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Research Article

Impacts of Grazing on the Selected Features of Herbaceous Species and Harvested Dry Matter Yield of Natural Pasture

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This study evaluated how grazing influenced the specific features of herbaceous species (basal cover, species richness, evenness, and diversity) as well as dry matter yield in the northwestern highlands of Ethiopia. For this study, the natural pastures were divided into three strata based on grazing types (grazing exclusion areas, controlled grazing, and continuous grazing). The areas in each grazing type were divided into two randomly selected (100 m × 50 m) sampling blocks. Then, each of the separated areas was divided into five 10 m × 10 m, and in each subdivided plot, (0.5 m × 0.5 m) were placed across the plots. Thus, a total of 30 (0.5 m × 0.5 m) quadrats were used to evaluate the effect of grazing on the basal cover, species richness, diversity, and dry matter yield of the herbaceous pasture layers. As the results showed, there were significant differences in dry matter yield, basal cover, species richness, evenness, and diversity among grazing areas. The dry matter yield, basal cover, species richness, and diversity were significantly ($P < 0.05$) higher in both grazing exclusion and controlled grazing areas than in continuous grazing areas. Therefore, to increase the dry matter yield of natural pasture and to ensure sustainable livestock production, the livestock producers in the study areas should practice either a cut-carry system or a controlled grazing system.

1. Introduction

In Ethiopia, the primary source of animal feed is natural pastures, which are mainly used for grazing by livestock and other animals and are composed of native or naturally occurring grasses and other herbaceous species [1, 2]. However, the production and size of the natural pastures in previous research were influenced by factors such as topography, temperature, precipitation, sunlight, soil fertility [3], expansion of cropland, expansion of aggressive plants, and overgrazing [4]. Grazing, one of the most significant land uses in natural pastures, has an impact on the species diversity, dry matter yield, and structure of the vegetation [4–6]. In addition to altering species diversity and dry matter yield, grazing has a significant impact on how vegetation communities form, the basal cover, and richness [7]. Overgrazing leads to significant land degradation, decreased biodiversity, a decline in the nutritional value of forage plants, and the gradual eradication of native grasses in favor of less palatable and nonpalatable plant species [8].

Contrary to overgrazing, which has led to a decline in forage quality and quantity as well as the general degradation of natural pasture, appropriate grazing management shows an increasing improvement in forage value, quality, and quantity [9]. According to the previous study [10], livestock grazing is seen as a reasonable solution for maintaining and improving grassland biodiversity.

The impact of grazing on the dry matter yield and biodiversity in Ethiopia's lowland areas has been examined in various studies [11–13]. However, there was no information available regarding the impact of grazing in Ethiopia's highland regions. Therefore, the goal of this study was to evaluate how grazing impacted specific herbaceous species characteristics (basal cover, species richness, evenness, diversity, and dry matter yield) of natural pasture in northwestern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The study was carried out in the east Gojjam zone of Amhara's national regional state, Ethiopia. The zone is located in Ethiopia's northwestern highlands between the latitudes of 10° 1′ 46″ and 10° 35′ 12″ N and the longitudes of 37° 23′ 45″ and 37° 55′ 52″ (Figure 1). It is located 300 and 251 kilometers from Addis Ababa and Bahir Dar, respectively. The zone's elevation ranged from 1500 to 3537 meters above sea level. The average annual rainfall is from 900 to 2000 millimeters, while the average minimum and maximum temperatures are 7–15 and 22–25 degrees Celsius, respectively. According to the East Gojjam Animal and Fishery Development Office, sheep, goats, cattle, donkeys, horses, mules, chickens, and bees were practiced farming systems in the zone.

2.2. Sampling Procedures. The study was conducted at three grazing sites: grazing exclusion areas, controlled grazing areas, and continuous grazing areas. Grazing exclusion areas were natural pastures where livestock were restricted from grazing for a period of four years. Controlled grazing areas were natural pastures that were only used for grazing for three months, from September to November, and not used for the remaining months of the year. Continuous grazing areas are pastures that are grazed all year long, having unrestricted access to the grazing unit (Table 1). All of the grazing areas have similar soil, temperatures, and amounts of rainfall. Samples were taken during the flowering stage of the forages in all grazing areas. Prior to the collection of pasture herbage samples, grazing had been excluded from the start of the pasture growth stage to maturity (flowering stage) in both continuous and controlled grazing areas. Therefore, in every grazing area, no portion of the herbage or forage was grazed or consumed before harvesting.

In each grazing site, two randomly selected (100 m × 50 m) sampling blocks were placed. Then, each of the separated areas was divided into five plots of 10 m × 10 m, and in each subdivided plot, three 0.5 m × 0.5 m quadrats were placed across the plots [14]. Thus, a total of 30 quadrats were used to evaluate the effect of grazing on the basal cover, diversity, and dry matter of herbaceous pasture layers.

2.3. Identification of Herbaceous Plant Species. Identifications of plant species are crucial for managing grazing lands because they are used to assess the condition of the grazing land and because species composition affects dietary quality [15]. To facilitate identification, samples were collected and identified from August to September, when plants were at their peak flowering stages. The herbaceous species in each quadrat were identified on-site, and those that proved difficult to identify were transported to the Addis Ababa National Herbarium for identification.

2.4. Estimation of the Dry Matter Yield of Natural Pasture. To estimate the dry matter yields of natural pasture, ten quadrats (0.5 m × 0.5 m) were placed randomly in each grazing site. Consequently, thirty quadrats in total were taken to measure the dry matter yield of natural pasture. All herbage inside the quadrat was harvested at the ground level, instantly weighed using a sensitive balance, and the weighted subsample was placed in plastic bags. To determine the dry matter yield of the natural pasture per hectare, the collected herbage was subsequently placed at 65°C for 72 hours. The following formula was used:

$$\mathrm{TDWs} = \frac{\mathrm{TFWs} * \mathrm{SDWs}}{\mathrm{SFWs}}, \quad (1)$$

where TDW is the total dry weight, TFW is the total fresh weight, SFW is the subsample fresh weight, and SDW is the subsample dry weight.

2.5. Determine Species Diversity and Evenness. The two components of species diversity, also known as heterogeneity [16], are species richness and evenness. Species richness refers to the total number of species in a community, whereas species evenness or dominance equitability describes the distribution of species abundance among species. Diversity has become the most widely known criterion for evaluating a site's potential for conservation and ecological value [17]. The Shannon–Wiener diversity index was used to analyze the species diversity of pasture vegetation.

$$H = -\sum p_i * \ln(p_i), \quad (2)$$

where H is the Shannon–Wiener diversity index, p_i is the proportion of the entire community made up of species i, ln is the natural logarithm, and i is the total number of individuals (or the relative abundance of the ith species).

The Shannon–Wiener evenness index, which is the standard measure of species evenness, was used to calculate species evenness.

$$E_H = \frac{H}{\ln(S)}, \quad (3)$$

where E is the evenness, H is the Shannon diversity index, and S is the total number of unique species.

2.6. Species Similarity or Dissimilarity. The degree to which the species composition of the study area is similar is indicated by the similarity value; as a result, the manipulation of the common species in the study areas depends greatly on the similarity or dissimilarity study of a given grassland community. The similarity-based richness of species was measured using the Czekanowski coefficient in the manner shown as follows. The Czekanowski coefficient similarity index is

$$\mathrm{Sc} = \frac{2\sum_{i=1}^{m} \min(Xi, Yj)}{\sum_{i=1}^{m} Xi + \sum_{i=1}^{m} Yj}, \quad (4)$$

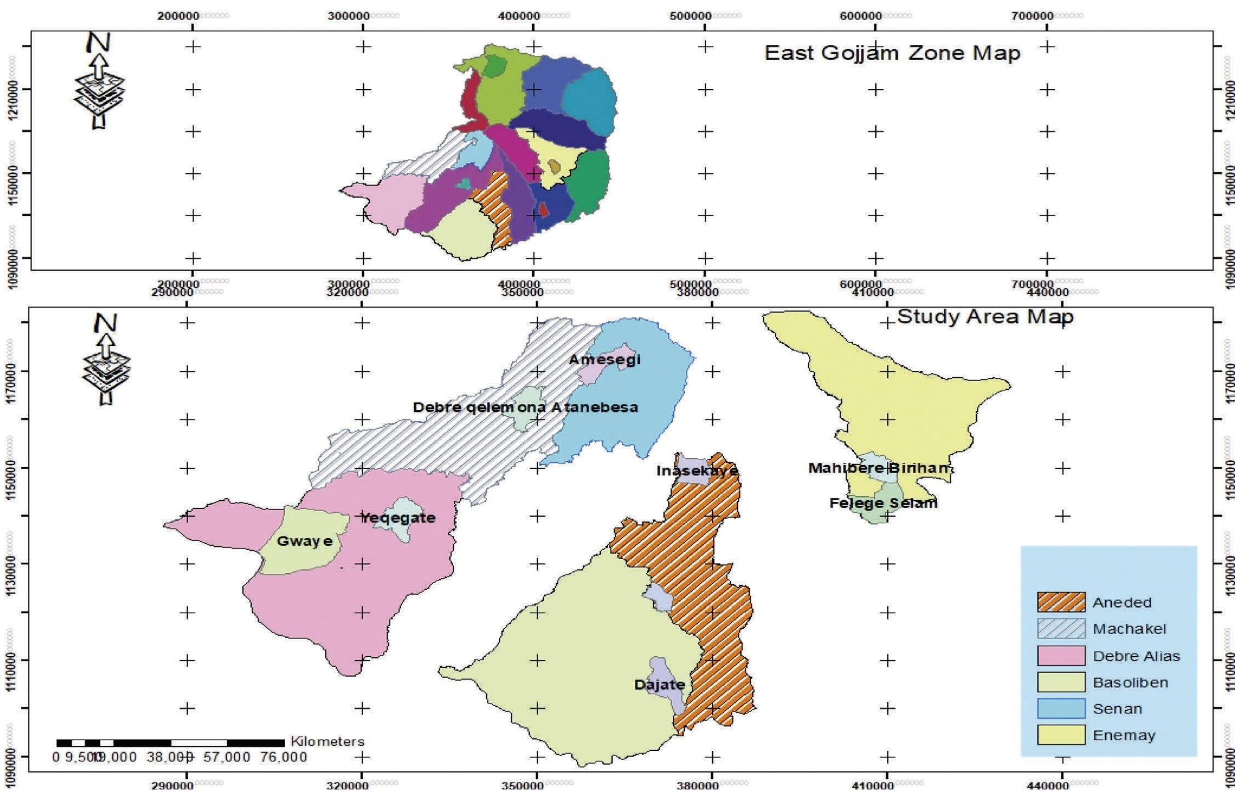

Figure 1: Location map of the six study areas.

Table 1: The sampled grazing types and the size of grazing areas in the study areas.

Parameters	Grazing system		
	Grazing exclusion	Controlled grazing	Continuous grazing
Description	Pasture excluded from grazing for more than four years	Pasture that had only grazed three months and rested for the remaining months	Pasture that allowed for continuous grazing throughout the year
Size of grazing areas (ha)	5	5	5

where Sc is the similarity coefficient, m is the number of species, $\sum_{i=0}^{m} \min(Xi, Yj)$ is the sum of the lesser scores of species i where it occurs in both quadrats, and Xi and Yj are abundance of species i.

2.7. Basal Cover. The area occupied at the points where living plant parts touch the soil is recognized as basal cover. It was estimated through the analysis of basal cover in a sample of $0.5\,\text{m} \times 0.5\,\text{m}$ ($0.25\,\text{m}^2$). For the surface of the basal cover of tufted grasses, the distribution was assessed as follows: the $0.5\,\text{m} \times 0.5\,\text{m}$ sample area was divided into halves. One half of it was then divided into eighths. In the designated $0.5\,\text{m} \times 0.5\,\text{m}$ area, all of the aboveground plant materials were cut, transferred, and kept; it has been drawn in the eighth part to facilitate visual evaluation, and the area of the rest of the plant material at the soil surface level was also estimated visually. The basal cover as a percentage was estimated by three persons, and the average value was used for analysis. Only the basal cover of living plants was taken into account.

2.8. Data Analysis. For the herbage dry matter yield, the data were analyzed using the general linear model procedure of SPSS (version 25). Significant differences comparisons between means were tested using the least significant difference (LSD). The following model was used for analysis: $\text{Yij} = \mu + G_i + E_{\text{ij}}$, where y_{ij} is the dry matter yield, μ is the overall mean, G_i is the grazing effect, and E_{ij} is the random error.

3. Results and Discussion

3.1. Herbaceous Plant Composition. A total of 59 plant species, including 32 Poaceae and 27 non-Poaceae species, were identified in the natural pasture land of the study areas. Eleven of the 27 non-Poaceae species belonged to the Fabaceae, five to the Asteraceae family, four to the Cyperaceae family, two to the Commelinaceae family, and one to each of the other families Acanthaceae, Plantaginaceae, Resedaceae, Santalaceae, and Urticaceae (Table 2). According to the results, the percentage of species from

Poaceae (54.2%) and Fabaceae (18.6%) was identified to be the largest in all grazing areas (Table 3), which is in line with the findings of [18], who reported that the species from Poaceae and Fabaceae were the dominant species in the east African mountain forest.

The grazing exclusion areas had the highest proportion of species from the Poaceae family compared to controlled and continuous grazing areas. In contrast to controlled grazing areas, continuous grazing areas had a lower proportion of species from the Poaceae family. This is due to the fact that grazing has a significant effect on species composition; as grazing density increased, species composition significantly decreased [19]. On the other hand, compared to grazing exclusion and continuous grazing areas, controlled grazing areas had the highest percentage of species from the Fabaceae family (Table 3). This might be due to the association ability of grass and legumes, in which grasses are taller than legumes, which highly compete for solar energy, which may be the cause of the higher percentage of species from the Fabaceae family in controlled grazing areas than grazing exclusion areas [20].

The percentage of species from the Apiaceae, Asteraceae, Cyperaceae, Commelinaceae, Santalaceae, and Urticaceae families was higher in continuous grazing areas than controlled grazing (Table 3). This may be due to the probability that continuous grazing areas with higher grazing intensities have caused the spread of less palatable species. More palatable species could disappear as a result of frequent cattle grazing on highly palatable grass and legume species, whereas less palatable species may spread out as a result of intense competition for sunlight and nutrients [19, 21].

3.2. Effects of Grazing on Selected Features of Herbaceous Species and Dry Matter Yield. The overall dry matter yield of natural pasture in the current study (2.31 $t{\cdot}ha^{-1}$) per single growing season was less than 6 $t{\cdot}ha^{-1}$ for well-managed natural pasture [22], 2.38 $t{\cdot}ha^{-1}$ [6], 4.5 $t{\cdot}ha^{-1}$ [23], and 5.4 $t{\cdot}ha^{-1}$ [24] in lowland Ethiopia. This variation could be caused by the amount of rainfall, the intensity of grazing, climatic conditions, and the condition of the natural pastures. It is possible that the difficulty of plants surviving at higher altitudes due to low temperatures is the cause of the lower biomass production in the highlands [25]. That is, low temperatures slow the decomposition of soil organic matter and the uptake of nutrients by roots [26].

Grazing had an impact on the selected features of herbaceous species (the basal cover, species richness, evenness, and diversity) and dry matter yield [27]. In the current study, the aboveground dry matter yield in grazing exclusion areas and controlled grazing was significantly higher ($P < 0.05$) than in continuous grazing areas (Table 4), which is supported by the findings of [5, 9, 28, 29]. Due to protection from grazing during the growth season, both grazing exclusion areas and controlled grazing areas produced higher aboveground dry matter yields than continuous grazing areas. This led to the recovery of the species, but year-round grazing in the continuous grazing area reduced biomass yields [30]. When compared to controlled-grazing areas, grazing exclusion areas had a higher aboveground dry matter yield. As a result of no cattle grazing, which allowed for the recovery of species and the accumulation of biomass, grazing exclusion areas produced higher aboveground biomass yields [9, 31]. The aboveground dry matter yield of plant communities is impacted by feeding, trampling, and other grazing livestock behaviors, which decrease plant leaf area, lower photosynthetic capacity, and alter forage structures [32].

The continuous grazing areas had significantly ($P < 0.05$) less herbaceous plant basal cover than grazing exclusion areas and controlled grazing areas, which was consistent with the findings of [28, 33–36]. In contrast to grazing exerted on continuous grazing areas, which are vulnerable to grazing and trampling, higher basal cover in the grazing exclusion areas indicated better management and less opportunity for the vegetation to be disturbed. According to [37], grazing pressure has an impact on soil loss and compactness, which has a significant impact on the state of the grazing land. This suggests that a decline in the quality of grazing land in continuous grazing areas has a direct negative impact on livestock production [38].

The findings of this study were consistent with [29, 39], and in that, there was a higher diversity of herbaceous plants in both grazing exclusion areas and controlled grazing areas than in continuous grazing areas. The high species richness and diversity in the grazing exclusion areas may be related to improved soil organic matter, increased litter accumulation, and improved soil nutrients within the grazing exclusion areas [40]. Another study found that the type and distribution of plants were higher in areas where there was no grazing disturbance [41]. However, the lower herbaceous plant diversity and richness in continuous grazing areas were due to indirect pressure on seedling germination and establishment patterns [10, 14, 27, 30, 34, 35].

On the other hand, herbaceous plant species richness and diversity were greater in grazing exclusion areas than in controlled grazing areas. This might be due to the fact that plant species abundance was affected by the length of grazing. The length of time livestock is allowed to graze in a particular grazing area has a significant impact on vegetation variation, which affects the sustainability of the plant community within the site. If grazing rates were high, the overall vegetation pattern would decline [42, 43]. A longer resting period for forage plants as a result of enclosing the natural pasture, which improved seedling germination and forage plant establishment [44, 45], increased species richness and diversity. Furthermore, as reported by [46], frequent grazing sites have less vegetation than less frequent grazing sites, and enclosing natural pastures increases their potential and boosts livestock productivity [47].

3.3. Herbaceous Plant Species Similarity. Figure 2 shows the estimated Czekanowski coefficient similarity index of the herbaceous species in terms of species composition based on species richness. The grazing exclusion areas to controlled grazing areas showed the highest similarity of herbaceous species. The greatest differences in herbaceous

Table 2: The distribution of plant families and their species in three grazing areas.

No	Scientific name	Family	Grazing system		
			Grazing exclusion areas	Controlled grazing	Continuous grazing
1	*Agrostis gracilifolia* CE. Hubb.	Poaceae	P	P	A
2	*Agrostis quinqueseta* (Hochst. ex Steud.) Hochst.	Poaceae	A	A	P
3	*Agrostis quinqueseta* (Hochst. ex Steud.) Hochst.	Poaceae	A	P	P
4	*Alysicarpus quartinianus* A. Rich	Fabaceae	P	A	P
5	*Alysicarpus rugosus* (Willd) DC.	Fabaceae	P	P	A
6	*Andropogon abyssinicus*	Poaceae	P	P	A
7	*Andropogon chrysostachyus* Steud.	Poaceae	A	P	A
8	*Andropogon distachyos*	Poaceae	P	A	A
9	*Andropogon selloanus* (Hack.) Hack	Poaceae	P	A	A
10	*Andropogon* spp.	Poaceae	P	A	A
11	*Anthemis tigreensis* J. Gay ex A. Rich.	Asteraceae	A	A	A
12	*Aristida adoensis* Hochst.	Poaceae	P	A	A
13	*Arthraxon micans* (Nees) Hochst.	Poaceae	P	A	A
14	*Arthraxon prionodes*	Poaceae	P	A	A
15	*Bothriochloa insculpta* (Hochst. ex A. Rich.) A. Camus	Poaceae	A	P	A
16	*Carex steudneri* Bock	Cyperaceae	A	A	P
17	*Centella asiatica* (L.) Urban	Apiaceae	A	P	P
18	*Commelina subula*	Commelinaceae	A	A	P
19	*Crotalaria* species	Fabaceae	A	P	A
20	*Cyanotis barbata*	Commelinaceae	A	A	P
21	*Cynodon dactylon* (L.) Pers.	Cyperaceae	P	P	P
22	*Cyperus dichroostachyus*	Cyperaceae	P	A	A
23	*Cyperus rigidifolius*	Poaceae	A	A	P
24	*Cyperus rotundus*	Cyperaceae	P	A	P
25	*Eleusine floccifolia*	Poaceae	P	P	P
26	*Eragrostis botryoides*	Poaceae	A	P	A
27	*Eragrostis paniciformis* (A. Br.) Steud.	Poaceae	A	P	A
28	*Eragrostis pascua*	Poaceae	A	P	P
29	*Eragrostis patentipilosa*	Poaceae	P	A	A
30	*Eragrostis porosa*	Poaceae	P	P	P
31	*Girardinia diversifolia* (Link) Friis	Urticaceae	A	A	P
32	*Gnaphalium rubriflorum* Hilliard	Asteraceae	P	A	P
33	*Guizotia scabra* (Vis.) Chiov	Asteraceae	A	P	A
34	*Guizotia scabra* (Vis.) Chiov	Asteraceae	P	A	P
35	*Hygrophila schulli*	Acanthaceae	P	A	A
36	*Hyparrhenia anthistirioides*	Poaceae	P	P	A
37	*Hyparrhenia diplandra* (Hack.) Stapf	Poaceae	P	P	A
38	*Hyparrhenia dregeana*	Poaceae	P	A	A
39	*Hyparrhenia rufa* (Nees) Stapf	Poaceae	P	A	A
40	*Medicago polymorpha*	Fabaceae	P	P	A
41	*Osyris quadripartita* Decne	Santalaceae	A	P	P
42	*Panicum coloratum* L.	Poaceae	P	P	A

Table 2: Continued.

No	Scientific name	Family	Grazing system		
			Grazing exclusion areas	Controlled grazing	Continuous grazing
43	*Pennisetum beckeroides*	Poaceae	P	P	P
44	*Pennisetum glabrum*	Poaceae	P	P	P
45	*Pennisetum glaucifolium*	Poaceae	P	A	P
46	*Pennisetum ramosum* (Hochst) Schweinf.	Poaceae	P	A	A
47	*Plantago lanceolata* L.	Plantaginaceae	A	P	A
48	*Poa schimperiana* Hochst. ex A. Rich	Poaceae	A	A	P
49	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	A	P	A
50	*Snowdenia polystachya*	Poaceae	P	A	A
51	*Sporobolus natalensis*	Poaceae	P	P	A
52	*Trifolium acaule*	Fabaceae	A	P	P
53	*Trifolium burchellianum*	Fabaceae	P	P	A
54	*Trifolium campestre*	Fabaceae	P	P	A
55	*Trifolium decorum*	Fabaceae	A	A	P
56	*Trifolium pratense*	Fabaceae	A	P	A
57	*Trifolium repens* L.	Fabaceae	P	P	A
58	*Trifolium rueppellianum*	Fabaceae	P	P	A
59	*Zennia elegans* Jaquin	Asteraceae	A	A	P

A, species absent; P, species present.

Table 3: The percentage distribution of plant families and their species in the three grazing sites.

Plant family	Grazing system			Overall
	Grazing exclusion areas	Controlled grazing	Continuous grazing	
Acanthaceae (%)	2.86	0.00	0.00	1.69
Apiaceae (%)	0.00	3.23	4.17	1.69
Asteraceae (%)	5.71	3.23	12.50	8.47
Commelinaceae (%)	0.00	0.00	8.33	3.39
Cyperaceae (%)	8.57	3.23	12.50	6.78
Fabaceae (%)	20.00	29.03	12.50	18.64
Plantaginaceae (%)	0.00	3.23	0.00	1.69
Poaceae (%)	62.86	54.84	41.67	54.24
Santalaceae (%)	0.00	3.23	4.17	1.69
Urticaceae (%)	0.00	0.00	4.17	1.69
Total (%)	100.00	100.00	100.00	100.0

Table 4: Impacts of grazing on the selected features of herbaceous species and dry matter yield.

Features of herbaceous species	Grazing type			Overall	P value
	Grazing exclusion areas	Controlled grazing	Continuous grazing		
Biomass (t·ha^{-1})	2.75 ± 0.2^{a}	2.41 ± 0.37^{ab}	1.75 ± 0.27^{b}	2.31 ± 0.17	0.023
Basal cover (%)	64.76 ± 1.98^{a}	62.60 ± 3.66^{ab}	55.00 ± 2.18^{b}	60.78 ± 1.87	0.008
Shannon–Weiner diversity index	1.81	1.70	1.68		
Richness	35	31	24		
Evenness	0.87	0.82	0.73		

Means within the same row with different superscript letters differ significantly ($P < 0.05$) among grazing types.

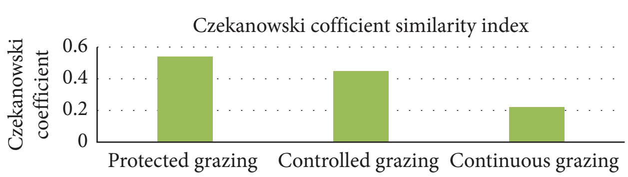

Figure 2: Czekanowski coefficient based on species richness.

species were found between grazing exclusion and continuous grazing types. This difference in similarity was brought about by grazing intensity. The level of disturbance in the species composition between the sites is correlated with the degree of species similarity and difference across grazing systems [48]. This is as a result of the reduction in livestock grazing, which allowed for the recovery of species and the buildup of biomass [9, 27, 34]. The degree to which the species composition of the vegetation samples from the various communities is similar is measured by the concept of species similarity. The degree to which the species composition of the study areas is similar is indicated by the similarity value; as a result, the manipulation of the common species in the study areas depends greatly on the similarity or dissimilarity study of a given grassland community [34, 49].

4. Conclusions

The duration of grazing had an impact on the dry matter yield, basal cover, species richness, evenness, and diversity of herbaceous species. The analysis showed that the dry matter yield in grazing exclusion areas for four years was in good condition, while the dry matter yield in areas that allowed for continuous gazing throughout was the lowest. Dry matter yields in controlled grazing areas were slightly lower compared to those in grazing exclusion areas. As a result, the dry matter yield and the diversity of herbaceous plants were impacted by grazing and resting periods. Therefore, to increase the dry matter yield of the natural pasture and for sustainable livestock production, the livestock producers in the study areas should use a controlled-grazing system. In controlled-grazing systems, there are more palatable plant species than in continuous-grazing areas. This affects the pasture's nutritional value and could eventually increase livestock production.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

Alemu Gashe (Msc), first author, is a Rangeland Ecology and Management Specialist at Debre Markos University in Ethiopia. Dr. Shashie Ayele, second author, often works at Bahir Dar University and has a PhD in Tropical Animal Production Meat Stream and Msc in Rangeland Ecology and Management. The remaining three authors ranked third. Workinesh Tiruneh (assistant professor, Msc) and Mesganaw Addis (assistant professor, Msc) are Animal Production Specialists at Debre Markos University in Ethiopia. Berhanu Alemu (associate professor) holds a PhD in Animal Nutrition and works at Debre Markos University in Ethiopia.

Authors' Contributions

Alemu Gashe Desta proposed the study; collected, analyzed, and interpreted the data; and wrote the manuscript. Shashie Ayele Yimenu proposed the study, collected the data, and gave valuable comments. Workinesh Tiruneh, Mesganaw Addis, and Berhanu Alemu collected the data.

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