

*Review*

# Grazing management systems and their effects on savanna ecosystem dynamics: A review

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**The savanna ecosystems support livestock production and livelihood of pastoral communities. The degradation of savanna ecosystems due to overgrazing had lead government commercializing communal grazing land to privately owned ranches. However, grazing policies in Southern Africa had recently been debated, and yet there are few studies comparing grazing management systems on ecological system. This article provides an overview of current knowledge on effect of grazing management systems on savanna ecosystems. Ranching and communal grazing do not necessarily affect soil, herbaceous and woody vegetation differently. Thus current management systems do not promote sustainability of savanna ecosystems and there is a need for further research and participation of local communities on addressing land degradation.**

**Key words:** Fencing policy, rangeland degradation, sustainability, livestock production.

## INTRODUCTION

Globally, managed grazing lands comprises the largest land use (Liebig et al., 2006) estimated to cover about 25% of Earth's land surface (Asner et al., 2004). The extensive area covered by rangelands makes them an essential resource for maintaining biodiversity (O'Connor, 2005) and a source of livelihood, especially for rural communities (Eriksen and Watson, 2009a; Muhumuza and Byarugaba, 2009). They are utilised for livestock production which has continually played a significant role in the economic development of rural communities world-wide. It is estimated that approximately 76% of Botswana's total land surface area is used for grazing by both domestic and wild animals (Asner et al., 2004). Thus, grazing land, especially communal rangelands, are being degraded due to overgrazing which threaten their sustainability (Vetter, 2005; Darkoh, 2009) and rural communities whose livelihoods depends on livestock rearing.

The savanna ecosystems are highly dynamic, characterized by erratic rainfall and high rate of vegetation dynamics (Herlocker, 1999; Dahdough-Guebas et al., 2002), soil nutrient levels, fire and herbivory (Sharpe, 1992). But, livestock management systems can exert a considerable change on the diversity, composition, structure, and development of native plant communities (Popolizio et al., 1994; Vavra et al., 2007) in rangelands. Most savannas are degraded and dominated by unpalatable and annual herbaceous plant species and encroached by woody plants (van Vegten, 1984; Abule et al., 2005). The changes in the composition of plant species in savanna ecosystems has a significant influence on the sustainability of livestock production (Sankaran et al., 2005). Proper understanding of effects of grazing management systems on savanna ecosystem dynamics is therefore essential in maintaining productivity and biodiversity (Sternberg et al., 2000;

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Mohammed and Bekele, 2010). The objective of this paper is to synthesis existing knowledge on grazing management systems and their effects on savanna ecosystem.

## **GRAZING MANAGEMENT SYSTEMS AND RELATED POLICY**

Grazing management systems refer to all production systems that are used to exploit the rangeland through grazing. Savanna systems have been used for many centuries extensively for grazing livestock, with communal grazing land and commercial ranching being the dominant land use management systems (Rohde et al., 2006; Masike and Urich, 2008; Terefa, 2011). In southern Africa, the communal grazing rangelands are located in tribal land and shared by all pastoral farmers (Rohde et al., 2006; Masike and Urich, 2008). The communal grazing system used to be mainly dominated by subsistence farmers, but has shifted towards a cash economy (Wigley et al., 2010) in recent years.

Livestock management in communal grazing land is mainly influenced by local ecological knowledge (Smet and Ward, 2005). Mixed livestock, dominated by cattle and goats, is the traditional practices in the communal grazing system (Wigley et al., 2010). Livestock herding used to be a key part of managing communal rangelands which was based on mobility, splitting and dispersing livestock over the landscape during the wet and dry seasons (Oba et al., 2000), to ensure limited dry concentrated continuous grazing (Kioko et al., 2012). However, with recent developments in some developing countries (for example, Botswana), herding is no longer a common livestock management practice (Reed et al., 2008), instead livestock is allowed to continuously and selectively graze without any control (Parsons et al., 1997) around water sources such as boreholes. Borehole rights provided by land authorities such as Land Boards in Botswana indirectly give the borehole owners control of grazing resources around the water points.

The communal rangelands are used for grazing throughout the year (Oba et al., 2001) by pastoral communities without paying any levy associated with livestock grazing (Weimer, 1977). Consequently, several studies have suggested that they are poorly managed and degraded (Ellis and Swift, 1988; Abel, 1997; Dougill et al., 1999; Hendricks et al., 2007). As illustrated by "Tragedy of Commons" (Hardin, 1968), it is argued that each pastoralist find it profitable to increase his herd size in communal rangeland. However, as pastoralists increases their herd size, the livestock density increases to exceed the rangeland's carrying capacity resulting in overgrazing and land degradation (van Vegten, 1984). Several countries have introduced policies and laws in response to land degradation due to poor management of communal rangelands. In Botswana, the government introduced commercial ranches through the Tribal

Grazing Land Policy (TGLP) (Botswana Government, 1975). The communal grazing land was demarcated into ranches owned by individuals or a group of farmers who paid a levy for exclusive use of fenced ranches (Dougill et al., 1999). According to the TGLP (1995) and Tsimako (1991), the TGLP served the following purposes:

- a) To control overgrazing and reduce land degradation through improved rangeland management such as rotational grazing and optimal stocking rates in commercial ranches and shifting large herds of livestock from already overstocked communal lands.
- b) To improve livestock productivity and farmers' income through better management practices (for example, controlled breeding and early weaning).
- c) To secure interest of the poor (social equity) by reserving the communal grazing land for small scale farmers and have reserve land for future generations.

The management of commercial ranches is based on a range-succession model, whereby the goal of management aligns stocking rates to the carrying capacity of ranches (Mphinyane et al., 2008). Commercial ranches are characterised by rotational grazing which, consist of alternating periods of use and rest, to promote vegetation growth. To facilitate rotational grazing, several paddocks are demarcated within ranches to spread the livestock grazing intensity uniformly across the rangeland. The main focus in commercial ranches is on cattle rearing (Smet and Ward, 2005). Ranches have been promoted as a sustainable livestock management system by policies in Southern Africa (TGLP, 1975; Tsimako, 1991; Rohde et al., 2006), although they have high costs associated with fencing, drilling and water reticulation (Motlopi, 2006). Commercial livestock ranches are suitable for farmers with adequate financial resources. Their establishment has marginalised poor pastoral farmers because the total area for animal production in communal grazing land has declined dramatically in recent years (Eriksen and Watson, 2009b). This is further exacerbated by dual grazing rights which allow farmers allocated ranches to continue grazing their livestock in communal rangelands (Thomas and Sporton, 1997).

Several studies have criticised the conversion of communal rangelands to commercial livestock ranches (Abel, 1997; Rohde et al., 2006). Abel (1997) indicated that fencing policy is based on wrong assumptions and subsequently has failed to reduce rangeland degradation (Dahlberg, 2000). The productivity and sustainability of communal rangelands and their contribution to the livestock industry is also being underestimated (Abel, 1997). The communal grazing system is suitable for arid-land ecosystems because it is adapted to rainfall variability and spatial heterogeneity through opportunistic management such as mobility (Westoby et al., 1989). The TGLP had a provision protecting the interests of the poor pastoral farmers through reserve areas and removal of farmers with large herd from the communal rangeland

(Weimer, 1977). However, it was not clearly documented how this was to be achieved, given the fact that communal rangelands continue to shrink as more ranches are being demarcated.

The appropriateness of commercial livestock ranches in dry savannas has been debated in recent years (Ellis and Swift, 1988; Dahlberg, 2000; Rohde et al., 2006). Processes in savanna ecosystems are primarily influenced by rainfall variability and thus suited to traditional practices in communal land (Ellis and Swift, 1988; Westoby et al., 1989). Yet, few studies have been conducted to compare the effects of livestock grazing management systems of savanna ecosystems dynamics (Dahlberg, 2000; Smet and Ward, 2005; Tefera et al., 2010). Most of these studies are site specific (Asner et al., 2004), despite the high variability of the savanna ecosystem. A broad-scale multivariate analysis of relationships between diversity, environmental variables and management systems are required to understand savanna ecosystem dynamics (van der Heijden and Phillips, 2009). Analysis of interactions between natural factors (for example, rainfall and soil type) and anthropogenic drivers (Scholes and Archer, 1997) may improve our understanding of how a particular factor influences vegetation conditions (Groffman et al., 2007) in arid-land ecosystem.

### **EFFECT OF LIVESTOCK GRAZING MANAGEMENT SYSTEMS ON SOIL HEALTH**

Soils with good physical and chemical characteristics are essential in maintaining productivity in terrestrial ecosystems and driving processes that maintain environmental quality (Moussa et al., 2008) and sustainability (Hopmans et al., 2005; Liebig et al., 2006). The biological, physical, and chemical properties of soil can be modified by livestock grazing. It has been demonstrated that intensive livestock grazing profoundly affects soils as it increases soil compaction, soil erosion and loss, decreases soil organic matter, affect nutrient cycling and reduces water infiltration (Kauffman and Kruger, 1984; Stephenson and Veigel, 1987; Fleischer, 1994; Belsky and Blumenthal, 1997; Ingram et al., 2008). Livestock grazing cause disturbances to surface soils and can influence savanna ecosystem productivity and fertility by altering the soil physical and chemical properties and thus cause land degradation (Neff et al., 2005; Liebig et al., 2006).

Livestock grazing compacts soil particularly under high grazing intensity (Fleischer, 1994; Kauffman and Krueger, 1984; Robertson, 1996; Asner et al., 2004; Fatunbi and Dube, 2008). Most studies have reported significant increases in bulk density in grazing land, especially in finer textured soils and in the soil surface layers (Warren et al., 1986; Abdel-Magid et al., 1987; Steffens et al., 2008; du Toit et al., 2009), caused by hoof traffic of livestock (Walker and Desanker, 2004). Compaction is

directly related to soil productivity (Liebig et al., 2006) because it reduces water and air movement into and through the soil, and therefore reduces water availability to plant roots, restricts and reduces soil microorganisms, reduces soil nutrient availability and increase soil surface runoff and soil erosion (Fleischer, 1994; Kauffman and Krueger, 1984; Robertson, 1996; Asner et al., 2004; Fatunbi and Dube, 2008).

The soil surface erosion has profound effects on soil productivity and the ecosystem function because microorganisms, organic matter, soil fauna and roots are all concentrated in the surface soil (Brandy and Weil, 2007). Research has shown that soil erosion increases with livestock grazing intensity (Bari et al., 1995; Belsky and Blumenthal, 1997). Studies conducted in grazing land and ungrazed enclosures have reported significantly higher sediments production rates in many plant communities under grazing land (Bohn and Buckhouse, 1985; Pluhar et al., 1987), and production was observed to be significantly related to grazing intensity (Beeskow et al., 1995; Bari et al., 1995; Warren et al., 1986).

Heavy grazing reduces vegetation cover and limit organic matter inputs into the soil, and subsequently affect soil structure stability, resistance to rainfall impact, infiltration rate and soil microbial activity (Roose and Barthes, 2001; Snyman and du Preez, 2005). Overgrazing caused by livestock grazing reduces plant biomass accumulation and cause a shift in plant species composition (Owen-Smith, 1999; Klumpp et al., 2009) by replacing highly palatable grass species with their unpalatable counterparts (Owen-Smith, 1999). The shift in species composition can affect soil fertility (Scholes, 1990) because of changes in root biomass (Klumpp et al., 2009) and quality of organic matter, and decrease soil's capacity to sequester carbon (Lal, 2002; Northup et al., 2005; Savadogo et al., 2007; Klumpp et al., 2009). Research has shown that soil nutrient depletion reduces the primary production of rangelands (Girmay et al., 2008) which in turn affect their carrying capacity.

Effects of livestock grazing management systems on soil quality are poorly understood. Kgosikoma (2011) showed that livestock grazing management systems do not affect soil properties in savanna ecosystems differently. The study observed that soil texture, bulk density and pH did not differ between management systems despite differences in grazing intensities, though significant differences may occur occasionally between and within the study sites. Another comparative study conducted by Tefera et al. (2007) found no significant effect of livestock grazing management on soil texture, bulk density and pH. Warren et al. (1986) found no relationship between soil bulk density and livestock stocking rates, which is in agreement with Kgosikoma (2011). A study conducted in South Africa also found no significant differences in soil chemical properties (for example, pH) between grazed communal land and ungrazed land (Moussa et al., 2008). The results of these studies could suggest that livestock management

systems do not have significant effect on soil properties especially in sandy regions. In contrast, other studies have shown that livestock grazing management systems affect soil pH (Geissen et al., 2009). The differences between these studies could probably be attributed to differences in environmental conditions such as rainfall and soil or management practices.

### **EFFECTS OF LIVESTOCK GRAZING MANAGEMENT SYSTEMS ON HERBACEOUS VEGETATION**

Savannas in Africa are largely exploited through livestock grazing (Scholes and Archer, 1997; Bilotta et al., 2007), and the grazing intensity (removal of plant biomass by livestock) influence their sustainability (Mphinyane et al., 2008). Most grasses in savanna ecosystems are fairly tolerant to grazing, however, prolonged intense grazing eventually lead to shift in species composition (Skarpe, 1992) and reduction in grass biomass especially when soil nutrients are depleted (van Auken, 2009). Overgrazing affect the botanical composition and species diversity by depressing the vigour and presence of dominant species, which then enables colonization by less competitive, but grazing tolerant plant species (Sternberg et al., 2000). Selective grazing of palatable herbaceous plants by livestock enhances the growth of annuals and unpalatable herbaceous plants as well as woody plants (Skarpe, 1992) resulting in the decline of palatable species (Fensham et al., 2010). Overgrazed rangelands are normally dominated by Increaser II species such as *Aristida congesta* (Trollope et al., 1989) which are indicators of poor rangeland conditions (Fatunbi and Dube, 2008), while Increaser I species dominate undergrazed rangelands or selectively utilised rangelands (Trollope, 1990; du Plessis et al., 1998).

Tefera et al., (2007) observed a higher density of palatable herbaceous plant in ranches than in communal grazed rangelands in Ethiopia. In contrast, Kgosikoma (2011) found no significant differences in palatable herbaceous plant cover between communal grazing land and ranches at two different sites in Botswana, which was supported by other studies in other African savannas (Parsons et al., 1997; Tefera et al., 2008b). This could suggest that rangeland vegetation does not always respond in a linear way to grazing intensity (Sasaki et al., 2010), partly because local environmental conditions such as high rainfall and soil fertility regulate the plants' ability to cope with grazing pressures. However, herbaceous biomass appears to be more responsive to differences in grazing intensities between communal grazing land and ranches. Ranches exhibited a higher herbaceous biomass than the communal grazing land at most sites, which could be due to the higher grazing intensities of the communal grazing lands compared with ranches. Kgosikoma (2011). Sternberg et al. (2000) and Mphinyane et al. (2008) have also demonstrated that the biomass of herbaceous plants is highly responsive to

grazing pressures.

### **EFFECTS OF LIVESTOCK GRAZING MANAGEMENT SYSTEMS ON BUSH ENCROACHMENT**

Woody plant encroachment has been widespread in grasslands and savanna ecosystems worldwide (Archer et al., 2001): Bush encroachment is an important indicator of land degradation (van Vegten, 1984; van Auken, 2009) which has become a global concern (Moleele and Perkins, 1998; Moleele et al., 2002; Sankaran, 2009). Woody plant encroachment into grassland-dominated savannas has contributed to a decrease in the productivity of rangelands (Wiegand et al., 2005; Douglass et al., 2011), and jeopardizes biodiversity in grasslands, which threatens the sustainability of pastoral, subsistence and commercial livestock grazing (Rappole et al., 1986; Noble, 1997). Some savanna landscapes are completely encroached by woody species, while in others savanna areas the process is in progress (Archer et al., 2001). Factors that contribute to bush encroachment are poorly understood. However, overgrazing (Moleele and Perkins, 1998), anthropogenic reductions in fire regimes (Heinl et al., 2008; Lehmann et al., 2008), frequent droughts (Cole and Brown, 1976; Scholes and Archer, 1997; Smith and Smith, 2001), and climate change (Fensham et al., 2005) are suspected to facilitate the process.

The increase in bushy vegetation in rangelands threatens livestock production in the savannas because encroaching woody species suppress palatable grasses and herbs (Scholes and Archer, 1997) through competition for soil moisture and nutrients. However, encroaching leguminous woody plants such as *Acacia mellifera* may enrich nutrient poor sandy soils in dry savannas through nitrogen fixation (Hagos and Smit, 2005). Research has shown that soils under the canopy of tree species such as *A. mellifera* have higher levels of nitrogen, organic matter and calcium than soils distant to trees (Hagos and Smit, 2005). Some woody plants are also an important fodder resource especially during dry periods (Moleele, 1998). Therefore, a management aim of bush encroached rangelands could be selective thinning of woody vegetation to reduce the grass-tree competition, whilst retaining the beneficial effects of soil enrichment from leguminous tree and shrub species (Hagos and Smit, 2005).

Bush encroachment is an environmental problem in both ranches and communal grazing land despite the difference in grazing intensity between the two grazing management systems (Oba et al., 2000; Kgosikoma et al., 2012). Meanwhile, Wigley et al. (2009) reported that bush encroachment was a slow process in communal grazing lands than ranches due to high utilization rate of woody plants for firewood by the community. High grazing pressure can also reduce fuel loads through consumption and compaction and consequently prevent

fire ignition (Douglass et al., 2011). In the absence of fire, bush encroachment may occur (van Langevelde et al., 2003; Sharp and Whittaker, 2003; Savadogo et al., 2007) which decreases rangeland's productivity.

## SUSTAINABILITY OF SAVANNA ECOSYSTEMS

The current grazing policies in southern Africa (for example, TGLP of Botswana) were based on the assumptions that ranches would promote sustainable land use and conserve rangeland resources. However, current evidence suggests that rangeland degradation is occurring in both communal and ranching lands (Vanderpost et al., 2011). This had led to others arguing that the current grazing policies had failed to address the land degradation problem and had instead exacerbated it (Rohde et al., 2006). In addition, the communal grazing land which supports the large population of livestock continues to shrink in size as more land is demarcated into ranches (Boone, 2005). Subsequently, grazing pressures have intensified in communal grazing land (Bennett et al., 2010) especially since owners of private ranches continue to use communal grazing land in addition to their ranches (Tsimako, 1991). Considering the limited land currently available for grazing by pastoral communities (Bennett et al., 2010), the existing policies need thorough revision and dual grazing rights to the farmers allocated ranches should be eliminated. This would address the current inequity of land distribution, which could ultimately threaten the sustainability of the entire savanna ecosystem (Eriksen and Watson, 2009a).

Sustainable agro-ecosystem management depend on understanding the effects of different land use and environmental factors on ecosystems dynamics (Wallgren et al., 2009). Savanna ecosystems are complex and therefore management policies should rely on research-based understanding of whole ecosystems. Given that long term ecological data is often missing, the local pastoral community could provide the long term perspective on changes in savanna ecosystem. The social, ecological and economic factors need to be taken into account and participatory management involving pastoral communities should be considered.

## CONCLUSION

The review of scientific literature shows that overgrazing and prolonged poorly managed rangelands led to removal of desirable plant species, decrease water infiltration into soil, increase soil erosion, reduce soil nutrients and alter the plant community composition to a less desirable state. These changes compromise both the short and long-term productivity of rangelands in savanna ecosystems. Grazing policies adopted by countries in arid zones, particularly those in Africa have failed to reduce land degradation because they were based on wrong

assumptions or models (Abel, 1997). Most of these policies need to be revised embracing indigenous knowledge systems, if rangeland resources in the savannas are to be used sustainably to benefit the future generation.

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