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Research Article

Fodder Tree Species Composition and Density in Grazing Gradients of Fenced and Unfenced Grazing Areas of the Gaborone North, Botswana

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Abstract | The extent to which degradation or changes in fodder tree species composition caused by grazing pressure is critical since fodder trees form the base diet for browser such as goat as well as maintenance purposes for cattle in the dry season. Thus understanding the dynamics on rangeland response to grazing could prove worthy in finding an equilibrium point for optimizing animal productivity, with limited range degradation. Therefore, the current study was aimed at determining and comparing fodder tree species composition along grazing gradient in fenced and unfenced grazing area in the Gaborone North Region. For each study area, two parallel transects measuring 1000 m radiating from the water points (borehole) were established. Sampling plots of sizes 10m x 10m were systematically placed along each transect at intervals of 50m for the first 500m and the last 500m the spacing interval was increased by 100m. The botanical composition ($P<0.05$) of fodder trees along grazing gradients was composed of 20 and 12 species for fenced and unfenced areas, respectively. The grazing gradient in fenced area recorded the highest mean density ($P<0.05$) of tree species (1928 units ha^{-1}) as compared to the unfenced area (968.3 units/ha^{-1}). Individual tree species exhibited random patterns of distribution along grazing gradients in both grazing gradients. The composition for fodder trees was composed mainly of low value species of which most were encroaching species which have spread and established throughout the gradients.

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Introduction

Botswana has a comparative advantage in raising of livestock on pastures and rangelands since they reduce the cost of feeding. Over the years, livestock production coupled with variable annual rainfall, soil topography changes and human interference have resulted in fluctuating rangeland productivity. The degradation of high value grass and their replacement by unpalatable woody species can have a negative impact on socio-economic livelihoods of farmers (Kangalawe, 2009). Aganga and Omphile (2000) found that during drought year when rain is scarce and range plants are poor in nutritional status stock mortality rate raises from 18% to 22 % in communal areas. Bush encroachment is widespread in both communal grazing areas and private ranches across Botswana (Dougill et al., 2016), thus raising the question on the sustainability of the farming systems. Livestock raised in rangeland of Botswana source water from central watering points adjacent to a either a borehole, well or river. According to Struth (1991), the location of foci points (water points and kraals/housing) determines livestock distribution and movement hence the influence on the abundance and diversity of forage species within a grazing gradient. According to Lange (1969) the livestock distribution and frequent movement of animals between foraging and watering grounds creates a gradient of decreasing intensity of grazing from the water points to sites far from the water point. According to Adamoli et al. (1990) the vegetation composition changes along the gradient occur in perennial grasses which are eliminated or replaced by short lived grasses, shrubs and poisonous plants in zones close to water points. The extent to which degradation or changes on fodder tree species composition caused by grazing gradients is critical since fodder trees form the base diet for browser such as goat as well as maintenance diets for cattle in the dry season. Variation in grazing gradients will create a variation in the fodder tree species composition from one grazing area to the other. Understanding the dynamic on rangeland response to grazing could prove worthy in finding an equilibrium point for optimizing animal productivity with limited range degradation. Therefore this study was aimed to determine and to compare fodder tree species composition along grazing gradients in fenced and unfences grazing areas of Gaborone North, Botswana.

Methodology

Study Area

The study was carried out in 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 areas in Gaborone North, respectively. BUAN farm was used for raising beef cattle (180) only with a total of 5 paddocks in the ranch. Mmamolongwana, which is a communal area used for pastoral (sheep, goat, donkeys and horses) and arable farming activities. Both sites had a central borehole/water point dating to the 1970's. The Mmamolongwana borehole was operated by a syndicate of eight farmers, who kept in total density of 491 animals (*i.e.* 270 cattle, 138 goat, 63 sheep and approximately 14 donkeys and 6 horses). Due to the communal nature of Mmamolongwana, grazing right was 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 (Council, 2009). The summers were very hot while winters are 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 500mm in any year (Berguss, 2006). 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 (Aganga and Omphile, 2000).

Field Procedure

The study was conducted during 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 piosphere methodology described by Lange (1969). 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 quadrates. 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 x 1000m transects radiating from the water points (borehole) were used and sampling plots of size a total of 15 quadrates of size 20m^2 were systematically placed along each transect at intervals of 50m for the first 500m and the last 500m the spacing interval was increased by 100m. Modification in the method by spacing sample plots in the first 500 m around the borehole by 50m is due to the fact that it is assumed that more details and variation in the vegetation can be observe than the area further from the water point. Woody tree species rooted within the plots were recorded for frequency and counted for density.

Data Analysis

The frequency was calculated as the proportion (%) of the number of quadrats in which each woody species was recorded from the total number of quadrats in each of the sites. Relative frequency of a species was computed as the ratio of the frequency of the species to the sum total of the frequency of all species at each study site.

$$Frequency\ formula = \frac{Number of\ quadrates\ with\ a species}{Total\ number\ of\ quadrates} \times 100$$

Density of the woody species was calculated by converting the total number of individuals of each woody species in all the quadrats and equivalent number per hectare. Relative density was calculated as the percentage of the density of each species divided by the total stem number of all species ha^{-1}.

$$Density = \frac{Number\ of\ individuals\ of\ all\ species/(100m^2)}{Total\ number\ of\ individuals\ of\ all\ species/(100m^2)} \times 100$$

Species richness was determined from the total number of woody species recorded in each of the two study sites. Similarity in the woody species composition (species, families and encroaching species) among the sites was analyzed using Jaccard's Similarity Coefficient (Kebs, 1989).

$$Jaccard\ Index = \frac{Number\ in\ both\ sets}{Number\ in\ either\ set} \times 100$$

Statistical Analysis

All data analyses were carried out with the SAS (2008) software package. Diversity attributes, frequency, relative frequency, density and relative density we calculated using the respective formulas. One-way ANOVA was applied in separating the means of the diversity attributes. Differences among means were accepted as significant at $P < 0.05$.

Table 1: *Fodder (woody) species recorded in the two study sites with their family, local names, mean frequency (%) and Nutritional Value(FV) (Low, Medium, High). Species with subscript eare known encroachers.*

Botanical name	Family name	Local name	NV	Mean Frequency %	
				Fenced	Unfenced
Acacia erubiscence[e]	*Fabaceae*	Moloto	L	100	7
Dychrostyches ceneria[e]	*Fabaceae*	Moselesele	L	100	20
Euclea undulata[e]	*Ebenaceae*	Motlhakola	L	100	53
Acacia tortilis[e]	*Fabaceae*	Mosu	L	100	100
Mayeinussenegalensis[e]	*Celastraceae*	Mothono	L	33	60
Acacia melifera[e]	*Fabaceae*	Mongana	L	33	27
RF of poor species				**30**	**50**
Terminelia sericea	*Combretaceae*	Mogonono	M	40	67
Xemenia Americanum	*Olacaceae*	moretlologa	M	13	-
Carissa bispinosa	*Apocynaceae*	Serokolo	M	7	-
RF of medium species				**15**	**8**
Grewia flava[e]	*Tiliaceae*	Mogwana	H	100	-
Combretum apiculatum	*Combretaceae*	Mohudiri	H	67	-
Combretum imberbe	*Combretaceae*	Motswere	H	67	20
Grewia flavescenes	*Tiliaceae*	Mokgomphatha	H	47	80
Grewia bicolor	*Tiliaceae*	Moretlwa	H	40	-
Boscia foetida[e]	*Capparaceae*	Mopipi	H	47	53
Combretum hereroinse	*Combretaceae*	Mokabi	H	33	-
Ziziphus mucrunata	*Rhamnaceae*	Mokgalo	H	27	-
Rhus leptodictya	*Anacardiaceae*	Motshotlho	H	27	13
Rigozium brevispinosum	*Bignoniaceous*	Lebuta	H	13	-
Peltophorum africanum	*Fabaceae*	Mosetlha	H	7	-
Boscia ulbitranca[e]	*Capparaceae*	Motlopi	H	-	53
RF of high species				**55**	**42**
Species richness				20	12
Similarity index (species)				52	-
Similarity index (family)				46	-
Similarity encroachers				100	

Table 2: *Mean density (MD ha-1) and relative mean density (RMD %) of fodder tree on the two sites.*

Botanical name	MD (ha-1)		RMD (%)	
	Fenced	Un-fenced	Fenced	Un-fenced
Acacia erubiscence	423	2	22	2
Dychrostyches ceneria	122	13	6	1
Acacia melifera	50	28	3	3
Euclea undulata	476	87	25	9
Acacia tortilis	290	312	15	32
Mayeinus senegalensis	10	32	1	7
Total for Poor species	**1371**	**474**	**72**	**54**
Carissa bispinosa	10	-	1	-
Terminelia sericea	52	272	3	28
Xemenia Americanum	10	-	1	-
Total for medium species	**72**	**272**	**5**	**28**
Grewia leptodictya	23	-	1	-
Ziziphus mucrunata	15	-	1	-
Grewia flava	177	123	9	13
Grewia retinervis	15	-	1	-
Combretum apiculatum	132	-	7	-
Combretum hereroinse	28	-	2	-
Combretum imberbe	31	7	2	1
Boscia foetida	47	27	2	3
Boscia ulbitranca		32	-	3
Rigozium brevispinosum	7	-	0	-
Rhus leptodictya	10	-	1	-
Peltophorum africanum	2	3	0	0
Total for high species	**487**	**192**	**26**	**20**
Total Means	1930	937	100	100
Std. Deviation	524	244		
Std. Error	135	63		
95% CI of mean	1637-2218	833-1104		
P value	0.0001	0.0001		

Results

Diversity and Frequency of Woody Tree Species in Grazing Gradients

The botanical composition (P<0.05) of fodder trees along grazing gradients was composed of 20 and 12 species for fenced and unfenced areas, respectively (Table 1). Jaccard's Index indicated that the two study sites had 52%, 46% and 100% similarity for genera, family and encroacher diversity, respectively (Table 1). *A. erubiscence*, *D. ceneria, A. tortilis, E. undulata* and *G. flava* were frequent (P<0.05) throughout (100%) the grazing gradient in fenced area meanwhile *A. tortilis* was the only species recorded throughout the grazing gradient in unfenced area. High frequencies (%) were also reported for *G. flava* (80), *T. sericea* (67) and *M. senegalensis* (60) in the unfenced area. *P. africanum* (7%), *C. bispinosa* (7%), *R. brevispinosum* (13%), *X. Americanum* (13%) and *Mucrunata* (27%) demonstrated lower frequencies in the fenced area but were not recorded in the unfenced area (Table 1).

Density and Relative Density of Woody Tree Species in Grazing Gradients

The grazing gradient in fenced area recorded the highest mean density (P<0.05) of woody tree species (1930 units ha^{-1}) as compared to the unfence area (938 units/ ha^{-1}) (Table 2). The five densest species (units/ ha^{-1}) in the fenced grazing gradient were *E. undulata, A. erubiscence, A. tortilis, T. sericea* and *Grewia flava.* Meanwhile in the unfenced communal grazing area *A. tortilis, T. sericea, G flava* and *E. Undulata* recorded the highest densities. According to Table 2, poor species accounted for the largest share in density and relative density in the fence (1371 ha^{-1}, 72 %) and unfenced areas (474 ha^{-1}, 54 %). The unfenced (272ha^{-1}, 28 %) exhibited significantly (P<0.05) high density and relative density for medium feeding value species as compared to the fenced area (72ha^{-1}, 5 %). High nutritional value species were significantly (P<0.05) low in unfenced areas as compared to (192ha^{-1}, 20 %) as compared to the fenced area (487ha^{-1}, 26 %)

Total Plant Density Relative to Distances from Water Point

There was as significantly (P<0.05) high variation of plant densities across the 15 quadrate along the grazing gradient in both study sites. In the fenced area plant density was significantly (P<0.05) low at 50m (1425/units ha^{-1}) but higher at the 1000m (2450/ units ha^{-1}). In the unfenced area plant density was low at 50m (750/units ha^{-1}) to the watering point as well as at the 1000m (750/units ha^{-1}) nevertheless total plant density increased steadily at 300m (1025/units ha^{-1}) till 400m(1350/units ha^{-1}) to and gradually decline (P<0.05) (Figure 1).

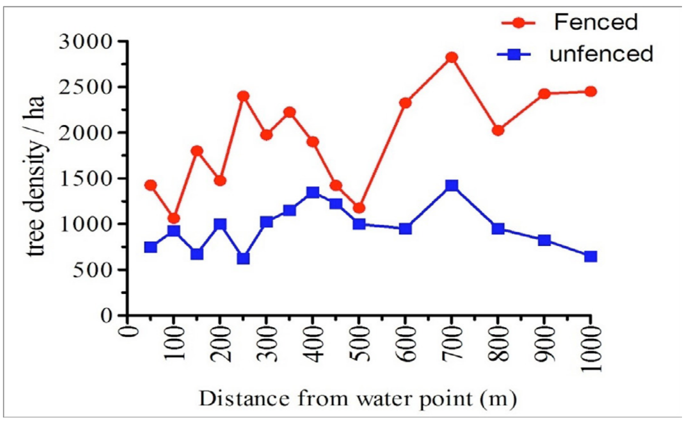

Figure 1: *Total fodder tree density relative to distance from water point in fenced and unfenced grazing gradient*

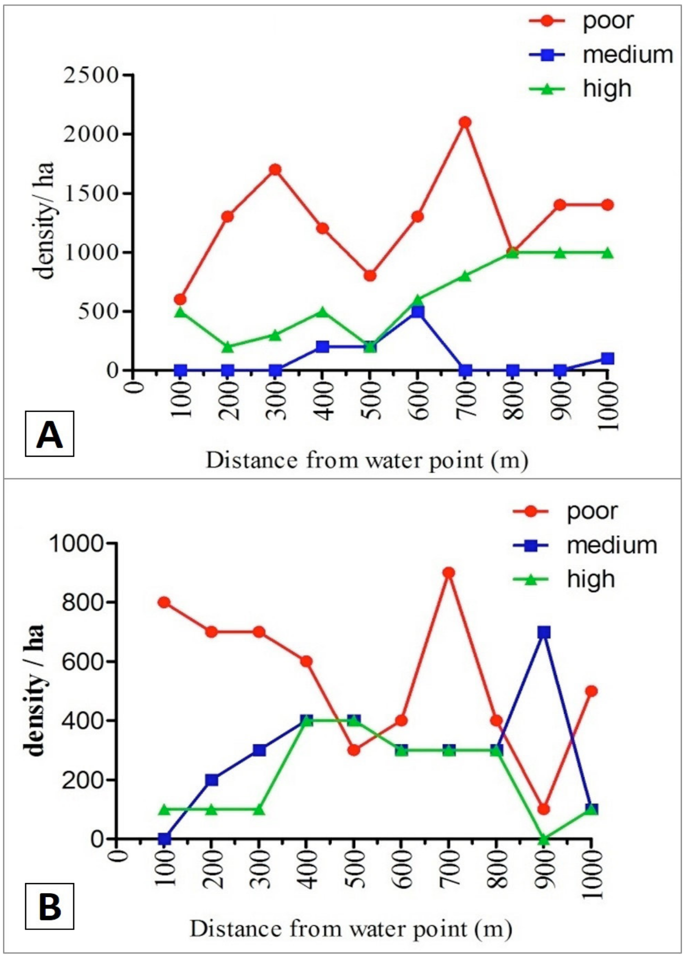

Figure 2: *Nutritional value of fodder trees relative to distance from water point in fenced (A) and unfenced (B) grazing gradient*

Interaction of Plant Nutritional Value Density to the Grazing Gradient

Species with low nutritional value were more dominant (P<0.05) at areas close to the water point (100m) and throughout the grazing gradients in both sites despite the fluctuating densities (Figure 2). In the fenced area the intermediate and high species increased steadily with the increase in distance from the water point and declined after 800m but a significant (P<0.05) drop in all plant densities was recorded at 500m. In the unfenced area medium and high species increased steadily with the increase in distance from the water point till 500m and then become constant. At 500m there was almost a balance in density for all the species. At 800m there was a significant drop in high and low species meanwhile the medium species significant increased (Figure 2).

Discussion

Diversity and Frequency of Woody Tree Species in Grazing Gradients

The current study (Table 1) exhibited contrasting results to those of Neelo et al. (2015) who found high composition numbers (46 species and 16 families) of different woody plant in woodlands adjacent to Molapo Farms in Northern Botswana. The similarities of woody species in terms of genera and families in the current study (Table 1) was in close consent to finding by 50% and 54%, respectively (Neelo et al., 2015). The results of the current study were close consistency with finding by Teketay et al. (2016) who reported 100% frequency for *Acacia erubiscence*, *Dychrostyches ceneria*, *Acacia tortilis*, *Euclea undulata* and *Grewia flava* in Mokolodi Nature Reserve, Southeastern Botswana. However, Teketay et al. (2016) demonstrated contrasting results to the current study reporting high frequencies were *P. africanum* (70), *C. bispinosa* (40), *X. Americanum* (13) and *Z. mucrunata* (70). The effects of continuous grazing in the unfenced grazing area were evident due to the significantly lower frequencies and counts of high nutritional value trees and the exceptionally high proportion of acacia spp. The high frequency of the *Acacia* species in both fenced and unfenced sites might suggest signs of bush encroachment due to overgrazing and over-exploitation of woody species as suggested by Neelo et al. (2015). According to Moleele et al., (2002), *D. ceneria*, *B. ulbitranca*, *B. foetida*, and *A. tortilis*, *A melifera* and *G. flava* are well-known encroacher species therefore a surge in their abundance maybe applied as an indicator for degradation. The lack of diversity and frequency of encroacher species in both sites suggest that both sites suffered bush encroachment regardless of land tenature. Previous findings by Dougill et al. (2016) reported that privately owned ranches did not archive any significant reduction the control of bush encroachment and cover as anticipated. As such raising questions on the credibility and practicability of current range management protocols employed when applying or bidding to acquire ranches. The ability of the low nutritional value encroach species to maintain higher frequencies throughout the grazing gradients in both sites (Figure 2) maybe associate with seed dispersal.

Density and Relative Density of Woody Tree Species in Grazing Gradients

The current study (Table 2) demonstrated dissimilarity to finding of Teketay et al. (2016), who reported a higher total density of 4,785 ha^{-1} in Mokolodi Nature Reserve, Southeastern Botswana despite the proximity and similarity in climate to the current study. The high densities of *A. tortilis*, *T. sericea*, *G flava* and *E.*

Undulata in both sites in the present study indicated that both the grazing land were encroached by these species thus consistent with previous studies in other parts of Botswana (Kgosikoma et al., 2012; Moleele and Perkins, 1998; Reed et al., 2015). The high total density in the fenced area (ranch) can be attributed to farming of cattle only, rotational grazing system. The practice allowed for the lesser use of certain species and defoliation of woody trees. Nonetheless, Reed et al. (2015) indicated that bush encroachment affected cattle production, but could support other livestock such goats, camel that are selective browsers capable of using the encroaching species. Rogosic et al. (2008) indicated that goats preferred to consume diets composed mainly of shrubs than sheep. Multiple land use involving high stocking densities of different livestock species, destruction of tree species for domestic purposes (fire wood, construction of livestock fencing and field fencing) and land clearing for arable crop farming was associated with the significantly low (968.3units/ ha^{-1}; Aganga et al., 2001) tree species density in the Mmamolongwana communal area (P<0.05) (Table 2). In addition, field observations made during sampling indicated that thorny species that include A. *erubiscence, D. ceneria, A. melifera, T. sericea* were adopted in livestock, arable land and homestead fencing. On the other hand, *T. sericea* and others were being used fencing. Neelo et al. (2013) and (2015) reported anthropogenic activities as clearing of land for crop production, heavy grazing pressure, cutting of stems and lopping of branches of woody species for fencing of farms as reasons for hampered regeneration of species. As such these activities temper with seed bank production. Field observation demonstrated that people in the Mmamolongwana communal area cut down live trees and use both the vegetative and stumps to harvest fire wood. In support of these results, White (1979) indicated that firewood collection is a time consuming activity in some areas as people have to travel up to 8-10km to gather firewood.

Plant Species Density in Relative to Distances from Water Point

The findings of the current study (Figure 1) demonstrated similarity to findings by Moleele and Perkins (1998), who reported that thorny palatable species were more frequent closer to foci points while non-thorny species that are easily browsed were more further away along grazing gradients were grazing pressure is lower. The high density of species *A.tortilis, A. erubiscence* and *M. senegalensis* at areas closer to the water point (100m) in both the study site can be attributed to the physical defense mechanisms which they possess. In support of this result, Skarpe (1992) reported that hooks, straight prickles and thorns on certain species (*A. tortilis, A. erubiscence, D. ceneria* and *M. senegalensis*) discourage browsing animals therefore the rate of consumption of poor species leaves, pods and seedlings may not be adequate to cause disturbances population resulting in large densities around the area foci areas. Orwa et al. (2009) found that *Acacia* species were capable developing into impenetrable cover 2-3 m high that can spreading hundreds of meters across a grazing area. The same phenomenon was observed onsite where *E. undulata, M. senegalensis* and *Acacia* spp. spread and developed into thick, impenetrable patches that was not accessible for utilization. Leaves of most poor species including *E. undulata* are rendered unpalatable, indigestible and unaccepted by cattle due to variable the anti-nutritional factors (tannins and saponins) (Owen-smith, 1993).

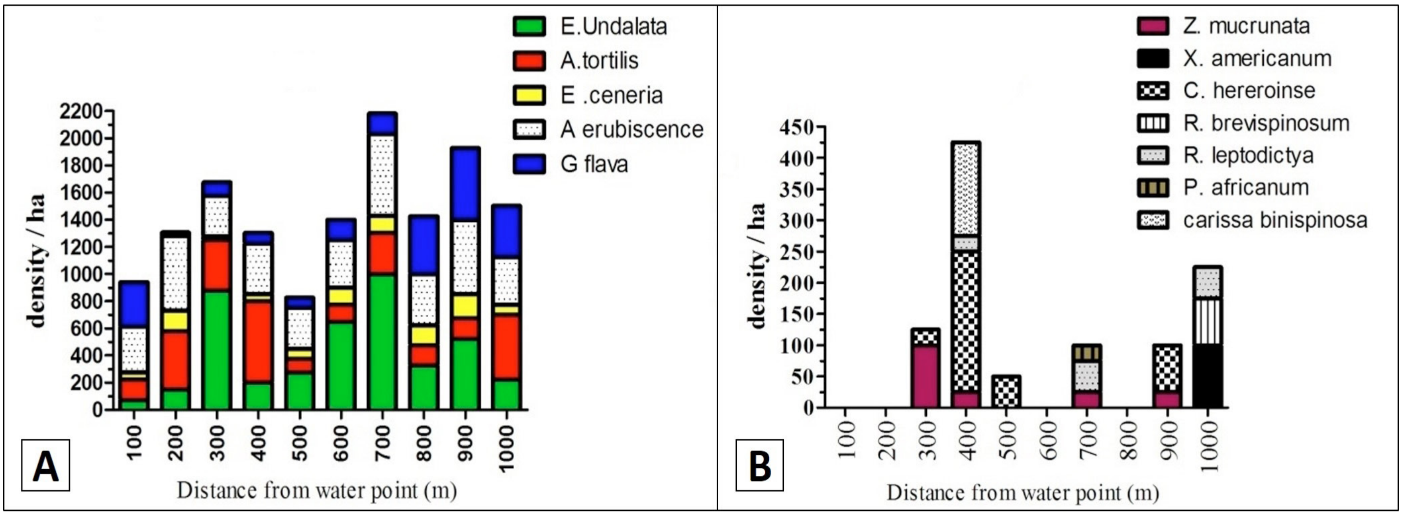

Figure 3: *Most (A) and least (B) dense fodder tree species relative to distance from water point in fenced grazing gradient*

Aganga et al. (2001) reported *E. undulata* to have high tannin levels up to (1.24 ppm/100ml) which makes the plant to possess a bitter taste and pungent smell that is unacceptable to most livestock. Therefore, the ability of the plant to thrive and maintain high seed level seed bank may have influenced it high density. Church and Goatcher (1970) indicated that *E. undulata* could be utilized by goats to a certain extent due to its accessible height and attractive evergreen colour. Rogosic et al. (2008) also reported that goats have a greater tolerance to secondary metabolites when compared to sheep. Therefore, for the absence of the species around the water point (100-200m) (Figure 4) as well as the low frequency (53%) (Table 1) in the unfenced area may be suggest its utility by goats as compared to the fenced area where it maintained high frequency (100%) and density due to lack of other animal species to use it. *G. flava* dominated the entire good species frequency and relative density in both study sites (Table 1 and 2). The results of the current study (Figure 3) shows that the species has the ability to establish in areas close to the water point as well as thrive along the grazing gradients alongside other encroacher species. According to Moleele and Perkins (1998), G. *flava* is among the mostly utilized species in dry season than any other species; hence, it is able to survive and establish well despite the high browsing intensity. van Vegten (1984) described *G. flava* as a broad leaved encroacher species and indicated that the species was reported to have an increasing density which was associated with anthropogenic activities especially high cattle densities in communal grazing areas unlike other good specie as such the high density of the species of the along grazing gradients in both sites may be associated cattle seed dispersal as described by Tews et al. (2004).

The absence of medium and high nutritional value trees *P. africanum*, *C. bispinosa, R. brevispinosa, X. Americanum* and *Z. Mucrunata* in areas close to the water point (100m) (Figure 3) as well low density in the fenced grazing gradient demonstrated that they were unable to survive high browsing pressure. The absence of the species in the unfenced area may point to the disappearance of their population due exploitation and over grazing. In support of these results, Negussie et al. (2008) found that excessive defoliation and trampling from animal could lead to high mortality of seedling and juveniles thus impacting regeneration, establishment and recovery of the species population. In the unfenced area gradient the high value species such as, *B. ulbitranca* has been able to survive in area around the water point (100-600m) meanwhile *B. foetida* was also able to survive at varying distances (Figure 4). The inaccessible height to cattle render the species unavailable, as large fraction of leaves on the plants are above reach of most ungulates including cattle hence able to establishing very well due to minimum disturbance. Furthermore field observation demonstrated that the species *B. foetida* and *B. ulbitranca* had limited use by the community since it's a taboo to use them as firewood. The fore it can be inferred that the Boscia species density and establishment is affected by the destruction of its juvenile as well as the death of mature trees by donkeys we tend to feed on the bark of the trees during dry season. According to Reed et al. (2008), *Boscia* spp. are capable of growing under high browsing pressure but at this will result in stunted grow and limited regeneration.

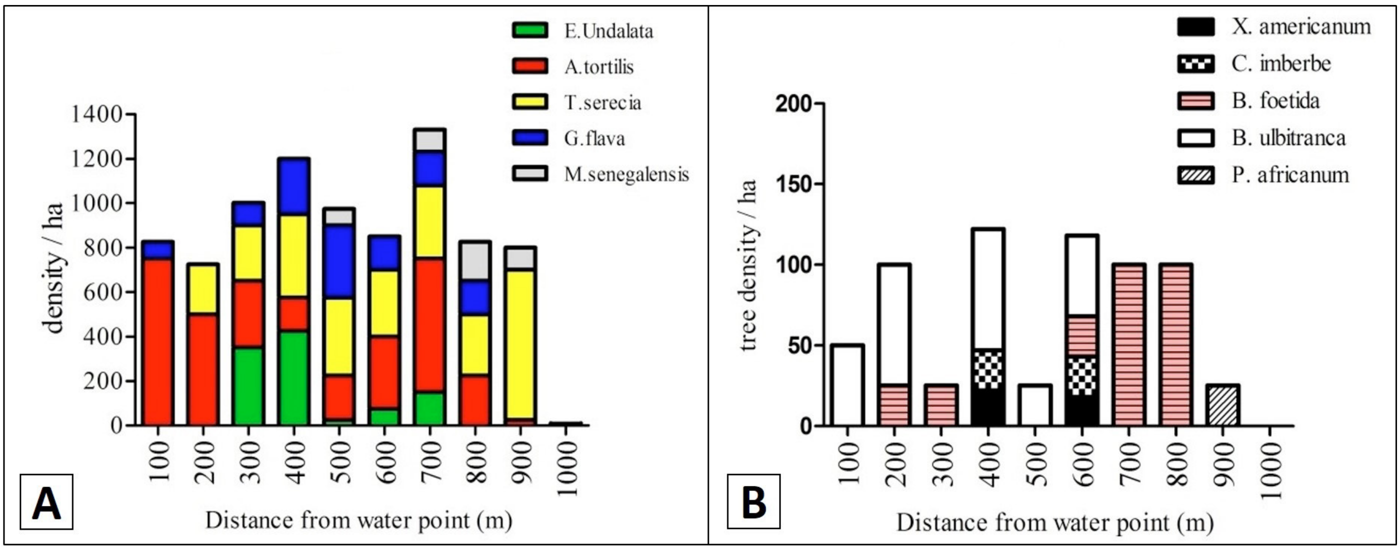

Figure 4: *Most (A) and least (B) dense fodder tree species relative distance from water point in unfenced grazing gradient*

Conclusion

The fenced grazing area had the largest botanical composition as compared to unfenced area. Individual tree species exhibited random patterns of distribution along grazing gradients in both grazing gradients. The composition for fodder trees was composed mainly of low value species of which most were encroaching species which have spread and established throughout the gradient. Controlling the density of the encroaching species before the seed may prove worthy in controlling their seed banks and populations. Reseeding of the high nutritional value species by introducing other lost species could help improve the animal productivity.

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Conflict of Interests

Authors have declared no conflict of interests.

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