Impacts of Grazing on Herbaceous Plant Species Diversity and Biomass Production in Borana Rangeland, Southern Ethiopia

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ABSTRACT

The study was carried out in three districts of Borana Zone, Oromia regional state, to determine the impacts of grazing on vegetation structure and herbaceous biomass yield of Borana rangelands under traditional enclosure and continuous grazing rangeland types at the end of the main rain season. Within both rangeland types of each district, three plots of 20 m x 20 m were placed at 200 m intervals, with a transect used to collect data on the herbaceous plant community by randomly throwing seventeen quadrats (1 m x 1 m) in the main plot. The vegetation diversity, richness, and density evenness were analyzed by General Linear Model (GLM) procures, and LSD was used for mean comparison. The herbaceous ground cover was a significant difference ($P < 0.05$) between rangeland use types. Additionally, a significant difference was seen ($P<0.05$) in the richness, evenness, and diversity of herbaceous species in connection with the various research locations and rangeland use types. The higher relative frequency of perennial grass and palatable species was recorded in the enclosure range land use types. Additionally, a significant difference was seen (0.05) in the richness, evenness, variety, and density of herbaceous species in connection with the various research locations and rangeland use types. On average, continuous grazing rangeland use types had the least amount of very desired herbaceous species (16.22 %), while the Arero and Yabello enclosures had the highest percentage (56.52 %). The results indicate that overgrazing is the main factor in the decline of the diversity and biomass yield of herbaceous plant species in both grazing use types of study sites, while traditional enclosure is better than continuous grazing rangeland use types.

Keywords: Continuous grazing, traditional enclosure, herbaceous species, and biomass

INTRODUCTION

Borana rangeland ecosystems are the main part of renewable natural resources, which have an important role in providing livestock feed resources and other ecosystem services, while it has been gradually declining and weakening in the pastoral resource base [10]. Grazing intensities are the main factors to alter rangeland resource productivity in both biological and physical resources of rangeland. Because grazing is one factor that governs the nature and productivity of rangeland ecosystems [8], Dadamouny, 2015. In arid and semi-arid parts of the country, improper grazing and climatic factors are the main issues to degraded rangeland resources [1].

Rangelands in Borana were extensively degraded because of overgrazing, which led to an increase in biomass of less desirable species (like infestation of bush and weed species) but a decrease in palatable and productive grasses [7]. Manipulating arid and semi-arid areas for natural resource conservation and sustainable usage requires an understanding of vegetation response to grazing intensities [9]. Since overgrazing is one of the most prominent harmful elements in arid and semi-arid rangelands. Additionally, [16] confirmed that overgrazing has negative effects on rangelands through the increase of unpalatable species and the loss of ground cover and biomass of palatable species. According to [12], uncontrolled grazing of livestock reduced the vegetation cover and changed species composition. In consequence, removals of ground cover alter the physical and chemical properties of soil, which reduces the soil nutrients and their cycle [14].

However, the impacts of grazing systems are less considered during rangeland administration and utilization. Pastoralists who rely heavily on Borana rangelands have been exposed to a significant livestock feed deficit because of the increasing replacement of desirable/palatable herbaceous species with undesirable ones, notwithstanding efforts made so far by various organizations to improve rangeland.

The comprehensive studies are necessary to investigate the response of vegetation to grazing, particularly in arid and semi-arid regions with delicate and vulnerable ecosystems. As a result, increased research and comprehension of the effects of grazing on plant species are the most crucial instruments for approving acceptable management practices in rangeland areas. Therefore, this study was designed to generate valuable information with the general objective of evaluating the current vegetation structure and herbaceous biomass of rangeland related to traditional enclosure and continuously grazing rangelands to develop effective management strategies in Borana rangelands, southern Ethiopia.

Specific objectives

To assess the effect of grazing on vegetation structure and herbaceous biomass of the rangelands in selected districts.

To assess the effect of grazing on herbaceous species diversity and biomass of the rangelands in selected districts.

MATERIAL AND METHODS

Description of Study Areas

The study was conducted in Yabello, Arero, and Teltele districts of the Borana zone, Southern Ethiopia. Yabello is located at 563 km southern part of Ethiopia. Arero and Teltele are located at an equidistant (100 km) east and west of Yabello town, respectively. It is demonstrating the bimodal nature of rainfall that accounting for 60 % of the long rain season (March to May) and 27 % of the short rain season (September to November).

Sampling Techniques and Data Collection

A systematic stratified sampling method was used to collect vegetation data after stratifying the rangeland use types into traditional enclosure and continuous grazing. The first sample plot was established by measuring 50 m from the border of edge effects, and three main plots, each measuring 20 m x 20 m, were established at 200 m intervals on a linear transect. In this, each main plot, located 17 sub-quadrants of 1 m x 1 m to collect herbaceous vegetation of traditional enclosure and continuous grazing rangeland use types (n=306 sub-quadrants) to determine herbaceous species biomass, diversity, richness, desirability, and ground cover.

Species Composition and Diversity

The plant species composition of the study sites was determined based on the frequency of occurrence in the plots. The plant species collected from each quadrat were primarily identified in the field based on field identification keys and the flora of Ethiopia books (Edwards et al., 2000). Herbaceous species were classified into desirability (highly desirable, intermediate, and less desirable), life form (Perennial and annual form), and component/growth form (grass and non-grass).

Shannon diversity (H) and Shannon evenness (E) indices were used for checking alpha diversity (Ali et al. 2022). Herbaceous species richness refers to the number of species in a particular area; herbaceous species diversity refers to a combination of richness and relative abundance.

The formula for calculating the Shannon diversity index is:

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where: H = Diversity of species in the same sub-habitat, with higher values indicating increased diversity, P_i = Proportion of individuals found in the i^{th} species, ln = Natural logarithm, and S = Total number of species in the sub-habitat, species richness

The Shannon evenness (E) was calculated by

$$E = \frac{\sum_{i=1}^{s} p_i \ln p_i}{\ln s}$$

Where: E =Shannon evenness and ln S = Maximum possible diversity

$$\textbf{Relative frequency} = \frac{\text{Frequancy of a species}}{\text{Frequancy of all species}} \mathbf{*100}$$

Dry matter yield of herbages was determined through clipping herbaceous plants at 2 cm above ground from subplots of the main plots and divided into grass and non-grass components, and transported to Yabello pastoral and dryland agriculture research center and oven dried at 105 ^{o}c for 24 hours (Whelly and Hardy, 2000).

Data Analysis Procedures

Plant diversity of the rangeland use types was analyzed using PAST version 3.10, Paleontological Statistical software (Hammer et. al, 2001). The variance of species diversity, richness, evenness, and above-ground biomass yield of herbaceous plants was statistically analyzed using the general linear model (GLM) procedure of the statistical analysis system of SAS version 9.1 (SAS Institute, 2002).

The model of ANOVA was $Yij = \mu + D_i + L_j + DL_{ij} + e_{ij}$

Where Yij = the whole observation, μ = the overall mean, Di = District effect, L_j = Rangeland use effect, DL_{ij} = Interaction of district and rangeland use effect, and e_{ij} = error effect.

RESULTS AND DISCUSSIONS

Relative frequency of Herbaceous plant species

Of the total herbaceous plant species identified, 24 species were perennial and 17 species were annual herbaceous species. Comparing the herbaceous composition of the two rangeland use types of three sites, high numbers of perennial herbaceous species were found in the traditional enclosure than in continuous grazing rangeland use, and the converse is true for annual grass species. Similarly, Saud (2010) reported that overgrazing had a positive effect on the total number and richness of weedy species, while it hurt palatable perennial herbaceous plant species.

The relative frequency and density of herbaceous species are presented in Table 1 to analyze the impacts of grazing on rangeland herbaceous species. Palatable species like Chrysopogon aucheri (32.19%), Digitaria naghellensis (15.00%), and Cyperus species (13.44%) were grass species, and Commelina Africana (17.50%), Chlorophytum gallabatense (8.44%), and Albuca abyssinica (7.81%) were forb species, which had high relative density as compared to other herbaceous species in the traditional enclosure of Arero sites. In relative frequency, Chrysopogon aucheri was a grass species and Commelina Africana was a forb species had the highest percentage as compared to other herbaceous species in the traditional enclosure rangeland use of Arero sites. In continuous grazing rangeland use of Arero, Cyperus spp (13.48%), Chrysopogon aucheri (6.18%), Digitaria milanjiana

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(4.49%), Commelina Africana (26.97%), Chlorophytum gallabatense (24.72%), and Volkensinia prostrata herbaceous species had the higher relative density. Commelina Africana and Indigofera spinosa were the forb species, which had a higher relative frequency of species as compared to other herbaceous continuous grazing of the Arero site.

Dyschoriste hildebrandtii, Volkensinia prostrata, Oxygonum sinuatum, and Amaranthus thunbergii were forbs, which had high relative density with the percentage of 22.77%, 14.85%, 13.74%, and 12.13% in the Teltele site of traditional enclosure rangeland use, respectively. Digitaria velutina (7.18%) and Pennisetum mezianum (6.81%) are grass species that had a high relative density in the traditional enclosure rangeland use type at the Teltele site. Digitaria velutina (28.69%), Aristida kenyensis (9.47%), Leptothrium senegalense (6.31%), and Aristida species (6.31%) are grass species, and Volkensinia prostrata (11.76%) and Dyschoriste hildebrandtii (11.33%) are forb species in continuous grazing rangeland use types of the sites.

Herbaceous species with high relative density observed in the traditional enclosure rangeland use of Yabello site that includes Oxygonum sinuatum, Dactyloctenium aegyptium, Cyperus species, Sporobolus pellucidus, and Aristida kenyensis were grass species. Dactyloctenium aegyptium was a forb species, while Digitaria velutina, Sporobolus pellucidus, Cyathula orthacantha, and Indigofera spinosa were herbaceous species that had a high relative density in continuous grazing rangeland use types of the Yabello site.

Therefore, the results indicated that grazing had an impact on the relative density and frequency of palatable species of rangeland. Because traditional enclosure rangeland use types of the study sites had higher relative density and frequency of palatable perennial grass than continuous grazing rangeland use types.

Table 1: The total frequency sum of herbaceous recorded in three districts of two rangeland use types of study sites (n=306)

Scientific Name	**Family**	**Growth form**	**Life Form**	**Desir ability**	**Yabello**		**Teltele**		**Arero**	
					Enc	Cont. Gra.	Enc	Cont. Gra.	Enc	Cont .Gra.
Albuca abyssinica	Hyacinthaceae	F	A	I	0.0	0.0	0.0	0.0	7.8	0.0
Amaranthus thunbergii	Amaranthaceae	F	A	I	0.0	1.9	12.5	4.3	0.0	0.0
Aristida kenyensis	Poaceae	G	A	I	5.4	0.0	1.9	9.5	0.0	2.2
Arstida Species	Poaceae	G	A	I	0.0	0.4	0.0	6.3	0.0	0.0
Bidens biternata	Asteraceae	F	P	I	0.0	0.0	1.3	0.0	0.0	0.0
Brachiaria eruciformis	Poaceae	G	A	H	0.8	0.0	0.5	1.3	0.0	0.0
Cenchrus ciliaris	Poaceae	G	P	H	0.0	0.0	0.0	0.0	0.0	0.6
Chloris roxburghiana	Poaceae	G	P	H	0.8	0.2	0.0	0.0	0.0	0.0
Chlorophytum gallabatense	Anthericaceae	F	A	H	0.0	0.0	0.0	0.0	17.5	24.7
Chrysopogon aucheri	Poaceae	G	P	H	0.0	0.0	0.0	0.0	32.2	6.2
Commelina africana	Commelinaceae	F	A	H	4.6	0.0	1.7	1.7	8.4	27.0
Cyathula orthacantha	Amaranthaceae	F	A	L	0.3	20.1	1.9	5.0	0.0	0.0

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Cyperus sp.	Poaceae	G	A	I	13.3	0.9	0.0	5.6	13.4	13.5
Dactyloctenium aegyptium	Poaceae	G	P	H	17.6	1.3	0.0	0.0	0.0	0.0
Dactyloctenium aegyptium	Poaceae	G	P	H	0.0	0.2	0.4	0.0	0.0	0.0
Digitaria milanjiana	Poaceae	G	P	H	0.3	0.0	0.0	0.0	0.0	4.5
Digitaria naghellensis	Poaceae	G	P	H	2.5	0.0	0.0	0.0	15.0	0.0
Digitaria velutina	Poaceae	G	A	I	0.0	31.0	7.4	28.8	0.0	0.0
Dyschoriste hildebrandtii	Acanthaceae	F	P	I	2.3	0.6	23.4	11.4	0.0	0.0
Endostemon kelleri	Lamiaceae	F	P	L	2.4	0.0	0.0	0.6	0.0	0.0
Enteropogon macrostachyus	Poaceae	G	P	I	0.0	0.0	0.0	0.0	1.3	0.0
Eragrostis capitulifera	Poaceae	G	A	I	0.0	0.0	0.0	0.0	0.0	1.1
Euphorbia indica Lam.	Euphorbiaceae	F	A	L	0.0	2.1	5.5	0.3	0.0	0.0
Hibiscus crassinervius	Malvaceae	F	P	I	3.0	0.9	0.0	1.6	0.0	0.0
Indigofera spinosa	Fabaceae	F	P	H	3.3	11.4	5.5	4.3	0.6	6.7
Kedrostis pseudogijef	Cucurbitaeae	F	P	I	0.0	0.0	0.0	0.4	0.0	2.2
Leptothrium senegalense	Poaceae	G	A	I	0.0	0.0	0.0	6.3	0.0	0.0
Macroculia species	Poaceae	G	P	H	1.3	0.0	0.0	0.0	0.0	0.0
Oxygonum sinuatum (Meisn.) Dammer		F	A	L	235	29.8	0.0	14.1	0.0	0.0
Panicum maximum	Poaceae	G	P	H	1.3	0.0	0.0	0.0	0.0	0.0
Pennisetum mezianum	Poaceae	G	P	I	0.0	0.0	7.0	0.4	0.0	0.0
Setaria verticillata	Poaceae	G	A	H	0.0	0.0	0.9	0.0	0.0	0.0
Solanum somalense	Solanaceae	S	P	L	0.0	1.1	0.0	0.0	0.0	0.0
Sporobolus pellucidus	Poaceae	G	P	I	6.5	23.7	0.0	0.0	1.6	0.0
Tephrosia pentaphylla	Fabaceae	F	P	I	0.0	0.0	0.0	0.1	0.0	0.0
Volkensinia prostrata	Amaranthaceae	F	P	I	1.5	3.0	15.3	11.8	2.2	11.2
Xerophyta humilis	Velloziaceae	F	A	I	0.0	0.5	0.8	0.1	0.0	0.0
Amaranthus species	Amaranthaceae	F	A	I	2.2	0.0	0.0	0.0	0.0	0.0
Dyschoriste species	Acanthaceae	F	A	I	1.0	0.7	0.0	0.0	0.0	0.0

Herbaceous plant species diversity, richness, and evenness

The Yabello traditional enclosure rangeland use type had high herbaceous species richness (13.00 ± 0.79), followed by Teltele enclosure and continuous grazing rangeland use types, while the lowest was observed at Arero continuous grazing land (6.00 ± 0.79). The herbaceous species of Teltele enclosure rangeland had high diversity (2.11 ± 0.14), followed by Yabello enclosure, but lowest in Arero enclosure rangeland land types (1.33±0.14), respectively (Table 2).

Table 2: Mean ± standard error of herbaceous plant species richness, diversity (H'), and evenness of the two rangeland use types (of three study sites, n=306).

Districts' Rangeland use types.		Parameters		
		Richness	Evenness	Diversity
Arero	Traditional enclosed	6.67±0.79[c]	0.59±0.06[ab]	1.33±0.14[b]
	Continuous grazing	6.00±0.79[c]	0.70±0.06[a]	1.42±0.14[b]
Teltele	Traditional enclosed	12.67±0.79 [a]	0.66±0.06[ab]	2.11±0.14[a]
	Continuous grazing	12.33±0.79[a]	0.59±0.06[ab]	1.98±0.14[a]
Yabello	Traditional enclosed	13.00±0.79[a]	0.65±0.06[ab]	2.10±0.14[a]
	Continuous grazing	9.33±0.79[b]	0.49±0.06[b]	1.51±0.14[b]

*Means with the same letter in the same column are not significantly different (P 0.05)

Within each rangeland use of the Arero and Teltele sites, there was no significant difference (P>0.05) observed in their herbaceous richness, evenness, and diversity due to recurrent drought. Traditional enclosures of rangeland types were overgrazing and damage to basal cover, likely open grazing land types. However, in Yabello, there was a significant difference (P<0.05), which may be because Yabello has good management practices that the traditional enclosure had better distribution of herbaceous species than continuous grazing rangeland. Juying et al. (2009) showed that the grazed area of desert grassland was accompanied by severe soil erosion, decline in soil nutrients, and loss of species diversity both in the plant community and the soil seed bank. Therefore, not only climatic variability and heavy grazing but also multiple factors like management systems have an impact on herbaceous community distribution and recovery of rangeland types. Even though there were no significant differences between the two types of rangelands, the traditional enclosure rangeland types had better herbaceous plant species richness, evenness, and variety when compared to the continuous grazing land at each study site. Since the highly desirable and perennial herbaceous species were found in the traditional enclosure rather than continuous grazing of rangeland (Table 2). Similarly, Yeyneshet (2011) and Kamau (2004) reported that light grazing had positive impacts on herbaceous species diversity, while overgrazing reduced herbaceous species, which reduced important species richness.

Biomass Yield and Ground Cover of Herbaceous Plants

The means of herbaceous species biomass yield of different rangeland types of the study sites were presented in Table 3. The percentage of ground cover of herbaceous plant species did not show a significant difference (P > 0.05) among the study sites. Because of the grazing pressure, there was a significant difference in the ground cover of each study site (P 0.05). Continuous grazing had less ground cover than traditional enclosure. It was agreed with Hailu (2016), who reported that the total dry matter of above-ground and grass species (highly, intermediate, and less desirable grass) was significantly highest in the enclosure as compared to communal grazing areas. The present study ground cover and above biomass weight tons per hectare of a herbaceous community of both rangeland types were lower than previous findings due to overgrazing and changes in rainfall amount and distribution. Similarly, Asfaw et al. (2008) reported that after drought breaks, total forage production may be lower than normal because of fewer plants per unit area.

Table 3: Ls mean ± standard error (MSE) for ground cover and biomass yield of herbaceous species for two rangeland use types of three districts (n=306)

District	Rangeland use	Ground cover	Dry matter weight in tons ha^{-1}		
			Grass	Forbs	Total
Arero	Traditional Enclosure	5.42^{a}	0.016^{b}	0.010^{c}	0.026^{b}
	Continuous grazing	2.35c	0.003^{b}	0.011^{c}	0.014^{b}
Teltele	Traditional Enclosure	4.84^{a}	0.009^{b}	0.044^{a}	0.053^{a}
	Continuous grazing	3b^{c}	0.007^{b}	0.014^{c}	0.022^{b}
Yabello	Traditional Enclosure	4.31^{ab}	0.043^{a}	0.024^{b}	0.068^{a}
	Continuous grazing	4.05^{abc}	0.012^{b}	0.010^{c}	0.023^{b}
SE		0.58	0.005	0.003	0.006
SL		*	*	*	*

$^{A, b,c}$ with the same letter under the same column under the same factor are not significantly different (P<0.05); Grass = grass dry matter weight; Forbs = non-grass dry matter weight, and Total = total dry matter weight.

The dry matter weight (t. ha^{-1}) of grass species showed a significant difference ($P < 0.05$) between rangeland types of the Yabello site, but no significant difference ($P > 0.05$) between Arero and Teltele sites. Due to the impact of grazing pressure, desirable forb species' biomass cover was decreased in rangeland types subjected to continuous grazing. The result showed a significant difference in the dry matter weight (t. ha^{-1}) of forb species between Yabello and Teltele sites (P 0.05). Tesemma et al (2011) reported that intensive grazing reduced herbaceous dry matter yield per hectare (kg ha-1). Also, Asrat et al. (2015) suggested that the herbaceous biomass was higher in the enclosure than in continuous grazing land.

There were significant differences ($P < 0.05$) in different types of herbaceous biomass between the districts of the study site. However, there is no significant difference between Teltele and Yabello. This result may be due to mismanagement of the grazing system in all study sites only small differences were observed between study sites.

Proportion of Desirable Herbaceous Plant Species

The total herbaceous plant species encountered in the study site of rangeland types were classified into highly desirable, intermediate, and less desirable, and the result was presented in Figure 1. The Arero and Yabello traditional enclosures had more highly desirable species than the continuous grazing rangeland type. The intermediate desirable herbaceous plant species were highly found in the continuous grazing range type of Teltele site, and the less desirable herbaceous plant species were found more at Yabello and Teltele study sites. Arero rangeland was found in better condition as compeer to Teltele and Yabello sites because both of its rangeland types had more highly desirable herbaceous species. In the Teltele site, intermediate herbaceous plant species were mostly found in both rangeland types due to the overgrazing effect annual forb species dominated. Similarly, Mengistu et al. (2015) suggested that due to continuous grazing and intensive grazing pressure, palatable plant species died and were replaced by less palatable species. Additionally, Tesfaye (2008) reported that an increase in grazing pressure altered species composition from highly palatable to less palatable species.

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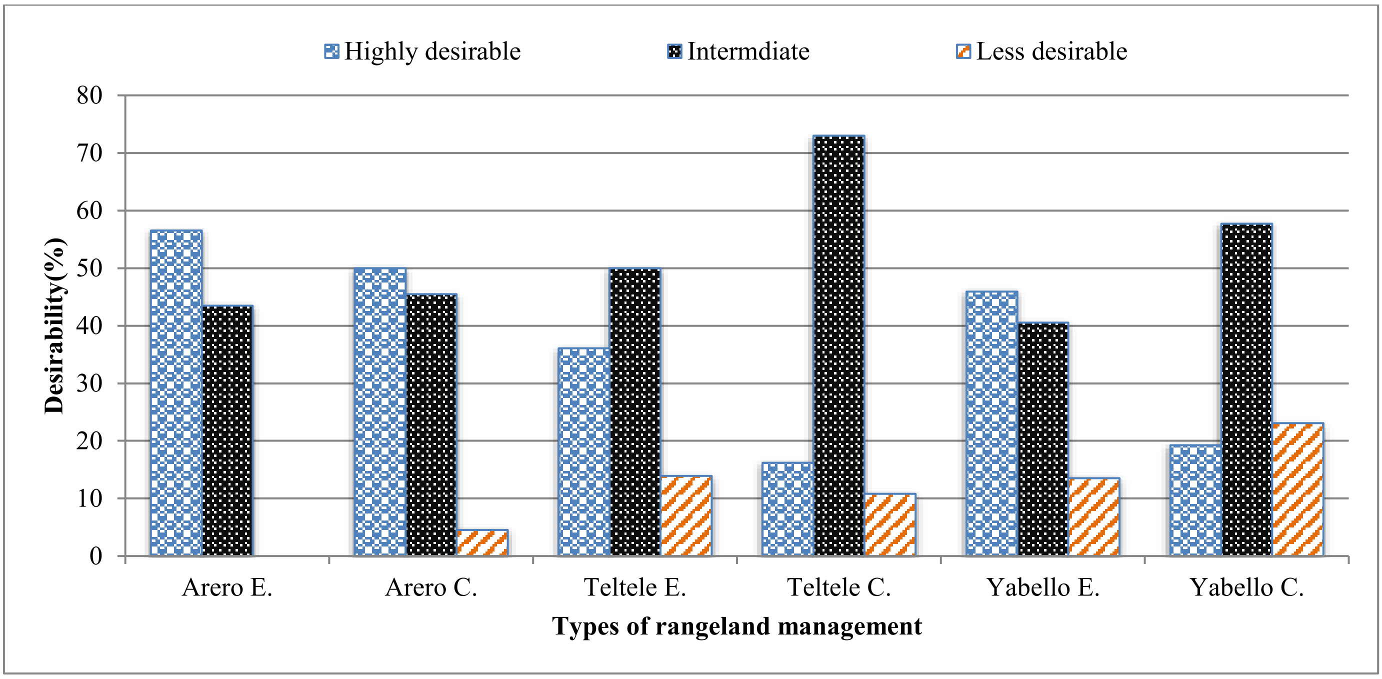

NB: E Traditional enclosure rangeland and continuous grazing rangeland

Figure 1: Desirable proportion (%) of herbaceous species among rangeland use and study sites.

The current study indicated that a high proportion of perennial grasses were found in the traditional enclosure than in continuous grazing rangeland types, while a high proportion of annual herbaceous species were found in continuous grazing than in the traditional enclosure. This finding agrees with Bikila and Tessema (2017), who reported that grazing induces bush encroachment by reducing competition by removing desirable species and changing the composition of the herbaceous layer to annual grass and unpalatable forbs. The current result revealed that the continuous grazing rangeland use of all study sites was affected by the encroachment of less desirable woody and herbaceous species. Similarly, Tessema (2007) and Angassa (2014) reported that open grazing had less herbaceous abundance due to intensive grazing pressure.

The highly desirable herbaceous vegetation that was recorded in the traditional enclosure, than continuous grazing rangeland use at all study sites, is Birchiaria species, Brachiaria eruciformis, Cenchrus ciliaris, Chloris roxburghiana, Chlorophytum gallabatense, Chrysopogon aucheri, Commelina Africana, Dactyloctenium aegyptium, Dactyloctenium aegyptium, Digitaria milanjiana, Digitaria naghellensis, Indigofera spinosa, Macroculia species, Panicum maximum, and Setaria verticillata. Similarly, Abesha (2014) reported that the increase of herbaceous species in enclosures compared to open grazing was due to light grazing intensity.

CONCLUSION AND RECOMMENDATION

Conclusion

This study concluded that overgrazing has a significant negative impact on herbaceous plant species diversity and biomass production in Borana rangeland. The more livestock that are continuously grazed in an area, the lower the species diversity and biomass production. This is because livestock overgrazing leads to the loss of palatable/productive plant species, which are replaced by less palatable and productive species. Overgrazing also damages the soil and reduces the capacity to grow plant species. Therefore, traditional enclosure grazing use types are better in herbaceous plant species diversity and biomass yield than continuous grazing use.

Recommendation

Due to mismanagement of the grazing system, the Borana rangeland ecosystem was highly degraded. So, the grazing system should be managed in a way that minimizes its negative impacts on herbaceous plant species diversity and biomass production. This can be done by:

Re-initiated and modified the indigenous rangeland management and utilization systems.

Developed and implemented the specific land use policy of rangeland.

Introduce better rangeland management systems like resting, rotational grazing, adjusting stocking rate, prescribed burning, etc.

Educating pastoralists about integrated rangeland management.

In addition to the above recommendations, further study should be conducted to identify more effective ways to manage grazing in rangelands.

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