Range Management and Agroforestry 45 (1) : 12-19, 2024
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2024.v45.i1.02

Research article

Effects of exclosures on mountain grassland floristic composition in Sidama, Ethiopia

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Received: 27th April, 2023 Accepted: 8th February, 2024

Abstract

This study was conducted to assess the effects of exclosure on mountain grassland's species composition, richness, diversity and dominance in Sidama, Southern Ethiopia. Locally established exclosures aged between 10 and 12 years old were compared against adjacent open-grazed areas in *Mollona-Meno Kebele* for this study. The study was replicated at four sites. An exclosure was paired with adjacent open-grazed lands having a similar land area and slope. Both in the exclosures and adjacent open-grazed lands, 87 and 86 plant species were recorded, representing 20 families, respectively. A significantly higher difference was observed between exclosures and adjacent open-grazed lands in terms of herbaceous species abundance, diversity, evenness and density. Higher herbaceous species' important value index (IVI) was recorded inside exclosures than in the open-grazed lands. The results suggested that the establishment of exclosures on degraded lands could support the restoration of degraded native herbaceous species which consequently enhanced ecosystem services.

Keywords: Herbaceous species, Land management, Open-grazed lands, Restoration

Introduction

Mountain ecosystems are important sources of feeds for animals and habitats for wildlife (Kricsfalusy, 2013; Denbeshu *et al*., 2018). Inaccessibility and cool environmental conditions of mountain areas in the past might have played an important role in their resilience (Kricsfalusy, 2013). However, there is a growing concern about mountain areas and associated vegetation composition because of demographic changes. The diverse cultural and natural remnants of mountain grasslands are threatened by increased grazing pressure (Angassa, 2014) and climate change (Denbeshu *et al*., 2018). This seems to be a common problem in the mountain grasslands of Ethiopia. Exclosures are operational land management practices in terms of protecting grasslands from disturbances (Denbeshu *et al*., 2018; Fenetahun *et al*., 2021). Exclosures are a normal practice in Ethiopia by prohibiting livestock grazing, and tree cutting to enhance the restoration of biodiversity (Husain *et al*., 2019). Angassa and Oba (2008) pointed out that the sizes of exclosures could vary from place to place within the range of one ha to 700 ha. Descheemaeker *et al*. (2009) argued that exclosures are a customary practice to revive hillside and degraded areas where grazing was severe in the past. According to Angassa *et al.* (2010), local exclosures are unfenced, but the local administration often hires guards to meet the intended goals of land management. Active participation of the local communities is also crucial for the management and protection of exclosures (Oba *et al*., 2008). Studies (Mekuria and Veldkamp, 2012) have shown the benefits of exclosures in terms of improved vegetation cover, reduced soil erosion (Abebe *et al*., 2006), enhanced ecosystem carbon stores (Mekuria *et al*., 2015; Aynekulu *et al*., 2017), improved soil fertility (Abebe *et al*., 2006), and restoration of biodiversity (Angassa *et al*., 2010). As a result of reduced disturbance and runoff, exclosures can also improve water availability in an ecosystem (Anwar *et al*., 2016), and minimize sediment load (Girmay *et al*., 2009; Anwar *et al*., 2016), restore groundwater recharge (Anwar *et al*., 2016) to improve the livelihoods of smallholder farmers (Tilahun *et al*., 2007). The role of exclosures as an approach to the restoration of degraded rangeland ecosystems has gained widespread popularity in many parts of the world (Verdoodt *et al*., 2009; Siebert *et al*., 2010; Wilkerson *et al*., 2013; Mureithi *et al*., 2014; Mekuria *et al*., 2018). According to Ombega *et al*. (2017), restoration of degraded areas substantially improved floristic composition and productivity. Mbaabu *et al*. (2020) stated that restoration of degraded rangelands optimizes carbon sequestration for climate change mitigation and enhancves the productivity of grassland, and numerous ecosystem services. The restoration of degraded rangelands through the establishment of exclosures has been promoted in different parts of the world, such as in China (Fenetahun *et al*., 2021), Pakistan (Qasim *et al*., 2017), Kenya (Wilkerson *et al*., 2013; Mureithi *et al*., 2014), and South Africa (Siebert *et al*., 2010). Exclosures have also been a common practice in many parts of Ethiopia (Angassa and Oba, 2008).

Despite the existing work done in Ethiopia and other parts of the world, little research has been carried out on the role of exclosures in the current study area. Generally, most studies in Ethiopia were carried out in the rangeland areas, focusing on mid and lower altitudes. This calls for the need to conduct the current research on mountain grassland floristic composition in response to the effects of exclosure. This paper presents scientific accounts of the causes of degradation and prospects of mountain landscape restoration and subsequent recovery of the grassland vegetation communities. The objective of the study was to assess the effects of exclosure on mountain grassland's species composition, richness, diversity, and dominance in Sidama, Southern Ethiopia.

Materials and Methods

Study site: The study was conducted in Meno highland mountain grasslands (Mollona Meno *Kebele*) in the Bursa district of Sidama Regional State in Southern Ethiopia. The word '*Kebele*' refers to the lowest administrative structure in Ethiopia. The area is located at 6° 42′16.73″ N and 38° 34′45.77″E with an altitude ranging between 2814 and 3157 amsl. The topography is hilly, with slope percentages ranging from 10 to 45% (Denbeshu *et al*., 2018). The mean annual rainfall is about 2000 mm. The rainy season extends from mid-March to mid-October. The mean annual temperature varies between 10 and 15°C. The two rainy seasons are the *Belg* rains, which are from March to May, and the *Kremt* rains, which fall from June to mid-October.

Experimental procedure: Four sites with two treatments (*i.e*., exclosures versus open-grazed areas) were selected to evaluate the effects of exclosures on herbaceous species composition, diversity, richness, abundance, density, dominance, and basal cover of native forages. Based on the information gathered from the local community, livestock had been excluded for more than a decade and since then, these exclosures were not grazed. Accordingly, exclosures against adjacent open-grazed areas were selected in Meno-Mollo Kebele for herbaceous vegetation sampling. Exclosures of 10 to 12 years old were selected from four sites (*i.e*., Dawalle, Mollo, Meno and Wosharbe) with their adjacent open-grazed lands all having similar land sizes, slopes, and soil types (Denbeshu *et al*., 2018). There were four exclosures and four adjacent open-grazed lands. Adjacent open-grazed areas were used as a control for each exclosure. The adjacent open-grazed lands were private grazing lands that were generally exposed to year-round grazing. The exclosures were also privately owned lands that were used previously for communal grazing (Denbeshu *et al*., 2018). Three transects were randomly established within each exclosure and in the adjacent open-grazed land. Quadrats of 1 x 1 m dimensions were placed along each transect at 30 m intervals. A total of 180 quadrats were placed inside exclosures (*i.e.*, 90 quadrats) and in the adjacent open-grazed lands (*i.e.*, 90 quadrats) in June 2018 to sample herbaceous vegetation attributes. As the four sampling sites were varied in size, unequal sampling sizes were collected in proportion to the size of each study site, targeting 90 quadrats individually for exclosures and adjacent open-grazed areas (Table 1). Data were collected in November 2019 for herbaceous forage species abundance, richness, diversity, frequency, density, importance value index (IVI), basal cover and dominance.

Vegetation survey: Herbaceous species composition and richness were assessed about grazing pressure (*i.e*., exclosures against adjacent open-grazed areas) across the study sites consistent with the procedures used by Crowder and Chheda (1982). The study was conducted from October to early November 2019, when the plants were at their flowering stage. Herbaceous species sampling was carried out using 1 m^2 quadrant at an interval of 30 m along each transact. The number of individuals of each herbaceous species was counted to estimate herbaceous species composition, diversity, richness, frequency, density, abundance, importance value index (IVI), dominance and basal area cover.

Table 1. Experimental setup across the study sites in exclosures and open-grazed areas in Sidama, southern Ethiopia

Site	Exclosures		Adjacent open-grazed areas	
	Size (ha)	No. of quadrats	Size (ha)	No. of quadrats
1	2	12	2	12
2	3	18	3	18
3	5	30	5	30
4	5	30	5	30

All herbaceous plant species encountered in each quadrat were identified in the field by a botanist from the Ethiopian Agricultural Research Organization, Holleta, by using the following illustrated plant identification guidebook (Hedberg *et al*., 2004). Other herbaceous plant species that were not identified in the field were collected from the study area, allotted collection numbers, pressed, dried, mounted and taken to the National Herbarium, Addis Ababa University for identification. Then the identification was done by comparing with already identified herbarium specimens and using taxonomic keys in the Flora of Ethiopia and Eritrea (Hedberg *et al*., 2004). Voucher specimens were eventually kept at the National Herbarium.

***Importance value index (IVI)*:** Herbaceous species phytosociological characters were evaluated by analyzing the frequency, density, abundance, basal area cover, dominance, and importance value index (IVI) using a procedure suggested by Curtis and McIntosh (1950).

***Species diversity*:** Herbaceous plant species richness, diversity, and evenness were measured using the following procedures. Herbaceous species richness was determined as the total number of species counted per unit area (Oba et al., 2001). Herbaceous plant diversity was determined using the Shannon species diversity index (Shannon, 1948). The formula was as follows: $H' = -[\Sigma(pi \ln pi)]$ by calculating the proportion of each plant species. Where: H′ = Diversity index of species, Pi = the proportion of individuals abundance of the i^{th} species, ln = log base. The Shannon diversity index was used for species diversity analysis because it takes both species richness and the relative abundance of each of these species into consideration. Species evenness (J) described how even the number of individuals in the species was. They had equal numbers of individuals with the same size and similarities in species abundance and could be calculated according to the formula described by Ambasht (1982): $J = (H'/\ln S)$, where: H′= Shannon diversity index; S = was the total number of species. Species composition was taken as the identity (names) of different species inside exclosures and open-grazed lands.

***Density and dominance*:** The average total density of plant species per hectare was derived from the total number of individuals recorded in the sampling quadrats in the exclosures and adjacent open-grazed lands. The types of plant species found in exclosures and adjacent open-grazed lands were described in terms of species composition, richness, and life forms (grasses, legumes, and forbs). The dominance of the plant species was determined using the importance value index (IVI) of these species. Vegetation composition was evaluated by analyzing the frequency, density, abundance and important value index (IVI), using the formula given by Mishra (1968) and Curtis and McIntosh (1951).

***Basal cover and data analysis*:** Basal cover or basal area for tufted herbaceous species (grasses) was determined by measuring the circumference ($C = 2\pi r$) of a tuft of grass or an herb using a caliber at a height of 2.5 cm from the ground and determining the cross-sectional area of that plant. Thus, basal area (BA) for an herbaceous species was calculated as $BA = \pi r^2$, where $\pi = 3.14$, r = radius of the grass base (Mishra, 1968). The remaining area proportion occupied by a spreading herbaceous species and bare ground/rock was estimated visually at 1 x 1 m (Sutherland, 2000). The differences between the exclosures and adjacent open-grazed land in vegetation variables were analyzed using descriptive statistics and paired t-tests using SPSS (2015) version 25.

Results and Discussion

***Floristic composition*:** The results showed more herbaceous plant species collection assemblage inside exclosures (87) than in the adjacent open-grazed lands (86). Species richness, percent composition, and basal cover of grasses, herbaceous legumes and forbs within exclosures against adjacent open-grazed lands were recorded (Table 2). The results disclosed that exclosures greatly improved the percent basal cover of grasses, herbaceous legumes and forbs as compared to the adjacent open-grazed lands. There was no significant difference between exclosures and adjacent open-grazed

Table 2. Effects of exclosures *versus* adjacent open-grazed lands on species richness, percent composition and basal cover of grasses, herbaceous legumes and forbs

Variables	Exclosures			Adjacent open-grazed areas		
	Species richness	Composition (%)	Basal cover (%)	Species richness	Composition (%)	Basal cover (%)
Grasses	35	40.23	56.1	35	40.7	50.6
Herb leguminous	11	12.64	12.2	10	11.63	10.4
Forbs	41	47.13	27.9	41	47.67	23.7
Total	87	100	96.2	86	100	84.7
Bare ground (%)			3.79			15.3
Total			100			100

lands in terms of the species richness of grasses and forbs. The results showed that exclosures enhanced the percent composition of herbaceous legumes as compared to the adjacent open-grazed lands.

The present study reaffirmed the higher abundance of herbaceous plant species in exclosures than in adjacent open-grazed lands. A probable explanation for the higher abundance of herbaceous species in exclosures might be attributed to the exclusion of disturbance that enhanced the restoration of most susceptible species to grazing and other human interferences. This could have positive management and policy implications for the restoration of the degraded mountain ecosystems. The most interesting part of the finding was that reduced disturbance within exclosures considerably improved the basal cover of grasses, herbaceous legumes and forbs against those from adjacent open-grazed lands. Similar results were reported in previous studies (Abebe *et al*., 2006; Gebregergs, 2019). The current finding was also consistent with that of Angassa *et al*. (2010), who reported that the basal cover of herbaceous plants was significantly higher inside exclosures than in the adjacent open-grazed lands. Generally, no significant difference was exhibited between exclosures and adjacent open-grazed lands in terms of the species richness of grasses and forbs. The probable reason for the absence of difference between exclosures and open-grazed lands could be attributed to the wide range of environmental adaptation of grasses and forbs as well as their tolerance to grazing. By contrast, it was interesting to note that exclosures improved the composition of herbaceous legumes as compared to those in the adjacent open-grazed areas. This could be an indication of the vulnerability of highly palatable legume species to the influence of grazing pressure in the adjacent open-grazed lands. Similar reports were recorded in heavily grazed savannas of Africa (Tadesse, 2002; Gemedo *et al*., 2006). Repeated grazing leads to a reduction in herbaceous species composition, which in turn accelerates the decline in rangeland conditions. In conformity with this argument, Van Der Westhuizen *et al*. (2001) explained that in rangelands, herbaceous species composition was greatly influenced by the effects of grazing pressure. This thought was also consistent with the report of Angassa *et al*. (2010), who stated that heavy grazing pressure could reduce plant species composition.

The top ten most dominant grass species inside exclosures and open-grazed lands were also recorded (Table 3). The results showed that exclosures improved the importance value index of certain grass species such as *Andropogon abyssinicus*, *A. amethystinus*, *Pennisetum clandestinum, Agrostis schimperana, Poa leptoclada* and *P. schimperana* as compared to the adjacent open-grazed areas. On the other hand, grasses like *Festuca abyssinica, Poaannua, A. gracilifolia* and *Pennisetum humile* had less IVI under exclosures than in the adjacent open-grazed areas. In terms of species dominance, the results revealed that *A. abyssinicus*, *P. clandestinum* and *A. schimperana* were more dominant in the exclosures than in the adjacent open-grazed areas. Conversely, the adjacent open-grazed areas promoted the dominance of certain grass species such as *A. amethystinus, F. abyssinica, P. annua, A. gracilifolia* and *P. humile* (Table 3). Generally, the results showed that *A. abyssinicus* and *A. amethystinus* were the two dominant grass species both in the exclosures and open-grazed areas.

The results of the present study indicated that exclosures enhanced the importance value index of *A. abyssinicus, A. amethystinus, P. clandestinum, A. schimperana, P. leptoclada* and *P. schimperana* as compared to the adjacent open-grazed areas. This occurrence could be explained by the fact that these grass species are highly palatable and susceptible to heavy grazing pressure. According

Table 3. Effects of exclosures versus adjacent open-grazed lands on plant life form, IVI and dominance of the most dominant grass species

Grass species	Life form	Exclosures		Open-grazed areas	
		IVI	Dominance	IVI	Dominance
A. abyssinicus R.Br.exFresen	A	38.0	14.3	31.0	12.5
A. amethystinus Steud.	P	34.6	12.6	31.4	13.9
P. clandestinum Chiov	P	10.4	4.2	8.7	1.9
F. abyssinica A. Rich	P	10.2	2.6	12.2	3.7
P. annua. L	A	9.9	2.9	11.9	3.8
A. gracilifolia C.E. Hubb	P	9.7	2.8	11.8	4.3
A. schimperana Steud.	P	8.4	1.3	6.6	0.3
P. humile Hochst. ex A. Rich.	P	7.4	1.6	11.3	4.1
P. leptoclada A. Rich.	P	4.5	0.6	3.9	0.1
P. schimperana	P	3.7	0.6	2.9	0.3

A: Annual; P: Perennial; IVI: Importance value index to Parthasarathy and Karthikeyan (1997), an analysis of IVI provides information about the status of a specific species that could be recognized as patterns of association of dominant species in a plant community. There are, however, other possible explanations whereby the seeds of some grass species may need favorable moisture conditions which could be improved by restoring degraded areas. This may be further explained by the fact that restoration and regeneration of grasses can improve the infiltration of runoff, which in turn increases the soil moisture content in the exclosures. Similar results have been reported by Angassa and Oba (2008), who suggested that reduced runoff inside exclosures and increased soil moisture most likely enhanced the dominance of certain species. Conversely, grass species such as *F. abyssinica*, *P. annua*, *A. gracilifolia* and *P. humile* had less IVI in the exclosures management than in the adjacent open-grazed areas. Such changes were also reported by researchers elsewhere (Sternberg *et al*., 2000; Angassa and Oba, 2007; Angassa and Oba, 2010), who suggested that exclosures might favor the dominance of grazing susceptible species whilst the unpalatable species might increase under increased grazing pressure in the open-grazed areas. This notion was consistent with the findings of Oba *et al.* (2003), who suggested that disturbances such as continuous grazing might favor the establishment of invasive species and the dominance of short-lived, annual plant species rather than the palatable perennial species. Similarly, previous studies (Angassa, 2014) concur with the idea that continuous grazing most likely affects the amount of plant litter at the soil surface and exerts indirect pressures on the germination and seedling establishment patterns of certain species. Herbivores can generally cause shifts in plant community composition toward the dominance of unpalatable plant species, where highly palatable plant species might decline or disappear in the community (Rutherford *et al*., 2012). Leguminous herbs (10) with the highest IVI and dominance values were recorded (Table 4). The current results disclosed that herbaceous legumes such as *Trifolium semipilosum, T. rueppellianum, T. multinerve, T. decorum* and *T. acaule* were more dominant in exclosures than in the adjacent open-grazed areas. On the other hand, certain legume species were better adapted to the adjacent open-grazed areas where disturbance was higher than inside exclosures. Overall, *T. semipilosum* was the single most dominant herbaceous legume inside exclosures, whilst *T. burchellianum* was the top dominant species in adjacent open-grazed areas.

The ten most dominant forb species inside exclosures versus adjacent open-grazed areas were recorded (Table 5). Exclosures greatly improved the dominance of all identified forbs species. Among the ten forbs species, *Alchemilla abyssinica* showed better adaptation or ability to tolerate varied disturbance regimes. In the current study, comparing exclosures with the adjacent open-grazed areas indicated that *A. abyssinicus, P. clandestinum,* and *A. schimperana* were more dominant in the exclosures than in the adjacent open-grazed areas. One unanticipated finding was that the adjacent open-grazed areas stimulated the dominance of *A. amethystinus, Festuca abyssinica, P. annua, A. gracilifolia,* and *P. humile*. The possible reason for the dominance of these species in open-grazed areas might be that grazing could promote the establishment and survival of these species by facilitating the dispersal of their seeds. Generally, the results showed that *A. abyssinicus* and *A. amethystinus* were the two most dominant grass species both in the exclosures and open-grazed areas.

***Herbaceous species diversity*:** Herbaceous species diversity was recorded (Table 6). The results showed a significantly higher diversity index, equitability

Table 4. Effects of exclosures versus adjacent open-grazed lands on plant life form, IVI and dominance of the most dominant legume species

Herbaceous legumes	Life form	Exclosures		Open-grazed areas	
		IVI	Dominance	IVI	Dominance
T. semipilosum Fresen	P	4.9	1.1	2.8	1.0
T. rueppellianum Fresen.	A	3.7	1.1	2.2	0.9
T. burchellianum Ser.	P	3.3	2.8	4.0	2.7
T. calocephalum Fresen.	P	2.8	1.7	2.8	1.6
T. multinerve A. Rich.	A	2.4	1.2	2.3	1.1
T. polystachyum Fresen	A	2.4	0.8	2.8	0.6
T. decorum Chiov.	A	2.1	1.4	1.7	1.1
T. simense Fres	P	1.8	1.0	2.2	0.9
T. acaule Steud.ex A. Rich.	P	1.7	0.6	1.5	0.5
T. repens - L.	P	1.5	1.0	1.5	1.0

A: Annual; P: Perennial; A: Annual or short-lived Perennial; IVI: Importance value index

Table 5. Effects of exclosures versus adjacent open-grazed lands on life form, IVI and dominance of ten most dominant forb species

Forbs	Life form	Exclosures		Open-grazed areas	
		IVI	Dominance	IVI	Dominance
Alchemilla abyssinica Fresen	P	8.5	4.7	5.6	3.0
Haplosciadium abyssinicum Hochst	P	6.7	3.2	2.3	0.8
Satureja paradoxa (Vatke) Engl. ex Seybold	P	6.3	3.9	3.5	1.7
Ipomoea purpurea (L.) Roth.	P	5.7	2.1	2.5	1.0
Haplocarpha schimperi (Sch.Bip.)	P	5.2	1.1	2.8	0.5
Stellaria sennii Chiov	A	4.1	0.4	2.2	0.3
Centella asiatica (L.) Urban	P	3.6	0.4	2.5	0.4
Thymus schimperi Ronniger	P	3.6	0.5	2.7	0.4
Alchemilla alpina L.	P	2.3	0.6	1.9	0.2
Sparmannia ricinocarpa (Eckl. & Zeyh.)	P	2.1	0.8	1.8	0.8

A: Annual; P: Perennial; A: Annual or short-lived Perennial; IVI: Importance value index; Lf: Life forms

Table 6. Effects of exclosures versus adjacent open-grazed lands herbaceous species, diversity, richness, evenness, density (individuals/m^2), and abundance (individuals/quadrat)

Variables	Mean exclosures	Mean open-grazing	*p-value*
Abundance	39.24^a ± 6.73	28.42^b ± 4.80	0.000
H’ (Shannon diversity index)	3.31^a ±.11	2.69^b ±.17	0.017
Shannon evenness	0.75^a ± 026	0.62^b ±.042	0.016
Species richness	83 ± 2.27	77 ± 3.03	0.232
Hmax	4.42±.028	4.34±.037	0.203
Density	30.33^a ±8.14	26^b ±6.9	0.000

Paired t-test was used to test for significant differences (n = 180) in quadrats in exclosures and adjacent grazed lands; Means within a row not bearing a similar superscript differed significantly ($p < 0.05$)w

(evenness), abundance, and density inside the exclosures than in the adjacent open-grazed lands ($p<0.05$). However, there was no significant difference ($p>0.05$) in species richness between exclosures and open-grazed lands. From the results on species diversity, key findings emerged, where exclosures dramatically had more accumulation of herbaceous species diversity than adjacent open-grazed areas. This suggested that reduced grazing pressure and disturbances favored the regeneration of grazing and disturbance-intolerant herbaceous species. Comparison of the findings with those of previous studies (*e.g.*, Angassa *et al*., 2010; Gebrewahd, 2014; Mureithi *et al*., 2016; Ombega *et al*., 2017) confirmed that high species diversity was recorded within exclosures as compared to adjacent open-grazed areas. A similar finding was reported by others (Mureithi *et al*., 2014), suggesting that the high diversity of herbaceous species might have been attributed to more accumulation of litter, the addition of organic matter to the soil, and increased soil moisture. The present study confirmed that the more diverse herbaceous plant communities were indications of more evenness in terms of species inside exclosures and restoration of mountain grassland ecosystems. This was an important finding in the understanding of the role of restoration of degraded mountain areas in terms of soil stability and enhancement of ecosystem services. According to the current results, a previous study (Mengistu *et al*., 2015) validated that exclosures facilitated the regeneration of more palatable herbaceous species that could be severely affected under continuous grazing pressure. The current result also tied well with the findings of previous studies (Angassa and Oba, 2010), which reported that palatable herbaceous species dominate inside exclosures. The current study found that exclosures considerably increased the abundance and density of herbaceous species as compared to the adjacent open-grazing lands. Within the country and elsewhere in the world several studies (Metzger *et al*., 2005; Park *et al*., 2013; Rong *et al*., 2014; Selemani, 2015; Al-Rowaily *et al*., 2015) showed that degraded plant communities could be restored in a relatively short time following the establishment of exclosures.

Conclusion

This study showed that the exclosure system of land management influenced herbaceous species' floristic composition and structure, resulting in a significant increase in herbaceous species diversity, species abundance, evenness, density, percent composition and percent basal cover inside exclosures than in the adjacent open-grazing lands. It also showed that the establishment of exclosures on degraded grazing lands in Sidama highlands is a viable option to restore herbaceous vegetation composition, diversity, evenness and density. Moreover, the study proved that area exclosure has the potential to enhance vegetation regeneration and, hence, forage productivity. The study indicated that exclosure land management is an advisable strategy for herbaceous species rehabilitation and restoration in Ethiopian highlands.

Acknowledgment

The authors acknowledge the financial support received from Hawassa University and the Ethiopian Institute of Agricultural Research (EIAR) through Dr. Getnet Assefa's project. The authors also sincerely thank the local communities in the study areas for their participation and cooperation during data collection.

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