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Dry Matter Biomass Productivity and Composition of Grasses along Grazing Gradient in Fenced and Unfenced Grazing Areas of the Gaborone North, Botswana

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Abstract

Objective: The present study was aimed at assessing and comparing grass species composition and biomass productivity along fenced and unfenced grazing gradient.

Methods: For each study area 2 × 1000 m transects radiating from the water points (borehole) were used and sampling plots of size a total of 15 quadrants of size 1 m^2 were systematically placed along each transect at intervals of 50 m for the first 500 m and the last 500 m the spacing interval was increased by 100 m. The total biomass of the selected plots was clipped, weighed; oven dried at 65˚C for 48 h and weight again in order to express the weight by dry matter.

Results: The grazing gradient in fenced area exhibited the highest dry matter biomass ($P<0.05$) for the grass species at 644.7 g/m^2) as compared to the unfenced area at 155.9 g/m^2. High-value species (341 g/m^2) significantly dominated the dry matter biomass composition in the fenced gradients while in the unfenced it was dominated by medium value species (66.8 g/m^2). Despite the fluctuation of biomass from one interval to another, logarithmic trend line estimations suggested an increasing plant biomass relative to the distance from the water point in both grazing gradients. Areas of high biomass were demonstrated at 900 m in both fenced (915 g/m^2) and unfenced (433 g/m^2) gradients. Dry matter biomass declined in areas close to and furthest from the watering points. The high biomass of the intermediate grass species dominated by *E. rigidior* suggests that it was highly unutilized.

Conclusions: Our findings indicate that dry matter biomass productivity of fenced gradients was higher as compared to that of unfenced grazing area. Dry matter biomass in fenced was mainly composed of high value species especially *U. trichopus* Meanwhile *E. rigidior* mid value species contributed the largest share to the biomass in the unfenced gradient.

Keywords: Biomass; *E. rigidior*; Dry matter; Gradient; Watering point

Introduction

Botswana is classified among most decertified countries in sub-Saharan Africa as such 75% of the country's human and animal populations are dependent on groundwater sources. Centralized and reticulated livestock watering points including boreholes and wells, create grazing gradients radiating from the water source [1]. Cattle posts are mostly located adjacent to a borehole, well in a river or in a pan as authorized by the local Land Board [2]. It is postulated that gradient grazing pressure intensifies in areas where animals are concentrated resulting in significant changes to soil nutrition and herbaceous cover [3]. According to the ability to diagnose grazing gradients may assistance in range evaluation and development of high-tech satellite imaging and remote sensing [4]. Range resource management recognizes the role of fencing in sustainable, economic and conservative farming. In Botswana, rangeland fencing is applicable mostly to private grazing areas meanwhile communal grazing are open an access resource. The communal sector accounts for 71% of the country's land and it is characterized by high stocking rates, uncontrolled livestock movement and breeding, traditional husbandry practices and lack of animal records and estimation of cattle numbers [5]. Despite the negative attributes of communal systems previous findings reported that privately owned ranches did not archive any significant reduction in the control of bush encroachment and cover as anticipated. This finding demonstrated that the current grazing management and livestock production systems have negative impacts on the rangeland resource hence the need for improvements [6]. Interrogating the current production system in communal grazing areas and ranches might help understand the level of degradation along the grazing gradients. Thus could help in the design of land allocation and management policies. Despite the fact that there is systematic change in vegetation cover with distance from water, [4], little is known on the grass species composition in BUAN farm and along Mmamolongwana communal grazing area thus impacting on fodder and pasture planning especially in semi-arid and arid areas such as Botswana were drought are recurrent. Therefore, the present study was aimed at assessing and comparing grass species composition and productivity along fenced and unfenced grazing gradient.

Methodology

Description of the study area

The study was carried out in the two sites in the Gaborone North region of Botswana. The Two sites comprised of Botswana University of Agriculture and Natural Resources (BUAN) ranch (latitude 24°33'56.40"S Longitude 25°57'28.67"E) and Mmamolongwana communal grazing area (latitude 24°27'55.08"S Longitude 26° 1'23.91"E) representing the fenced and unfenced grazing gradients. Both sites had a central borehole dating to the 1970's, but of due to rotational grazing practice in BUAN farm water was reticulated to each paddock. BUAN farm was under private land holding and focused only on raising beef cattle (180). The ranch was partitioned into 5 paddocks and employed rotation grazing. Therefore the study was focused on the paddock that was currently being grazed at the time. Mmamolongwana which was a communal area used for pastoral (sheep, goat, donkeys, and horses) and arable farming activities. The Mmamolongwana borehole was operated by a syndicate of 8 farmers who kept in total (270 cattle, 138 goats, 63 sheep and approximately 14 donkeys and 6 horses). Due to the communal nature of Mmamolongwana, grazing rights were open to other members of the community and no fencing allowed.

Ecological zone and climate

Both areas are located in the hardveld ecological zone of Botswana and spaced at a distance of approximately 7 km, therefore, similarities in the climatic and vegetation conditions. The average annual maximum and minimum temperature were estimated at 28 and 13°c respectively [7]. The summers were hot while winters were mild with temperatures rarely falling below freezing point. The average annual precipitation ranges from 450 to 500 mm with 40-50% probability of rainfall acceding 500 mm in any year. The vegetation type is Acacia/Combretum Tree Savanna in both the study areas. The biome in the areas is composed of a mixture of vegetation including the tree savanna dominated by of Acacia and Combretum species. Acacia dominated sites are common on flat terrain while Combretum types are associated with rocky outcrops [8]. Furthermore (open) shrub savanna has been established as such the grass layer varies in coverage from 10-70% and dominated *by Eragrostis lehmanniana*, *Stipagrostis uniplumis*, and *Anthephora pubescens* (Burgess, 2006).

Field procedure

The study was conducted during the peak of the rainy season (December –March 2010). An inspection survey was conducted to assess, identify and select study site. The design of the study followed the methodology described by [9]. Satellite images of the two study areas were studied and used for selecting the layout of the long transect and for accuracy in allocation and spacing of the sampling quadrats. Quadrates GPS coordinate adopted from satellite images were stored in a GPS receiver and tracked in the field to identify the sampling plots. For each study area, 2 × 1000 m transects radiating from the water points (borehole) were used and 15 sampling plots (quadrants) of size 1 m^2 were systematically placed along each transect at intervals of 50 m for the first 500 m and the last 500 m the spacing interval was increased by 100 m. The reason in differentiating the distances was to gain a better understanding of factors affecting patterns of grass species around water points [10].

Clipping of grasses and calculation of dry matter biomass

Grass species rooted within the plots were recorded for frequency and counted for density. The total biomass of the selected plots was clipped by harvesting the whole grass based on the method by [11]. In the procedure, we excluded all parts of herbaceous plants whose stems originate outside of the plot, even though their foliage overlapped into the plot. After clipping each species in the plots was weighed. The average weight of each species was calculated by dividing the total weight/grams by a number of plots sampled. The grasses we then oven dried at 65˚C for 48 hours in order to express the weight by dry matter.

Statistical analysis

All data analyses were carried out with the SAS, software package. Means of the biodiversity attributes separate using t-test and analysis of variance. Differences among means were accepted as significant at P<0.05.

Results

Dry matter biomass of grass species in grazing gradients

Table 1 shows the dry matter biomass and relative dry matter biomass of grasses on the two grazing gradients. The grazing gradient in fenced area exhibited the highest dry matter biomass (P<0.05) at 644.7 g/m^2 as compared to the unfenced area at 155.9 g/m^2. High-value species (341 g/m^2) significantly dominated the dry matter biomass composition in the fenced gradients while the low-value species contributed a less share (69.3 g/m^2). Species, *U. trichopus* (171 g/m^2), *E. rigidior* (130.7 g/m^2), *E. lehmaniana* (70.7 g/m^2), and *A. congesta* (54.7 g/m^2), contributed significantly to the total dry matter biomass of the fenced gradient. In contrary, the unfenced fenced gradient dry matter biomass was composed (P<0.05) mainly of the medium value species (66.8 g/m^2) while the high-value species were the least (30 g/m^2). In the unfenced communal grazing area *E. rigidior* (65.8 g/m^2), *A. pattens* (24.8 g/m^2), A. congest (19 g/m^2), *D. milanjiana*, (12.7 g/m^2), and *C. dactylon* (10 g/m^2), recorded the highest dry matter biomass.

Total grass dry matter biomass composition relative to distance from water point

As shown in **Figure 1**, both grazing gradients recorded a significant (P<0.05) variation and fluctuation of grass dry matter biomass at different intervals from the water point. The lowest Dry matter biomass in both the fenced and unfenced was the area closest (50 m) to the watering point. Despite the fluctuation of biomass from one interval to another, logarithmic trend line estimations suggested an increasing plant biomass relative to the distance from the water point in both grazing gradients. Areas of high biomass were demonstrated at 900 m in both fenced (915 g/m^2) and unfenced (433 g/m^2) gradients.

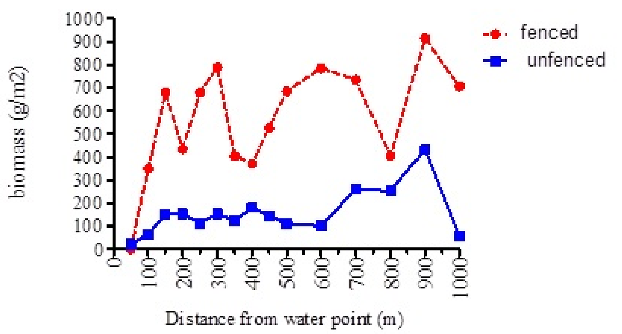

Figure 1: Total dry matter biomass relative to the distance from water points in fenced and unfenced grazing gradients.

Grass nutritional value relative to distance from water point

There was a significant variation (P<0.05) in the grass nutritional value biomass relative to the distance from water points in both gradients (**Figure 2**). In the fenced area, the intermediate dominated throughout the gradient with the exception of intervals at 150, 300,500 and 900 m were high values species dominated. In the unfenced gradient species with intermediate nutritional value dominant (P<0.05) at areas 300-900 m while low value species dominated the 100-200 m from the water point. *E. rigidity* contributed significantly to the biomass at intervals of 200-800 m in the unfenced gradient as well as 500-1000 m in the fenced area (**Figure 3**). Furthermore, *U. trichopusat* intervals of 250-700 m in the fenced gradient contributed significantly to the total dry matter.

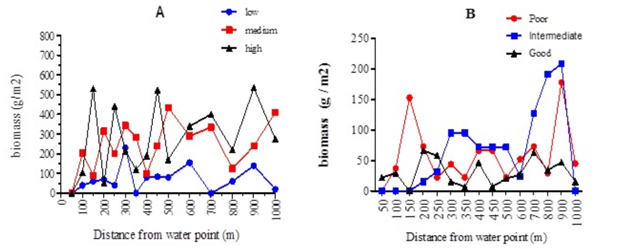

Figure 2: Dry matter biomass nutritional value relative to the distance from water points in fenced (A) and unfenced grazing gradients (B).

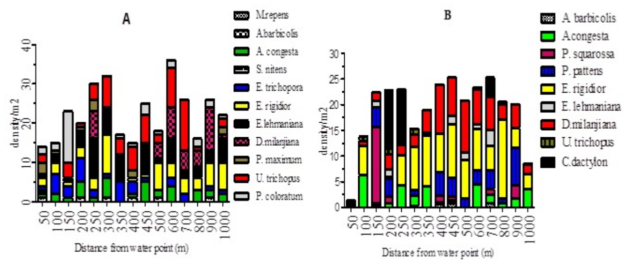

Figure 3: Grass species dry matter biomass relative to the distance from water points in fenced (A) and unfenced grazing gradients (B).

Discussion

Grass dry matter biomass decreased in areas close and furthest from the watering points. According to [12] about 50% of the perennial plant biomass produced on any grazing lands should remain with the plant in order for the plants to maintain healthy and productive growth. A such, rotational grazing in the fenced gradient may have played a significant role in reducing the grazing pressure and allowing for grasses to establish a significantly higher DM biomass as compared to the unfenced gradients [12]. The significantly lower (P<0.05) dry matter biomass thought out the unfenced gradient is an indication that continuous grazing impacted negatively on grass productivity (**Table 1**). Multiple land use involving high stocking densities of different livestock species, destruction of grass species for domestic purposes (house thatching) and land clearing for arable crop farming were associated with low productivity of grasses in the communal area [13]. The fact that the fenced gradient was grazed by cattle only while the unfenced gradient was being grazed by multiple animal species suggests that grasses in the unfenced gradient had varying degrees of damage due to variation in grazing behavior and grazing patterns. It has been demonstrated that animal and pasture interactive behavior which includes trampling, selecting grazing, fouling plants and soil with urine and manure affect grass yield [14]. Further studies are required to model overlapping animal behavior and their impacts on grass productivity. Grazing and trampling of herbaceous vegetation around watering points over a long period of time may indirectly result in loss of juvenile plants and reduced herbaceous plant productivity [15]. Since most of the good grass species have high leaf production they are easily susceptible to trampling by animals which do not recover easily after being destroyed. Low value grasses tend to bear fewer leaf leaves while their stems and seeds are resistant to trampling as such they can easily reseed and develop [16]. Cattle graze up to 30 km and further from their home watering point during the rainy season since they drink from puddles and pans. As such there is a possibility of grazing gradient overlaps since livestock is capable of moving beyond the standard 8 km distance between underground water sources in communal land. Findings by [13] reported a decline in the abundance of palatable native perennial grasses in areas approximately>2 km of distance from the water point in communal grazing area in Namibia. Since the unfenced gradient did not provide any grazing restriction more research is required to find out the changes to grasses beyond the 1 km transect as well the effects of gradient overlaps. However, in the fenced gradient, onsite observations revealed the accumulation of dung at areas along the fences (transect end point) thus support the low DM biomass recorded at 1000 m from water point (**Figure 1**) [13].

The decrease in grass dry matter biomass in areas close to the watering point may be attributed to high compaction in the areas thus reducing infiltration which might have hampered nutrient leaching to lower soil levels [15,17], found that cattle tracks, as well as trampling, may severely reduce infiltration. The fact that most areas around watering points were cleared of trees suggests that more water was unavailable to support grass growth. Research by [18] reported high densities (units/ha^{-1}) of *A. tortilis* (290; 321), *T. sericea* (52;272), *G flava* (177; 123), *E. Undulata* (476,87) in the similar quadrate of the current study in the fenced and unfenced gradients respective. Furthermore it was suggested that both the gradients were encroached by these species thus consistent with previous studies in other parts of Botswana [18-21]. The above-stated woody species are well-known encroacher species; therefore, a surge in their abundance may be applied as an indicator for degradation [22]. According to [23] trees in savanna enable grasses to establish and thrive by altering microclimatic conditions and providing grasses protection from grazing. Nonetheless [24,25] demonstrated contrasting results that bush encroachment reduced grass dry matter biomass due to competition for nutrients and growing space since their growth results in impenetrable stretches across the gradients [23-25].

Low dry matter biomass areas ($P<0.05$) were exhibited at 400 m and 800 m in fenced area while the unfenced area exhibited them at 300 and 1000 m (**Figure 1**). It can be postulated that animals in the previous years might have concentrated their feeding approach to these areas since low dry matter biomass of high-value grasses *P. maximum*, *D. milanjiana* and *E. trichopora* were observed. If grazers base their foraging approach on time minimization, rather than energy maximization they tend to choose areas of high biomass [26]. Therefore it is likely that cattle would not prefer these areas as such they might recover with time to host low value grasses. As reported in **Figure 2** the fenced gradient areas at intervals of 150, 300, 500 and 900 m demonstrated a peak for high-value species. Research models by [27] suggested that if large grazers are to maximize energy intake, they tend to choose areas of intermediate dry matter biomass over high dry matter biomass. According to [28], forage DM biomass is often inversely related to digestibility as such highly digestible grasses have lower retention time in the gut. Since cattle are heavy grazers if they opt for highly digestible grasses they require a large quantity of the grass to satisfy their daily dry matter requirement at the expense of more energy as such opting for areas of intermediate over high dry matter biomass [26]. *Urochloa trichopus* a high value species exhibited the highest biomass in the fenced gradient (**Table 1 and Figure 3**) thus suggesting that it was highly unutilized by cattle. Moreover, its abundance may suggest environmental disturbance due to grazing effects since [29] demonstrated that the grass thrives in disturbed locations also as an arable weed. The intermediate grass species *E. rigidior* dominated others species in dry matter biomass production while being frequent at different interval both study sites. The high relative dry matter biomass of *E. rigidior* in both fenced (20.3%) and unfenced (42.2%) sites might suggest that it is not highly utilized by animals reporting that the surge in the biomass for species such as *E. rigidior*, *A. congesta* demonstrates over-exploitation due to overgrazing. Furthermore, the disappearance of high value species such as *P. maximum*, *U. trichopus* and *P. colorotum* in the unfenced gradient might point to the over-exploitation and their failure to regenerate due to the lack of seed banks [2].

Table 1: Dry matter biomass (MB g/m^2) and relative dry matter biomass (RMB %) of grasses on the two grazing gradients.

		Fenced		Unfenced	
Botanical name	**Local name**	**MB**	**RMB**	**MB**	**RMB**
Melenis repens	Natal red top	4	0.6	-	-
Aristida barbicolis	Seloka	10.3	1.6	3.4	2.2
Aristida congesta	Seloka	54.7	8.5	19	12.2
Sporobolus nitens	African Bermuda	0.3	0.1	-	-
Pogonarthria squarossa	Lefheto	-	-	11.7	7.5
Perotis pattens	Bottle-brush	-	-	24.8	15.9
Total for low-value species		69.3^c	10.8	58.9^c	37.8

Eragrostis trichopora	Hairy love grass	33	5.1	-	-
Eragrostis rigidior	Rathathe	130.7	20.3	65.8	42.2
Eragrostis lehmaniana	Rathathe	70.7	11	1	0.6
Total for medium value species		234.3[b]	36.3	66.8[c]	42.8
Digitaria milanjiana	Namele/Moseka	87.7	13.6	12.7	8.2
Panicum maximum	Mhaha/Mphaga	31.3	4.9	-	-
Urochloa trichopus	Phoka/Sugwagaga	171	26.5	7.3	4.7
Panicum coloratum	Buffalo grass	51	7.9	-	-
Cynodon dactylon	Motlho/Motlhwa	-	-	10.2	6.6
Total for high value species		341.0[a]	52.9	30.2[d]	19.4
Total means		644.7	100	155.9	100
Total Means Density/m^2		58.61		17.32	
Std. Deviation		53.86		19.6	
Std. Error		16.24		6.533	
P value		0.05*		0.03**	

a, b, c, d Means in the same row with different letters differ (P<0.05).
- Indicate the absence of a species
*P<0.05 and **P<0.01

Conclusion

Our findings indicate that dry matter biomass productivity was higher in fenced gradients as compared to the unfenced gradient. Dry matter biomass was low in areas close and furthest from watering points. Dry matter biomass in fenced was mainly composed of high value species especially *U. trichopus.* Meanwhile *E. rigidior* mid value species contributed the largest share to the biomass in the unfenced gradient.

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