Ecological Sustainability: Miombo Woodland Conservation with Livestock Production in Sub-Saharan Africa

Peter Rogers Ruvuga, Ismail Said Selemani, and Anthony Zozimus Sangeda

Abstract Miombo woodlands cover approximately 3.6 million km^2 in sub-Saharan Africa and have been identified as one of the global priority areas for conservation. Nonetheless, it is debatable whether the presence of the pastoralists and livestock in Miombo woodlands is linked to the ecological degradation and resources use conflicts. Besides, the impact of Miombo woodlands utilization in relation to biodiversity and ecosystem service provision is not well understood. The current review describes the various concurrent issues underlying livestock production in Miombo woodlands and ecosystem resilience. Analytical review established that livestock in Miombo woodlands have a crucial role in enhancing food security and animal source protein requirement in the future. Ecologically, pastoralists' presence in the Miombo serves biodiversity conservation, enhances nutrient recycling, and regulates wildfires. On the other hand, pastoralists are faced with several challenges including pests and diseases and persistent drought that leads to scarcity of water and pasture resources. Other setbacks include high enteric methane emission due to poor livestock productivity, unsustainable rangeland management practices, land tenure, and poor water management. Observations of wildlife interactions with the natural ecosystem elsewhere provide crucial evidence for the potential of livestock-woodland beneficial symbiotic interaction. It is concluded that, since there is high ecological compatibility of livestock production in Miombo woodlands, there is need to reform management policy to promote livestock interaction on the Miombo woodlands.

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1 Introduction

Miombo woodlands have been identified as one of the unique areas for conservation considering their distribution, resilience, high endemicity, and shelter provision for rare species (Jew et al. 2016). This phyto-region covers approximately 3.6 million km^2 in sub-Saharan Africa; it consists mostly of trees (*Brachystegia* species) and understory grasses (Abdallah and Monela 2007; Njana et al. 2013; Sangeda and Maleko 2018a). They are located in the semiarid rangelands of Eastern, Central, and Southern Africa (Malmer 2007). Based on amount and distribution of rainfall, Miombo ecosystems are categorized into dry and wet. The dry Miombo woodlands receive <1000 mm rainfall/year, while wet Miombo woodlands are located in the regions receiving >1000 mm/year (Abdallah and Monela 2007). Some important ecological services offered by Miombo include provision of forage for wild and domestic animals, water catchments, carbon sequestration, and biodiversity conservation (Lawton 1982; Williams et al. 2008: Munishi et al. 2010). Additionally, Miombo woodlands have cultural values to local communities such as provision of thatching grasses for house roofing, edible wild fruits (e.g., *Tamarindus indica*, *Adansonia digitata*, *Vitex* spp., and *Parinari curatellifolia*), honey, and wild vegetables. Another remarkable Miombo woodlands role is its richness in medicinal plants. Various plant species in Miombo (including *Cassia abbreviata* and *Combretum zeyheri)* are used in curing of different anomalies for humans and livestock particularly in the areas where health services are inadequate (Njana et al. 2013; Olekao and Sangeda 2018).

Therefore, the immediate rural communities surrounding Miombo woodlands are direct beneficiaries and derive their daily livelihood through these woodlands. Others communities also benefit indirectly through intrinsic forest services in the global systems and consumption of forestry products (Monela and Abdallah 2007). Nevertheless, in rural communities, agriculture is still a common socioeconomic activity, and it combines both crop cultivation and livestock husbandry. Crop cultivation is mostly under subsistence farmers in form of either small-scale sedentary or shifting cultivation (Nduwamungu et al. 2008). Livestock on the other hand are reared in extensive traditional system managed by pastoralists and agropastoralists. These traditional herders move around with their herd on the communal rangelands as dictated by seasonal and spatial varied forages and water resources (Nindi et al. 2014; Sangeda and Maleko 2018b). Moreover, upon forage scarcity, pastoralists tend to trespass and graze into conserved areas. For that matter, pastoralists and livestock in Miombo woodlands are blamed for causing ecological degradation (Nduwamungu et al. 2008; Benjaminsen et al. 2009; Nindi et al. 2014; Mtimbanjayo and Sangeda 2018).

There are sufficient resources in Miombo to support the livestock population within ecological carrying capacity (Fynn and O'Connor 2000; Aubault et al. 2015; Mtimbanjayo and Sangeda 2018). The balance between livestock production and conservation in Miombo could be sustained through good rangeland management practices (Alkemade et al. 2013). Proper grazing management within Miombo could be of ecological value as it favors tree regrowth and masks fire effects (Gambiza et al. 2000). On the other hand, uncontrolled grazing intensity could lead to change in land cover and could also result into disputes among different land users (Benjaminsen et al. 2009; Alkemade et al. 2013; Njana et al. 2013; Nindi et al. 2014). This chapter addresses the possibilities of combining forestry activities and livestock production while sustaining the ecological capacities of the land in the sub-Saharan Africa. At the time of this research, many of the forested lands, specifically Miombo woodlands, are being converted into protected areas by either central or local governments. The chapter reviews the key issues underlying livestock production in Miombo woodlands and seeks to propose a balance between the livestock productivity and the ecosystem resilience.

2 Opportunities of Livestock Production in Miombo Woodlands

2.1 Food Security

Human population has been increasing exponentially; at the current population growth rate, global human population is estimated to reach 9.15 billion by 2050 from the current 7.2 billion (Thornton 2010; Pimentel and Burgess 2015). This tremendous increase in human population, requires a 50% increase in the current food production to meet the demand of the growing population in the upcoming years (Philipsson et al. 2011). Unfortunately there has been a diminishing return in terms of yield of the major cereal crops globally, affecting mostly poor developing countries in sub-Saharan Africa and Asia (Ehrlich and Harte 2015). Despite livestock greenhouse gas emission, animal husbandry might offer the alternative and ensure global food security in the near future. Luckily, sub-Saharan Africa is endowed with a large livestock population. In 2014 it was estimated that the region comprised about 100 million ruminants (44.8 million cattle, 43.4 million goats, and 11.7 million sheep) collectively reared in the countries with vast Miombo woodlands (Fig. 1), with Tanzania at the top of the list (FAOSTATS 2017a). This large livestock herd could provide animal source of protein that is needed to balance diet and combating malnourishment, especially in the poor rural areas (Ehrlich and Harte 2015).

The average per capita consumption of animal products is approximately 11 kg of meat and 27.2 kg of milk in sub-Saharan Africa (Otte and Chilonda 2002). Growing human population has kept pace with growing demand of food of animal origin, while per capita production is only marginally increasing. It is estimated that

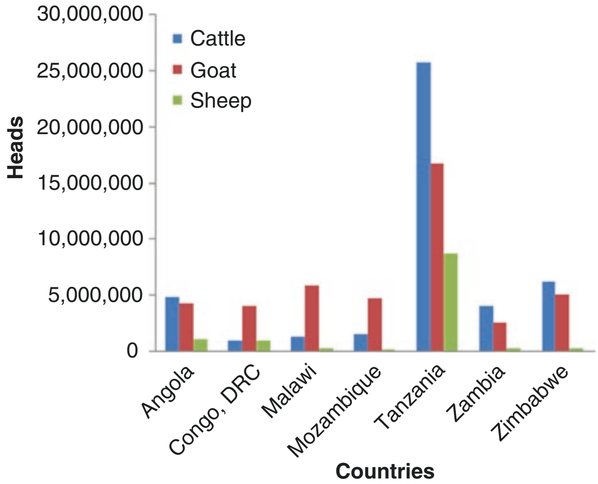

Fig. 1 Livestock herds distribution in some countries with Miombo woodlands in 2014. (Adopted from FAOSTAT (2017a))

the demand for animal source protein will increase by 63% in the future, because of the increased population size and purchasing power (Philipsson et al. 2011). Expansion in livestock production can significantly contribute to food security through improving supply of meat and milk (Philipsson et al. 2011; Peter 2017).

2.2 *Pastoralism, Animal Genetic Resources, and Biodiversity Conservation*

There is a difference in genetic makeup of farm animals among and within the breeds; this is attributed to natural selection and human influence (Wollny 2003). In sub-Saharan Africa, traditional herders have been, for a long time, selecting animals which are adapted to their environment and meet their demands. Disease resistance and drought tolerance are some of the selection criteria (Zander et al. 2009; Philipsson et al. 2011; Chenyambuga and Lekule 2014). Nonetheless, 30% of the farm animal breeds are at risk of becoming extinct worldwide, mostly because they are considered unproductive and culled in favor of exotic productive breeds, which are less adaptive to tropical environment (Drucker et al. 2001; Wollny 2003). Conservation of appropriate farm animal genetic resources is very crucial due to changes in market preferences and environmental requirement for livestock diversity (Philipsson et al. 2011). Temperature rise is expected to range between 0.85 and 1.06 °C courtesy of global warming (Shaffril et al. 2017). This might lead to changes in livestock diseases etiology and decline in forage quantity and quality, and hence it is likely that animals with prior exposure and adapted to these environments will survive compared to their counterparts (Philipsson et al. 2011).

Sustainability of livestock production in the Miombo woodlands is favored by ecological adaptation and community-based conservation (CBC) of the indigenous livestock breeds (Zander et al. 2009). Although indigenous breeds in sub-Saharan Africa such as Nguni and Zebu are considered to have poor growth performance and relatively low tender meat, yet they have high disease resistance and drought tolerance (Muchenje et al. 2009). In addition, keeping of these indigenous livestock breeds in extensive farming system is advantageous in several ways. It is a relatively cheap and reliable means of farm animals' genetic resource conservation, unlike in vivo conservation that is subjected to policy shift and often operates on government subsidies, which is difficult to conduct in developing countries (Philipsson et al. 2011; Paiva et al. 2016). The Convention on Biological Diversity (2010) acknowledges traditional herders for their contribution in sustainable use and conservation of biodiversity. They noted that rearing of indigenous livestock breeds under extensive traditional system and foraging on the mixed fodder simulates their corresponding wild herbivores grazing patterns and interactions with the environment.

2.3 Forage Diversity and Composition

Miombo woodlands are very diverse in terms of botanical composition amidst trees, browsing plants, and grasses which could be used to support different class of livestock (Mtimbanjayo and Sangeda 2018). The dominant woody species in Miombo such as *Brachystegia* spp. and *Harrisonia abyssinica* are potential browsed plants, and dominant grasses (Table 1) such as *Setaria*, *Digitaria*, *Dactyloctenium*, *Brachiaria*, and *Hyparrhenia* are potential feed source for grazers (Nyathi and Campbell 1994; Mtambanengwe and Kirchmann 1995; Baloyi et al. 1997; Chidumayo and Kwibisa 2003; Mbwambo et al. 2008; Nampanzira et al. 2016). For example, due to high protein content, *Brachystegia spiciformis* (12.13 g/kg DM) can be utilized as source of the livestock feed (Nyathi and Campbell 1994; Baloyi et al. 1997).

Table 1 Forages with livestock consumption potential in Miombo

Trees	Browsing plants	Grasses
Brachystegia spiciformis	*Harrisonia abyssinica*	*Dactyloctenium aegyptium*
Acacia spp.	*Flueggea virosa*	*Setaria* spp.
		Digitaria spp.
		Andropogon spp.
		Hyparrhenia spp.
		Brachiaria spp.

Adapted and modified from Mtambanengwe and Kirchmann 1995; Baloyi et al. 1997; Chidumayo and Kwibisa 2003; Mbwambo et al. 2008; Nampanzira et al. 2017

Additionally, inclusion of *Harrisonia abyssinica* has shown to boost crude protein content in goat ration, which in return improves feed intake and carcass quality (Nampanzira et al. 2017). The detailed information on the nutritive values of the Miombo woodlands forage species are shown in Table 2.

On the other hand, aboveground biomass in wet Miombo woodlands is ranging between 66.9 g/m^2 and 110.7 g/m^2 (Chidumayo and Kwibisa 2003). There is growing evidence that these grasses contribute significantly to the topsoil organic carbon through litter decomposition (Mtambanengwe and Kirchmann 1995).

2.4 Grazing Potential

In sub-Saharan Africa, Miombo woodlands have potential for livestock grazing and wildlife habitat. The clear symbiotic relationship exists between Miombo woodland and grazing herbivores. While Miombo woodlands provide cheap forage resources for animals, the controlled grazing in Miombo would contribute to the control of bush encroachment and reduce frequent and intensive burning of the grazing lands through reduction of fuel load (García et al. 2012; Tsegaye et al. 2013; Sangeda and Maleko 2018a). Seed dispersal and germination in Miombo woodland is one of the ecosystem services provided by grazing herbivores. Cattle are considered as the most dispensers of seeds and also facilitate seed germination through endozoochory process where seeds germinate after passing through animals' guts (Mouissie et al. 2005). Moderate grazing pressure is associated with high biodiversity level, while a high grazing pressure momentarily could be a good tool in weed control (García et al. 2012). Proper grazing management is the subject of harmony between utilization and ecological conservation of the rangelands within Miombo woodland (Gambiza et al. 2000; Alkemade et al. 2013). It is widely agreed that keeping livestock within the ecological carrying capacity not only improves productivity but also conserves environment (Fynn and O'Connor 2000; Aubault et al. 2015; Sangeda and Maleko 2018b). Holechek et al. (1998) attributed high financial returns from

Table 2 Nutrition composition of selected forage species in Miombo woodlands

Forage	DM (%)	Ash (g/kgDM)	CP (g/kgDM)	NDF (g/kgDM)	ADF (g/kgDM)	Digestibility (%)
Brachystegia spiciformis	93.8	32.0	10.1	441	333	42.6
Harrisonia abyssinica	39.1	63.0	16.9	296	245	74.3
Acacia angustissima	92.1	57.8	22.9	354	171	34.3
Brachiaria brizantha	24.0	36.7	18	620	350	62.0
Setaria anceps	13.5	67.0	14.9	682	445	46.5
Digitaria decumbens	22.6	107.4	7.2	790	442	62.8

Adapted and modified from Kabuga and Darko 1993; Nyathi and Campbell 1994; Baloyi et al. 1997; Merkel et al. 1999; Archiméde et al. 2000; Hove et al. 2001; Rubanza et al. 2007; Tikam et al. 2010; Fukushima et al. 2015; Nampanzira et al. 2016; Chibinga and Nambeye 2016; Nampanzira et al. 2017.

livestock keeping, trend in ecological condition, forage productivity, and soil stability with appropriate grazing intensity. For the Miombo woodland to offer sustainable grazing, it is recommended to use conservative stocking rate.

Conservative stocking rate is defined as the level of grazing in which forage utilization does not exceed 35% (Holechek et al. 1999). However, for a while the question among range ecologist has been the accurate ways of estimating livestock carrying capacity (Gillson and Hoffman 2007). Some scholars propose the use of livestock population against vegetation composition a model known as equilibrium, while others want to focus on the abiotic factors like rainfall hence non-equilibrium model (Vetter 2005; Gillson and Hoffman 2007). It is still debatable however as to which model, between the equilibrium and non-equilibrium, is appropriate for sustainable grazing management; Vetter (2005) proposed integration of both models in highly variable arid and semiarid ecosystems. Derry and Boone (2010) on their spatial models demonstrated a decrease in number of animals in rangelands, with the increased variation in annual rainfall, hence support for the role of abiotic factor as stipulated in non-equilibrium models. Furthermore, it is argued (Sasaki 2010) that integration of equilibrium and non-equilibrium models is appropriate rangeland ecosystems approach that provides desirable outcome. Nevertheless, relying only on the one model in Miombo woodlands with high variable and unpredictable rainfall is not recommended. It is common knowledge that in the forested areas, livestock density is highly influenced by rainfall amount (Boone and Wang 2007). Hence in dry Miombo woodlands, livestock production can only be productive within the balanced ecosystem and well-planned management operation. Generally, the impact of livestock grazing on ecological thresholds needs to be investigated regularly (Sasaki 2010).

From the above, it is clear that livestock production in forested lands like Miombo has several benefits, ranging from improving human livelihoods and animal welfare to enhancement of environmental conservation. These multiple benefits are often realized when proper rangeland management principles are followed. The benefits aside, livestock production in Miombo is attended by some challenges, some of which are the subject of the next section.

3 Challenges of Livestock Production in Miombo Woodlands

3.1 Tsetse Fly and African Trypanosomiasis

Miombo ecosystem consists of various forms of life such as pests and vectors for animal diseases. Tsetse (*Glossina morsitans*), the annoying biting fly, is one of the biological vectors of zoonotic disease trypanosomiasis affecting both human and animals (Lawton 1982; Simukoko et al. 2011). *Trypanosoma congolense* is the common causative agent of African animal trypanosomiasis in Miombo; its prevalence ranges from 2.36% to 33.5%, and cattle are the most affected among the farm animals (Simukoko et al. 2007; Malulu et al. 2017). It is urged that disease incidences are determined by several predisposing factors. These include a proportion of meals by tsetse on the host species of interest, tsetse fly density, and trypanosomal infections prevalence within the tsetse fly (Simukoko et al. 2011). Several efforts to eradicate tsetse fly have been made, including the huge forestry clearance program during colonial era in the 1920s (Barrow and Shah 2011). While the tsetse control program was reported to be successfully achieving the long-term fly suppression, less has been documented on its effect on the Miombo ecosystem (Campbell 1996). Although, on the continental scale, wildlife has been reported to be affected by anti-tsetse operation program (Matthiessen and Douthwaite 1985), there is no clear projection of the future impact on Miombo ecosystem as tsetse suppression methods are changing over time. Tsetse flies and trypanosomiasis control efforts in Miombo woodlands face various challenges, including observed changes in feeding behavior of the tsetse fly and manifestation of drug resistance in affected human and animal hosts (Delespaux and de Koning 2007; Torr and Vale 2015). The major challenge facing the range ecologists and animal health experts if the Miombo woodlands are to be utilized for animal husbandry today is how to balance between production and control of tsetse flies without altering the entire ecosystem.

3.2 Greenhouse Gas Emission

Livestock production contributes 18% of the global anthropogenic greenhouse gas emission (GHG). These GHG include methane as the by-product of the ruminal fermentation (Table 3), nitrous oxide from manure, and carbon dioxide from respiration (Steinfeld et al. 2006; Eckard et al. 2010; Morgavi et al. 2010). However it is methane gas that caught attention of most range nutrition scientist as it is strongly influenced by the livestock diet (Knapp et al. 2014). Despite its lower emission levels in relation to carbon dioxide, methane has almost 28 times global warming potential compared to the latter (Du et al. 2017).

Table 3 Enteric methane emission in countries with Miombo woodlands as per 2014

Country	Methane (Gg)	CO_2– eq. (Gg)
Angola	167.8301	3524.43
Congo, DRC	48.2779	1013.836
Malawi	65.3455	1372.256
Mozambique	61.9952	1301.9
Tanzania	676.6869	14,210.42
Zambia	131.5575	2762.71
Zimbabwe	146.6	3078.60

Adapted and modified from FAOSTAT (2017b)

CO_2 – eq. (Carbon dioxide equivalent of methane emission)

The enteric methane production is associated with energy loss in the feed consumed; there could be up to 12% loss of gross energy intake, which could affect both feed utilization efficiency and animal productivity (Stergiadis et al. 2016). There are several proposed methodologies of reducing enteric methane emission, though the practical one in sub-Saharan Africa would be to increase the production efficiency (Grainger and Beauchemin 2011; Knapp et al. 2014; Mushi et al. 2015). Poor productivity is associated with increased methane emission (up to 450 g methane/cow/day) in per unit of produce in the developing countries (Philippe and Nicks 2015; Chibinga et al. 2012; Mushi et al. 2015). Unfortunately, most pastoralists rearing livestock in Miombo woodlands are considered inefficient in terms of resources use (Monela and Abdallah 2007; Nduwamungu et al. 2008). They keep large number of livestock and add the burden to already scarce resources in these dry woodlands and hence reduce production potential (Monela and Abdallah 2007). For instance, the average mature live weight of 20 kg is attained within 2 years by the goats raised in the extensive traditional system (Mushi 2004; Shija et al. 2013). This is owing to the seasonal fluctuation of the forage in form of quantity and quality (Adjorlolo et al. 2014). However, underlying cultural and ecological trade-offs among pastoralists need to be addressed before adoption of the intensive livestock production system in Miombo woodlands that will reduce per unit enteric methane emission (Wollny 2003; Zander et al. 2009).

3.3 Unsustainable Rangeland Management Practices

Pastoralists in sub-Saharan Africa are characterized by large number of livestock exceeding the grazing limit of the rangeland (Holechek et al. 2017). Miombo woodlands in sub-Saharan Africa are experiencing heavy grazing pressure associated with overstocking. Despite all of these, little is done by pastoralists to alleviate the pressure on the depreciating resources. While some pastoralists normally move away during dry season to allow recovery on the grazed land, mismanagement of communally grazed rangelands leads to increased bush encroachment risks and soil compaction, with severe effects on soil water (Solomon et al. 2007; Treydte et al. 2017). Other than migration, pastoralists employ bushfire as the tool in order to improve rangelands and control of encroached bushes. However, uncontrolled fire in Miombo woodlands has negative effects, regardless of availability of fire-resistant tree species (Gambiza et al. 2000; Malmer 2007; Solomon et al. 2007). The young growing trees, dry litter, topsoil humus, and dry herbaceous layer are vulnerable to wildfire (Sangeda and Maleko 2018a). On the contrary, if the fire is controlled, the carbon and nitrogen losses are minimized compared to effects of wildfire (Malmer and Nyberg 2008). However, other scholars argue that low to moderate intensity fire causes increase in soil water repellency in the semiarid grazing lands and also affects water and air quality in the surrounding areas (Stavi et al. 2017). Generally, uncontrolled fire is responsible for ecological and economical damage of approximately 350 million hectares of global land yearly and renders them unfit for other uses (García et al. 2012). Nevertheless, it should be known that stocking density has indirect influence on bush fire. Very low stocking rate may result into huge accumulation of fuel load, which is a risk factor for wildfire. Although prescribed fire is very useful for controlling bush encroachment, application of controlled fire may not be relevant in the arid and semiarid grazing land, provided that grazing intensity is still high (Lohmann et al. 2014; Sangeda and Maleko 2018a).

3.4 Land Tenure and Water Resources Management

In sub-Saharan Africa, Miombo woodlands are categorized into two forms of ownership: general land (open access) and conserved areas. The general is a source of continuous concern due to lack of proper management and is susceptible to anthropogenic interventions leading to forest degradation (Abdallah and Monela 2007; Monela and Abdallah 2007; Murwira et al. 2010). Management of Miombo woodland requires strong ownership and regulated access to the land. Continuous modification of Miombo woodland through anthropogenic activities like clearance of trees for commercial cultivation, charcoal production, fuel wood collection, and rampant fire is associated with poor land tenure institutions. Miombo woodlands suffer from high illegal wood utilization, pressure stemming from the need to fulfill alternative energy demands created by persistent electricity shortages, and an unstable economic environment in sub-Saharan African countries. Lack of land tenure and poor institutional arrangement contributes to unsustainable Miombo woodlands utilization. This results in decline of the fertile soil for various activities and increases more pressure on the already scarce resources in Miombo including water (Benjaminsen et al. 2009; Nindi et al. 2014).

With increased grazing, the soil will be compacted and impede water from infiltrating into the soil, where it would be accessible for growing plants and regeneration of ground water. Dry Miombo woodlands are located in the semiarid areas with lower rainfall and long dry seasons (Malmer 2007). It is widely known that groundwater recharge and dry season stream flow are highly influenced by the silvicultural practices such as succession of some young indigenous species after deforestation (Malmer 2007; Malmer and Nyberg 2008). Ultimately in addressing this in dry woodlands, it is important to design the ecological model that will consider water resources, especially now when the global water demand is high (Ran et al. 2016).

It might be difficult to conclude whether the analysis of benefits accrued from livestock production in Miombo outweighs the challenges or vice versa due to the subjectivity and interests of stakeholders in question. However, to reduce this anomaly, Tanzania (a country highly populated with livestock among Miombo woodlands states) is used as a case study to draw experiences and lessons from multiple land uses in Ngorongoro Conservation Area, to explain the livestock-woodland interaction that has existed for more than seven decades.

4 Lessons from Multiple Land Uses in Tanzania and Ngorongoro Conservation Area

Tanzania is one of the world's biological richest countries, harboring millions of endemic flora and fauna species. It is approximated that around 11,000 species of plants, many which are endemic, are found in Tanzania's forestry and woodlands particularly within Miombo woodland (IUCN 2017). It is approximated that forestry and woodlands cover 48.1 million hectares of Tanzania land (NAFORMA 2015). Tanzania is committed to conservation of biological diversity through establishment of protected areas under different conservation categories. A total land area of 731,806.24 km^2 has been set aside as protected areas of different categories equivalent to 33.5% of terrestrial land of the country (IUCN 2017). Expansion of these protected areas, coupled with increasing human population, has created serious land use conflicts in the country, particularly between pastoralists and conservation authorities (Nindi et al. 2014). There is growing debate among ecologists, scientists, and politicians on whether integration of livestock within protected areas under multiple land use system is ecologically compatible and socially acceptable (Mtimbanjayo and Sangeda 2018). It is hypothesized that, coexistence of grazing livestock within Miombo woodland will reduce land use conflicts and enhance ecosystem services. To discuss these debates, this section has drawn on the experiences of multiple land uses in Ngorongoro Conservation Area (NCA) in Tanzania and recommends policy reforms that could promote integration of livestock in Miombo woodland in a compatible manner.

Ngorongoro Conservation Area (NCA) is the only world heritage site and biosphere reserve in Tanzania with multiple land use, where both wildlife conservation and selected human activities such as livestock grazing are allowed (Masao et al. 2015). The NCA (Fig. 2) is located in the northern part of Tanzania, largely occupied by Maasai pastoralists who are also the main participants of livestock grazing in Miombo. The NCA has total area of 8300 km^2 lying between the rift valley and Serengeti plains. The heart of this area is Ngorongoro crater, a large volcanic caldera within the area.

The NCA contains renowned wildlife population and increasing human population with diversified economic activities (Boone et al. 2006). The area has been managed under multiple land uses (wildlife conservation, ecotourism, and livestock grazing) since 1959 when it was separated from Serengeti National Park (Byers 1994). Despite the growing population of Maasai, the livestock population has remained stable, wildlife conservation has generally been successful, and ecotourism has expanded dramatically (Byers 1994). The unique scenic, conservation, and cultural and ecological value of NCA have led to international recognition, and thus in 1979 it was accepted as a UNESCO World Heritage, and in 1982 it was approved as biosphere reserve (Boshe 1989). All these happened when wildlife, humans, forest, and livestock resources are in a common area.

Since the World Heritage Convention by UNESCO 1972 encourages identification, protection, and preservation of cultural and natural heritage around the world,

Fig. 2 Map of Ngorongoro Conservation Area in Northern Tanzania. (Source: ESA 2017)

the dynamic relationship between Maasai people and nature in NCA is of fundamental need (Masao et al. 2015). Despite the attractive advantages of integrating conservation with human development, various ecological, economic, social, and political factors need to be harmonized. For example, the sustainability of multiple land uses in NCA is in the hands of community-based conservation, a concept that integrates biodiversity conservation by engaging people in the conservation process. People, who daily live with natural ecosystem like Maasai, are inseparable from nature, and thus it is important that conservation efforts should integrate and promote their livelihood needs (Olekao and Sangeda 2018). Maasai are typically pastoralists and have managed to survive in natural ecosystems with minimal retrogressive impacts on ecosystems. Nelson (2012) pointed out that there is a historical influence of pastoralists on savanna ecosystems, and therefore, there is a general compatibility between pastoralists and wildness. Pastoralists in NCA provide economically viable ecological services by conserving wildlife on their land, which in turn helps to sustain the natural assets that tourism industry depends on.

The key lesson from NCA is the high degree of overlap and coexistence between nature conservation and human development. Pastoralists adapted to highly variable and unpredictable natural ecosystem through various coping strategies such as mobility and economic diversification (Olekao and Sangeda 2018). Nelson (2012) highlighted that pastoralists could still respond to non-equilibrium condition by moving between different local pastures, depending on rainfall distribution and pattern. NCA experience can be a useful conservation strategy in similar natural ecosystems including Miombo woodlands. Miombo ecosystems are vital natural resources with more or less similar economic role as those of wildlife conservation in the rest of the country; and therefore, integrating conservation efforts of Miombo and human development is imperative. One of the possible and compatible options for Miombo-human interaction is through sustainable grazing. Livestock grazing and biodiversity conservation of Miombo woodland can be complementary activities if well managed.

5 Future Prospects and Possible Solutions

Livestock should play a central role in the food security and in the economic growth of sub-Saharan Africa (Philipsson et al. 2011). Diminishing grazing land due to other land uses will put increased pressure on livestock productivity. Therefore, the continued presence of the pastoralists in natural woodlands, particularly Miombo, is necessary. However, the vital question is how to address environmental impact of their practices. Land use plan initiatives that involve local community in sustainable forest utilization may provide possibilities for livestock-Miombo woodland integration (Gmünder et al. 2014). Currently, lands assigned for grazing in these areas do not cope well with the large livestock herd, since most of these communal semiarid rangelands are less productive (Vetter 2005; Nindi et al. 2014). Thus the wide adoption of the land use program and institutional intervention for technical support or direct management of the general managed land could be beneficial as it has been demonstrated elsewhere (Basupi et al. 2017). The lesson from multiple land use in the NCA Tanzania provides empirical evidence for possible integration of sustainable conservation with human development. The well-managed pastoralists' herds within acceptable carrying capacity can enhance the livelihoods of pastoralists while maintaining the stable woodland ecosystems.

Furthermore, traditional breeds selection and breeding procedures offer sustainable solutions to the tsetse fly (*Glossina morsitans*) control problem, instead of previously adopted forest clearing method (Mapedza 2007; Murwira et al. 2010; Munang'andu et al. 2012). Trypano-tolerant livestock breeds, such as Djallonke sheep as well as N'dama and Muturu cattle, could remain productive in the infested areas without trypanocidal drugs. They suffer low casualty and most importantly contribute to efforts toward vaccine development through deciphering of the parasites' complex antigen behavior (Yaro et al. 2016). Further understanding of the vector behavior among veterinary entomologist is expected to add efforts in turning the disease trends. It is already known that *G. morsitans* is more active during the beginning of the rain season in Miombo woodlands (Simukoko et al. 2011). All of these tools individually could be combined in several fronts to eradicate animal trypanosomiasis in Miombo woodlands and thus foster both livestock production and Miombo woodland conservation.

The remaining question is one of sustainability and the place of pastoralism in a changing world, with anticipated more mouth to feed, scarce resources, and constantly degraded rangeland (Vetter 2005; Pimentel and Burgess 2015). On top of this, there is the critical situation in the form of climate stress through greenhouse gas emission (Mushi et al. 2015; Benjaminsen et al. 2009). The solution in the future would be to improve the production system through sustainable grazing management within the ecological threshold comprising of both biotic and abiotic components (Sasaki 2010; Nindi et al. 2014). Efficient utilization of available resources is crucial including adoption of enclosures (like *Olalili* and *Ngitiri* among Maasai and Sukuma pastoralists in Tanzania) and use of forage conservation techniques when they are abundant so they could be used during critical dry season (Maleko and Koipapi 2015; Treydte et al. 2017). Important point of consideration among policy makers and scholars in case of intervention in the future is to capitalize on pastoralists' traditional ecological knowledge (Olekao and Sangeda 2018). As it is manifested in many areas of Africa, some pastoralists are coming up with adaptation strategies for their challenges including change in their herd composition by increasing browsing animals like goats and camels (Coppock et al. 2018; Sangeda and Malole 2014). This is done in response to changes in the rangeland vegetation. Woody plants encroachment has increased and understory herbaceous species for grazers declined (Liao et al. 2016). These strategies are important for sustainable livestock-woodland conservation.

6 Conclusions and Recommendations

Inappropriate rangeland management practices such as overgrazing and wildfire could result into deterioration of Miombo woodlands. However, there are many positive ecological roles of livestock and pastoralists presence in Miombo, such as farm animal gene conservation, nutrient recycling, and reduction of wildfire intensity. Therefore, livestock production in Miombo woodlands could be perceived as both competitive and complementary. Nevertheless, the future is very uncertain with food insecurity challenges and increased grazing land degradation, all of which call for efficient utilization of the available Miombo woodland resources. This could be obtained through integrated resource management in form of sustainable land use plan, accurate estimation of allocated grazed land carrying capacity involving both biotic and abiotic factors, and forage and water conservation techniques. Based on the facts that there is ecological compatibility between livestock production in Miombo woodland, there is a need for policy reform for the sub-Saharan Africa region on the conventional Miombo woodland management that promotes livestock interaction.

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References

Abdallah JM, Monela GG (2007) Overview of Miombo woodlands in Tanzania. Work Pap Finnish Forest Res Inst 50:9–23

Adjorlolo LK, Adogla-Bessa T, Amaning-Kwarteng K, Ahunu BK (2014) Seasonal effect on rumen function in sheep on range in the Accra Plains of Ghana. Trop Anim Health Prod 46:1223–1228

Alkemade R, Reid RS, van den Berg M, de Leeuw J, Jeuken M (2013) Assessing the impact of livestock production on biodiversity in rangeland ecosystems. Proc Natl Acad Sci U S A 110(52):20900–20905

Archiméde H, Boval M, Alexandre G, Xanddé A, Aumont G, Poncet C (2000) Effect of regrowth age on intake and digestion of *Digitaria decumbens* consumed by Black-belly sheep. Anim Feed Sci Technol 87(3–4):153–162

Aubault H, Webb NP, Strong CL, McTainsh GH, Leys JF, Scanlan JC (2015) Grazing impacts on the susceptibility of rangelands to wind erosion: the effects of stocking rate, stocking strategy and land condition. Aeolian Res 17:89–99

Baloyi JJ, Ngongoni NT, Topps JH, Ndlovu P (1997) Chemical composition and degradability of *Brachystegia spiciformis* (musasa) leaves and stems harvested over 4 months from three sites in Zimbabwe. Anim Feed Sci Technol 69:179–186

Barrow E, Shah A (2011) TEEBcase: traditional forest restoration in Tanzania. Available at: TEEBweb.org

Basupi LV, Quinn CH, Dougill AJ (2017) Using participatory mapping and a participatory geographic information system in pastoral land use investigation: impacts of rangeland policy in Botswana. Land Use Policy 64:363–373

Benjaminsen TA, Maganga FP, Abdallah JM (2009) The Kilosa killings: political ecology of farmer-herder conflict in Tanzania. Dev Chang 40(3):423–445

Boone RB, Wang G (2007) Cattle dynamics in African grazing systems under variable climates. J Arid Environ 70(3):495–513

Boone RB, Galvin KA, Thornton PK, Swift DM, Coughenour MB (2006) Cultivation and conservation in Ngorongoro conservation area, Tanzania. Hum Ecol 34:809–828

Boshe J (1989) Wildlife conservation in Ngorongoro conservation area in Tanzania: social and ecological implication of increasing pastoralists and declining per capita livestock population. In: Transaction of XIXIUGB Congress, International Union of Game Biologists, September, 1989, Trondheim, Norway, pp 84–100

Byers BA (1994) Population growth, environmental degradation, and conflict in Ngorongoro conservation area, Tanzania. Paper prepared for workshop on the state of environment, conflict in the North East Africa

Campbell B (1996) The Miombo in transition: woodlands and welfare in Africa. Center for International Forestry Research. Malaysia
Chenyambuga SW, Lekule FP (2014) Breeding preferences and breeding practices for goats in agro-pastoral communities of semi-arid and sub-humid areas in Tanzania. Livest Res Rural Dev 26(6):117
Chibinga OC, Nambeye E (2016) Nutritive value of some selected indigenous livestock browse species in the drylands of Southern Province, Zambia. Int J Appl Pure Sci Agric 2(1):61–66
Chibinga OC, Musimba NRK, Nyangito MM, Simbaya J, Daura MT (2012) Climate variability; enhancing adaptive utilization of browse trees for improved livestock production among agro-pastoralists communities in Southern Zambia. Afr J Environ Sci Technol 6(7):267–274
Chidumayo EN, Kwibisa L (2003) Effects of deforestation on grass biomass and soil nutrients status in Miombo woodlands, Zambia. Agric Ecosyst Environ 96(1–3):97–105
Coppock DL, Bailey D, Ibrahim M, Tezera S (2018) Diversified investments of wealthy Ethiopian pastoralists include livestock and urban assets that better manage risk. Rangel Ecol Manag 78(1): 138–148
Delespaux V, de Koning HP (2007) Drugs and drug resistance in African trypanosomiasis. Drug Resist Updat 10(1–2):30–50
Derry JF, Boone RB (2010) Grazing systems are a result of equilibrium and non-equilibrium dynamics. J Arid Environ 74(2):307–309
Drucker AG, Gomez V, Anderson S (2001) The economic valuation of farm animal genetic resources: a survey of available methods. Ecol Econ 36(1):1–18
Du M, Peng C, Wang X, Chen H, Wang M, Zhu Q (2017) Quantification of methane emissions from municipal solid waste landfills in China during past decade. Renew Sust Energ Rev 78:272–279
Eckard RJ, Grainger C, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production: a review. Livest Sci 130(1–3):47–56
Ehrlich PR, Harte H (2015) Opinion: to feed the world in 2050 will require a global revolution. Proc Natl Acad Sci U S A 112(48):14743–14744
European Space Agency (ESA) (2017) Ngorongoro Conservation Area. https://www.esa.int/SPECIALS/Eduspace_Global_EN/SEMX9X05VQF_0.html
FAOSTAT (2017a) Statistical database of the Food and Agriculture Organisation of the United Nations on agriculture, nutrition, fisheries, forestry, food aid, land use and population. http://www.fao.org/faostat/en/#data/QA. Last accessed 3rd July, 2017
FAOSTAT (2017b) Statistical database of the Food and Agriculture Organisation of the United Nations on agriculture, nutrition, fisheries, forestry, food aid, land use and population. http://www.fao.org/faostat/en/#data/GE. Last accessed 27th July, 2017
Fukushima RS, Bacha CB, Fuzeto AP, Port ACR, Herling VR, Velásquez AV (2015) Utilisation of equations to predict carbohydrate fractions in some tropical grasses. Anim Feed Sci Technol 208:12–22
Fynn RWS, O'Connor TG (2000) Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. J Appl Ecol 37:491–507
Gambiza J, Bond W, Frost PGH, Higgins S (2000) A simulation model of Miombo woodland dynamics under different management regimes. Ecol Econ 33:353–368
García RR, Celaya R, García U, Osoro K (2012) Goat grazing, its interactions with other herbivores and biodiversity conservation issues. Small Rumin Res 107(2–3):49–64
Gillson L, Hoffman MT (2007) Rangeland ecology in a changing world. Science 315:53–54
Gmünder S, Zah R, Rainhard J, Charron-Doucet F (2014) Transforming Tanzania's charcoal sector: life cycle assessment component. *Quantis*, Dübendorf, Switzerland
Grainger C, Beauchemin KA (2011) Can enteric methane emissions from ruminants be lowered without lowering their production? Anim Feed Sci Technol 166–167:308–320
Holechek JL, Gomes H, Molinar F, Gait D (1998) Grazing intensity: critique and approach. Rangelands 20(5):15–18
Holechek JL, Gomes H, Molinar F, Gait D (1999) Grazing studies: what we learned? Rangelands 21(2):12–16

Holechek JL, Cibils AF, Bengaly K, Kinyamario JI (2017) Human population growth, African pastoralism and rangelands: a perspective. Rangel Ecol Manag 70(3):273–280

Hove L, Topps JH, Sibanda S, Ndlovu LR (2001) Nutrient intake and utilization by goats fed dried leaves of the shrub legumes *Acacia angustissima*, *Calliandra calothyrsus* and *Leucaena leucocephala* as supplements to native pasture hay. Anim Feed Sci Technol 91(1–2):95–106

IUCN (2017) Governance of protected and conserved areas in Tanzania, Phase 1 workshop as part of an IUCN-assisted process of assessment and action to enhance governance for conservation and sustainable livelihoods, Dar es Salaam, Tanzania 21–22 March 2017

Jew EKK, Dougill AJ, Sallu SM, O'Connell J, Benton TG (2016) Miombo woodland under threat: Consequences for tree diversity and carbon storage. Forest Ecology and Management 361:144–153

Kabuga JD, Darko CA (1993) In Sacco degradation of dry matter and nitrogen in oven dried and fresh tropical grasses and some relationships to in vitro dry matter digestibility. Anim Feed Sci Technol 40:191–205

Knapp JR, Laur GL, Vadas PA, Weiss WP, Tricarico JM (2014) Invited review: enteric methane in dairy cattle production: quantifying the opportunities and impact of reducing emissions. J Dairy Sci 97(6):3231–3261

Lawton RM (1982) Natural resources of Miombo woodland and recent changes in agricultural and land-use practices. For Ecol Manag 4:287–297

Liao C, Ruelle ML, Kassam KS (2016) Indigenous ecological knowledge as the basis for adaptive environmental management: evidence from pastoralist communities in the Horn of Africa. J Environ Manag 182:70–79

Lohmann D, Tietjen B, Blaum N, Joubert DF, Jeltsch F (2014) Prescribed fire as a tool for managing shrub encroachment in semi-arid savanna rangelands. J Arid Environ 107:49–56

Maleko DD, Koipapi ML (2015) Opportunities and constraints for overcoming dry season livestock feed shortages in communal semi-arid rangelands of Northern Tanzania: a case of Longido district. Livest Res Rural Dev 27(4):70

Malmer A (2007) General ecological features of Miombo woodlands and considerations for utilisation and management. Work Pap Finnish Forest Res Inst 50:34–42

Malmer A, Nyberg G (2008) Forest and water relations in Miombo woodlands: need for understanding of complex stand management. Work Pap Finnish Res Inst 98:70–86

Malulu DJ, Kimbita E, Tuntufye H, Kinugh'i S, Nyingilili H, Mbilu T, Kaboya J, Lyaruu E, Malele I (2017) An investigation on *Glossina* species and the prevalence of trypanosomiasis in cattle in Meatu district, Tanzania. J Parasitol Vector Biol 9(2):13–18

Mapedza E (2007) Forestry policy in colonial and postcolonial Zimbabwe: continuity and change. J Hist Geogr 33(4):833–851

Masao CA, Makoba R, Sosovele H (2015) Will Ngorongoro conservation area remain a world heritage site amidst increasing human footprint? Int J Biodivers Conserv 7(9):394–407

Matthiessen P, Douthwaite B (1985) The impact of tsetse fly control campaigns on African wildlife. Oryx 19(4):202–209

Mbwambo L, Valkonen S, Kuutti V (2008) Structure and dynamics of Miombo woodland stand at Kitulangalo Forest Reserve, Tanzania. Work Pap Finnish Forest Res Inst 98:10–19

Merkel RC, Pond KR, Burns JC, Fisher DS (1999) Intake, digestibility and nitrogen utilization of three tropical tree legumes: I. As sole feeds compared to *Asystasia intrusa* and *Brachiaria brizantha*. Anim Feed Sci Technol 82(1–2):91–106

Monela GC, Abdallah JM (2007) Principle socio-economic issues in utilisation of Miombo woodlands in Tanzania. Work Pap Finnish Forest Res Inst 50:115–122

Morgavi DP, Forano E, Martin C, Newbold CJ (2010) Microbial ecosystem and methanogenesis in ruminants. Animal 4(7):1024–1036

Mouissie AM, Vos P, Verhagen HMC, Bakker JP (2005) Endozoochory by free ranging, large herbivores: ecological correlates and perspectives for restoration. Basic Appl Ecol 6:547–558

Mtambanengwe F, Kirchmann H (1995) Litter from savanna woodlands (Miombo): chemical composition and C and N mineralisation. Soil Biol Biochem 27(12):1639–1651

Mtimbanjayo JR, Sangeda AZ (2018) Ecological effects of cattle grazing on Miombo tree species regeneration and diversity in Central-Eastern Tanzania. J Environ Res 2(1):3

Muchenje V, Dzama K, Chimonyo M, Strydom PE, Hugo A, Raats JG (2009) Some biochemical aspects pertaining to beef eating quality and consumer health: A review. Food Chemistry 112 (2):279–289

Munang'andu HM, Siamudaala V, Munyeme M, Nalubamba KS (2012) A review of ecological factors associated with the epidemiology of wildlife trypanosomiasis in the Luangwa and Zambezi valley ecosystems of Zambia. Interdiscip Perspect Infect Dis 2012:372523

Munishi PKT, Mringi S, Shirima DD, Linda SK (2010) The role of the Miombo woodlands of the Southern highlands of Tanzania as carbon sinks. J Ecol Nat Environ 2(12):261–269

Murwira A, Skidmore AK, Huizing HJG, Prins HHT (2010) Remote sensing of the link between arable field and elephant (*Loxodanta africana*) distribution change along a tsetse eradication gradient in the Zambezi valley, Zimbabwe. Int J Appl Earth Obs Geoinf 12(1):123–130

Mushi DE (2004) Studies on marketing of meat goats and carcass composition – a case study of Gairo auction markets. MSc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania

Mushi DE, Eik LO, Bernués A, Ripoll-Bosch R, Sundstol F, Mo M (2015) Reducing GHG emissions from traditional livestock system to mitigate changing climate and biodiversity. In: Lal R (ed) Sustainable intensification to advance food security and enhance climate resilience in Africa. Springer International Publishing, Switzerland

NAFORMA (2015) National Forest Resources monitoring and assessment of Tanzania Mainland. Tanzania Forestry Service Agency

Nampanzira DK, Kabasa JD, Katongole CB, Okello S, Tabuti JRS (2016) Natural gastro properties of *Ficus natalensis*, *Rhuss natalensis* and *Harrisonia abyssinica* in native East African goats. Livest Sci 187:31–34

Nampanzira DK, Kabasa JD, Katongole CB, Okello S, Tabuti JRS (2017) Ameliorative effects of *Ficus* and *Harrisonia* on Small East African goat meat yield. Small Rumin Res 153:189–193

Nduwamungu J, Bloesch U, Munishi PKT, Hagedorn F, Lulu K (2008) Recent land cover and use changes in Miombo woodlands of Eastern Tanzania. Tanzania J Forestry Nat Conserv 78(1):50–59

Nelson F (2012) Natural conservationists? Evaluating the impact of pastoralist land use practices on Tanzania's wildlife economy. Res Policy Pract 2(15):1–19

Nindi SJ, Maliti H, Bakari S, Kija H, Machoke M (2014) Conflicts over land and water resources in the Kilombero Valley Floodplain, Tanzania. African Study Monographs Suppl. 50:173–190

Njana MA, Kajembe GC, Malimbwi RE (2013) Are Miombo woodlands vital to livelihoods of rural households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania. Forests, Trees and Livelihoods 22(2):124–140

Nyathi P, Campbell P (1994) Leaf quality of *Sesbania sesban*, *Leucaena leucocephala* and *Brachystegia spiciformis*: potential agroforestry species. For Ecol Manag 64:259–264

Olekao SK, Sangeda AZ (2018) Traditional ecological knowledge in management of dryland ecosystems among the Maasai pastoralists in Kiteto district, Tanzania. J Environ Res 2(1):2

Otte MJ, Chilonda P (2002) Cattle and small ruminant production systems in sub-Saharan Africa : a systematic review. Rome: FAO

Paiva SR, McManus SM, Blackburn H (2016) Conservation of animal genetic resources - a new tact. Livest Sci 193:32–38

Peter AS (2017) Cyber resilience preparedness of Africa's top 12 emerging economies. Int J Crit Infrastruct Prot 17:49–59

Philippe F-X, Nicks B (2015) Review on greenhouse gas emissions from pig houses: production of carbon dioxide, methane and nitrous oxide by animals and manure. Agric Ecosyst Environ 199:10–25

Philipsson J, Zonabend E, Bett RC, Okeyo AM (2011) Global perspectives on animal genetic resources for sustainable agriculture and food production in the tropics. In: Ojango JM, Malmfors B, Okeyo AM (eds) Animal genetics training resource, version 3, 2011. International

Livestock Research Institute, Nairobi, Kenya, and Swedish University of Agricultural Sciences, Uppsala, Sweden
Pimentel D, Burgess M (2015) World human population problems. Reference Module in Earth Systems and Environmental Sciences, https://doi.org/10.1016/B978-0-12-409548-9.09303-9
Ran Y, Lannerstad M, Herrero M, Van Middelaar CE, De Boer IJM (2016) Assessing water resource use in livestock production: a review of methods. Livest Sci 187:68–79
Rubanza CDK, Shem MN, Bakengesa SS, Ichinohe T, Fujihara T (2007) The content of protein, fibre and minerals of leaves of selected Acacia species indigenous to North-Western Tanzania. Arch Anim Nutr 61(2):151–156
Sangeda AZ, Maleko DD (2018a) Regeneration effectiveness post tree harvesting in natural Miombo woodlands, Tanzania. J Plant Sci Agric Res 2(1):10
Sangeda AZ, Maleko DD (2018b) Rangeland condition and livestock carrying capacity under the traditional rotational grazing system in northern Tanzania. Livest Res Rural Dev 30:Article #79
Sangeda AZ, Malole JL (2014) Tanzanian rangelands in a changing climate: impacts, adaptations and mitigation. Net J Agric Sci 2(1):1–10
Sasaki T (2010) Paradigm integration between equilibrium and non-equilibrium concepts for evaluating vegetation dynamics in rangeland ecosystems. Global Environ Res 14:17–22
Secretariat of the Convention on Biological Diversity (2010) Pastoralism, nature conservation and development: a good practice guide. Montreal, 40 + iii pages
Shaffril HAM, Samah AA, D'Silva JL (2017) Adapting towards climate change impacts: strategies for small-scale fishermen in Malaysia. Mar Policy 81:196–201
Shija DS, Mtenga LA, Kimambo AE, Laswai GH, Mushi DE, Mgheni DM, Mwilawa AJ, Shirima EJM, Safari JG (2013) Chemical composition and meat quality attributes of indigenous sheep and goats from traditional production system in Tanzania. Asian Australas J Anim Sci 26(2):295–302
Simukoko H, Marcotty T, Phiri I, Geysen D, Vercruycce J, Van den Bossche P (2007) The comparative role of cattle, goats and pigs in the epidemiology of livestock trypanosomiasis on the plateau of eastern Zambia. Vet Parasitol 147(3–4):231–238
Simukoko H, Marcotty T, Vercruycce J, Van den Bossche P (2011) Bovine trypanosomiasis risk in an endemic area on the eastern plateau of Zambia. Res Vet Sci 90(1):51–54
Solomon TB, Snyman HA, Smit GN (2007) Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of Southern Ethiopia. J Environ Manag 82(4):481–494
Stavi I, Barkai D, Knoll YM, Glion HA, Katra I, Brook A, Zaady E (2017) Fire impact on soil-water repellency and functioning of semi-arid croplands and rangelands: implications for prescribed burnings and wildfires. Geomorphology 280:67–75
Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (2006) Livestock's long shadow environmental issues and options. Food and Agriculture Organisation, Rome, Italy
Stergiadis S, Zou C, Chen X, Allen M, Wills D, Yan T (2016) Equations to predict methane emissions from cow fed at maintenance energy level in pasture-based systems. Agric Ecosyst Environ 220:8–20
Thornton PK (2010) Livestock production: recent trends, future prospects. Philosophical Transactions of the Royal Society B: Biological Sciences 365 (1554):2853–2867
Tikam T, Mikled C, Vearaslip T, Phatsara C, Sűdekum K (2010) Digestibility of nutrients and evaluation of energy of Pangola Grass in sheep compared with Napier Grass. Conference of international research on food security, natural resources management and rural development ETH Zurich, September 14–16, 2010
Torr SJ, Vale GA (2015) Know your foe: lessons from the analysis of tsetse fly behaviour. Trends Parasitol 31(3):95–99
Treydte AC, Schmiedgen A, Berhane G, Tarekegn K (2017) Rangeland forage availability and management in times of drought – a case study of pastoralists in Afar, Ethiopia. J Arid Environ 139:67–75

Tsegaye D, Vedeld P, Moe SR (2013) Pastoralists and livelihoods: a case study from northern Afar, Ethiopia. J Arid Environ 91:138–146

Vetter S (2005) Rangelands at equilibrium and non-equilibrium: recent developments in the debate. J Arid Environ 62:321–341

Williams M, Ryan CM, Rees CM, Sambane E, Fernando J, Grace J (2008) Carbon sequestration and biodiversity of re-growing Miombo woodlands in Mozambique. For Ecol Manag 254(2):145–155

Wollny CBA (2003) The need to conserve farm animal genetic resources in Africa: should policy makers be concerned? Ecol Econ 45(3):341–351

Yaro M, Munyard KA, Stear MJ, Groth DM (2016) Combatting African Animal Trypanosomiasis (AAT) in livestock. The potential role of trypanotolerance. Vet Parasitol 225:43–52

Zander KK, Drucker AG, Holm-Müller K (2009) Costing the conservation of animal genetic resources: the case of Borana cattle in Ethiopia and Kenya. J Arid Environ 73(4–5):550–556