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Role of traditional enclosures on the diversity of herbaceous vegetation in a semi-arid rangeland, southern Ethiopia

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Abstract

Grazing management and seasonality strongly influence the recovery potential of herbaceous vegetation in semi-arid rangelands of southern Ethiopia after history of heavy grazing. We investigated effects of management (enclosures versus grazed landscapes), age of enclosures and seasonality related to rainfall (i.e., independent variables) on herbaceous biomass, grass basal cover, herbaceous species abundance, species richness and diversity in a savanna rangeland of southern Ethiopia. We further assessed the relationship between the herbaceous biomass and species richness.

Management significantly affected most of the herbaceous response variables (i.e., comparing enclosures and open grazed). Herbaceous biomass, grass basal cover, herbaceous species richness and diversity were greater in enclosures than in grazed areas. Rainfall was also influential on herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity. Herbaceous biomass, abundance and diversity did not however vary with the age of enclosures, while herbaceous species richness appeared to decrease as the age of enclosures advanced. Grass basal cover initially decreased and later on increased with the age of enclosures, so that the older enclosures disclosed improvement of grass basal cover.

Keywords: Herbaceous layer, management, rainfall variability, savannas, Southern Ethiopia

Introduction

The use of traditional range enclosures locally known as *kalo* is widely practiced by pastoralists in East African rangelands (Behnke 1985, 1988; Coppock 1994; Hogg 1997; Oba et al 2001; Angassa and Oba 2010) for dry season grazing. Traditional range enclosures can be used as a method of rangeland restoration where the rangelands are often heavily grazed to allow the herbaceous vegetation diversity to recover (e.g., Aronson et al 1993; Asefa et al 2003; Mengistu et al 2005; Abebe et al 2006). Despite the expansion of range enclosures in the communal rangelands, only few studies have documented the role of range enclosures and seasonality on the conservation of herbaceous vegetation diversity (e.g., Oba et al 2001; Abebe et al 2006). Earlier studies (Oba et al 2001; Asefa et al 2003; Mengistu et al 2005; Abebe et al 2006) suggested that species diversity is higher in enclosures than continuously grazed areas. We investigated whether rangelands excluded from grazing over various time spans could help in the accumulation of herbaceous biomass and conservation of herbaceous plant biodiversity compared to continuously grazed rangelands. Furthermore, previous research (e.g., Cossins and Upton 1988) has shown that rainfall variability substantially influenced the seasonal availability of forage in the savanna ecosystems of southern Ethiopia. Others have demonstrated that seasonality in terms of rainfall variability could play an important role in affecting rangeland vegetation productivity (e.g., Le Houerou and Hoste 1977; Deshmukh 1984). Yet, little is known about the role of seasonality with respect to management and age of enclosures on herbaceous plant biodiversity in Borana rangelands of southern

Ethiopia.

A recent study in the northern parts of Ethiopia (e.g., Mengistu et al 2005) suggests that plant species diversity in the enclosures increased with an increase in the age of the area enclosures, while others (e.g., Hiernaux 1998; Lenzi-Grillini et al 1996; Rosenstock 1996; Eccard et al 2000) suggested that exclusion of an area from grazing would increase plant species diversity in the short-term, but the long-term benefits are reduced (Oba et al 2001; Asefa et al 2003).

In southern Ethiopia, the use of traditional range enclosures is widely used by local herders as part of the conservation of pasture for young animals near settlement rangelands that are often heavily grazed and where forage for livestock is more scarce during the dry season (Angassa and Oba 2008). In the region where range scientists often have not directly involved in land restoration, it might be worthwhile for local herders using their "traditional experiments" not only to serve as demonstrations in land rehabilitation but also use the "traditional management experiments" for ecological evaluations in terms of performance of rangeland production-inferred from biomass accumulation, changes in herbaceous plant species diversity and basal cover of grasses that would indicate the health conditions of individual plant species. Overall, heavy grazing pressure and seasonality could have accelerated the decline in herbaceous plant diversity in southern rangelands of Ethiopia.

However, the effects of management practices (i.e., grazing versus enclosures) on herbaceous plant biodiversity have rarely investigated as joint factors in terms of age of enclosures and seasonality. There is less information available on whether the traditional range enclosures compared to open rangelands reduced loss of grass species and improved ground cover.

In this study, we analyzed effects of management systems (enclosure versus grazed), age of enclosures and seasonality on the dynamics of herbaceous vegetation to understand the role of traditional range enclosures. We investigated herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity in six enclosures of varied ages and adjacent grazed rangelands in Dida-Hara in Borana, southern Ethiopia. The age of the traditional enclosures, relative to the grazed rangelands, varied between 12 and 30 years. The system presents a unique opportunity to observe long-term changes in herbaceous vegetation components with respect to grazing management and climatic conditions.

The objectives of the study were: (1) to assess the effect of management (enclosure versus grazed) and seasonality on herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity; (2) to investigate the effects of age of enclosures on herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity; (3) to predict trends of herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity in response to the age of enclosure. We assumed that the enclosure management would help in the accumulation of more herbaceous biomass and conservation of herbaceous species diversity than the grazed rangelands. We also expected that the responses might vary with seasonality, being lower when measured during the dry season.

Materials and methods

Study area and selection of the study sites

The study was conducted in the Yabello district in Dida-Hara area (04º 48.663'N and 038º 19.101'E) in semi-arid rangeland in southern Ethiopia. Rainfall is bimodal with the main rainy season expected between March and May, while the short rain occurs between October and November. The two intervening dry seasons are from June to August, and December to February when forage resources become scarce. Total annual rainfall in 2003 and 2004, i.e., during the time of the study was 445 and 427 mm, respectively (Southern Rangeland Development Unit Meteorological Section, unpublished data).

Changes in the pattern of traditional range management from seasonal to year-round grazing resulted in the scarcity of pasture in the settlement areas, particularly for dry season grazing by calves. In response to the shifts in patterns of land use, the community of individual settlements in Dida-Hara established range enclosures that were protected from livestock grazing during the rainy season. Generally, calves were allowed to graze the enclosures during the dry season between December and February before being shifted to the open grazed rangelands during the rainy season (Angassa and Oba 2010). Traditionally, Borana pastoralists used to burn the rangelands in order to control the expansion of bush encroachment (Oba 1998). However, since the early 1970s fire has been withdrawn from the rangelands of Ethiopia because of the official suppression of fire. Due to changes in land use patterns, the Dida-Hara community was settled in semi-permanent settlements locally referred to as *olla* in the early 1980s. The official banning of range burning in the southern rangelands of Ethiopia in the early 1970s (Coppock 1994) and increased grazing pressure in the settlement areas (Oba 1998) were followed by the consequent expansion of bush encroachment.

Six traditional range enclosures of varying ages (12 to 30 years) were selected for this study to measure herbaceous vegetation variables over three seasons. For each enclosure, the adjacent open grazed sites were selected as controls.

Data collection

The vegetation was sampled using systematic random sampling at a regular distance along a transect walk down a slope in enclosures and the adjacent grazed rangelands as controls. We located 30 plots of 1 x 1 m for herbaceous vegetation in individual enclosures and the adjacent grazed rangelands during two wet seasons (November 2003 and May 2004) and one dry season (February 2004) (n = 360 plots for measuring both herbaceous and woody species). The proportion of grass basal cover (%) was estimated visually based on the area covered by grass base compared to a bare ground in 1 x 1 m. Herbaceous species richness was determined as total number of species count per unit area (Oba et al 2001). Herbaceous biomass was hand-harvested from the entire quadrat and reported as dry-weight (gm^{-2}). Samples were oven dried at 65^0C for 48 hours for dry matter estimation at Awassa College of Agriculture, Hawassa University. Herbaceous diversity was assessed using the Shannon species diversity index (Shannon 1948). $H' = - [\sum (p_i ln p_i)]$ is determined by calculating the frequency of each plant species (p_i = proportion of individual species in each plot at which species i was recorded).

Statistical analysis

We used a general linear model to analyze the effects of management (a categorical variable with two levels: enclosure and grazed) and season (a categorical variable with three levels: wet season 2003, wet season 2004 and dry season 2004) on herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity. Because the response of vegetation dynamics to disturbance (here grazing) may vary with the age of the range enclosure, we included age (a continuous variable) in all our models. In order to adequately control for the effect of age, we first assessed whether its influence was linear or not by testing simultaneously the effect of age and its quadratic term on all the response variables. This was done by comparing a linear model of age with a quadratic (polynomial regression of order two) using the Akaike Information Criterion (AIC; Burnham and Anderson 1998), the model with the lower AIC being the most parsimonious. The model including the quadratic term appeared most parsimonious only for the effect of age on basal cover. Indeed, the relationship between age and basal cover was best described by a quadratic function (linear: AIC=2256.8; quadratic: AIC=2249.5), despite the marginal difference in AIC. Accordingly, only the main effect of age was included in the model for the other response variables. We tested the association between the spatial and temporal responses of herbaceous species variables using Pearson correlation. Least square means of individual response for each season by management were further estimated from the models. All the analyses were performed in SAS (SAS 2001), with a 95% significance level.

Results and discussion

Effects of management and season

Management significantly influenced herbaceous biomass ($F = 145$, $P < 0.001$), grass basal cover ($F = 140$, $P < 0.001$), herbaceous species richness ($F = 17.6$, $P < 0.001$) and diversity ($F = 13.2$, $P < 0.001$), but not species abundance ($F = 0.00$, $P = 0.982$). For all seasons pooled, there was more herbaceous biomass and more grass basal cover (difference ± SE: 97.1 ± 12.0 g m^{-2}; 4.12 ± 0.98%, respectively; Figure 1, a and b) in enclosures than in the grazed areas.

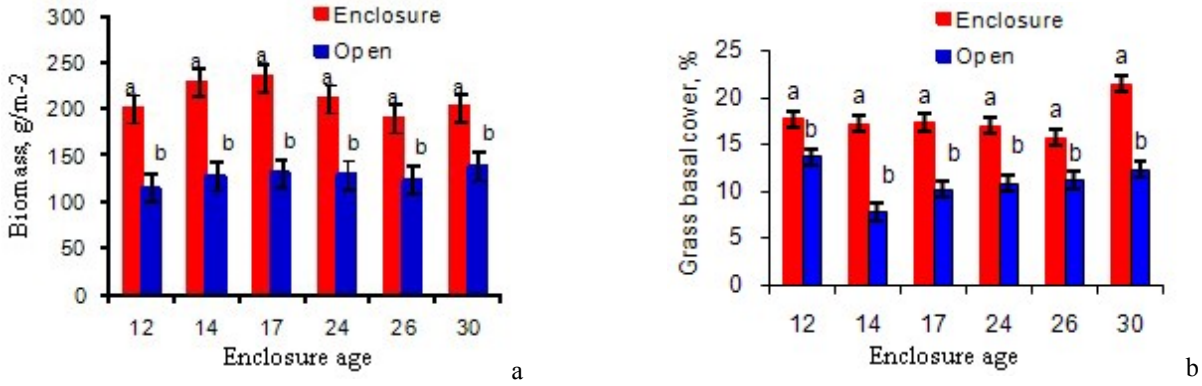

Figure 1. Mean (±SE) comparisons of enclosures and open grazed sites in terms of (a) herbaceous biomass, (b) grass basal cov wet seasons and one dry season between 2003-2004 in Dida Hara, Boran Southern Ethiopia. Different l

Particularly in the younger enclosures, herbaceous biomass was more than twice as high compared to areas outside of enclosures (Figure 1a). There was a strong seasonal variation in the response of all herbaceous variables, irrespective of management (Table 1).

Table 1. Responses of herbaceous biomass, grass basal cover, abundance of herbaceous species, herbaceous species richness and diversity to seasonality by management in Borana, southern Ethiopia. We used paired t-tests to test for significant differences (n = 60 plots each in enclosures and adjacent grazed plots per season).

Variable	Season	Management		Tests
		Enclosure	Grazed	
Biomass	Short rain (2003)	209±9.2	76.0±9.2	***
	Dry season (2004)	173±8.1	75.4±8.1	***
	Main rain (2004)	252±8.0	233±8.0	NS
Grass basal cover	Short rain (2003)	20.0±0.9	12.0±0.9	***
	Dry season (2004)	15.0±0.6	10.4±0.6	***
	Main rain (2004)	19.0±0.6	11.0±0.6	***
Abundance	Short rain (2003)	56.1±2.7	57.0±2.7	NS
	Dry season (2004)	38.2±1.8	41.0±1.8	NS
	Main rain (2004)	39.4±1.5	36.0±1.5	NS
Richness	Short rain (2003)	5.0±0.2	4.2±0.2	**
	Dry season (2004)	4.9±0.2	4.5±0.2	NS
	Main rain (2004)	5.3±0.2	4.7±0.2	*
Diversity	Short rain (2003)	2.4±0.1	2.2±0.1	NS
	Dry season (2004)	1.8±0.1	1.8±0.1	NS
	Main rain (2004)	2.2±0.1	1.7±0.1	***

** $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS $P > 0.05$*

However, the effect of management varied between seasons (Table 1) and sites (Figures 1a,b and c). Indeed, there was significant interaction between season and management for herbaceous biomass (F =

23.8 $P = < 0.001$), grass basal cover (F = 5.32, $P = < 0.005$) and diversity (F = 3.35, $P = 0.0395$), but not for species richness (F = 0.40, $P = 0.668$) and abundance (F = 1.23, $P = 0.295$; Table 1). For example, herbaceous biomass was significantly higher in enclosures than in grazed areas both in the short rainy season and dry season, but not in the main rainy season, while grass basal cover was higher in enclosures than in grazed areas during all the three seasons (Table 1) and the abundance of herbaceous vegetation did not vary among seasons or management. Differences in terms of herbaceous species richness by management were reflected by three out of six enclosures (Figure 1c), but overall the difference between herbaceous species richness in enclosures versus grazed areas was not significant. The enclosure management had slightly higher herbaceous species richness (26 species) than the grazed rangelands (24 species; Table 2).

Table 2. Percent composition of herbaceous species assessed in area enclosure and grazed rangelands in Borana, southern Ethiopia

Species	Local name	Response to grazing	% Composition	
			Enclosure	Grazed
Aristida adoensis Hochst.	Biilaa	Decrease	1.8	0.8
Bothriochloa radicans A.Camus	Bokkoolaa	Decrease	0.9	0.5
Brachiaria lachnantha (Hochst.) Stapf.	Unidentified	Decrease	0.1	
Chloris roxburghiana Schult.	Billaa	Decrease	4.1	3.8
Chrysopogon aucheri (Boiss.) Stapf.	Alaloo	Decrease	28.1	18.7
Cenchrus ciliaris L.	Matguddeessa	Increase	3.0	3.3
Cyprus species Vahl.	Buridde	Stable	0.1	0.1
Dactyloctenium aegyptium (L.) Pers.	Unidentified	Decrease	0.1	
Digitaria milanjiana (Rendle) Stapf.	Unidentified	Increase	0.2	0.3
Echinochloa haploclada (Stapf.) Stapf.	Unidentified	Stable	0.1	0.1
Eleusine jaegeri Pilger	Coqqorsa	Increase	1.1	1.6
Eragrostis papposa (Roem. & Schult.) Stued.	Samphee/samphile	Increase	1.2	2.4
Eragrostis senni Chiov.	Unidentified	Decrease	0.2	0.1
Enteropogon somalensis Chiov.	Unidentified	Stable	0.1	0.1
Harpachne schimperi Hochst. ex. A. Rich.	Biilaa seerricha	Decrease	0.2	0.1
Heteropogon contortus (l.) Beauv. ex. R. & Sch.	Seerricha	Decrease	4.6	1.4
Herbaceous legumes	Hagaggaroo-ree'ee	Increase	7.8	13.3
Hyparrhenia hirta (L.) Stapf.	Gaaguroo	Increase	0.1	0.5
Lintonia nutans Stapf.	Ardaa	Increase	1.2	3.5
Leptothrium senegalensis (Kunth) Clayton	Ilmogorii	Increase	4.4	14.7
Panicum coloratum L.	Hiddoo qaqallaa	Increase	7.7	16.7
Panicum maximum jacq.	Lolloqaa	Stable	0.1	0.1
Panicum turgidum Forsk.	Hiddoo-dabbasicha	Decrease	2.5	1.0
Pennisetum stramineum Peter	Lu'oo	Stable	0.1	0.1
Sporobolus pyramidalis Beauv.	Bukkicha	Decrease	25.1	15.8
Themeda triandra Forsk.	Marra-saalaa	Decrease	5.3	1.1

Among the herbaceous species, *Chrysopogon aucheri* (Boiss.) Stapf. and *Sporobolus pyramidalis* Beauv. had greater frequencies both in the enclosures and grazed rangelands (Table 2). Generally, *Chrysopogon aucheri* (Boiss.) Stapf, *Heteropogon contortus* (L.) Beauv. ex. Roem. & Schult., *Panicum turgidum* Forsk., *Sporobolus pyramidalis* Beauv. and *Themeda triandra* Forsk. showed a declining pattern with heavy grazing, while others such as *Eragrostis papposa (*Roem. & Schult) Stued., *Leptothrium senegalensis* (Kunth) Clayton and *Panicum coloratum* L. was higher in the grazed rangelands (Table 2). However, the majority of the herbaceous species were stable regardless of management factors.

The results of our finding showed significant variations in terms of herbaceous plant biodiversity between enclosures and open grazed areas. The variations may be explained in terms of decreased grazing pressure in the enclosures that had contributed to the recovery of herbaceous species diversity. We

observed more accumulation of herbaceous biomass and increased grass basal cover in the enclosures as a result of protection from grazing during the growth season, while in the open areas, continuous grazing contributed to their reduction. Previous studies in the western part of Ethiopia confirmed that biomass in the enclosures was accumulated more than in the open grazed plots (Tadesse et al 2002). The patterns of herbaceous biomass and species richness between the enclosures and open grazed areas in the current study were comparable to the findings from northern Kenya (Oba et al 2001) and in the Queen Elizabeth National Park in Uganda (Lenzi-Grillini et al 1996). Similar findings have also been reported in the Kondoa region in Tanzania (e.g., Mwalyosi 2000) and central and northern Ethiopia (Asefa et al 2003; Mengistu et al 2005), showing that the relative increase in herbaceous biomass in enclosures reflected the effects of resting during the previous growth season. Hayashi (1996) in Kitui in Kenya also reported that exclusion of livestock grazing for a period of 5 years promoted herbaceous biomass production as compared to the open grazed areas.

In the Sahel, Hiernaux (1998) reported that protection from grazing increased herbaceous species richness only in the short-term. Similarly, other studies (e.g., Asefa et al 2003; Mengistu et al 2005) reported greater plant species richness in enclosures than in the open grazed areas. Rosenstock (1996) however reported the opposite, suggesting that biomass was not affected by resting from grazing. Our results show that grazing reduced the occurrence of certain species of grasses such as *Chrysopogon aucheri* (Boiss.) Stapf, *Heteropogon contortus* (L.) Beauv. ex. R. & Sch., *Panicum turgidum* Forsk., *Sporobolus pyramidalis* Beauv. and *Themeda triandra* Forsk., while other species, e.g., *Eragrostis papposa (*Roem. & Schult.) Stued., *Leptothrium senegalensis* (Kunth) Clayton and *Panicum coloratum* L. increased in the presence of grazing (see Table 2). The former species could be grazing intolerant and the latter might be tolerant to the effect of grazing. The results of our finding suggested that some species of plants are highly susceptible to the effect of disturbance, while others could not survive without the presence of disturbance such as grazing.

We found that seasonal variation considerably influenced herbaceous species productivity and diversity, suggesting that inter-annual rainfall variability is an important factor in regulating the availability of forage in dry savanna ecosystems. Similarly, O'Connor (1994), Fynn and O'Connor (2000) showed that variation in seasonal rainfall greatly influenced herbaceous biomass. We found that herbaceous biomass was considerably increased during the main rainy season compared to the dry and short rainy seasons (see Table 1). The impacts were more pronounced during the long rains than the short rainy season. Indeed, during the long rainy season, we found no significant differences between the enclosures and open grazed areas. The differences during short rains and dry season implied that the reduced biomass in the open grazed areas reflected the removal through livestock.

Differences in terms of herbaceous vegetation in response to seasonality therefore reflected the effect of rainfall variability on primary productivity and the conservation of herbaceous species rather than reflecting the effect of management alone. O'Connor (1994) reported a similar pattern in Southern Africa, suggesting that the changes in plant productivity could be attributed to rainfall variability rather than grazing. The inference we draw was that grazing pressure is not a single factor regulating herbaceous plant productivity. Indeed, interactions between management and seasonality greatly influenced herbaceous biomass, grass basal cover and herbaceous species diversity (O'Connor and Roux 1995). The impact of rainfall on herbaceous vegetation disclosed seasonal patterns by management (enclosure vs. grazed). The lack of response to the interactions between management and seasonality in terms of the abundance of herbaceous species and herbaceous species richness implied that the effects were probably mediated through rainfall.

Effects of age

There was no clear evidence that the response of herbaceous variables to management changed with age of the enclosure. Indeed, the effect of age was significant only for grass basal cover ($F = 15.3$, $P < 0.001$) and herbaceous species richness ($F = 6.30$, $P = 0.013$). Surprisingly, herbaceous species richness decreased with increasing age of enclosure (Estimate ± SE –0.029 ± 0.011). Similarly, the relationship between grass basal cover and age was quadratic, decreasing first and increasing afterward (age: -1.509 ±

0.401; age^2: 0.038 ± 0.010). The age of enclosures showed no significant effects on herbaceous biomass (F = 0.20, *P* = 0.657), abundance of herbaceous species (F = 3.43, *P* = 0.065) and herbaceous species diversity (F = 9.11, *P* = 0.166). However, when we separated individual age effects, the medium age of enclosure accumulated more herbaceous biomass (177±8.8 g m^{-2}) than the younger (164±8.8 g m^{-2}) and older (168±8.8 gm m^{-2}) enclosures. Grass basal cover increased in the older age of enclosure (15.2±0.6%) than the medium (13.8±0.6%) and younger (14.1±0.6%) enclosures. Herbaceous species richness was higher in the medium age (4.9±0.0.1 species m^{-2}), than the younger (4.8±0.1 species m^{-2}) and older (4.6±0.1 species m^{-2}) enclosures.

Our results suggest that age of enclosure did not influence herbaceous biomass, abundance of herbaceous species and diversity probably due to alternation between seasonal grazing and resting regardless of the age of establishments of enclosures in comparison with the continuously grazed rangelands. Furthermore, herbaceous vegetation was more strongly influenced by seasonality than by enclosure age. Similarly in the highlands of Bolivia, Buttolph and Coppock (2004) found no effects of age of enclosures on above-ground biomass. Our findings confirmed that herbaceous species richness peaked at the medium age, which was similar to the earlier investigations (Oba et al 2001; Asefa et al 2003). The result was somewhat unexpected and suggests that the age effect was negative for most of the herbaceous vegetation variables. As opposed to our expectation the older enclosures accumulated less herbaceous biomass, herbaceous species richness and diversity as compared to the younger and medium enclosures. Similarly in the Sahel, Hiernaux (1998) reported greater plant species richness in the 3-year old than in the 14-year old enclosures. The probable explanation for the decline in herbaceous plant biodiversity with increasing age of enclosure could be attributed to the increased composition by few species. Our results are consistent with the findings of Franklin et al (1987) who suggested a gradual decline in the number of individual plants as a result of age-dependent physiological processes (i.e., self-thinning mortality).

Relationships between herbaceous variables

Herbaceous biomass showed a significantly positive correlation with grass basal cover and herbaceous species richness (Table 3).

Table 3. Correlation between herbaceous vegetation variables in Borana, southern Ethiopia.

	Biomass	Grass basal cover	Herbaceous Abundance	Herbaceous cover	Herbaceous richness
Biomass					
Grass basal cover	0.83***				
Herbaceous Abundance	-0.12*	0.40***			
Herbaceous cover	-0.02^{NS}	0.06^{NS}	-0.01^{NS}		
Herbaceous richness	0.57***	0.45***	0.11*	-0.03^{NS}	

** P < 0.05, ** P < 0.01, *** P < 0.001, NS P > 0.05*

Generally, herbaceous biomass showed a negative and very weak correlation with the abundance of herbaceous species and no significant correlation with herbaceous cover (Table 3). Grass basal cover showed a significantly positive correlation with the abundance of herbaceous species and herbaceous species richness, but no significant correlation with the herbaceous cover (Table 3). Herbaceous abundance was positively correlated with herbaceous species richness (Table 3).

The results of our findings showed a strong relationship between herbaceous biomass and grass basal cover, suggesting that the level of herbaceous productivity might be influenced by the condition of grass basal cover. From the relationships between herbaceous biomass and herbaceous species richness, it seems possible that the type and number of herbaceous species present in the community would probably be important in determining forage availability. The current study found that increased abundance of herbaceous species might not lead to increasing ground cover. The results of the study suggest that shifts

in herbaceous species richness would probably influence the condition of grass basal cover implying that some species are probably more tufted than others in providing protection for the ground.

Conclusion

- We expected more biomass accumulation and herbaceous species diversity with increased age of enclosures, but this was never confirmed. Herbaceous biomass and grass basal cover were significantly greater in the zones protected from grazing than in the used grazed areas.
- The enclosure management had higher herbaceous species richness than the grazed rangelands. *Chrysopogon aucheri* (Boiss.) Stapf. and *Sporobolus pyramidalis* Beauv. were the most frequent species both in the enclosures and grazed rangelands.
- Overall, the enclosure management promoted the recovery of few herbaceous species, while some others were more frequent in the grazed areas, with the majority maintaining a stable condition despite of the different management systems. However, the older enclosures had no superior benefits over the younger in terms of herbaceous production, herbaceous species richness and diversity probably due to the exclusion of fire as a diversifying factor from savannas of southern Ethiopia for decades.
- From the current finding, it can be concluded that management alone and seasonality were more influential in controlling the productivity and diversity of herbaceous plants than the interaction thereof.

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Go to top