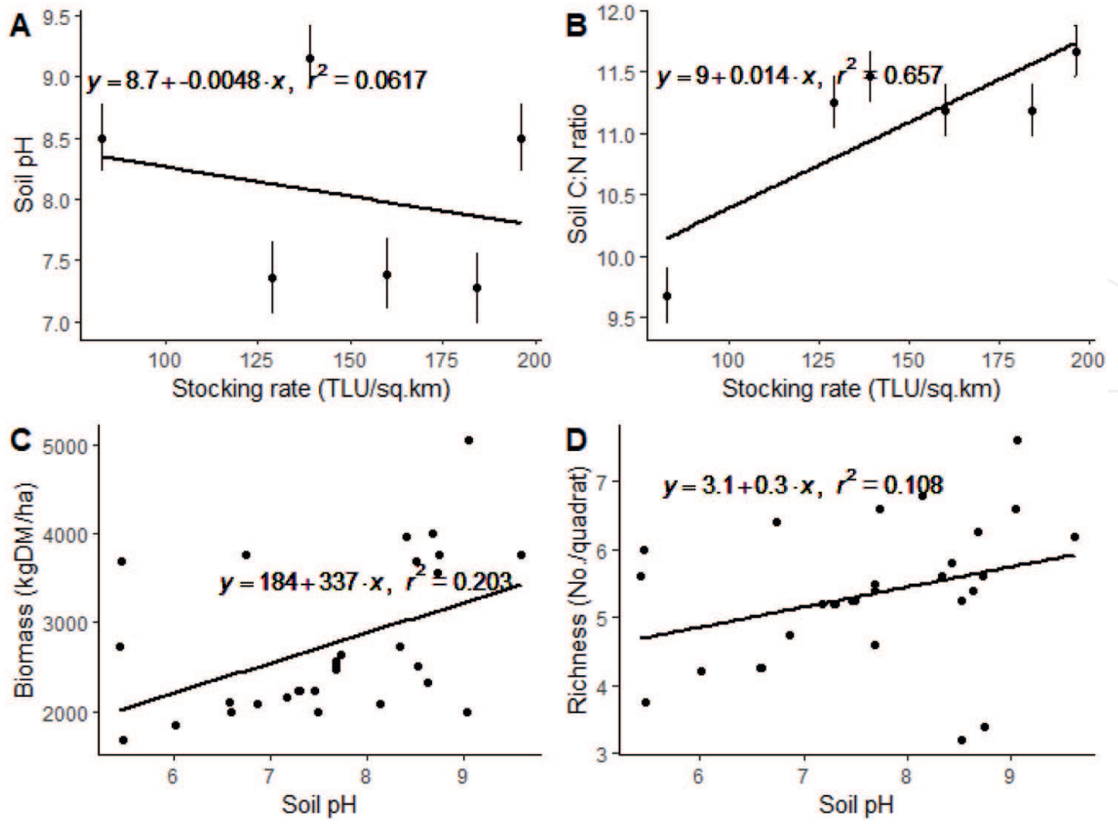

Figure 7.
Effect of animal density on soil properties and consequent effect on herbaceous plants attributes.

2.6 Legal framework on natural resources conservation in relation to grasslands

Wildlife Conservation Act No. 5 of 2009: The Act provides for the conservation of wildlife and ensures protection, management, and sustainable utilization of wildlife resources, habitats, ecosystems, and the non-living environment supporting such resources, habitats, or ecosystems with actual or potential use or value. The Act is important in grassland conservation as wildlife habitats in the sense that grasses form the main basal diet for wild herbivores in Tanzania.

Plant Protection Act No. 13 of 1997: The Act provides for the prevention of the introduction and spread of harmful organisms, to ensure sustainable plant and environmental protection, to control the importation and use of plant protection substances, and to regulate the export and import of plants and plant products. The Act is important in grassland conservation as it inhibits the introduction and spread of organisms that may alter grassland species' composition and ecosystem functions.

Land Act No. 4 of 1999 and Village Land Act No. 5 of 1999: The Land Act and Village Land Act have provisions that are important for environmental management. The fundamental principle of the Land Act is to ensure that land is used productively and that any such use complies with the principles of sustainable development. Among others, the Act prohibits any development activities in environmentally sensitive areas such as wetlands and swamps and 60 m from the shoreline and riverbanks. The Village Land Act also empowers the village government to have legal control of village land and its uses. This also includes prohibiting or minimizing land problems

like bushfires as well as land use-related conflicts between farmers and livestock keepers/pastoralists. This Act limits human activities that may be detrimental to grassland ecosystems; for example, most of the grasslands in the Ugalla ecosystem are found in seasonally flooded lands. These areas are regarded by the Land Act as sensitive areas that require users to comply with sustainable development principles.

Water Resource Management Act No. 11 of 2009 and Water Supply and Sanitation Act No. 12 of 2009: The Water Resources Management Act (WRMA) provides the legal framework for the management of water resources within the integrated water resources management (IWRM) framework. The Act provides for pollution control and issues discharge permits for effluents to water bodies, including the underground strata. The Act also provides flood mitigation and control measures to inhibit or lessen the risk of flooding, flood damage, and water pollution. The Water Supply and Sanitation Act provides a legal framework to ensure water quality by protecting water works and storage facilities against pollution. The Act further gives a mandate to the Local Government Authorities to enact by-laws concerning water supply and sanitation for efficient and sustainable provision of these services in their areas. Grasslands are considered to regulate water above groundwater quantity and flow and limit soil erosion that contributes to water quality by minimizing sedimentation in rivers and lakes. This conquers the Act that emphasizes flood mitigation and pollution control.

2.7 The Grazing-Land and Animal Feed Resources Act (Act No. 13 of 2010)

This law sets the necessities to manage and control grazing lands, animal feed resources, and trade. The law establishes the National Grazing-land and Animal Feed Resources Advisory Council, which is responsible for promoting participatory, equitable use and management of grazing-land resources. The council works to foster collaboration with public and private institutions or authorities in issues related to the use and management of grazing land. Since most of the grazing lands are grasslands, this Act is concerned with the sustainable use of grasslands in a broad sense. However, it is bound to grazing lands that leave out grasslands with no grazing value but are important for the provisioning of ecosystem services.

2.8 Impacts of agro-pastoralism on grassland natural resources

Sustainable standing plant biomass production to support livestock and wildlife in grasslands requires understanding critical variables in soil, plant, and grazing effects imparted by grazers. A study conducted in western Serengeti showed that agro-pastoral activities resulted in low residue standing biomass availability in communal grazing and cultivated lands [3]. High livestock grazing pressure was the leading cause of low-standing biomass in communal grazing lands. It was shown that an increase in the stocking rate of grazing animals caused a decline in plant biomass. Heavy grazing due to a high stocking rate removes the growing points of grazed plants [32], thereby reducing plants' growth potential and, thus, a decline in plant biomass. Overgrazing and continuous cultivation in grasslands contribute to the deterioration of soil properties [29]. Agro-pastoral systems in the Western Serengeti and Ugalla ecosystems are mainly rain-fed.

The productivity of grasslands depends on the availability of water, either for plant growth or for livestock and wildlife production. Water for crop production and pasture growth comes from rainfall, while livestock and wildlife drink water from rain-fed water sources. It has been observed that streams and natural water

sources have been shrinking due to rainfall variability and dry spells in ecosystems. Agricultural expansion, human population growth, and bushfires are considered to be salient ecological drivers of changes in the abundance of plants [33]. Agricultural expansion and human population growth are common phenomena in Western Serengeti and Ugalla ecosystems [3, 34, 35]. This situation leads to the shrinkage of grassland due to land clearance for cultivation. Therefore, the shrinkage of grassland and its product results in a consequential effect that devastated the sustainability of agro-pastoralism. The sudden effect of overgrazing and cultivation on the remaining part of grassland results in soil erosion, which affects the re-growth of plant and grass species. The pressurized grassland then starts to offer ecosystem services at a declining rate which results in a reduction in productivity.

2.9 Efforts to alleviate impacts of agro-pastoralism in Serengeti and Ugalla ecosystems

The performance of agro-pastoral systems is determined by the availability of land, water, and energy, which hit hard by climatic perturbation. In an endeavor to ameliorate the impact of agro-pastoralism and climate change in grasslands, the government, in collaboration with NGOs tried to introduce climate-smart agriculture. Climate-smart agriculture intends to increase productivity and income, the ability to adapt and build community resilience to climate change, and enhance food and nutrition security while achieving mitigation co-benefit in line with national economic development priorities. However, the adoption rate ranges from 4–30% [36, 37]. It was observed that climate-smart agriculture is site-specific that needs to consider local factors and co-design solutions with the communities that make use of grasslands.

3. Conclusion

Community livelihoods within the Serengeti and Ugalla grassland ecosystems are influenced by agriculture and livestock keeping, known as agro-pastoralist farming. Despite this, the study showed that agro-pastoralism adversely affects grasslands' natural resources. Plant composition, soil properties, and grassland ecosystem services are all affected by the continuous expansion of cultivated land and the keeping of large herds of grazing animals within limited grazing areas. Due to overgrazing and cultivation, soil fertility and plant biomass have been reduced, resulting in insufficient feed for grazing animals. As grasslands and natural resources are under pressure, sustainable grassland use is at risk.

3.1 Way forward

Integrated and participatory approaches are needed to ensure the sustainability of the Serengeti and Ugalla ecosystems. In order to preserve grasslands, agro-pastoralism policies, and management strategies should balance economic benefits and grassland ecology conservation. Emphasis should be placed on promoting sustainable land use practices that consider the land's carrying capacity and grasslands' ecological needs. Using rotational grazing, climate-smart agriculture, and soil conservation strategies can mitigate the adverse effects of agro-pastoral practices. Furthermore, involving local communities in decision-making will enhance a sense of ownership

and stewardship, resulting in better community involvement in the management of natural resources. These interventions' success depends on the cooperation of government agencies, NGOs, and local communities. These holistic approaches can help to maintain the delicate balance between human livelihoods and preserving grasslands' biodiversity and ecosystem services.

Declaration

Some parts of this chapter are based on an unpublished part of the main author's Ph.D. thesis on 'influence of agro-pastoralism on herbaceous plants diversity and livelihood of communities in western Serengeti' submitted to the Senate of Sokoine University of Agriculture in Tanzania.

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