

**Changes in vegetation structure and aboveground biomass in response to traditional grazing
land management practices in mixed crop-livestock production system of central highlands
of Ethiopia**

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Abstract

Traditional grazing land management practices have become weak in highland crop-livestock farming areas of Ethiopia due to land shortage because of population pressure which aggravated the continual conversion of pasture lands into arable lands. Information from phytosociological data analysis on the effect traditional grazing land practices on vegetation structure and aboveground biomass yield is limited. The current study was undertaken to evaluate changes in vegetation structure and aboveground biomass yield and soil attributes in response to traditional grazing land management practices in the central highlands of Ethiopia. At highland and mid-highland agro ecologies, 10 plots of 40 m X 40 m (five plots each for enclosure and the adjacent open access) were established. Sixteen 0.5 m X 0.5 m quadrants at a distance of 10 m transect were nested per plot and in total 320 quadrants were used for data collection in September, 2018. The mean aboveground biomass yield was significantly higher ($P < 0.001$) for enclosure area than free grazing in mid-highland agro ecology. *Andropogon amethystinus* (Important value index (IVI) = 86.9) and *Pennisetum thunbergii* (IVI = 79.2) from enclosure area and *Pennisetum thunbergii* (IVI = 100.6) from open access were the most dominant, abundant with the highest density from identified herbaceous species from highland agro ecology. From mid-highland agro ecology, *Eleusine floccifolia* (IVI = 119.5 and 125.7 respectively for enclosure and open access area) was the most dominant, abundant with highest density species. Herbaceous species richness was higher in free grazing than enclosure areas at both agro ecologies. Soil parameters such as total nitrogen from highland and available phosphorous, calcium and sodium from mid-highland and cation exchange capacity from both agro ecologies were significantly greater for enclosures than open access management practices. In conclusion, enclosures performed better in the most parameter considered than open access grazing land management practices at both agro ecologies.

Keywords

Biomass; Enclosure; Grazing land; Management; Open access; Vegetation structure

Introduction

The crop-livestock mixed production system of the highlands of Ethiopia occupies approximately 90 percent of the human and 60 percent of the livestock population (Hurni et al. 2010). In this production system, animals are dependent on a variety of feed resources that can vary both in quantity and quality throughout the year. Grazing is the predominant form of ruminant feeding system in most part of the extensive and smallholder mixed crop-livestock farming system in Ethiopia (Alemayehu 2004). Livestock in the central highlands graze on fallow, permanent pasturelands during cropping seasons and on croplands after crop harvest (Lemma 2002).

Grazing land resources are shrinking due to intense degradation as a consequence of deforestation, agricultural land expansion and continuous heavy grazing (Mengistu et al. 2005). The evidence available on the impact of grazing systems on the dynamics of native vegetation and soils is inconsistent (Vetter and Bond 2012). Grazers alter landscape heterogeneity (Belsky 1992), rates of nutrient cycling (Frank et al. 1998), vegetation composition and productivity (Eccard et al. 2000). Similarly, grazers affects different grassland ecosystems including increases (Pucheta et al. 2004), decreases (Gao et al. 2008) and no changes (Mcnaughton et al. 1998) in biomass of root system and belowground net primary productivity. Additionally, others consider grazing as a positive process that improves plant production and survival (Papanastasis 2009), promotes biodiversity (O’connor et al. 2010) and improves soil fertility. Light grazing increases aboveground biomass, canopy cover and height of the species, but from a long-term perspective, moderate grazing would balance the biomass production of different species and livestock production (Wei et al. 2011). Generally, vegetation response to different grazing land management practices has been investigated in several studies (Tessema et al. 2011; Mekuria et al. 2015; Gebregerges et al. 2017) in which the results indicated that overgrazing causes a change in vegetation structure by decreasing the vegetation density and biomass.

According to Fekede (2013), pasture lands in the highland areas have significantly dwindled and are limited to areas where conditions are adverse for cropping partly due to topographic, edaphic and climatic limitations. Consequently, livestock are forced to concentrate on very limited pastureland that becomes unproductive in the long run and makes the mixed crop-livestock production system unsustainable (Girma et al. 2002). According to the same author, in those areas,

animals will go extinct unless ecosystems are managed to feed people and protect wild species simultaneously. The massive deforestation and the resultant shortage of fuel wood led to the use of dung and agricultural residue as fuel which prevent nutrient recycling through manure. In order to utilize the available grazing lands in a sustainable manner, it appears important to implement knowledge based grazing land management strategies. Generally in the highlands of Ethiopia, the traditional grassland management practices are weak and when coupled with land shortage, it results in shortage of grazing land (Alemayehu 2006).

Numerous studies have been conducted on the effect of grazing pressure on plant and soil properties of grasslands, but most have been in the pastoral rangelands. Relatively little research has been conducted to evaluate effect of different grazing land management practices on vegetation and soil attributes in the highland in mixed crop-livestock production system of Ethiopia (Girma et al. 2002; Habtemicael et al. 2014). The available evidence so far showed that better vegetation and soil attributes are obtained in moderate grazing than continuous heavy grazing. But no study has been conducted by using the phytosociological data analysis method to compare traditional grazing land management practices in the central highlands of Ethiopia. Such analysis is important to provide detailed information on vegetation social status and to offer insights on grazing land ecosystem function and its restoration. Although the national average with regard to the contribution of grazing lands as a source of feed has gone down to less than 45%, central highland areas are one of the area that still maintains better grazing land resources. This shows that implementation of improved grazing land management practices and enabling environments might play an important role in increasing feed resource availability, environmental sustainability and productivity of the farming system in the study area and beyond. The present study was conducted with the hypothesis that enclosure area management practices can improve grassland productivity and sustainability compared to free grazing management practices. Therefore, this study was undertaken to evaluate changes in vegetation structure and aboveground biomass yield and soil attributes in response to traditional grazing land management practices in mixed crop-livestock production system in the central highlands of Ethiopia.

Materials and Methods

Study area

The study was conducted in Kofele district of West Arsi Zone of Oromia Regional State, Ethiopia located at highland: 7°06'-7°07' N and 38°48'-38°49' E and mid-highland: 7°00'-7°02' N and 38°48'-39°00' E (Fig. 1). Kofele district is located at 305 km from Addis Ababa on the road towards Robe via Shashemene. The agro ecologies of the district are highland (90%) and mid-highland (10%) having loam soil type in the highland and sandy loam in mid-highland (District Agricultural and Natural resource Management Office 2017; unpublished data). The district is found within 2200-3200 m.a.s.l. and receives an average rainfall of 1800 mm per annum and average temperature of 19.5 °C. It has bi-modal rainfall distribution with the short rain starting from March to May and the main rainy season extending from June to September/October. The area is characterized as high potential for crop-livestock farming and cattle and sheep are the most predominant livestock species (CSA 2015). Farmer in the study area cultivates crops such as barely, wheat, maize and enset as food crops and potato, head cabbage, beet root and carrot as cash crops (Hussien 2017).

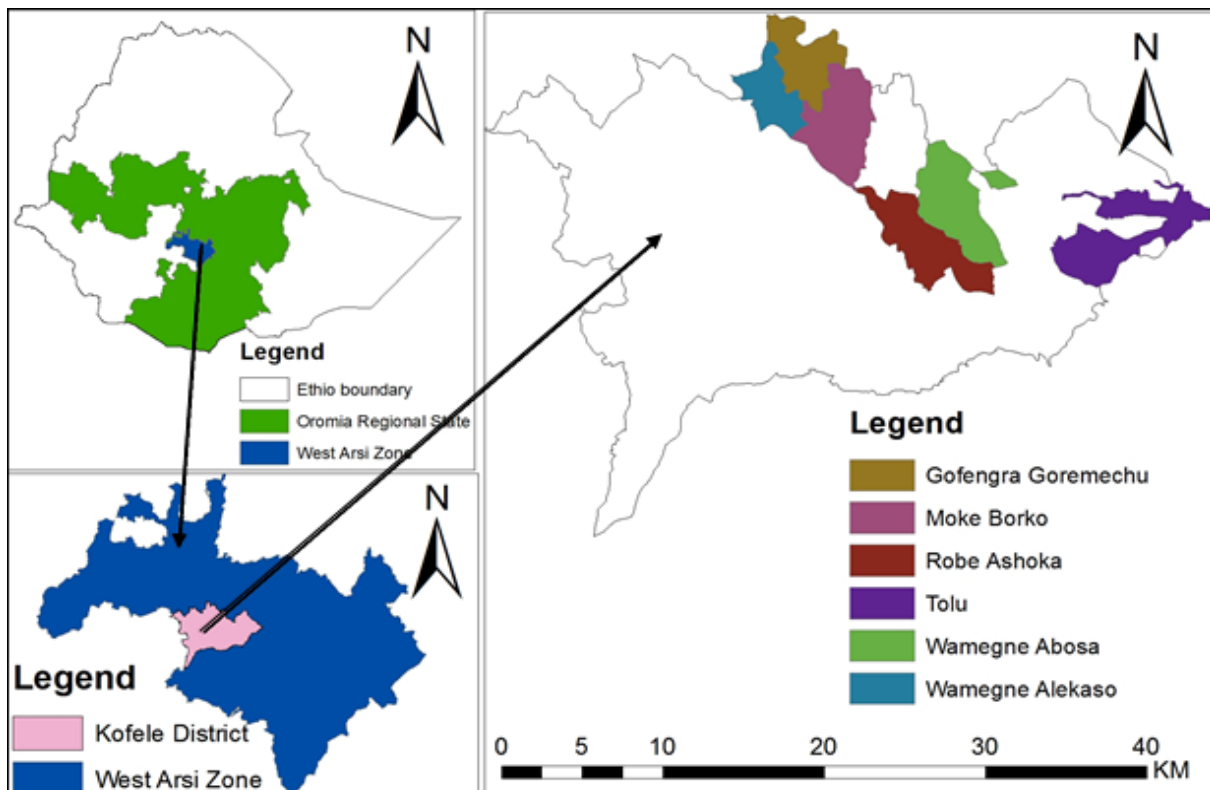


Fig. 1 Map of the study area, Kofele district, central highlands of Ethiopia

Traditional grazing land management history

The study area is historically (before 60 years) known for livestock rearing and cultivation of crop is relatively a recent phenomenon in the system. The land use includes farmlands and grazing lands which in turn consisting of enclosure area during rainy season which is traditionally known as “Kalo” and an openly grazed area (free grazing) throughout the year. The enclosure area refers to a specific land unit that is protected from the activities of particular class of animals by using appropriate barriers such as fencing and/or controlling the entrance of the animals following the onset of short rainy season. This particular type of grazing land is used for rotational grazing during short and main rainy seasons, cut and carry system and in rare cases used as conserved standing hay for use during the dry period. Open accesses grazing refers to an area of land which is exposed to unregulated and year round grazing by a large number of mixed livestock species. According to the information obtained from elite farmers in the study area, these traditional grazing land management practices ages for more than 30 years and such areas were purposively selected for the current study.

Site selection and study design

From the two agro ecological area (highland and mid-highland) two traditional grazing land management practices, enclosure during wet season and the adjacent open access grazing land, were systematically selected. The selection criteria used includes similarity in landscape, soil and land use to minimize variability in the abiotic determinants of grass land vegetation composition and functioning. At both agro ecologies, 10 plots of 40 m X 40 m (five plots each from enclosure and the adjacent open access area) were established. All plots were enclosed uniformly for five months from May, 2018 to September, 2018. Sixteen, 0.5 m X 0.5 m, quadrants by using metal wire at a distance of 10 m transects were nested per plot for sample collection (Fig. 2). In total, 320 quadrats (two agro ecologies X two management systems X five plots X 16 quadrants) were used to collect pasture species samples. To avoid any edge effects, the plots were laid 50 m away from the boundaries of the enclosure and the adjacent open access, respectively.

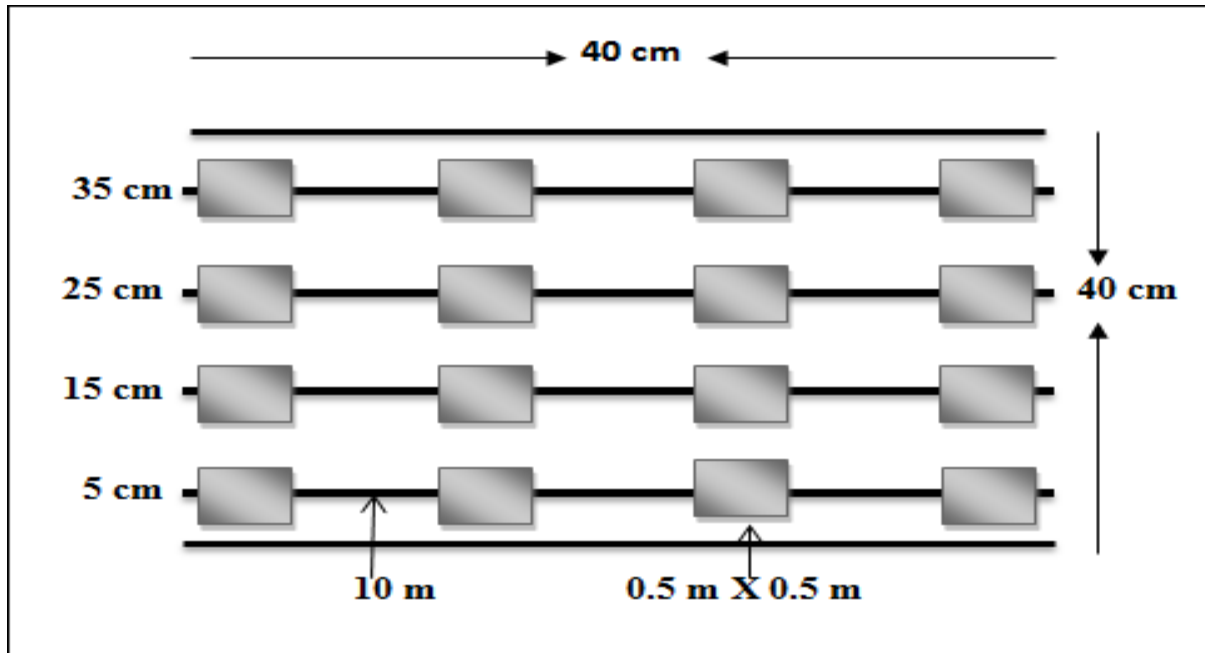


Fig. 2 Sampling design and plot layout of the experimental site used for herbaceous species and soil sampling.

Vegetation sampling and analysis

Vegetation sampling in individual enclosure and the adjacent open access grazing land were conducted in September, 2018 at the end of main rainy season when most of the pasture plants were flowering and setting seeds and easily identified. Herbage biomass yield were determined by mowing the pasture at 5 cm aboveground using sickle from an area of 0.25 m² quadrants. Fresh biomasses were immediately weighted by using a 0.1 g scale. Forage species were identified by using guide books on the site and for those plant species that were difficult to identify at the field, their local names were recorded and herbarium specimens were collected, pressed and dried properly by using a plant presser and identified and confirmed at the national herbarium, Addis Ababa University, Ethiopia. Individual forage species in each quadrant were counted and weighted fresh to estimate biomass yield and vegetation composition were evaluated by analyzing the frequency, density, abundance and important value index (IVI) by using the following formula given by Mishra (1968) and Curtis and McIntosh (1951):

$$\text{Frequency} = \frac{\text{Total number of quadrates in which the species occurred}}{\text{Total number of quadrates studied}} \times 100$$

Relative Frequency = $\frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$

Density = $\frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates studied}}$

Relative density = $\frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$

Abundance = $\frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates in which the species occurred}}$

Relative Dominance of Herbaceous Species = $\frac{\text{Basal area of a species}}{\text{Basal area of all the species}} \times 100$

IVI = Relative frequency + Relative density + Relative dominance

The distribution of species similarity between enclosed area and open access grazing land were computed by using index of similarity which was calculated by applying formula given by Jaccard (Zobel et al. 1987):

$$IS_J = (C/A+B-C) \times 100$$

Where IS_J = Jaccard's Index of Similarity, C= the number of species common to both grazing management practices; A = the number of species unique to enclosure area; B= the number of species unique to open access grazing area.

About 20% of above ground biomass for each species was retained and oven-dried to a constant weight at 60 °C for 48 hours in order to use for dry matter determination. Species richness was estimated by counting all species within the sample quadrats. Species diversity was computed for each grazing land management practice using the Shannon–Wiener diversity index (H') (Shannon and Wiener 1963):

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

Where s = number of species; p_i = proportion of individuals or abundance of the i^{th} species expressed as a proportion of total cover; and $\ln$ = log base n .

Equitability or species evenness was calculated using the formula given by Pielou (1969):

$$\text{Equitability (J)} = H'/H'_{\max}$$

Where $H'_{\max}$ = Maximum possible diversity; H' = Shannon–Wiener diversity index.

Soil sampling and analysis

Soil samples were collected from the center of 0.25 m² quadrants after aboveground biomass removed by using an Auger at depths of 0–10, 10–20, 20–30, 30–40 and 40–50 cm. The soil samples at each site were pooled to form one composite soil sample per sampling site yielding a total of 20 soil samples for each depth (two management practices X 10 sample sites) to determine the cumulative effect of grazing management on soil attributes. Samples were taken to the lab, air dried, crushed and passed through a 1 mm and 2 mm mesh size sieve. Soil pH was determined by using pH meter in 1:2.5 soil water suspension ratios (Lewis and Freitas 1984). Electrical Conductivity (EC) was determined in a 1:2.5 soil water suspension following the steps and procedures suggested by Chopra and Kanwar (1976). Total nitrogen was determined using the Kjeldahl procedures suggested by Jackson (1970). Soil organic carbon was determined following the method recommended by Walkey and Black (1934). Then, soil organic matter was calculated by multiplying the percentage of the organic carbon by a factor of 1.724 following the method recommended by Brady and Weil (1999). The level of available phosphorous was determined by using the methods and procedures specified by Olsen et al. (1954). Calcium was determined by atomic absorption spectrometry and potassium and sodium were determined by flame photometry. Texture was analyzed with the help of the hydrometer method (Bouyoucos 1962).

Statistical analysis

The effect of traditional grazing management (enclosures area vs. open access grazed) i.e. independent variable on herbaceous aboveground biomass yield and proportions of different life forms, species frequency, abundance, density, richness and evenness and soil properties (dependent variables) were analyzed using ANOVA (SAS 9.1) by using the General Linear Model Procedure (SAS 2001). Sampling plots and quadrants were used as replicates to assess the impact of traditional grazing land management practices on variables measured. Tukey's HSD test with $P < 0.05$ was employed for mean comparison. Before analysis, data were transformed to optimize normality and homogeneity of variance using Shapiro–Wilk test (Steel and Torrie 1980).

Results

Vegetation biomass across grazing land management practices

The mean aboveground biomass yield for the enclosure area were significantly higher ($P < 0.001$) than open access grazing in mid-highland agro ecology. Similar pattern was observed at highland agro ecology even though the enclosure area was not statistically different from the open access grazing area (Table 1). Within the different botanical groups (grasses, legumes, sedges and forbs), the mean aboveground biomass yield for grasses from the enclosure area were significantly higher ($P < 0.001$) than open access grazing at both agro ecologies. The same trend was observed for legumes at mid-highland agro ecology but the reverse was true in the highland agro ecology. No statistical difference ($P > 0.05$) was observed for sedges between the two grazing land management practices at both agro ecologies and the mean above ground biomass yield for forbs in open access grazing was higher ($P < 0.001$) than the enclosure area at highland agro ecology. The proportion of grass species among the botanical groups were 79.0 and 71.4% from highland and 93.6 and 90.4% from mid-highland respectively for enclosure and open access grazing areas.

Table 1 Total aboveground herbaceous biomass yield and proportions for botanical groups on dry matter basis (t/ha) under the two traditional grazing land management practices in the central highlands of Ethiopia (mean $\pm$ SEM).

Vegetation variables	Agro ecology			
	Highland		Mid-highland	
	Enclosure	Open access	Enclosure	Open access

Total aboveground biomass	3.3 ± 0.2	3.0 ± 0.2	6.6 ± 0.4 ^a	4.7 ± 0.5 ^b
Herbaceous components				
Grasses	2.61 ± 0.2 ^a	2.15 ± 0.2 ^b	6.18 ± 0.36 ^a	4.25 ± 0.47 ^b
Legumes	0.12 ± 0.04 ^b	0.42 ± 0.12 ^a	0.27 ± 0.04	0.28 ± 0.06
Sedges	0.23 ± 0.05	0.14 ± 0.03	0.17 ± 0.03	0.16 ± 0.03
Forbs	0.39 ± 0.04 ^b	0.56 ± 0.07 ^a	0.17 ± 0.03	0.21 ± 0.03

^{a,b} Different superscripts within the row for each agro ecology show significant difference (P <0.05). SEM=standard error of mean.

Herbaceous species composition across grazing land management practices

In the highland agro ecology, a total of 29 herbaceous species were recorded of which 22 and 27 herbaceous species were recorded for the enclosure and open access grazing area, respectively (Table 2). From identified herbaceous species, *Andropogon amethystinu* (IVI=86.9) and *Pennisetum thunbergii* (IVI=79.2) were the most dominant species in the enclosure area with a frequency of 81.1 and 95.8%, respectively while the co-dominant species in the enclosure area were *Centella asiatica* (IVI=35.8), *Uebelinia abyssinica* (IVI= 22.7) and *Cyperus rigidifolius* (IVI= 18.8) with a frequency of 93.8, 85.4 and 81.3%, respectively. Similarly, *Andropogon amethystine*, *Pennisetum thunbergii* and *Centella asiatica* were the most abundant with the highest density among others in the enclosure areas.

In contrast, in the open access grazing area *Pennisetum thunbergii* (IVI= 100.6) was the most dominant and *Andropogon amethystinus* (IVI= 44.2), *Centella asiatica* (IVI= 36.5) and *Uebelinia abyssinica* (IVI= 23.3) were the co-dominant herbaceous species with 97.9, 60.4, 75.0 and 89.6% frequency, respectively. Similar to enclosure area, *Pennisetum thunbergii*, *Andropogon amethystine* and *Centella asiatica* were the most abundant with greater density than other species in the open access grazing areas. Four grass species (*Cynodon dactylon*, *Pennisetum humile*, *Pennisetum sphacelatum* and *Sporobolus pyramidalis*) and two forbs (*Cerastium octandrum* *Crepis schultzei*.) which were recorded in open access grazing were absent from enclosure area.

Table 2 Herbaceous species attributes for enclosure vs. open access traditional grazing land management practices in the highland agro ecology

Species scientific name	Frequency		Abundance		Density		A/F		IVI	
	E	O	E	O	E	O	E	O	E	O
Grasses										
<i>Andropogon amethystinus</i>	81.3	60.4	798.0	305.9	648.4	184.8	9.8	5.1	86.8	44.2
<i>Brachiaria scalaris</i>	2.1	2.1	66.0	10.0	1.4	0.2	31.7	4.8	0.4	0.4
<i>Cynodon dactylon</i>	0.0	43.8	0.0	71.6	0.0	31.3	0.0	1.6	0.0	11.9
<i>Eragrostis botryodes</i>	2.1	8.3	11.0	55.8	0.2	4.6	5.3	6.7	0.7	1.7
<i>Eragrostis tenuifolia</i>	6.3	10.4	14.3	36.2	0.9	3.8	2.3	3.5	1.0	2.1
<i>Helictotrichon elongatum</i>	25.0	10.4	36.3	93.2	9.1	9.7	1.5	8.9	0.5	3.9
<i>Ischaemum afrum</i>	2.1	12.5	24.0	88.2	0.5	11.0	11.5	7.1	0.4	5.9
<i>Pennisetum humile</i>	0.0	12.5	0.0	34.7	0.0	4.3	0.0	2.8	0.0	3.1
<i>Pennisetum sphacelatum</i>	0.0	12.5	0.0	54.0	0.0	6.8	0.0	4.3	0.0	4.7
<i>Pennisetum thunbergii</i>	95.8	97.9	471.0	401.1	451.4	392.7	4.9	4.1	79.2	100.6
<i>Sporobolus pyramidalis</i>	0.0	4.2	0.0	40.5	0.0	1.7	0.0	9.7	0.0	1.58
Legumes										
<i>Trifolium cryptopodium</i>	16.7	8.3	53.6	79.8	8.9	6.6	3.2	9.6	3.2	2.0
<i>Trifolium mattirolanum</i>	12.5	12.5	69.2	87.7	8.6	11.0	5.5	7.0	4.4	2.9
<i>Trifolium simense</i>	4.2	18.8	128.0	141.0	5.3	26.4	30.7	7.5	7.1	5.6
<i>Trifolium tembense</i>	20.8	50.0	50.9	59.2	10.6	29.6	2.4	1.2	4.1	12.7
Sedges										
<i>Cyperus rigidifolius</i>	81.3	50.0	74.5	40.7	60.5	20.3	0.9	0.8	18.8	12.5
<i>Cyperus rubicundus</i>	0.0	4.2	0.0	20	0.0	0.8	0.0	4.8	0.0	0.7
<i>Cyperus sp.</i>	6.3	6.3	178.0	24.0	11.1	1.5	28.5	3.8	1.8	1.4
<i>Scleria hispidula</i>	37.5	4.2	71.0	108.0	26.6	4.5	1.9	25.9	7.6	1.2
<i>Scleria schimperiana</i>	20.8	0.0	190.7	0.0	39.7	0.0	9.2	0.0	6.4	0.6
Forbs										
<i>Alchemilla pedata</i>	4.2	18.8	62.0	50.8	2.6	9.5	14.9	2.7	0.8	3.9
<i>Centella asiatica</i>	93.8	75.0	314.7	259.9	295.0	195.0	3.4	3.5	35.8	36.5
<i>Cerastium octandrum</i>	0.0	4.2	0.0	10.0	0.0	0.4	0.0	2.4	0.0	1.1
<i>Crepis schultzei</i>	0.0	25.0	0.0	49.2	0.0	12.3	0.0	2.0	0.1	5.9
<i>Cyanotis barbata</i>	4.2	0.0	29.0	0.0	1.2	0.0	7.0	0.0	0.8	0.0
<i>Haplocarpha hastata</i>	47.9	22.9	19.0	11.8	9.1	2.7	0.4	0.5	8.5	5.8
<i>Oldenlandia monanthos</i>	12.5	14.6	104.5	23.7	13.1	3.5	8.4	1.6	3.3	2.7
<i>Satureja paradoxa</i>	4.2	6.3	27.0	20.7	1.1	1.3	6.5	3.3	0.8	1.1
<i>Uebelinia abyssinica</i>	85.4	89.6	55.0	48.0	47.0	43.0	0.6	0.5	22.7	23.3

A/F= abundance to frequency ration; E=enclosure; O=open access; IVI=important value index

In the mid-highland agro ecology, a total of 26 herbaceous species were recorded of which 19 and 22 herbaceous species were recorded for the enclosure and open access grazing area, respectively (Table 3). Among the identified species from enclosure area, *Eleusine floccifolia* (IVI= 119.5) was the most dominant, abundant with highest density species followed by *Andropogon amethystinus* (IVI= 67.3), *Trifolium tembense* (23.8), *Sporobolus pyramidalis* (IVI= 19.5) and *Cyperus rigidifolius* (IVI=16.7) as co-dominant species with frequency of 97.9, 52.1, 64.6 and 62.5%,

respectively. Similarly in open access grazing area, *Eleusine floccifolia* (IVI= 125.7) was the most dominant, abundant with highest density species in open access grazing area with co-dominant species such as *Andropogon amethystinus* (IVI= 29.6), *Pennisetum thunbergii* (IVI= 25.7), *Cyperus rigidifolius* (IVI= 18), *Sporobolus pyramidalis* (IVI= 15.6) and *Cerastium octandrum* (IVI= 15). Two annual legumes (*Trifolium mattirolanum*; *Trifolium rueppellianum*) and three annual sedges (*Cyperus sp.*; *Scleria hispidula*; *Scleria schimperiana*) which were recorded in open access grazing were absent from enclosure area. Three perennial forbs present in enclosure area (*Agrocharis melanantha*, *Alchemilla pedata* and *Centella asiatica*) were not recorded in open access grazing area.

Table 3 Herbaceous species attributes of enclosure and open access traditional grazing land management practices from the mid-highland agro ecology.

Species scientific name	Frequency		Abundance		Density		A/F		IVI	
	E	O	E	O	E	O	E	O	E	O
Grasses										
<i>Andropogon amethystinus</i>	52.1	47.9	425.7	146.1	221.7	70.0	8.2	3.0	67.3	29.6
<i>Cynodon dactylon</i>	10.4	4.2	8.6	15.5	0.9	0.6	0.8	3.7	2.2	0.9
<i>Eleusine floccifolia</i>	97.9	66.7	224.9	304.8	220.2	203.2	2.3	4.6	119.5	125.7
<i>Eragrostis botryodes</i>	0.0	8.3	0.0	214.5	0.0	17.9	0.0	25.7	0.0	6.0
<i>Pennisetum humile</i>	10.4	4.2	17.4	2.5	1.8	0.1	1.7	0.6	2.5	0.8
<i>Pennisetum thunbergii</i>	4.2	41.7	47.5	156.7	2.0	65.3	11.4	3.8	1.4	25.7
<i>Poa leptoclada</i>	39.6	25.0	61.6	30.8	24.4	7.7	1.6	1.2	13.1	7.2
<i>Snowdenia polystachya</i>	4.2	0.0	42.5	0.0	1.8	0.0	10.2	0.0	1.4	0.0
<i>Sporobolus pyramidalis</i>	50	31.3	59.6	57.1	29.8	17.9	1.2	1.8	19.5	15.6
Legumes										
<i>Trifolium cryptopodium</i>	20.8	22.9	25.3	52.4	5.3	12.0	1.2	2.3	5.1	7.8
<i>Trifolium mattirolanum</i>	0.0	8.3	0.0	60.5	0.0	5.0	0.0	7.3	0.0	3.2
<i>Trifolium rueppellianum</i>	0.0	12.5	0.0	27.8	0.0	3.5	0.0	2.2	0.0	4.0
<i>Trifolium simense</i>	14.6	6.3	74.9	70.0	10.9	4.4	5.1	11.2	4.7	2.5
<i>Trifolium tembense</i>	64.6	31.3	78.6	56.2	50.8	17.6	1.2	1.8	23.8	10.2
Sedges										
<i>Cyperus rigidifolius</i>	62.5	62.5	30.4	33.4	19	20.9	0.5	0.5	16.7	18
<i>Cyperus sp.</i>	0.0	12.5	0.0	8.5	0.0	1.1	0.0	0.7	0.0	2.7
<i>Scleria hispidula</i>	0.0	4.2	0.0	44	0.0	1.8	0.0	10.6	0.0	1.2
<i>Scleria schimperiana</i>	0.0	22.9	0.0	51.9	0.0	11.9	0.0	2.3	0.0	7.1
Forbs										
<i>Agrocharis melanantha</i>	14.6	0.0	12.0	0.0	1.8	0.0	0.8	0.0	3.2	0.0
<i>Alchemilla pedata</i>	8.3	0.0	23.0	0.0	1.9	0.0	2.8	0.0	2.0	0.0
<i>Centella asiatica</i>	4.2	0.0	2.0	0.0	0.1	0.0	0.5	0.0	0.8	0.0
<i>Cerastium octandrum</i>	16.7	54.2	12.9	27.4	2.1	14.8	0.8	0.5	3.7	15
<i>Cyanotis barbata</i>	0.0	22.9	0.0	16.1	0.0	3.7	0.0	0.7	0.0	6.1
<i>Haplocarpha hastata</i>	10.4	6.3	24.0	43.0	2.5	2.7	2.3	6.9	2.5	1.8
<i>Satureja paradoxa</i>	25.0	6.3	46.5	16.0	11.6	1.0	1.9	2.6	7.4	1.4

<i>Uebelinia abyssinica</i>	12.5	27.1	17.5	25.8	2.2	7.0	1.4	1.0	3.1	7.4
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A/F= abundance to frequency ration; E=enclosure; O=open access; IVI=important value index

Species richness, diversity and similarity indexes

Herbaceous species richness was higher in open access grazing area than the enclosure area for both agro ecologies. While herbaceous species evenness and diversity index (Shannon) were comparable between the grazing management systems in the highland agro ecology whereas the values for species richness and Shannon diversity index were slightly higher in open access grazing than enclosure area in the mid-highland agro ecology. The overlap of herbaceous species across the two grazing regime were comparable for both agro ecology as indicated by Jaccard's index of similarity (Table 4).

Table 4 Herbaceous species richness, evenness, diversity and similarity indexes across the two traditional grazing land management practices in the central highlands of Ethiopia.

Index	Agro ecology			
	Highland		Mid-highland	
	Enclosure	Open access	Enclosure	Open access
Species richness	22	27	19	22
Species evenness	0.54	0.52	0.54	0.67
Shannon diversity index (H')	1.68	1.71	1.59	2.07
Maximum possible diversity (Hmax)	3.09	3.29	2.94	3.09
Jaccard's Index of Similarity (IS _J)	68.9		57.7	

Soil physico-chemical properties across grazing land management practices

The mean soil physio-chemical properties under the two traditional grazing land management practices are presented in Table 5. From highland agro-ecology, soil total nitrogen (TN) and cation exchange capacity (CEC) were significantly higher ($P<0.05$) for enclosure area than open access grazing practices. No significant differences ($P>0.05$) were observed between the two grazing land management practices in terms of their effect on pH, electric conductivity (EC), soil organic carbon (SOC), soil organic matter (SOM), available phosphorous (AP), calcium (Ca), potassium (K), sodium (Na) and soil texture (Table 5). On the other side, in the mid-highland agro-ecology, mean values for soil parameters such as AP, CEC, Ca and K were significantly higher ($P<0.05$)

for enclosure area than open access grazing land management practices. However, mean values for other soil parameters such as pH, EC, SOC, SOM, TN, Na and soil texture were not significantly different between the two grazing management practices (Table 5).

Table 5 Soil physico-chemical properties (mean $\pm$ SEM, 0-20 cm depth) for enclosure and open access grazing land management practices

Parameters	Highland		Mid-highland	
	Enclosure	Open access	Enclosure	Open access
pH	5.4 $\pm$ 0.2	5.3 $\pm$ 0.2	5.8 $\pm$ 0.18	5.9 $\pm$ 0.04
EC (ds/m)	0.012 $\pm$ 0.009	0.001 $\pm$ 0.0001	0.008 $\pm$ 0.007	0.009 $\pm$ 0.006
SOC (%)	9.5 $\pm$ 1.9	7.6 $\pm$ 1.1	5.6 $\pm$ 1.0	5.9 $\pm$ 1.2
SOM (%)	16.4 $\pm$ 3.2	13.1 $\pm$ 1.9	9.7 $\pm$ 1.8	10.3 $\pm$ 2.1
AP (mg/kg)	9.6 $\pm$ 1.3	11.3 $\pm$ 3.5	21.9 ^a $\pm$ 2.1	10.0 ^b $\pm$ 3.3
TN (%)	0.51 ^a $\pm$ 0.09	0.42 ^b $\pm$ 0.09	0.35 $\pm$ 0.04	0.35 $\pm$ 0.04
CEC (Cmol(+)/Kg)	34.1 ^a $\pm$ 2.6	28.7 ^b $\pm$ 1.1	27.2 ^a $\pm$ 1.1	20.2 ^b $\pm$ 1.7
Ca (Cmol _k /kg)	44.0 $\pm$ 6.5	36.9 $\pm$ 6.2	44.3 ^a $\pm$ 3.6	36.2 ^b $\pm$ 4.3
K (Cmol _k /kg)	9.4 $\pm$ 1.1	10.3 $\pm$ 1.0	12.4 ^a $\pm$ 0.7	9.9 ^b $\pm$ 1.3
Na (Cmol _k /kg)	21.6 $\pm$ 1.1	21.5 $\pm$ 1.0	21.6 $\pm$ 0.1	21.2 $\pm$ 0.4
Texture				
Sand (%)	39.8 $\pm$ 2.9	45.5 $\pm$ 4.4	50.3 $\pm$ 4.3	49.8 $\pm$ 3.1
Silt (%)	21.2 $\pm$ 2.2	21.5 $\pm$ 2.9	23.3 $\pm$ 4.6	23.2 $\pm$ 2.3
Clay (%)	39.0 $\pm$ 2.2	33.0 $\pm$ 3.6	26.3 $\pm$ 1.7	27.8 $\pm$ 2.3

^{a, b}, Different letters within each row indicate significant difference for the two grazing land management practices (p<0.05) for each agro-ecology. AP= available phosphorous; Ca=calcium; CEC= cation exchange capacity; EC=electric conductivity; K=potassium; Na=sodium; SOC=soil organic carbon; SEM=standard error of mean; SOM= soil organic matter; TN=total nitrogen

Discussion

Vegetation biomass across traditional grazing land management practices

In this study the lower aboveground biomass yield recorded for grasses in open access grazing area compared to enclosure area could be due to the effect of continuous heavy grazing, which adversely affects the growth of plant species. The result of this study agrees with the findings of Tadesse et al. (2002); Yayneshet et al. (2009) and Habtemicael et al. (2014) who found higher above ground biomass yield in the enclosure area as compared to free grazing in the highland mixed crop-livestock farming system of Ethiopia mainly due to reduced grazing disturbance by livestock. Similarly, Gebregergs et al. (2018) observed greater aboveground biomass yield from cut and carry than open grazing lands in semi-arid areas of Tselemti district in the north western Tigray region of Ethiopia. The higher aboveground biomass yield recorded for the Trifolium species in open access than enclosure area might be associated to the stimulatory effect of grazing on the growth of palatable leguminous plant species as observed by Grima et al. (2002) who found more of this species in area where there is livestock grazing than no grazing practices. Similarly, the higher proportion of forbs species recorded in freely grazed area than rotationally grazed area in the highland agro ecology might be due to their broad ecological amplitude and greater adaptability of forb species against biotic influences.

Herbaceous species composition across traditional grazing land management practices

Information about social status of a species and patter of association of dominance of species in a community can be provided by analyzing IVI for each species (Parthasarathy and Karthikeyan 1997). Analysis of IVI in the two traditional grazing land management practices represented different combinations of species with different dominants and co-dominants. The higher domination with highest IVI for few species in enclosure area at both agro ecology in the current study agrees with Haftay (2017), who showed that variation of herb distribution in the enclosure areas may be attributed to the survival and reproduction of maximum species due to moderate level of species competition during early regeneration which has led to the domination of only a few species in his study conducted in Harishin Rangelands of Eastern Ethiopia. This condition has affected the plant species which are susceptible to species' inter-competition. Similarly, Grime (1973) noted that with an increase in environmental stress, the species adapted to low levels of environmental stress lose their competitive advantage whereas those that are more resistant to environmental stress can increase in abundance.

The higher species richness of perennial grass species in open access grazing than enclosure area in our finding did not agree with the result of Bilotta et al. (2007), who reported that lightly grazed sites were dominated by perennial grasses and herbaceous legumes, whereas heavily grazed sites were dominated by annual forbs and weedy species. *Andropogon amethystinus*, the most desirable and dominant perennial grass species, in the enclosure area in the highland agro ecology decline when open access grazing was practiced, and this might be due to the inability of the species to tolerate heavy grazing than other climatic conditions, as the two grazing regimes were located within the same agro ecology and similar climate. The dominance of *Eleusine floccifolia*, a perennial grass species with tough branching rhizome, in both grazing practices in mid-highland agro ecology might be due to longer dry season period compared to highland agro ecology in which both grazing areas grazed freely for a longer period until the onset of short rainy season when the enclosure area protected from the entrance of the animals.

The higher proportions of annual Trifolium species recorded in open access grazing than enclosure area in the mid-highland agro ecology for this study agrees with the finding of Girma et al. (2002) who recorded Trifolium species only in grazed plots as compared to none grazed plots in mixed crop-livestock production system in western highlands of Ethiopia. This indicates that livestock grazing is more advantageous in the growth of palatable leguminous plant species compared to none grazed plots. Similarly, the absence of three annual sedge species in the enclosure area in our study in mid-highland agro ecology showed the dominance of annual species in open access grazing than enclosure area which confirms the previous finding. But many of the annual plants promoted by heavy grazing have low production potential due to their small size and short growing cycle (Zerihun and Mohamed Saleem 2000). However, grazing can dramatically change the species composition of grazing systems overtime (Milchunas and Lauenroth 1993). The presence of chronic over grazing over many years (Bard et al. 2000) in the mixed crop-livestock system of northern Ethiopia has changed the species composition of the grazing lands in ways that greatly differed from the seasonal grazing and cut and carry regimes.

Species richness, diversity and similarity indexes

Greater herbaceous species richness was observed in the current study for open access grazing area than enclosure area at both agro ecologies where a slightly higher Shannon diversity index, maximum possible diversity and species evenness were recorded for open access grazing land practices at mid-highland agro ecology. This finding agree with the finding of Pokharel et al. (2007), who observed higher species richness in open plots in two seasons than controlled plots in their study conducted in Trans- Himalayan Rangeland. Similarly, the findings of the present study are in agreement with the generalization made by Sternberg et al. (2000) and McIntyre et al. (2003), who reported that grazing increases the species diversity at small scale. But our findings disagree with that of Habtemicael et al. (2014) who showed higher species richness in cut and carry and seasonal grazing area than free grazing. Many previous studies (Mwendera et al. 1997; Girma et al. 2002; Tessema et al. 2011) investigated that light or moderate grazing increases species richness when compared to no grazing and heavy grazing practice. The overlap in enclosure area and open access grazing land as measured by Jaccard's index of similarity indicates that the two grazing regimes share many of the same species.

Soil physico-chemical properties across grazing land management practices

The higher soil total nitrogen found in this study in the highland agro ecology for enclosure area as compared to the open access area agree with the finding of Habtemicael et al. (2014) who reported highest soil total nitrogen in areas under cut and carry or seasonal grazing management practices than continuous grazing in semi-arid highland mixed crop-livestock farming system in Atsbi-Womberta district of eastern zone of Tigray in northern Ethiopia. Similarly, Jeddi and Chaieb (2009) obtained greater total nitrogen in 12 year enclosure than continuous grazing from their study conducted in degraded arid environments of South Tunisia. Although urine and faeces depositions increase soil nitrogen and phosphorus in many grazed systems (Augustine 2003), this was not observed in the current study for areas under open access grazing management practices where livestock freely graze on year-round basis. This might be due to dung collection by children for fuel which was a case reported earlier in the mixed crop-livestock production system in the highland areas (Girma et al. 2003). The possible explanation for the increased nitrogen under enclosure area could be also due to high concentration of soil organic matter in enclosure area than open access grazing practices (Table 5). Additionally, tall grasses such as *Pennisetum thunbergii*

and *Andropogon amethystines*, dominated the enclosure area in the highland agro ecology due to this light is the primary limiting factor which might be decreasing plant growth and reduce accumulation of both water and N in the soil (Seastedt 1995). Cation exchange capacity was greater in enclosure area than open access, and this might be due to higher concentration of soil organic carbon in enclosure area than open access grazing (Table 5).

The higher soil available phosphorus observed for enclosure area compared to the open access grazing area in the mid-highland agro ecology did not agree with the findings of previous studies (Jeddi and Chaieb 2009; Teague et al. 2011; Habtemicael et al. 2014) that showed insignificant difference in available phosphorus due to different grazing land management practices. Our results in soil calcium and potassium concentration were in line with Jeddi and Chaieb (2009) who showed greater soil calcium and potassium in enclosure area than free grazing. Similar finding was observed by Haftay (2017) who reported higher soil available potassium in enclosure area than open access grazing land management practices (Table 5). In this study, the concentration of SOC and SOM were not affected due to grazing land management practices at both agro ecologies and this disagree with the earlier result reported by Haftay (2017) who found higher SOC and SOM for enclosure area than open access grazing. Similarly, soil pH, EC, Na and texture were not affected by the two grazing management practices and this might be due to slight similarity in vegetation coverage and biomass yield among the two grazing land management practices particularly in the highland agro ecology (Table 5). Haftay (2017) observed similar results for EC and soil texture which were insignificant due to grazing management effect. Contrary to our result, Jeddi and Chaieb (2009) observed greater soil pH, EC and Na for free grazing than enclosure area.

Conclusion

The finding in the present study generally show that traditional grazing land management practices have an effect on aboveground biomass yield and soil quality parameters in the crop-livestock mixed production system in the central highlands of Ethiopia. Higher aboveground biomass yield and better soil quality parameters were observed for enclosure area than open access grazing land management practices. This shows that implementation of improved grazing land management practices play an important role in increasing feed resource availability, environmental

sustainability and productivity of the farming system in the study area. In conclusion, enclosure area performed better in most parameters studied than open access traditional grazing land management practices at both agro ecologies, even though it is necessary to conduct the trial in other highlands in the country to draw holistic conclusion.

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References

- Alemayehu M (2004) Pasture and forage resource profiles of Ethiopia. FAO, Addis Ababa, Ethiopia, pp. 19.
- Alemayehu M (2006) Country pasture/forage resources profiles. In: Francias. J.M. Suttie and S.G. Reynolds (eds).
- Augustine DJ (2003) Long-term, livestock-mediated redistribution of nitrogen and phosphorus in an East African savanna. *J. Appl. Ecol* 40:137–149. <https://doi.org/10.1046/j.1365-2664.2003.00778.x>
- Bard AK, Coltorti M, Diblasi CM, Dramis F, Fattovich R (2000) The environmental history of Tigray, Northern Ethiopia in the middle and late holocene: a preliminary outline. *Afr. Archaeol. Rev* 17:65–86.
- Belsky J (1992) Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. *J. Veg. Sci* 3:187–200. <https://doi.org/10.2307/3235679>

529

530 Bilotta GS, Brazier RE, Haygarth PM (2007) The impacts of grazing animals on the quality of
531 soils, vegetation, and surface waters in intensively managed grasslands. *Advanced Agronomy*
532 94:237–250. [https://doi.org/10.1016/S0065-2113\(06\)94006-1](https://doi.org/10.1016/S0065-2113(06)94006-1)

533

534 Bouyoucos (1962) Hydrometer method improved for making particle size analysis of soils. *Agron.*
535 *Jouw* 54:464-465. <http://dx.doi.org/10.2134/agronj1962.00021962005400050028x>

536

537 Brady NC, Weil RR (1999) *The nature and properties of soil*, 12th ed. Print Ice Hall: Upper Saddle
538 River, NJ, USA.

539

540 Chopra SL, Kanwar K (1976) *Analytical agricultural chemistry*; Kalyani University Publishers:
541 New Delhi, India.

542

543 CSA (2015) Central Statistical Agency of Ethiopia. *National Statistics Abstracts*. Addis Ababa,
544 Ethiopia.

545

546 Curtis JJ, McIntosh RP (1951) An upland forest continuum in the prairie forest border region of
547 Wisconsin. *Ecology* 32:476-496. <http://dx.doi.org/10.2307/1931725>

548

549 Eccard JA, Walther RB, Milton SJ (2000) How livestock grazing affects vegetation structures and
550 small mammal distribution in the semi-arid Karoo. *J. Arid Environ* 46:103–106.

551

552 Fekede F (2013) *Evaluation of feed resources and assessment of feeding management practices*
553 *and productivity of dairy cattle in the central highlands of Ethiopia*. PhD Dissertations, National
554 dairy research institute, karnal-132001 (Haryana), India.

555

556 Frank DA, McNaughton SJ, Tracy BF (1998) *The ecology of the earth's grazing ecosystems*.
557 *BioScience* 48:513–521. <https://doi.org/10.2307/1313313>

558

Gao YZ, Giese M, Lin S, Sattelmacher B, Zhao Y, Brueck H (2008) Belowground net primary productivity and biomass allocation of a grassland in Inner Mongolia is affected by grazing intensity. *Plant Soil* 307:41–50. <https://doi.org/10.1007/s11104-008-9579-3>

Gebregerges T, Tessema ZK, Birhane E (2017) Effect of exclosure ages on woody plant structure, diversity and regeneration potential in the western Tigray region of Ethiopia. *Journal of Forestry Research* 29:697-707. <https://doi.org/10.1007/s11676-017-0512-6>

Gebregergs T, Tessema ZK, Solomon N, Birhane E (2018) Carbon sequestration and soil restoration potential of grazing lands under exclosure management in a semi-arid environment of northern Ethiopia, *preprints*. <https://doi.org/10.20944/preprints201803.0207.v1>

Girma T, Peden D, Abiye A, Wagnew A (2003) Effect of manure on grazing lands in Ethiopia, East African highlands. *Mt. Res. Dev* 23:156–160. [https://doi.org/10.1659/0276-4741\(2003\)023\[0156:EOMOGL\]2.0.CO;2](https://doi.org/10.1659/0276-4741(2003)023[0156:EOMOGL]2.0.CO;2)

Grime JD (1973) Control of species diversity in herbaceous vegetation, *J. Environ. Manag* 1:151–167.

Habtemicael M, Yayneshet T, Anna C Treydte (2014) Responses of vegetation and soils to three grazing management regimes in a semi-arid highland mixed crop-livestock system. *Afr. J. Ecol* 53:75–82. <https://doi.org/10.1111/aje.12185>

Haftay H (2017) Analysis of vegetation phytosociological characteristics and soil physic chemical conditions in Harishin rangelands of eastern Ethiopia. *Land* 6:1-15. <https://doi.org/10.3390/land6010004>

Hurni H, Solomon A, Amare B, Berhanu D, Ludi E, Portner B, Birru Y, Gete Z (2010). Land degradation and sustainable land management in the Highlands of Ethiopia. *In: Hurni, H., Wiesmann, U., (eds.); with an international group of coeditors. Global Change and Sustainable Development: A Synthesis of Regional Experiences from Research Partnerships*. Perspectives of

the Swiss National Centre of Competence in Research (NCCR) North South, University of Bern,
Vol. 5. Bern, Switzerland: Geographica Bernensia.

Hussein A (2017) Farming system and traditional grassland management practices: The case of
Kofele district, Western Arsi Zone, MSc Thesis, Hawassa University, Hawassa, Ethiopia.

Jackson ML (1970) Soil Chemical Analysis. Prentice-Hall, Englewood Cliffs, NJ.

Jeddi K, Chaieb M (2009) Changes in soil properties and vegetation following livestock grazing
exclusion in degraded arid environments of South Tunisia. *Flora* 205:184–189.
<https://doi.org/10.1016/j.flora.2009.03.002>

Lemma G (2002) Crude protein and mineral status of forages grown on pelvis vertisol of Ginchi,
central highlands of Ethiopia. PhD dissertation Presented to the University of the Free State,
Bloemfontein.

Lewis J, Freitas F (1984) Physical and chemical methods of soil and water analysis; Food and
Agriculture Organization (FAO): Rome, Italy, p. 275.

McIntyre S, Heard KM, Martin TG (2003) The relative importance of cattle grazing in subtropical
grasslands: does it reduce or enhance plant biodiversity? *Journal of Applied Ecology* 40:445–457.
<https://doi.org/10.1046/j.1365-2664.2003.00823.x>

Mcnaughton SJ, Banyikwa FF, Mcnaughton MM (1998) Root biomass and productivity a grazing
ecosystem: the Serengeti. *Ecology* 79:587–592. [https://doi.org/10.1890/0012-9658\(1998\)079\[0587:RBAPIA\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079[0587:RBAPIA]2.0.CO;2)

Mekuria W, Langan S, Johnston R, Belay B, Amare D, Gashaw T, Desta G, Noble A, Wale A
(2015) Restoring aboveground carbon and biodiversity: a case study from the Nile basin, Ethiopia.
Forest Science and Technology 11:86–96. <http://www.tandfonline.com/loi/tfst20>

Mengistu T, Teketay D, Hulten H, Yemshaw Y (2005) The role of enclosures in the recovery of woody vegetation in degraded dry land hillsides of central and northern Ethiopia. *J. Arid Environ* 60:259-281. <https://doi.org/10.1016/j.jaridenv.2004.03.014>

Milchunas DG, Lauenroth WK (1993) Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecol. Monogr* 63:328–366. <https://doi.org/10.2307/2937150>

Mishra R (1968) Ecology work book. Calcutta, New Delhi: Oxford and IBH Publishing Company.

Mwendera EJ, Mohamed Saleem MA, Zerihun W (1997) Vegetation response to cattle grazing in the Ethiopian highlands. *Agriculture, Ecosystems and Environment* 64:43–51. [https://doi.org/10.1016/S0167-8809\(96\)01128-0](https://doi.org/10.1016/S0167-8809(96)01128-0)

O’connor TG, Kuyler P, Kirkman KP, Corcoran B (2010) Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland. *Afr. J. Range Forage Sci* 27:67–76. <https://doi.org/10.2989/10220119.2010.502646>

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium carbonate. *USDA Circular* 939: 1-19.

Papanastasis VP (2009) Restoration of degraded grazing lands through grazing management: can it work? *Restor. Ecol* 17:441–445. <https://doi.org/10.1111/j.1526-100X.2009.00567.x>

Parthasarathy N, Karthikeyan R (1997) Biodiversity and population density of woody species in a tropical evergreen forest in Courtallum reserve forest, Western Ghats, India. *Trop. Ecol* 38:297–306.

Pielou EC (1969) An introduction to mathematical ecology. New York: John Wiley and Sons. <https://doi.org/10.1002/bimj.19710130308>

Pokharel A, Chhetri M, Upadhyaya CP (2007) Effects of grazing on plant species diversity and above ground biomass in a Trans- Himalayan Rangeland. *Banko Janakari* 17:25-28.

Pucheta E, Bonamici I, Cabido M, Díaz S (2004) Belowground biomass and productivity of a grazed site and a neighboring ungrazed enclosure in a grassland in central Argentina. *Aust. Ecol* 29:201–208. <https://doi.org/10.1111/j.1442-9993.2004.01337.x>

SAS (2001) Statistical Analysis System/GLM Software. Institute Inc., Cary, NC, USA.

Seastedt TR (1995) Soil systems and nutrient cycles of the North American Prairie. In: Joern A., Keeler K.H. (Eds.). *The Changing Prairie: North American Grasslands*. Oxford University Press, New York, 157–176.

Shannon CE. Wiener W (1963) *The mathematical theory of communication*. Urbana, IL: University of Illinois Press.

Steel RGD, Torrie JH (1980) *Principles and procedures of statistics. A biometrical approach*. 2nd edition. McGraw-Hill, New York, USA, pp. 20-90.

Sternberg M, Gutman M, Perevolotsky A, Ungar ED, Kigel J (2000) Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. *Journal of Applied Ecology* 37:224-237. <https://doi.org/10.1046/j.1365-2664.2000.00491.x>

Taddese G, Mohamed Saleem MA, Abyie A, Wagnew A (2002) Impact of grazing on plant species richness, plant biomass, plant attribute, and soil physical and hydrological properties of vertisol in east African highlands. *Environmental Management* 29:279–289. <https://doi.org/10.1007/s00267-001-0014-2>

Teague WR, Dowhower SL, Baker SA, Haile N, DeLaune PB, Conover DM (2011) Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological

properties in tall grass prairie. *Agriculture, Ecosystems and Environment* 141:310–322.
<https://doi.org/10.1016/j.agee.2011.03.009>

Tessema ZK, de Boer WF, Baars RMT, Prins HHT (2011) Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna of Ethiopia. *J. Arid Environ* 75:662-670. <https://doi.org/10.1016/j.jaridenv.2011.02.004>

Vetter S, Bond WJ (2012) Changing predictors of spatial and temporal variability in stocking rates in a severely degraded communal rangeland. *Land Degrad. Dev* 23:190–199.
<https://doi.org/10.1002/ldr.1076>

Walkley A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci* 37:29–38.
<https://doi.org/10.1097/00010694-193401000-00003>

Wei L, Hai-Zhou H, Zhi-Nan Z, Gao-Lin W (2011) Effects of grazing on the soil properties and C and N storage in relation to biomass allocation in an alpine meadow. *Journal of soil science and plant nutrition* 11:27-39.

Yayneshet T, Eik LO, Moe SR (2009) The effects of exclosures in restoring degraded semi-arid vegetation in communal grazing lands in northern Ethiopia. *J. Arid Environ* 73:542-549.
<https://doi.org/10.1016/j.jaridenv.2008.12.002>

Zerihun W, Mohamed Saleem MA (2000) Grazing induced biodiversity in the highland eco zone of East Africa. *Agriculture, Ecosystems and Environment* 79:43–53.
[https://doi.org/10.1016/S0167-8809\(99\)00141-3](https://doi.org/10.1016/S0167-8809(99)00141-3)

Zobel DB, Jha PK, Yadav UKR, Behan MJ (1987) A practical manual for ecology. Ratna book distributors, Kathmandu, Nepal.

713

714