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ORIGINAL RESEARCH

The influence of management systems on rangeland conditions under different environments in Botswana

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KOE, conceived idea, designed study, collected data & analysis, prepared manuscript; MW, prepared manuscript; HB, designed study, statistical analysis

ABSTRACT

The present study investigated rangeland conditions in communally grazed lands and ranches in different parts of semi-arid Botswana. Soils and vegetation assessments were carried out along 23 transects randomly located in both communal grazing land and ranches. The soil organic carbon was low in sandveld regions, but did not differ significantly (P > 0.05) between management systems except at Goodhope. Observations on herbaceous vegetation showed that both communal land and ranch at Goodhope were not degraded, with a balance of increase II and decreaser species. Other rangelands poor conditions were dominated by increaser II species. Bush encroachment was observed in both communal and ranches at Matlolakgang and Xanagas, which further confirm that these rangelands were degraded. The results suggest that rangeland degradation is highly pronounced in the sandveld region, but is not limited to communal lands only as suggested by Tribal Grazing Land Policy of Botswana.

Keywords: Bush encroachment, degradation, rangeland management, savanna, soil organic carbon

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INTRODUCTION

Savanna ecosystems are globally important and cover about 20 percent of the Earth's land surface area (Bond and Midgley, 2000; Sankaran *et al.,* 2005) and 50 percent of Africa (Wang *et al*., 2010). These ecosystems are characterised by scattered trees and continuous layer of herbaceous plants (Sankaran *et al*., 2005; Wiegand *et al*., 2006). The productivity of these ecosystems is at stake because there are largely degraded due to overgrazing by livestock (Fernandez-Gimenez, 2000). Overgrazing reduces palatable herbaceous plant species and increases their unpalatable counterparts (Smet and Ward, 2005). It also affects the soil quality (Snyman and du Preez, 2005; Elmore and Asner, 2006), herbaceous plant species composition (Tefera *et al.*, 2007) and woody vegetation cover (Van Vegten, 1984). The reduction in vegetation in overstocked rangelands leads to low organic matter feedback into the soil and prolonged overgrazing consequently decreases soil carbon (Klumpp *et al.*, 2009). The reduction in herbaceous vegetation cover allows the establishment of woody plants due to increased access to limited resources such as soil nutrients and moisture (Yanoff and Muldavin, 2008; van Auken, 2009). The loss of soil fertility, palatable herbaceous vegetation and bush encroachment are all indicators of rangeland degradation (Fatunbi and Dube, 2008; Moussa *et al.*, 2008) and knowledge on how various land uses affects these indicators is essential for sustainable ecosystem management (Sternberg *et al.*, 2000).

Proper management of savanna ecosystems is essential to sustain environmental services, and livelihoods of pastoral communities. This depends on understanding the effects of different land uses and environmental factors on ecosystems dynamics. To address the problem of land degradation in communal grazing areas in Botswana, the Government in 1975 introduced privately owned ranches through the Tribal Grazing Land Policy (TGLP) (Botswana Government, 1975; Tsimako, 1991). The TGLP was considered necessary because rangeland degradation was occurring at an alarming rate, threatening the livelihoods of pastoral farmers (Van Vegten, 1984; Tsimako, 1991). Rangeland degradation and decline in vegetation diversity are indicators of ecological change (Detsis, 2010) due to livestock overgrazing (Cheng *et al.*, 2011), particularly under communal grazing land (Fernandez-Gimenez, 2000). Though communal rangelands are generally considered degraded (Moussa *et al.*, 2008), on the other hand there is limited evidence to suggest that ranches are ecologically sustainable. This study was therefore aimed at investigating the impact of livestock grazing under communal grazing land and ranches in a savanna ecosystem under different environments. The specific objectives were to evaluate (i) soil organic carbon (ii) herbaceous vegetation composition and (iii) bush encroachment in communal grazing land and ranches. The study used multi-variables of savanna ecosystems such as soil, herbaceous and woody vegetation as indicators of range condition in response to management systems and environmental variability.

MATERIALS AND METHODS

Study sites

The study was conducted at Goodhope, Matlolakgang and Xanagas rangelands. The sites are located in different part of Botswana (Figure 1). Matlolakgang is located between Ngware and Malwelwe. The three sites differ in rainfall, soil characteristics and vegetation type (Table 1). Goodhope is located in the hardveld and has the highest mean annual rainfall relative to other sites. Matlolakgang and Xanagas are located in the Kalahari sandveld.

Figure 1: Location of Goodhope, Matlolakgang and Xanagas (Kgosikoma 2011)

ion of Goodhope, Matlolakgang and Xanagas (Kgosikoma 2011)

Data collection

A total of 23 transects were randomly established in both the communal grazing land and ranches

Soil samples were collected along each transects at 100 m intervals and taken to the Department of Agricultural Research laboratory for soil carbon analysis using dichromate oxidation method of Walkey & Black according to Anderson and Ingram, (1989) and Meersmans *et al.* (2009). The herbaceous vegetation cover was measured using a Tidmarsh wheel-point method along each transect according to Everson *et al*. (1990) and Brockett (2001). Herbaceous plant species were categorized as increaser I, increaser II and decreaser in relation to their ecological response to grazing according to Dyksterhuis (1949), Trollope *et al.* (1989) and du Plessis *et al.* (1998).

Savanna ecosystems in excellent condition and moderately utilised are dominated by decreaser species, which tend to decrease when overgrazed (Trollope *et al.*, 1989).The ecosystem dominated by increaser I species indicate low utilisation by livestock, especially cattle, whereas the dominance of increaser II species indicate overgrazing (Trollope *et al.*, 1989; du Plessis *et al.*, 1998). The woody vegetation density was measured in 10 x 10 m quadrats at 100 m interval along each transect and converted to number of plants *per* hectare (ha^{-1}).

Statistical analysis

The ANOVA was used to compare soil and herbaceous vegetation variables between communal grazing land and ranches at each site. The general linear model (GLM) was used to compare woody plant density between management systems (communal grazing land and ranches) and sites. All data were checked for normality and transformed when required (Hair et al., 1998). All statistical analyses were run in Minitab 15 (Minitab Inc. 2007)

RESULTS

Soil organic carbon in relation to rangeland management system

The soil organic carbon (SOC) in the top soil layer (<10 cm) was not affected ($P > 0.05$) by rangeland management systems Rather, SOC in the top soil layer varied significantly between sites ($P < 0.001$), with the communal grazing land and ranch at Goodhope having the highest SOC (Figure 2). Soil organic carbon percentage was significantly higher ($P < 0.05$) in the ranch than communal grazing land at Goodhope but no differences were observed at the other two sites.

Table 1: Mean annual precipitation (MAP), soil and vegetation type at Goodhope, Matlolakgang and Xanagas

Site name	District	MAP (mm) (1988−09)	Soils	Main Vegetation Type
GH[1]	Southern	475	Non-calcareous loam	Acacia giraffae tree savanna
MK	Kweneng	434	Non-calcareous sand	Central Kalahari bush savanna
XG	Gantsi	368	calcareous	Northern Kalahari tree and bush savanna

[1]GH = Goodhope; MK = Matlolakgang; XG = Xanagas

Table 2: Stocking rates at Goodhope, Matlolakgang and Xanagas

	Management systems (hectare *per* livestock unit)*	
Site name	Communal	Ranch
Goodhope	3.75±0.29	12.90±12.91
Matlolakgang	5.01±0.23	15.90±1.98
Xanagas	30.57±2.16	19.03±1.68

Rangeland conditions based on herbaceous composition

There were significant differences (P < 0.01) in the percentage cover of decreaser species between sites. These were also significantly higher (P < 0.05), in ranches than in the communal grazing land at Matlolakgang and Xanagas but not at Goodhope (Figure 3). The communal grazing land and ranch at Goodhope had a higher (P < 0.01) percentage cover of increaser I species than Matlolakgang and Xanagas. However highly significant (P < 0.001) differences in increaser I species between the ranch and communal grazing land were only observed at Xanagas (Figure 3). The difference in the percentage cover of increaser II species was highly significant (P < 0.001) between sites and was higher (P < 0.05) in the communal grazing land than ranches at Matlolakgang and Xanagas.

Woody vegetation density in relation to rangeland management system

The woody plant density varied greatly across the landscape at each site as reflected by high standard errors (Table 3).

Table 3: Total woody plant density at Goodhope, Matlolakgang and Xanagas

	Management systems (plants ha^{-1})*	
Site	Communal	Ranch
[1]GH	411 ± 244	508 ± 157
MK	8342 ± 2144	7692 ± 1082
XG	2642 ± 289	4108 ± 544

[1]GH = Goodhope; MK = Matlolakgang; XG = Xanagas

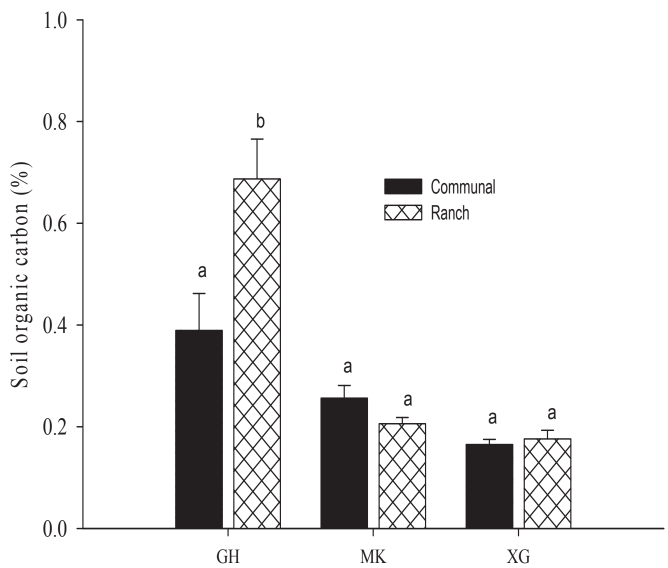

Figure 2: SOC in top soil layers at Goodhope (GH), Matlolakgang (MK), and Xanagas (XG). Different letters indicate a significant difference (P < 0.05). The vertical bars indicate standard error of the mean

The total woody plant density differed significant (P < 0.001) between sites, but not (P > 0.05) between the communal grazing land and ranches. Matlolakgang rangelands had the highest woody plant density of 8017 plants ha^{-1}, followed by Xanagas with 3375 plants ha^{-1} and lastly Goodhope with 467 plants ha^{-1}. There was a higher woody plant density at Goodhope and Xanagas ranches than communal grazing land but this difference was not significant (Table 3).

DISCUSSION

Soil organic carbon in relation to rangeland management system

Soil organic carbon did not differ significantly between communal grazing land and ranches at Matlolakgang and Xanagas. These results are consistent with results of studies conducted in other parts of Southern Africa (Tefera *et al.*, 2010) and elsewhere (Tefera *et al.*, 2007) which found no significant difference in SOC between ranches and communal grazing land. The amount of SOC observed at Xanagas and Matlolakgang is comparable to figures reported in studies conducted in other parts of Botswana (Ringrose *et al.*, 1998; Wang *et al.*, 2007) and other dry savannas of Southern Africa (Scholes, 1990)

A study by Smet and Ward, (2006) observed a significant difference in SOC between communal grazing land and ranches only close to watering points which could probably be due to time the animals spend and the amount of faecal matter deposited. Lack of significant differences in SOC between the communal grazing land and ranches in the present study probably indicate that livestock grazing systems, especially for cattle, do not affect the savanna ecosystems differently, which is contrary to the assumptions of the TGLP.

Soil organic carbon at Goodhope was significantly higher in ranches than communal grazing land, which could reflect differences in impact of grazing intensity. Livestock grazing intensity influence the amount of soil carbon (Savadogo *et al.*, 2007; Steffens *et al.*, 2008; Bagchi and Ritchie, 2010) and low grazing intensity allow plant biomass to build up and increase carbon stocks (John *et al.*, 2006) but may lead to low growth vigour. The low grazing intensity observed at Goodhope leads to lower rates of vegetation defoliation causing biomass build up and increases in soil carbon (John *et al.*, 2006; Savadogo *et al.*, 2007; Steffens *et al.*, 2008). Subsequently, it could be expected that the impact of different grazing intensities under different management systems will be indirectly reflected in SOC content, especially at local scale, by regulating the vegetation composition (Girmay *et al.*, 2008). Organic matter input and output to the soil (Lawrence, 2005; John *et al.*, 2006; PiÑEiro *et al.*, 2006; Bagchi and Ritchie, 2010) would also be affected by grazing intensity. The variation in SOC between Goodhope and other sites could also be attributed to several local factors such as soil type (Girmay *et al.*, 2008; Aarrestad *et al.*, 2011) and rainfall (Girmay *et al.*, 2008).

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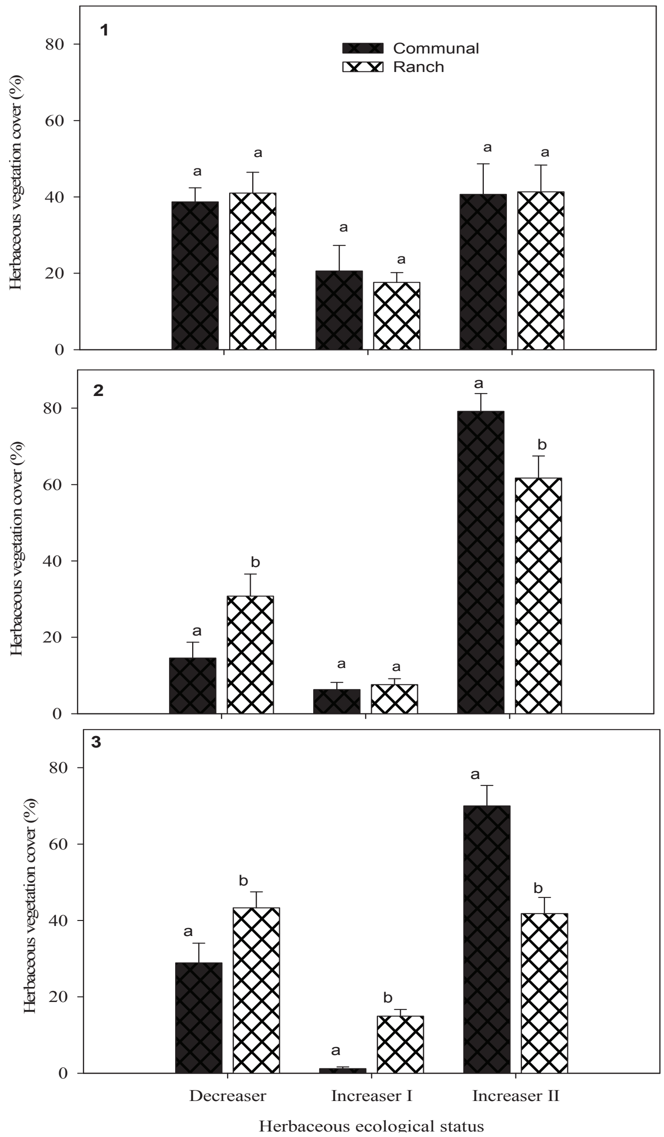

Figure 3: Rangeland ecological status as indicated by herbaceous vegetation at Goodhope (1), Matlolakgang (2) and Xanagas (3). Different letters indicate a significant difference ($P < 0.05$). The vertical bars indicate the standard error of the mean

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Rangeland conditions based on herbaceous composition

The results of the present study exhibited a balanced distribution of increaser II and decreaser herbaceous species at Goodhope communal grazing land and the ranch. This balanced distribution probably indicates that the rangelands were not overgrazed (du Plessis *et al.*, 1998). According to Trollope *et al.* (1989) increaser II species indicate overgrazing and their abundance in the communal grazing land and ranches at Matlolakgang and Xanagas suggest that rangelands are undergoing degradation. Abundance of increaser II species in communal grazing land than ranches at Xanagas and Matlolakgang, but not Goodhope probably suggests that the response of herbaceous vegetation to grazing is not always linear (Sasaki *et al.*, 2011) and that local environmental conditions such as rainfall and soil type also influence the response of plants to grazing (Carr *et al.*, 2009).

Woody vegetation density in relation to rangeland management system

Lack of significant difference in the woody vegetation density between the communal grazing land and ranches is consistent with results of studies conducted elsewhere (Smet and Ward, 2005; Tefera et al., 2008). The woody plant density at Goodhope communal grazing land and ranch was below the threshold of 2400 plants ha^{-1} suggested by Roques *et al.* (2001) and Dalle *et al*. (2006), while at Matlolakgang and Xanagas the woody vegetation density was above the threshold. According to Roques *et al*., (2001) and Dalle *et al*., (2006) the woody plant density above the threshold of 2400 plants ha^{-1} is an indication of rangeland degradation. The low woody plant density at Goodhope rangelands could probably be attributed to local environmental conditions, especially rainfall and soil fertility that favours high growth by dominant herbaceous plant species and thus limits tree seed germination, seedling establishment and survival through competition for water and soil nutrients (Hagenah *et al.*, 2009). The alternative explanation could be that woody plants are cut for fuel-wood and construction material by local communities (Nkambwe and Sekhwela, 2006; Wigley *et al.*, 2009; Wessels *et al.*, 2011) because the site is closer to a highly populated major village than other sites. Some cuttings were actually observed during the study. The results of the present study suggest that bush encroachment is a common environmental problem in both the communal grazing land and ranches. This is contrary to assumptions of the TGLP that bush encroachment occurs mostly in communal grazing land due to overstocking and poor rangeland management (Botswana Government, 1975; Moleele and Perkins, 1998) and that ranches would promote proper utilisation of rangeland resources and limit land degradation (Botswana Government, 1975).

CONCLUSIONS

The SOC was not affected by rangeland management system, except at Goodhope. The Kalahari sandveld (Matlolakgang and Xanagas) was characterized by low organic carbon, relative to hardveld (Goodhope) a phenomenon likely to be reflected in the respective ecosystem productivity. The herbaceous vegetation composition indicated that Goodhope rangelands were in fair condition, while other rangelands are overgrazed as indicated by abundance of Increaser II species. That was further supported by bush encroachment at Matlolakgang and Xanagas rangelands, but not Goodhope. There was no difference in impact of communal and ranching management on ecological condition of rangelands, which contradicts assumptions by the TGLP policy. It is therefore essential that other control measures to rangeland degradation be established, particularly in the sandveld where there was strong evidence of degradation, to minimize its impact on the livelihood of pastoralists.

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Conflict of interest: None

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