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Research Article

Assessment of farmers' perception and forage species diversity of grazing lands in area enclosures and non-enclosures in the Highlands of Ethiopia

Hirut Ketemaw[1, 2]*, *Bimrew Asmare*[2], *Yeshambel Mekuriaw*[2]

[1]Department of Animal Science, Debre Tabor University, P.O. Box 272, Debre Tabor, Ethiopia,
[2]Department of Animal Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, P.O. Box 5501, Bahir Dar, Ethiopia
***Corresponding author:** hirutketemaw23@gmail.com

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Abstract: *The objective of this study was to assess farmers' perception and forage species composition of area enclosures and free grazing lands in Farta District, Ethiopia. The study area was classified into three altitudinal zones, and within each altitude, one kebele was purposively selected. A total of 150 households (40 in the mid-altitude, 60 in the high altitude, and 50 in the very high altitude) were randomly selected and interviewed. For the assessment of species composition, richness, diversity, and evenness of forages, three area enclosures and one free grazing land were purposively selected. Within each site, five 1 m × 1 m (a total of 60) quadrats were established. Data from farmers' perceptions were analysed using SPSS, version 23. Forage species composition data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS (2002) version 9.0. Of the respondents, 60% in the mid-altitude, 96.27% in the high altitude, and 54% in the very high altitude areas reported that the establishment of area enclosures in the communal grazing lands is a very important and effective land management option. Overall, the majority (72.7%) of the respondents had a positive attitude towards the availability of better quality and more abundant feed sources for their livestock. The main benefit identified by all respondents (100%) of the three sites in the area enclosures is that they can harvest feed for animal and help them to follow a feeding system such as cut and carry system and making hay. The forage diversity assessment showed that a total of 18 (28.6%), 10 (15.9%), 29 (46%), and 6 (9.5%) grass, legume, forb, and sedge species, respectively, and 15 woody species were identified in the study area. Of the total herbaceous species,according to respondents, 22.2, 19.0, 39.7, and 19.0% were classed as highly palatable, palatable, less palatable, and unpalatable, respectively. The highest species richness (22.75) at very high altitude and diversity (2.26) and evenness (0.82) in mid-altitude were recorded in the area enclosures. Overall, it can be concluded that the establishment of area enclosures provides socioeconomic and environmental benefits, including better availability of grass for animal feed, improved forage composition, control of soil erosion, and increased productivity of adjacent farmlands.*

Keywords: Herbaceous species, Livestock feed, Palatability, Species richness
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1. Introduction

Ethiopia has the largest livestock population in Africa and is an essential component of the overall farming system; the contribution of livestock amounts to approximately 17% of total GDP and 39% of agricultural GDP (Shapiro et al., 2017). Livestock rearing in Ethiopia not only contributes to economic development but also provides livestock products and by-products like meat, milk, eggs, cheese, and butter, which provide a nutritious diet (CSA, 2018). Furthermore, livestock are used as draft power for crop cultivation and threshing and as a means of transport (CSA, 2017). Manure is also an important resource coming from the livestock industry and could be used as organic fertiliser for crop production (Abule et al., 2017) and pasture improvement (Gezahagn et al., 2016). Nevertheless, the productivity of animals remains low due to feed shortages in terms of quantity and quality, limited knowledge, poor genetic potential of indigenous animals, disease and parasites, land shortage, and shortage of water (Selamawit et al., 2017; Getahun and Tegene, 2018). Among these constraints, lack of feed, both in quality and in quantity, is one of the major constraints to livestock productivity (Alemayehu et al., 2017).

The available grazing lands are overgrazed and unproductive due to continuous heavy grazing and mismanagement of grazing lands, leading to low dry matter yield, which results in a critical shortage of animal feed, below the maintenance requirements of livestock throughout the year (Endale et al., 2016). Overgrazing of the natural pasture and poor pasture management also cause low botanical composition and low nutritive value of natural pastures (Gezahagn et al., 2016). Furthermore, because of mismanagement, natural pastures are having gullies, which cause land shrinkage. Continuous grazing would aggravate the deterioration of palatable species and promote the growth of unpalatable species (Yoseph et al., 2017). Hence, the natural pastures in Ethiopia demand intervention, like an area enclosure strategy to allow the available grazing land to be rehabilitated and used for the intended purpose.

Area enclosure is an effective pasture management strategy in Ethiopia used to restore degraded lands, increase pasture availability, and enhance biodiversity by restricting grazing for a period, allowing vegetation to recover. Enclosure land management is a recommended strategy for rehabilitating and restoring herbaceous species in the Ethiopian highlands (Debeko et al., 2024). Studies by Ibrahim (2016) and Gebremedhn et al. (2023) indicate that area enclosures have a significant role in restoring plant species composition, cover of herbaceous species, greater herbaceous species richness, abundance of desirable species, and higher biomass in comparison to open grazing and browsing management sites, which implies pasture restoration and improved livestock feed resources. This arises from slight disturbance by grazing livestock in the area (Mengistu et al., 2015). The higher abundance of species in light- to moderate-grazing areas reflects the effect of heavy grazing on individual species (Ayana, 2014). Beyond ecological benefits, area enclosure also improves the livelihood of the local community by providing animal feed, fodder, beekeeping activity, and other non-wood forest products (Abdo and Muluye, 2022).

In the Farta district, an innovative local practice of area enclosure on communal grazing land has been introduced to address feed shortages and grazing land degradation. However, there is limited information regarding farmers' perceptions of area enclosure and the diversity of forage speciesfound in both enclosed and non-enclosed grazing lands. Such information is crucial for designing development strategies, research plans, and intervention options for livestock production and natural resource management. Therefore, this study was conducted to assess farmers' perception and forage species composition of area enclosures and free grazing lands in Farta district, Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The study was conducted in Farta district (Fig. 1), located in the Ethiopian highlands between 11°51′N latitude and 38°17′E longitude. The agro-ecological conditions of the district are characterised by 56% midland, 42.5% highland, and 1.5% extreme highland (wurch). The altitude ranges from 1,920 to

4,135 m.a.s.l., with temperatures varying between 9°C and 25°C and an average annual rainfall of 1,250 mm. The total area of the district is 11,788 ha, of which 11,567 ha is grazing land. The estimated livestock population consists of 168,307 cattle, 80,792 sheep, 32,667 goats, 28,849 equines, and 186,861 poultry (FDoA, 2016).

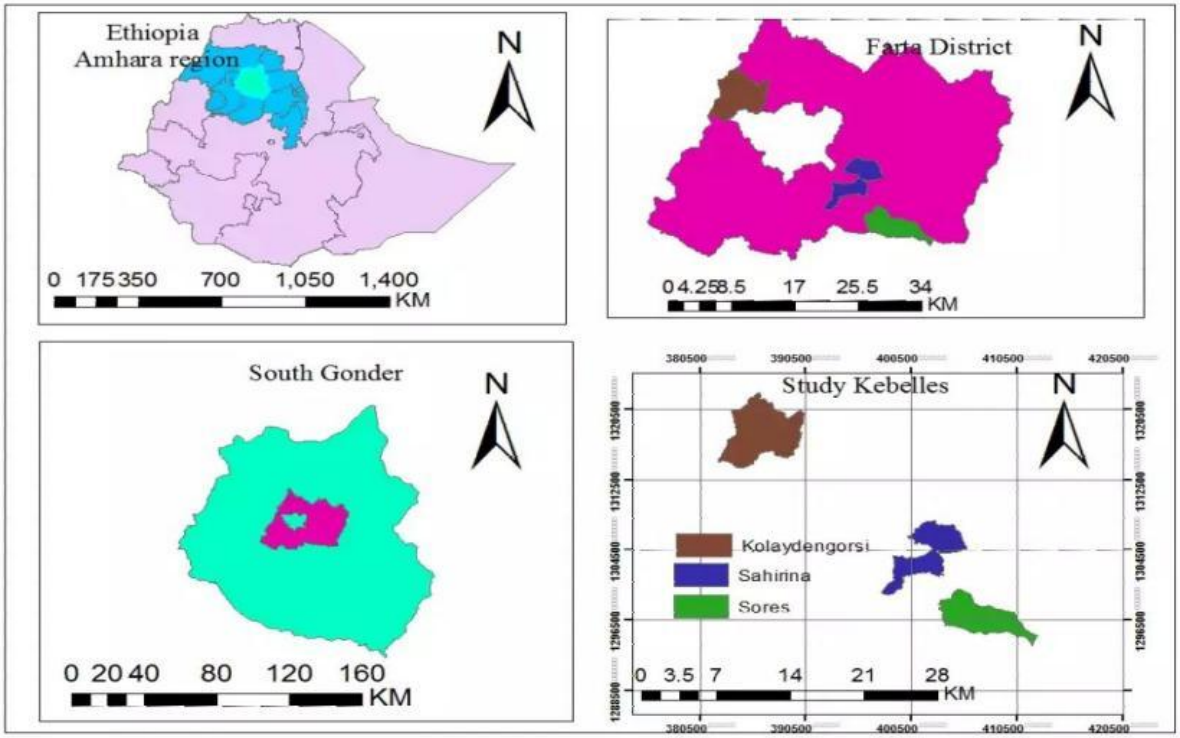

Figure 1: Map of the study area
Source: Own computation using Ethiopia's GIS map (2020)

2.2. Sampling procedures

The study area was classified into three altitudinal zones (the mid-altitude, the high altitude, and the very high altitude), and within each altitude, one kebele was purposively selected. For the assessment of species composition, richness, diversity, and evenness of forages, three area enclosures and one free grazing land were purposively selected. Within each site, five 1 m × 1 m (a total of 60) quadrats were established. Sample collections were conducted from the beginning to the end of September 2018, when all pasture plants are expected to be fully grown and at the flowering stage of most herbaceous species to be easily identified (Gebrekiros and Tessema, 2018).

2.3. Data Collection Method

2.3.1. Assessment of farmers' perception of area enclosures

To assess farmers' perception, observation and a semi-structured questionnaire were employed to collect information related to households' perception of the role of area enclosures. In the focus group discussion, five participants in each altitude took part, including (three communal grazing land committee, one forage expert and one Kebele leader) are participated. A total of 150 households (40 in the mid-altitude, 60 in the high altitude, and 50 in the very high altitude) were selected randomly for interview by using the Yamane (1967) formula:

$$n = \frac{N}{1+N(e^2)} = \frac{30354}{1+30354(0.08^2)} = 150; \; ni = n\frac{Ni}{N}$$
;

Where: - i = mid-altitude, high altitude, and very high altitudes
n = sample size,
N = the total households in the study area and
e = the level of precision (0.08)

The total sample size of the study that was taken from the proportion of the sample household in each altitude is given as follows (Table 1).

Table 1. The proportion of the sample household in each altitude

Altitudes	Total household	Proportion	Sampled household
Mid-altitude	3305	27	40
High altitude	4951	33	60
Very high altitudes	4121	40	50
Total	12377	100	150

2.4. Species composition, richness, diversity, evenness, and ground cover of pastureland

Herbaceous species composition is the relative contribution of individuals on the site and was calculated using relative density as described by Jim Baxter (2014). Density is estimated by quantifying the number of individuals of a species per unit area.

$$\text{Relative density } (RDi) = \frac{\text{Numbers of individuals of a species}}{Numbers\ of\ individuals\ of\ all\ species} X\ 100$$

Each species was identified and recorded in the field by asking purposively selected knowledgeable local farmers. Nomenclature follows that of the published volumes of Honeybee Flora of Ethiopia (Reinhard and Admasu, 1994) and Flora of Ethiopia and Eritrea (Phillips, 1995; Edwards et al., 1997; Mesfin, 2004; Azene, 2007). The herbaceous species within each quadrat were classified into grasses, legumes, sedges, and forbs to determine the contribution of each group in the quadrat (ILCA, 1990). The palatability of each species was also recorded based on interviews with herders. Species diversity and evenness were computed using the Shannon-Wiener index (Shannon, 1948). Species richness was defined as the number of species per site (Hoare, 2009). To determine species richness, all vascular species were counted from five quadrats in each free- grazing and area enclosure (Mengistu et al., 2013). Evenness is a measure of the abundance of the different species that make up the richness of the area.

Ground cover is expressed in terms of the percentage of ground surface covered by vegetation (Elzinga et al., 1998). Ground cover of pasture is estimated by visualising a square 1 × 1 m quadrat, looking vertically into the pasture, and estimating the percentage of the area that is covered by grass and herbaceous species (Des Lang and McDonald, 2005).

The Shannon-Wiener diversity index and evenness were calculated as follows:

$$H` = -\sum_{i=1}^{s} \text{pi} \ln pi$$

$$J` = \frac{H`}{lnS}$$

Where H’ = Shannon diversity index
J = Equitability/Evenness
S = the number of species
Pi = the abundance of the ith species expressed as a proportion of total cover
ln = log base n

2.5. Data analysis

Farmers’ perception data were summarised using the statistical package for social sciences (SPSS, 2015) version 23. The data obtained from the vegetation variables were subjected to ANOVA using the GLM procedure of Statistical Analytical System (SAS, 2002) version 9. Duncan’s Multiple Range Test was used for mean comparison. Descriptive statistics such as mean, frequency, percentage, and standard error of mean were used. The livestock feed resource and major livestock constraints were analysed and summarised by an index method. The index was computed with the principle of weighted average according to the following formula as employed by Musa et al. (2006):

Index = Rn*C1+Rn-1*C2…R1*Cn/∑ Rn*C1+Rn-1*C2…R1

Where Rn is the value given for the least ranked level (example: if the least rank is 5th rank, then Rn=5, Rn-1=4, and … R1=1).

Cn: Counts of the least ranked level (in the above example, the count of the 5th rank = Cn, and the count of the 1st rank = C1).

The following statistical model was used for data analysis.

$$Y_{ijk} = \mu + A_i + G_j + (AG)_{ij} + E_{ijk}$$

Where Yijk = the observed k variable in the ith altitudinal range and jth grazing land use type.

μ = Overall mean
Ai = effect due to the ith altitudinal ranges (2000-2500, 2500-3000, and >3000 m.a.s.l.)
Gj = effects due to jth grazing land use types (free grazing and area enclosure)
(AG)ij = Interaction effect of the ith altitudinal range and the jth grazing land use type
Eijk = Random error
.

3. Results and Discussion

3.1. Household characteristics of the respondents

The household characteristics of respondents in the study area are shown below in Table 1. The mean ages of the respondents in the study area were 47.60, 48.12, and 47.92 years in mid-altitude, high altitude, and very high altitude areas, respectively, with an overall average age of 47.91 years. This was comparable with the report of Lema et al. (2018), who reported those ages as 48.5, 47.5, and 49.8 years for the same district, respectively. The family sizes of the respondents in the current study were 5.18, 4.58, and 5.56 at mid-altitude, high altitude, and very high altitude, respectively, with an overall average of 5.07 family members in the household. The result was lower than the report by Bimrew and Zemenu (2018), with an overall mean family size of 6.55 persons in the Fogera district. The majority of respondents in the mid-altitude (37%) were able to read and write, followed by illiterate (30%), and respondents who attended primary schools were 28%.

At the high altitude, illiterate respondents held the largest proportion (38%), followed by those who could read and write (37%), and at the very high altitude of the study area, the majority of respondents were able to read and write (42%), followed by the illiterate (38%). Of the total respondents in the study area, the majority of the respondents were able to read and write (38%), followed by illiterate (36%). Whereas the remaining 22%, 3%, and 1% attended primary school, secondary school, and religious education, respectively. The finding indicated that the majority of the respondents (64%) were literate in the current study area. The report of illiterate households (36%) in the current finding was lower than the report of Menberu and Addisu (2018), who reported that the majority of 39.5% of household heads were illiterate, and Solomon et al. (2019), who reported that the majority of the respondents were illiterate (64%) in Ethiopia. This relatively higher literate class has positive implications for better technological adoption of grazing land management, such as pastureland enclosure and controlled grazing practices. In fact, the educational level of farmers is assumed to increase the ability to obtain the process of using agricultural-related information and use technologies in a better way, as reported by Yikaaly (2015).

Table 2: Household characteristics of respondents (n=150)

Characteristics of respondents	Altitudes				
	Mid-altitude	High altitude	Very high altitude	Overall	P-value
	N=40 Mean ± SE	N=60 Mean ± SE	N=50 Mean ± SE	N=150 Mean ± SE	
Age	47.60±1.73	48.12±1.25	47.92±1.46	47.91±0.83	0.97
family size	5.18±0.25^{ab}	4.58±0.24^{b}	5.56±0.17^{a}	5.07±0.13	0.007
Education level					
Illiterate	12(30)	23(38)	19(38)	54(36)	
Read and write	15(37)	22(37)	21(42)	58(38)	
Primary	11(28)	12(20)	10(20)	33(22)	

Secondary	2(5)	2(3)	0(0)	4(3)
Preparatory and above	0(0)	1(2)	0(0)	1(1)
Total	40(100)	60(100)	50(100)	150(100)

Note: [a] and [b] mean in a row with the same category having different superscripts differ (P<0.05); Note: N: Number of respondents; figures in brackets indicate the percentage of respondents, and SE = standard error of the mean.

3.2. Landholding and land use patterns of respondents

The landholdings of respondent households in the study area are shown below in Table 3. The average landholding per household was 0.74 ha, of which 0.65 ha was allocated for crop cultivation, while 0.07 ha and 0.002 ha were allocated for private grazing land and homestead gardening, respectively. The overall landholding size was comparable with the report of Bimrew (2018), who found an average of 0.73 ha.

However, the current result was lower than the 1.26 ha per household reported by Solomon et al. (2019). The average size of private grazing landholding in this study was very small compared with the findings of Shewangzaw et al. (2018), who reported a mean size of 0.30 ± 0.60 ha. This indicates that a shortage of grazing land could be one of the factors contributing to feed scarcity in the study area. Across altitudes, the average landholding per household in the mid-altitude area was larger (0.88 ha) than in the high-altitude (0.72 ha) and very high-altitude (0.64 ha) areas. In addition, land in the very-high-altitude areas is more undulating and mountainous, making it prone to degradation and unsuitable for agricultural activities. The current finding agrees with Solomon et al. (2019), who also reported that mid-altitude households had larger landholdings than those at high altitudes, mainly due to population pressure and the mountainous terrain in the highlands. Overall, the landholding size of households across all altitudes in the study area was lower than the national average of 1.1 ha per household reported by FAO (2022) for Ethiopia. This limited landholding size may negatively affect livestock production and productivity due to feed shortages.

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Table 3: The landholding per household and land use characteristics of respondents

	Altitudes				
Landholding (ha)	Mid Altitude N=40 Mean ± SE	High Altitude N=60 Mean ± SE	Very high Altitude N=50 Mean ± SE	Total N=150 Mean ± SE	P-value
Total landholding size	0.88±0.07a	0.72±0.05[ab]	0.64±0.07 [b]	0.74±0.04	0.044
Farm land	0.81± 0.06 [a]	0.62±0.05 [b]	0.57±0.06 [b]	0.65±0.03	0.012
Private grazing land	0.07±0.02	0.07±0.01	0.07±0.01	0.07±0.01	0.963
Homestead gardening	0	0	0.01±0.001	0.002±0.001	0.133

Note: [a] and [b] mean in a row with the same category having different superscripts differ (P<0.05); ha = hectare, N = number of respondents, and SE = standard error of the mean.

3.3. Livestock holding of respondents

The overall livestock holding in tropical livestock units (TLU) per household in the study area is shown below in Table 4. The overall mean of livestock holding per household in the study area was 3.0 TLU, of which 2.01, 0.21, 0.03, 0.73, and 0.04 TLU per household were cattle, sheep, goats, equines, and poultry, respectively.

The total livestock holding in this study was comparable with the reports of Addisu et al. (2016), which showed cattle, sheep, goats, and equines at 2.48, 0.12, 0.10, and 0.2, respectively, in Ethiopia. However, the result was lower than the value of 5.8 TLU/hh reported by Solomon et al. (2019). Cattle are the predominant livestock species reared in the study area. The finding was in agreement with the results of Lemma et al. (2018), who reported that cattle are the predominant livestock species kept in the area due to multipurpose animals. Farmers are used as drought power, provide products with milk and meat drought power, and provide products with milk and meat

The livestock holding at the mid-altitude of 3.86 TLU/hh was significantly higher (p<0.05) than that of high-altitude (2.7) and very high-altitude areas (2.68 TLU/hh), which might be due to better landholding per household in the mid-altitude as compared to the high- and very high-altitude areas of the study area. This might be due to the fact that the mid-altitude of the study area, which has higher livestock per household due to higher farmland size, uses the production of crop residues and fallow land, which satisfies the larger population. The cattle holding of the respondent in the mid-altitude was higher (3.11 TLU/hh), followed by the high altitude (2.03) and the very high altitude (1.09 TLU) of the study area. The mean equine holding of household heads in the very high altitude area was higher (1.28 TLU) than the mid-altitude (0.5 TLU) and the high altitude (0.41 TLU) areas of the study area.

Table 4: Average tropical livestock unit (TLU) holding per household

Variables	Altitudes Mid-Altitude N=40 Mean± SE	High Altitude N=60 Mean ± SE	Very high Altitude N=50 Mean ± SE	Total N=150 Mean ± SE	CF	P-value
Cattle	3.11±0.21^{a}	2.03± 0.14^{b}	1.09±0.04^{c}	2.01 ±0.10	0.7	<0.0001
Sheep	0.15±0.04^{b}	0.18±0.02^{b}	0.28±0.04^{a}	0.21 ±0.02	0.1	0.023
Goat	0.05±0.02	0.03±0.02	.00	0.03 ±0.01	0.1	0.1904
Equine	0.5±0.07^{b}	0.41±0.07^{c}	1.28±0.13^{a}	0.73±0.06	0.8	<0.0001
Poultry	0.06±0.006^{a}	0.05±0.004^{a}	0.02±0.002^{b}	0.04±0.003	0.01	<0.0001
Overall	3.86±0.28^{a}	2.7±0.16^{b}	2.68±0.14^{b}	3.00±0.12		<0.0001

Note: ^{a,} and ^{b,} mean in a row with the same category having different superscripts differ (P<0.05); CF= conversion factor, N = number of respondents, TLU=Tropical livestock unit (ILCA, 1990), SE= standard error.

3.4. Livestock feed resources

The major livestock feed resources in both the wet and dry seasons of the study area are presented in Table 5. The common livestock feed resources of the study area include green fodder grazing (like weed and green grass), crop residues, hay, improved forage, fallow land, and byproducts. Grazing had the first index value of the feed resource, especially in the wet season, followed by crop residues. However, crop residues and hay were reported to be the major sources of feed during the dry season. While the contribution of improved forage, fallow land, and byproducts were very small. Thus, green fodder/grazing, crop residues, and hay were the major feed resources of the study areas, which is consistent with previous reports (Kassahun et al. 2015; Endale et al. 2016; and Muluken et al. 2018).

Table 5: Ranking index of livestock feed resources in wet and dry seasons

	Altitudes								
	Mid			High			Very high		
Feed source and season	Wt.	I	R	Wt.	I	R	Wt.	I	R
Wet Season									
Green fodder/grazing	178	0.58	1	216	0.3	1	229	0.44	1
Crop residue	90	0.29	2	199	0.28	2	209	0.4	2
Hay	0	0	5	119	0.17	3	6	0.01	5
Improved forage	0	0	5	31	0.04	4	0	0	6
Fallow land	0	0	5	7	0.01	5	27	0.05	4
By-products	6	0.02	4	69	0.1	5	0	0	6
Other homemade feed	32	0.11	3	71	0.1	5	48	0.09	3
Dry season									
Green fodder/grazing	40	0.11	3	111	0.16	3	199	0.37	2
Crop residue	171	0.45	1	201	0.29	2	231	0.43	1
Hay	110	0.29	2	204	0.3	1	11	0.02	7
Improved feed	0	0	7	24	0.04	7	12	0.03	5
Fallow land	10	0.03	6	35	0.05	6	53	0.1	3
Byproducts	18	0.05	5	47	0.07	5	12	0.03	5
Other house made feed	28	0.07	4	59	0.09	4	25	0.05	4

Where: -Wt. = Weight, I = Index, and R = Rank

3.5. Grazing land use practice

Grazing land use practices of respondents during the wet season and dry season in the study area are shown in Table 6. In the mid-altitude, the majority of the respondents (77.5 and 85%) used free grazing during the wet and dry seasons, respectively. About 15 and 12.5% of the respondents used a cut and carry feeding system during the wet and dry seasons, respectively, and the remaining 7.5 and 2.5% of respondents used both free grazing and a cut and carry feeding system during the wet and dry seasons, respectively.

At high altitude, the majority of the respondents (62 and 60%) used a cut-and-carry system during the wet and dry seasons, respectively. About 19% and 15% of the respondents at high altitude used a control grazing system during the wet and dry seasons, respectively. About 11.7 and 16.7% of respondents used both free grazing and cut-and-carry feeding systems during the wet and dry seasons, respectively, and only 5% and 8.33% of the respondents used the free grazing system during the wet and dry seasons, respectively, in mid-altitude.

Table 6: Grazing land use practice of respondents during wet season and dry season

Grazing land use type	Altitudes			Overall
	Mid altitude (N=40)	High altitude (N=60)	Very high altitude (N=50)	
Wet season				
Free grazing (Fg)	31(77.5)	3(5)	14(28.0)	48(32)
Control grazing (Cg)	0	11(18)	0	11(7.33)
Cut and carry(CC)	6(15)	37(62)	5(10)	48(32)
Both CC and Fg	3(7.5)	7(11.7)	31(62.0)	41(27.33)
All (Fg, Cg and CC)	0	2(3.3)	0	2(1.34)
Total	40(100)	60(100)	50(100)	150(100)
Dry season				
Free grazing (Fg)	34(85)	5(8.33)	22(44.0)	61(41)
Control grazing (Cg)	0	9(15)	0	9(6)
Cut and carry(CC)	5(12.5)	36(60)	7(14.0)	48(32)
Both CC and Fg	1(2.5)	10(16.67)	21(42.0)	32(21)
Total	40(100)	50(100)	60(100)	150(100)

Where:- N is the number of respondents, and figures in brackets indicate the percentage of respondents, CC = cut and carry, Cg = control grazing and Fg = free grazing.

The cut and carry system was better practiced at high altitude than at mid-altitude and very high altitude. At very high altitudes, about 62 and 42% of respondents were using both free grazing and a cut-and-carry system during the wet and dry seasons, respectively. About 28 and 44% of the respondents used the free grazing system during the wet and dry seasons, respectively, and only 10 and 14% of respondents used the cut and carry system during the wet and dry seasons, respectively, in the high-altitude area.

Grazing land use practice in the study area: about 32 and 41% of the respondents used free grazing during the wet and dry seasons, respectively. Equal proportions (32%) of the respondents used a cut and carry system during the wet and dry seasons while 27.33 and 21% of the respondents used both cut and carry and free grazing systems during the wet and dry seasons, respectively. The remaining 1.34 and 6% of respondents used a control grazing system during the wet and dry seasons, respectively, in the study area.

3.6. Constraints of livestock production

The major livestock production constraints in the study area are presented in Table 7. The major constraints reported at different altitudes of the study area were shortages of feed, disease and parasites, water scarcity, and labour shortage. In the mid-altitude and very high altitude, shortage of feeding, disease, and parasites were the 1st and 2nd ranks, respectively. On the other hand, in high-altitude areas, shortages of feed and lack of money were the 1st and 2nd ranked constraints affecting livestock production, respectively. In general, the results show that the first-rank constraint of livestock production in the study area was shortage of feed. The results of the study showed that a shortage of feed is occurring due to the increase in the human population. As a result, the benefits obtained from communal grazing lands and area enclosures have decreased. The finding was in line with earlier findings by Getahun and Tegene (2018) and Selamawit et al. (2017).

Table 7: Ranking of Livestock Production Constraints Respondents

Constraints	Altitudes											
	Mid altitude			High altitude			Very high altitude			Overall		
	Wt.	I	R	Wt.	I	R	Wt.	I	R	Wt.	I	R
Feed shortage	85	0.51	1	225	0.84	1	195	0.74	1	505	0.74	1
Disease and parasites	40	0.24	2	5	0.02	5	36	0.14	2	81	0.12	2
Water Scarcity	6	0.04	5	8	0.03	4	9	0.03	4	23	0.03	5
Labor shortage	8	0.05	4	12	0.04	3	6	0.02	5	26	0.04	4
Lack of money	27	0.16	3	18	0.07	2	16	0.06	3	49	0.07	3

Where: I = Index and R = Rank, Wt. = Weight

3.7. Farmers' perception on area enclosures and utilization practices of area enclosures

Farmers' perceptions of the establishment of area enclosure in their locality are shown in Table 8. About 60%, 96.27%, and 54% of the respondents in the mid-altitude, high-altitude, and very-high-altitude areas, respectively, said that area enclosure establishment in the communal grazing land was a very important and effective land management option. The current finding was supported by Mengistu and Mekuria (2015).

The majority (72.7%) of respondents had a positive attitude towards the availability of better quality and quantity of feed sources for their livestock production. However, 27.3% of the respondents were concerned that area enclosures cause a shortage of communal grazing area, leading to a reduced number of livestock holdings. The respondents also believed that the height of vegetation in the enclosed area is very short due to the air conditioning being cool. Due to this, they did not benefit from area closures. About 81.3% of the respondents said that they have seen many changes, such as regeneration of grass and herbaceous legumes like Andropogon abyssinicus, Cynodon dactylon, Eleusine floccifolia, Hyparrhenia rufa, Pennisetum macrourum, and Sporobolus africanus; increased stream flow; decreased run-off; reduction of soil erosion; and increased DMY. About 58.7, 38.0, and 3.3% of respondents revealed that area enclosure productivity was very high, high, and moderate in terms of DMY, species composition, and palatability compared to free grazing lands. The majority of respondents (64.7%) have a willingness to use the rest of the communal free grazing lands to establish additional area enclosures, while 35.3% were disinclined to turn the rest of the communal free grazing lands into additional area enclosures because of the absence of private grazing lands for recreation of their animals. The current result was supported by the findings of Ayana (2014), who described an increase in the natural regeneration of grasses, herbs, and trees, as well as an increase in plant biodiversity, as the major positive changes observed after the establishment of area enclosures.Similarly, regeneration of grasses and a reduction of soil erosion (Yosef et al., 2015); an increase in ground cover and biomass production of grasses, herbs, and trees; and positive environmental implications for enclosures (Ayana, 2016).

Table 8: Farmers' perceptions on the establishment of area enclosure in their locality

Farmers' perceptions	Altitudes			
	Mid Altitude	high Altitude	Very high Altitudes	Overall
Is AE establishment important				
Yes	24(60)	58(96.7)	27(54)	109(72.7)
No	16(40)	2(3.3)	23(46)	41(27.3)
Changes observed				
Yes	30(75)	56(93.3)	36(72)	122(81.3)
No	10(25)	4(6.7)	14(28)	28(18.7)
Willingness				
Yes	29(72.5)	44(73.3)	24(48)	97(64.7)
No	11(27.5)	16(26.7)	26(52)	53(35.3)
LS holding per hh				
Increased	16(40)	27(45)	16(32)	59(39.3)
Decreased	11(27.5)	33(55)	32(64)	76(50.7)
Constant	13(32.5)	0	2(4)	15(10)
LS productivity per head				
Increased	29(72.5)	41(68.3)	33(66)	103(68.7)
Decreased	2(5)	7(11.7)	6(12)	15(10)
Constant	9(22.5)	12(20)	11(22)	32(21.3)
Change in AE				
Very high	29(72.5)	37(61.7)	22(44)	88(58.7)
High	10(25)	21(35)	26(52)	57(38)
Moderate	1(2.5)	2(3.3)	2(4)	5(3.3)

Where: - Note: N: Number of respondents, and figures in brackets indicate the percentage of respondents. AE = Area enclosure, Change = Change of area enclosure in terms of ground cover and species composition, hh= household, LS = livestock, and Willingness = Willingness of respondents to establish further area enclosure in the future

3.8. Contribution of area enclosures to local livelihood improvement

The contributions of area enclosures as perceived by respondents are shown in table 9. The first benefit identified by all respondents (100%) in all study sites in the area enclosures is the harvesting of animal feed in the form of a cut and carry system and making hay. In addition to the harvest of livestock feed, 20%, 15%, and 13% of respondents perceive that bee flora, fuel wood, traditional medicinal plants, and human food, respectively, were other products of the area enclosures. This study result was in agreement with the findings of Abera et al. (2016), who stated that the availability in the area for livestock, notably for oxen used for plowing ploughing, has significantly increased following the establishment of area enclosures.

Table 9: Natural products obtained from the area enclosures

Products obtained from the area enclosed		Altitudes			
		Mid-altitude (N=40)	High altitude (N=60)	Very high altitude (N=50)	Overall
Source of animal feed	Yes	40(100)	60(100)	50(100)	150(100)
	No	0	0	0	0
Bee flora	Yes	13(32)	17(28)	0	30(20)
	No	27(68)	43(72)	50(100)	120(80)
Fuel wood	Yes	8(20)	15(25)	0	23(15)
	No	32(80)	45(75)	50(100)	127(85)
Traditional medicinal plants	Yes	7(18)	6(10)	4(8)	17(13)
	No	33(82)	54(90)	46(92)	113(87)
Human food	Yes	0	0	8(16)	8(5)
	No	40(100)	60(100)	42(84)	142(95)

Note: N is the number of respondents, and figures in brackets indicate the percentage of respondents

3.9. Management and utilization practices of area enclosures

The management practices of area enclosures in the study area are listed in table 10. According to the information obtained from the group discussions and respondents, in all altitudes of the study area, the primary responsibilities for managing area enclosures were the communities. Area enclosure management practices employed in the study area included fencing (100%) at all altitudes; weeding (70%), (73.3%), and (56%) at mid-altitude, high altitude, and very high altitudes, respectively; introducing improved forage species (47.5%) and (41.7%) in mid-altitude and high altitude, respectively; and applying fertilizer (22.5%) and (21.7%) of respondents in mid-altitude and high altitudes, respectively.

Table 10: Area enclosure management and utilization practices applied by respondents

Management practice	Altitudes			
	Mid-Altitude (N=40)	High Altitude (N=60)	Very high Altitude (N=50)	Total (N=150)
Primarily responsible to protect AE				
Community	40(100)	60(100)	50(100)	150(100)
Government	0(0)	0(0)	0(0)	0(0)
Fencing	40(100)	60(100)	50(100)	150(100)
Apply fertilizer				
Yes	9(22.5)	13(21.7)	0(0)	22(14.7)
No	31(77.5)	47(78.3)	50(100)	128(85.3)
Introducing improved forage species				
Yes	19(47.5)	25(41.7)	0(0)	44(29.3)
No	21(52.5)	35(58.3)	50(100)	106(70.7)
Weeding				
Yes	28(70.0)	44(73.3)	28(56.0)	100(66.7)
No	12(30.0)	16(26.7)	22(44.0)	50(33.3)
Form of utilization				
Cut and carry	40(100)	60(100)	33(66)	133(88.7)

Seasonal grazing	0	0	17(34)	17(11.3)

Note:N is the number of respondents, and figures in brackets indicate the percentage of respondents.

As shown above in Table 10, the utilisation practices applied to area enclosures for sources of animal feed in the study area are cut and carry and direct grazing. In the mid-altitude and high-altitude areas, the common area enclosure utilisation practice was a cut-and-carry system, with a frequency of once to twice per year (using fresh fodder and making hay harvesting from the end of November to mid-December for dry seasons), depending on the growth of the forages. The results of the study showed that hay is harvested at a late stage of maturity from the end of November to mid-December, when farmers are free after they collect their crops. This was due to a lack of awareness of the appropriate time of hay harvesting. The utilisation system using cut and carry and direct grazing was in agreement with the findings of Mengistu and Mekuria (2015), who reported that the cut and carry mode of using grass is an activity allowed in enclosures. Similarly, Wolde et al. (2015) reported that grass harvesting using a cut and carry system was the only activity allowed in area enclosures. Farmers were not allowed to graze their livestock inside the enclosures and harvest grass using the cut-and-carry system (Tesfay, 2016). Introducing improved forage species and applying fertilizer are not practices in very high-altitude areas of the study sites. This was due to a lack of awareness and a lack of money, respondents said. In general, fencing, applying fertilizer, weeding, and sowing of forage seed were the major management practices of area enclosures in the study area. The management practices of area enclosures in the study area were in agreement with the report of Yoseph et al. (2017), who reported that fencing, applying fertiliser, and weeding were management practices of grazing land.

In very high-altitude areas, the majority of the respondents (88.7%) used a cut-and-carry feeding system, and the rest (11.3%) used direct animals that were allowed to graze in the area enclosure at a frequency of two times/year at the beginning of one month (June) and the end of one month (October) of the rainy season. This direct grazing system was due to the height of the forage in that area being short and difficult to harvest in the form of a cut and carry system. In some cases, the enclosures are also used for seasonal grazing (Mohammed et al., 2017).

3.10. Forage species composition of natural pasture lands

3.10.1. Botanical composition of forages

A total of 63 herbaceous species from 12 families were recorded in the free grazing areas and the enclosure areas at all altitudes of the study area. From available species, the components of grass, legumes, forbs, and sedge were 18 (28.6%), 10 (15.9%), 29 (46%), and 6 (9.5%), respectively. Out of these 18 grass species, 9 (50%) were identified as annual species, whereas 9 (50%) were perennial grass species. Based on the palatability to livestock identified by the perceptions of experienced local farmers of the total herbaceous species, 22.2%, 19%, 39.7%, and 19% were classed as highly palatable, palatable, less palatable, and unpalatable, respectively.

The results of relative density analysis showed that there was a difference in the dominance of herbaceous vegetation composition between the altitude ranges and grazing land use types, dependent on environmental characters and the management or grazing system of the site. This was in agreement with Usman et al. (2016) in West Arsizone, Ethiopia. The family composition of herbaceous species revealed that 12 families were recorded in the study area. Poaceae, Asteraceae, Fabaceae, Costaceae, and Cyperaceae were the most dominant families.

3.10.2. Botanical composition of woody species

As shown in Table 11, a total of 15 woody species representing 12 families were identified in the area enclosures in the mid-altitude and the high altitude of the study area. Of the species recorded, 12 were indigenous, which were identified in the mid-altitude enclosure areas, and three species were improved fodders, which were identified in the high-altitude area of enclosed areas only. Based on the palatability of trees and shrubs to livestock, available species were classified into different palatability groups (highly palatable, palatable, less palatable, and unpalatable), identified based on the perceptions given by experienced local farmers. Accordingly, among the identified species, highly palatable, palatable, less palatable, and unpalatable accounted for 20%, 20%, 6.7%, and 53.3%, respectively.

In the mid-altitude, the most dominant woody species were Clutia abyssinica (21.79%), Vernonia auriculifera (20.51%), Brucea antidysenterica (11.54%), and Buddleia polystachya (11.54%). At high altitude, Papilionoideae (81.82%) was dominant. Out of this, 16.70% were highly palatable, 16.70% palatable, 8.30% less palatable, and 58.30% were unpalatable. In high-altitude areas, three woody species were identified, which were improved fodders that have equal proportions of highly palatable, palatable, and unpalatable.

Table 11: Species composition (%) of woody species in enclosures area

Botanical name	Family	Composition (%)	P	FG
Mid-altitude				
Acacia abyssinica	*Mimosoideae*	2.56	HP	Tree
Bersama abyssinica	*Melianthaceae*	1.28	UP	Shrub/small tree
Brucea antidysenterica	*Simaroubaceae*	11.54	UP	Shrub
Buddleja polystachya	*Buddlejaceae*	11.54	P	Shrub/small tree
Calpurnia aurea	*Papilonoideae*	1.28	LP	Shrub
Clutia abyssinica	*Melianthaceae*	21.79	UP	Shrub
Dodonaea viscosa	*Sapindaceae*	7.69	HP	Shrub
Lippia adoensis	*Verbenaceae*	3.85	P	Shrub
Maesa lanceolata	*Myrsinaceae*	7.69	UP	Shrub
Osyris quadripartite	*Santalaceae*	7.69	Up	Shrub
Rosa abyssinica	*Rosaceae*	2.56	UP	Shrub
Vernonia auriculifera	*Asteraceae*	20.51	UP	Shrub
High altitude				
Chamaecytisus proliferus	*Papilionoideae*	81.82	HP	Shrub
Leucaena leucocephala	*Mimosoideae*	5.19	P	Shrub
Populusallal	Salicaceae	12.99	UP	Shrub

FG = Functional group, HP = highly palatable, P = palatable, UP = unpalatable.

3.11. Effect of altitudes on the species composition at different grazing land use types

The species richness, diversity, evenness, and ground cover of the pastureland in the area enclosure and free grazing land at different altitudes in the study area are shown in table 12. Herbaceous species richness in the very high altitude area was significantly (P<0.05) higher than in the mid-altitude and high altitude areas.

The current result is in agreement with Zinabu et al. (2020) in Semiarid Savanna Grasslands in Southern Ethiopia; an increase in species richness along an elevation gradient could be due to the effect of the soil nutrient-moisture availability along the elevation gradient. Similarly, Teame et al. (2014) reported that species richness increases with altitude. The species diversity had a significant (P<0.05) difference between altitudinal variations. Species diversity at the mid-altitude of the study site was higher (2.26) than at the high (1.82) and very high altitudes (1.75) of the study area. Species evenness showed a significant (P<0.05) difference among altitudinal variations. Species evenness in the mid-altitude was higher (0.82)than high (0.68) and higher altitudes (0.57). This might be related to the distribution of climatic factors and land suitability due to the factor of altitude determinants. Species diversity and evenness in the current study decreased with altitude increase. This might be related to climatic factors, topography, and the moisture of the soil. Species evenness decreased with increasing soil moisture, whereas it increased with decreasing soil moisture, as reported by Dorji et al. (2014). Similarly, the result was in agreement with Gebrehaweria (2011), who stated that the lower and mid-altitudes had significantly higher species evenness than the upper altitudes. However, this result contradicts Zinabu et al. (2020), who reported that species diversity and evenness increase with increasing elevation. The difference between the current finding and earlier reports might be due to the variation in the locations of the study area.

3.12. Effect of grazing land use type on the forage species composition

Grazing land use type had a significant (P<0.05) effect on species richness, diversity, and ground covers (Table 11). Herbaceous species richness was significantly (P<0.05) higher in the enclosures than in free grazing areas. This could be due to high grazing pressure and the trampling effect on free grazing lands, which leads to loss of individual species due to disturbance of soil, and heavy grazing severely impedes the regenerative ability of herbaceous species. The higher herbaceous species richness in area enclosures was in agreement with the findings of Haftay et al. (2013) in eastern Ethiopia. Species diversity of natural pasture was significantly (P<0.05) higher in the enclosures than in the free grazing areas, where there was high grazing pressure. This might be related to herbaceous species damage being high in free grazing areas due to heavy animal grazing and human activities.

The result showed that, statistically, there was no significant difference (p>0.05) between altitudinal ranges on the ground cover of pasture lands. The mean values of ground cover in the high-altitude areas were higher (91.5±3.86) than in very high (90.5±3.36) and mid-altitude areas (89.5±4.83). Grazing land use type had a significant (P<0.05) impact on the ground cover of the pasture lands in the current finding, in which area enclosures maintain a better ground cover of pasture lands (98.22± 0.58) than free grazing lands. Overall, it has been observed that the ground cover of free grazing lands was in poor condition. This might be due to the presence of a high livestock population grazing on free grazing lands and the disturbance due to the high grazing intensity throughout the year. This result was in agreement with Mengistu et al. (2013), who reported that freely open communal grazing land management aggravated the deterioration of ground cover and intensified the incidence of soil erosion on natural pasture lands. The ground cover of herbaceous species was denser in the area enclosure than in the free grazing lands (Tesfay, 2016).

Table 12: Species composition of pastureland

Source of variation	**Species richness**	**(H`)**	**(J`)**	**Ground cover (%)**
Altitude				
Mid- altitude	16.25±2.72 [b]	2.26 ±0.21 [a]	0.82 ±0.02 [a]	89.5±4.83 [a]
High altitude	15.00 ±1.49 [b]	1.82± 0.12 [b]	0.68±0.02 [b]	91.5 ±3.86 [a]
Very high altitude	22.75 ±3.33 [a]	1.75±0.14 [b]	0.57 ±0.04 [c]	90.5 ±3.36 [a]
grazing land use type				
Area enclosure	20.33±1.62 [a]	2.07±0.11 [a]	0.70±0.04 [a]	98.22± 0.58[a]
Free grazing	11.00±1.15 [b]	1.56±0.06 [b]	0.66±0.05 [a]	67.33±4.83 [b]
Overall mean	18±1.73	1.94±0.11	0.69±0.03	90.5±2.14
CV	13.86	10.29	8.54	10.71
Altitude	0.0469	0.0151	0.0094	Ns
Grazing land use type	0.0014	0.0084	Ns	<0.0001
Altitude *lut	0.0050	0.0210	0.0126	<0.0001

Where:- [a, b, c] mean that in a column with the same category having different superscripts differ (P<0.05); CV = Coefficient of variations, AE = area enclosures, Fg = free grazing, H`=Shannon diversity index J` = Evenness (J`), lut=grazing land use type, ns=not significant difference, S = Species richness

3.13. Species richness, diversity and evenness of woody species

In the study area, woody species appear only in enclosure areas of mid-altitude and high-altitude areas. In the free grazing lands, there were no fodder trees and shrubs attributed to human disturbance, such as deforestation for construction purposes, for the purpose of fuel wood, and fencing their cultivated lands. The highest species richness (14), diversity (2.19), and evenness (0.83) were recorded at mid-altitude of area enclosures rather than high altitude (species richness (3), diversity (0.84), and evenness (0.77)), which might be associated with environmental differences, such as temperature, moisture, soil characteristics, and precipitation of the study area. The results of the current study were in agreement with the findings of Fekadu et al. (2018), who reported that the highest diversity index mean value of shrubs and trees was recorded at lower altitudes than mid-altitudes and high altitudes. This might be due to the relationship between altitude and soil depth, which probably acted upon the decrease in species occurrence, because the highest soil depth inhibited the species from utilising beneficial soil nutrients as altitude increased.

4. Conclusion and Recommendations

Forage species richness, diversity, and evenness were higher in the enclosures than in the free grazing areas. The altitude variation has affected the botanical composition and species diversity of the natural pasture. More species richness was recorded in the very high altitude area, and higher species diversity and evenness were recorded in the mid-altitude area. The botanical composition, species richness, species diversity, species evenness, and ground cover of pastureland in the area enclosures of all altitudinal ranges were higher than in free grazing areas due to management differences, because of reduced disturbances in area enclosures. Area enclosure establishment in the communal grazing area is a very important and effective land management option. The establishment of area enclosures provided both socioeconomic and environmental benefits, including the control of soil erosion, improved availability of grass for animal feed, and increased productivity of adjacent farmlands. Such perceptions form an important benchmark for ensuring the future sustainability of area enclosure practices in the study area, as well as in similar locations within the region and beyond. To improve the productivity of the area enclosure, management activities like fertilization and the introduction of improved new forage species s should be strengthened in the future.

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Data availability statement

Data will be made available up on request.

Conflicts of interest

The authors declare there is no conflict of interest in the publication of this manuscript.

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