Exclosure land management for restoration of herbaceous species in degraded communal grazing lands in Southern Tigray

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ABSTRACT
Herbaceous species contribute to the largest proportion of the fodder. Despite the profound benefits obtained, anthropogenic disturbances are hindering its development. On the other hand, to ensure the sustainability of herbaceous species, communities and governments have been putting efforts in managing herbaceous species through the establishment of area exclosure (AE). Thus, the main importance of this research paper is to provide information about the role of AE on the restoration of herbaceous species. The objective of this study was to assess the effect of restoration on the herbaceous species following AE established on communal grazing land (CGL). A total of 124 and 73 quadrats of 1 x 1 m² size were laid down at 50 m intervals along parallel transects at AE and CGL, respectively, and data were analyzed by t-test unequal variances using R-software. AE displayed higher plant species richness and diversity than the CGL and showed a significant difference (p<0.001). Similarly, the AE had significantly (p<0.001) higher forage biomass than the CGL. In general, herbaceous species diversity index and species richness were significantly (p<0.001) higher in the AE compared to the CGL. The study concluded that effective AE has the potential to enhance the restoration of herbaceous species and hence forage productivity.

Introduction
Native herbaceous plant species contribute to the largest proportion of the livestock feed across all agro-ecological zones of Ethiopia (Getnet 2003). However, degradation of lands due to uncontrolled and excessive use of communal grazing land (CGL) of the undulated topography in the highlands and erratic rainfall in semi-arid areas have further reduced the availability of feed resources (Solomon and Teferi 2010). A common restoration practice in Ethiopia is the use of area exclosures (Tekle and Bekele 2000; Tekle 2001; Asefa et al. 2003; Mengistu et al. 2005). Restoration of plant species diversity is an important management strategy for rehabilitating landscapes, which have lost vegetation cover (Ormerod 2003). In the absence of restoration, the overall sustainability of ecological/ecosystem processes, including species diversity, will be further threatened (Martinez-Garza and Howe 2003). The restoration of degraded lands should, therefore, begin with a clear appraisal of the effects of management on plant biodiversity (Ormerod 2003; Ruiz-Jaen and Aide 2005). Earlier studies (Oba, Vetaas, and Stensteth 2001; Asefa et al. 2003; Mengistu et al. 2005; Abebe et al. 2006) suggested that species diversity is higher in exclosures than continuously grazed areas.

Exclosures are (AE) areas closed from the human and domestic animals interferences with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands (Mekuria and Aynekulu 2013; Teketay et al. 2018). An exclosure refers to a specific land unit that is protected from the activities of a particular class of animals using appropriate barriers such as fencing to control the influence of animals (Young 1958). As the exclosures are not fenced, guards are hired by the local administration on a food-for-work basis (Yayneshet, Eik, and Moe 2009). In AE, it is generally believed that all the land resources will be protected from degradation (Tefera 2001). The effects of AE on the recovery of woody species diversity, population structure, and regeneration status, restoration of soils, and restoration of ecosystem carbon stocks have been well studied (e.g., Kindeya 2003; Aerts et al. 2004; Tefera et al. 2005; Descheemaeker et al. 2006; Muluberhan et al. 2006; Yayneshet, Eik, and Moe 2009; Wolde and Aynekulu 2011; Wolde et al. 2011b; Yayneshet 2011; Wolde and Mastewal 2013; Ombega et al. 2017; Eltalib, Lazim, and Dawelbait 2018; Tsegay et al. 2019; Tesfay, Anteneh, Tessema, and Tsegay 2019). In addition, in the Tigray region, Northern Ethiopia, some studies that were conducted earlier (Kindeya 2003; Aerts et al. 2004; Tefera et al. 2005; Muluberhan et al. 2006; Yayneshet, Eik, and Moe 2009; Yayneshet 2011; Wolde and Mastewal 2013; Tesfay et al. 2019) were specifically trying to estimate the role of AE in the recovery of vegetation diversity without considering...
specifying indigenous palatable herbaceous species. However, a replicated study on multiple sites that investigates the dynamics of vegetation restoration following the establishment of exclosures has not been conducted. Such information is, however, crucial for managing the existing exclosures in a sustainable manner, and for establishing new exclosures in the future (Mekuria and Veldkamp 2012). It is very important to have basic information about herbaceous plant species diversity and biomass production, as these may facilitate the efficient and effective use of range-land resources as livestock feed.

Even though there are a lot of AE in the South zone of Tigray including forests in different agro-ecologies and land uses their roles regarding herbaceous species diversity and above ground, biomass has not been well studied and documented. So this study on the restoration of herbaceous species following exclosure establishment in communal grazing lands was conducted to fill the gap on this demand for basic information about the diversity restoration potential of the area with their variation across the land-use system. A change in species diversity is often used as an indicator of anthropogenic or natural disturbances in an ecosystem. Therefore, the characterization of biodiversity through inventories can be useful in the planning of operations that aim to conserve biodiversity (Kalema 2010). Based on the stated goals of restoration by AE, we hypothesize that: AE assisted enrichment planting would increase herbaceous species diversity and above ground biomass inference to the adjacent CGL in Northern Ethiopia. Therefore, this study was initiated to generate quantitative information and thereby evaluate whether AE has an impact on the biomass and diversity of herbaceous plant species in the South zone of Tigray, Northern Ethiopia.

**Materials and methods**

**Description of the study area**

The study was conducted in all districts of the Southern zone of Tigray. It is located at 680 km North of Addis Ababa and 180 km South of Mekele, the capital city of the Tigray regional state. The zone consists of five administrative districts, namely Raya Alamata, Alaje, Endamohoni, Ofla, and Raya Azebo Figure 1. The Southern Tigray Zone is one of the seven zones of the region bordered to the south and west by Amhara Regional State, to the north with the southeastern zone of Tigray, and to the east with the Afar Regional State. Geographically, it is located between 12°15′ and 13°41′ north latitude and 38°59′ and 39°54′ east longitude with an altitudinal range of 1350–3925 m.a.s.l. Based on the traditional classification system, the Southern zone covers “Kola”, “Weynadega” and “Dega” agro-ecologies which support the growth of a variety of crops, livestock and tree species. Mixed farming is the major economic activity in the area.

The southern zone is characterized by a bimodal rainfall pattern and about 70–80% of the rain falls during the major rainy season that extends from June to September (Araya and Stroosnijder 2011). The mean annual rainfall of the zone is 600 mm (Tesfay et al. 2019). The mean minimum and maximum temperatures are 8 °C and 30 °C, respectively. Urban agriculture is a common practice in the southern zone (Ashebir, Pasquini, and Bihan 2007). Livestock production is a major component of the livelihood system and provides draught power, food, and income. In the study area, indigenous and multipurpose plant species like Acacia tortilis, Balanites aegyptiaca, Carissa spinarum, Grewia mollis, Olea europaea, Pittosporum viridiflorum, Tecleasimplicifolia, and Ziziphus spina-christi are found. The principal feed resources available for

![Figure 1. Location map of the southern zone of Tigray and its districts.](image-url)
livestock in the Southern zone are crop-residue, grass hay, crop aftermaths, grazing lands, and weeds. Herbaceous plants also has a significantly important feed resource of livestock similar in the dry and wet season (Tesfay et al. 2018). Dominant soil types in the southern zone are Vertisol, Fluvisols, Luvisols and Cambisols (Tesfay et al. 2019). The major geological formations in the area can be broadly grouped into the trap volcanic and the alluvium. The geological structure to the east of the escarpment is complicated by north/south trending grabens separated by horsts (Hunting 1976). A number of large and small streams draining from the mountains and hills of southern Tigray flow to the low-lying flat to undulating plain. Most of the streams are intermittent and flow only during the rainy season (Amanuel, Girmay, and Atkilt 2015).

**Sampling and data collection methods of herbaceous species**

**Site selection and sampling procedure**

A reconnaissance survey was undertaken in 5 districts of the Zone to identify the presence of AE and adjacent CGL in consultation with agricultural experts and user groups. The priority areas were identified by the local agricultural experts and user groups who agreed to strictly protect them from any form of grazing, manual harvesting of grass, and tree cutting (Yayneshet, Eik, and Moe 2009). Accordingly, five CGL and five AE (5-10 km apart and established in the same year) were systematically selected for sampling across the Southern zone of Tigray. To minimize the effects of spatial variability, an AE was included only when its location relative to others was not farther than 10 km (Yayneshet 2011). These rangeland sites were selected based on management practices, and the similarity in slope and soil type of the sites. In the absence of undisturbed reference sites (Ruíz-Jaen and Aide 2005), CGL was chosen as a benchmark against which the rehabilitation success was compared. The AE ages ranged from 5 to 7 years. The AE and CGL covered a total area of 50-150 and 25-70 ha, respectively (Southern Zone bureau of agriculture and rural development (BOARD) 2018). Adjacent to the AE in a similar scenario, there is CGL used by the local community with no restriction to access resources that were used as a control for each exclosed area. Therefore, this study was conducted in these two land-use systems. It is ensuring that the AE and CGL were homogenous in biophysical factors before the AE are restricted for rehabilitation and are similar in topographic and climatic characteristics.

A systematic line transect sampling technique was used in this study following the vegetation type and distributional pattern. Thirty parallel transect lines (land-use systems x 5 locations x 3 transect lines) were established each 50 m apart from the other in order to assess vegetation in the two land-use systems. Along the transect lines, a total of 197 quadrats (124 for AE and 73 for CGL) was used for sampling herbaceous vegetation attributes (biomass, diversity, richness, and evenness) from the two land-use systems. At each site/location, 24–39 quadrats were designated and an average 8 quadrats/transect was used. The ratio/proportion of the number of species identified in the two areas (1.5) is almost comparable to the ratio of the number of quadrats in the two areas (~1.7). The proportion of the area covered in the two areas (~2-2.14). The number of quadrats per site was established based on the vegetation density, spatial heterogeneity of vegetation and areas of the land-use system (Mengistu et al. 2005). Indigenous grass and legumes species assessment was conducted after the main rainy season in the month of October when most plants were at over 50% flowering, which makes the identification of the plants easy.

Comprehensive data on grasses and legumes were collected from the quadrat with 1 m x 1 m. To study the composition and diversity of species identity, and the number of individual grasses and legume species were counted (Brady et al. 1995). Herbaceous aboveground biomass production was estimated using the destructive method (‘t’Mannefte and Jones 2000). Forb and grass materials rooted within the quadrat (1 m²) were clipped 2 cm above the ground level (clipping at grazing height to give a more applicable measure of forage biomass). The various plant species clipped were then sorted into their relevant functional groups (perennial grasses, forbs, and annual grasses). Their fresh biomass was immediately weighed to determine their aboveground fresh biomass and later oven-dried to a constant weight at 70 °C for 48 h, after which aboveground biomass production was then determined and expressed in tons DM/ha (Verdoordt, Mureithi, and Van Ranst 2010). The dry matter (on air-dry matter basis) per quadrate was obtained by dividing the total weight of all quadrants by their numbers. Herbaceous species were classified based on the succession theory described by Dyksterhuis et al. (1949) and on the ecological information (Vorster 1982). Accordingly, these species were grouped into (i) highly palatable species: those which occur in rangeland in good condition and decrease with over-grazing and (ii) less palatable species: those which occur in rangeland in good condition. In addition, species were grouped into annuals and perennials as well as by their abundance (widely distributed and most widely distributed) (Solomon, Snyman, and Smit 2007).

**Data analysis**

For identification of species in the field, vernacular names from key informants were used and the specimens were identified by Edwards et al. 000)
and Hedberg, Ensermu Kelbessa, and Demissew 006). The herbaceous species were classified into grasses, legumes and non-leguminous forbs (Hannaway et al. 1999) within each quadrat to determine the contribution of each group in the quadrat (ILCA (International Livestock Center for Africa) 1990). The Shannon diversity indices and evenness were used to look at the level of species diversity and evenness of species distribution (Kent and Coker 1992). Species diversity in AE and adjacent CGL was determined using species richness, Shannon index of diversity (H') and Shannon equitability or evenness (E) (Magurran 1988). The similarity in the herbaceous species composition of the two land-use systems was computed using Sørensen’s similarity coefficient (Magurran 1988, 2004). Prior to further statistical analysis, normality and equality variance of the data was checked using Kolmogorov- Smirnov and Levene’s test, respectively (Mekuria et al. 2015). T-test with unequal variances was used to determine if there were significant differences between means of the various herbaceous characteristics with respect to different land management practices using R-software version 3.3.3 (The R Core Team 2018). Significant differences were declared at p< 0.05. For data that did not require analysis, simple descriptive statistics were employed where appropriate.

Results

Specificities and anomalies in herbaceous species composition and functional groups

The total number of herbaceous species identified was 66 in the AE and 44 in the CGL of the study area. Figure 2(A-C) shows the life forms, desirability and functional grouping of herbaceous species in the study areas. The life form distribution of herbaceous species is 56.06% grass, 36.36% legumes and 7.58% forbs, at AE. On the other hand, the life form distribution of herbaceous plant species is 54.55% grass, 25.00% legumes and 20.45% forbs in the CGL Figure 2A. AE (79.17%) had a higher percentage of perennial grasses and CGL (63.64%) the lower Figure 2C. The proportion of highly and less palatable grass species were different between the land-use systems. AE had a higher proportion of highly palatable (86.49%) species and CGL had the lower (79.17%). Less palatable species were greater in the AE than in the CGL areas Figure 2B. The estimated Sørensen similarity index between land uses system was 0.37%; which means that there was 0.63 (63%) difference in herbaceous species composition between the two land-use systems.

Herbaceous species diversity

Palatable herbaceous species diversity, evenness, and species richness in the study area are presented in

![Figure 2](attachment:image.png)

Figure 2. The functional group (A), desirability (B) and life forms (C) of herbaceous species in the two land-use systems (HPG= high palatable grasses, LPG= less palatable grasses, HPL= high palatable legumes, LPL= less palatable legumes, PG= Perennial grass, AG= annual grass, PL= Perennial legume, AL= annual legume).
Table 1. Mean values of vegetation characteristics in enclosures and adjacent grazing lands (AE=Area Enclosure, CGL=Communal Grazing land).

| Land-use type | Number of quadrats | Number of individuals | Shannon diversity | Species richness | Species Evenness |
|---------------|--------------------|-----------------------|-------------------|------------------|-----------------|
| AE            | 124                | 60.95                 | 1.24              | 4.98             | 0.79            |
| CGL           | 73                 | 44.46                 | 0.98              | 3.14             | 0.74            |
| P-value       | 0.001              |                       | <0.001            | <0.001           | <0.001          |

Table 2. Aboveground herbaceous biomass (tons/ha) in AE and CGL of the study area (AE=Area Enclosure, CGL=Communal Grazing land).

| Land-use type | Number of quadrats | Grass | Legumes |
|---------------|--------------------|-------|---------|
|               |                    | Annual | Perennial | Annual | Perennial | Forbs | Overall |
| AE            | 124                | 10.24  | 20.30    | 3.39   | 6.76      | 5.26   | 9.19    |
| CGL           | 73                 | 5.06   | 10.02    | 1.69   | 3.37      | 7.06   | 5.44    |
| P-value       | 0.001              | <0.001 | <0.001   | <0.001 | <0.001    |        |         |

Table 3. Dry matter yield (tons/ha) (Mean) of herbaceous species in AE and CGL of the study area (AE=Area Enclosure, CGL=Communal Grazing land).

| Parameter     | AE     | CGL    | p-value |
|---------------|--------|--------|---------|
| Grass         | 4.03   | 2.20   | <0.001  |
| Legumes       | 1.55   | 0.73   | <0.001  |
| Forbs         | 1.53   | 2.03   | 0.001   |
| Total biomass | 2.36   | 1.66   | <0.001  |

Table 1. Palatable herbaceous species diversity in the AE had significantly higher than the CGL (t =4.34, df =135, p<0.001). Higher species richness was observed in the AE (4.98), while the lower was recorded in CGL (3.14) and the difference is statistically significant (t=5.00, df =171, p<0.001 Table 1. The number of individuals herbaceous species was statistically significant between the two land-use systems (t = 3.26, df = 182, p = 0.001).

Aboveground herbaceous biomass

There was a highly significant difference (p < 0.001) in the biomass of herbaceous plants between AE and CGL plots. Aboveground biomass of perennial grasses was significantly (t = 5.37, df = 40.32, p-value < 0.001) higher in the AE than in the CGL Table 2. Statistically, management practice shows significant effect on the aboveground biomass of annual grasses (t = −3.45, df = 37.90, p-value = 0.001) Table 2. Forbs aboveground biomass was significantly (p<0.001) difference between the land use system (AE and CGL) and higher results were obtained in CGL practice.

Dry-matter yield of herbaceous species

Dry matter yields were significantly (p<0.001) different among the land-use system (AE and CGL) and higher results were obtained from the AE practice Table 3. Dry matter yields of grass species were higher in the AE than CGL (4.03 and 2.20 ton/ha, respectively). The total dry matter yields measured in AE was 42.17% higher than that of the adjacent CGL.

Discussions

Specificities and anomalies in herbaceous species composition and functional groups

The number of individual perennial grasses and legumes were higher at the AE than CGL in the study area. This finding could be an indication that perennial grasses were replaced with annual grasses on the CGL which was subjected to higher grazing pressure. Similar reports have been frequently recorded in heavily grazed arid and semi-arid savannas of Africa (Gemedo, Maass, and Isselstein 2006; Mphinyane and Rethman 2006; Solomon, Snyman, and Smit 2007). The higher composition of the perennial grasses may imply the potential productive nature of the rangeland for livestock production (O’connor, Pickett, and Pickett 1992; Amaha 2006; Mapako 2011). Repeated grazing might lead to a reduction in herbaceous species composition, which might accelerate the decline in rangeland conditions. Similarly, Van Der Westhuizen et al. 001 argued that in arid and semiarid rangelands, herbaceous species composition is greatly influenced by the effects of grazing pressure. As reported by Angassa et al. 010, heavy grazing pressure may reduce plant species composition. Abundance and dominance of forbs and annual grasses is an indication of the poor range condition due to mismanagement or changes in plant species composition in the ecosystem (Camp 1997). Anderson and Hoffman 007 noted that poorly managed CGL had a lower proportion of perennial grasses compared to forbs and annual grasses. The increased number of perennial grasses compared to forbs and annuals in the AE could also be an indication of reduced runoff, a fact attributable to improved ground cover (De Groot, Field-Juma, and Hall 1992). Similar results were reported by De-Val and Crawley 005 indicating that in AE highly desirable perennial grasses were found to be abundant. Livestock herbivory can cause shifts in plant species composition by replacing highly palatable grasses with unpalatable species (Rutherford, Powrie, and Husted 2012). The dominance of annuals in the CGL could be attributed to poor land management as a result of overgrazing (Solomon, Snyman, and Smit 2007). Rangelands are ecologically favored when perennials dominate the ecosystem. In semiarid savannahs, perennial grasses give a better indication of the health status of rangelands than annuals. Perennials yield higher dry matter and provide better soil protection than annuals (Van Wyk and Van Oudtshoorn 1999).

The present result suggests that the main reason for a lower number of grass species in communal grazing
land is the high grazing intensity throughout the year. Hence, heavy grazing tends to reduce the presence of palatable species and consequently become dominated by other herbaceous plants or bushes (DeHaan, Steinfeld, and Blackburn 1997). The same result was reported in eastern Tigray in CGL and AE by Emiru (2002); Gebrewahd (2004) reported that there was an increment of herbaceous species in the AE due to the absence of grazing animals. Ayana (1999) reported that species composition could depend on grazing management and livestock population. Tesemma et al. (2011) reported that the rapid disappearance of the perennial grass community and their subsequent replacement by annual herbs is due to heavy grazing. Selective grazing of palatable herbaceous plants by livestock enhances the growth of annuals and unpalatable herbaceous plants (Sakrpe et al. 1992) resulting in the decline of palatable species (Fensham et al. 2010). On the contrary, annual grasses were higher within the CGL compared to the AE (Ombega et al. 2017).

The forb proportion in the CGL was higher than in the AE. The CGL was highly dominated by forbs, this is in line with prior studies (e.g., Sternberg et al. 2000; Mphinyane et al. 2008; Kgosikoma 2011) reporting that herbaceous plants are highly responsive to grazing pressure. The dominance of forbs in the CGL could be attributed to poor land management as a result of overgrazing (Solomon, Snyman, and Smit 2007; Ombega et al. 2017). Overgrazing affects the botanical composition by depressing the vigor and presence of dominant species, which then enables colonization by less competitive, but, grazing-tolerant plant species (Sternberg et al. 2000; Ayana and Oba 2007; Angassa and Oba 2010). The unpalatable species might increase the total species pool, thereby indicating higher plant diversity than often expected (Oba et al. 2003). Nonetheless, disturbances such as overgrazing favor the establishment of invasive species, survival, and the dominance of short-lived, unflavored annual plant species rather than the palatable perennial species (Byers 2002).

### Herbaceous species diversity

The overall diversity of herbaceous plants is much higher in AE than CGL, which may be a consequence of the high species richness in AE. The findings of this study are consistent with those of Emiru (2002); Angassa et al. (2016); Gebrewahd (2004), Mureithi et al. (2016), and Ombega et al. (2017) who reported a higher species richness and diversity in areas under AE than in CGL. The present result suggests that the main reasons for low palatable herbaceous species richness in CGL are increased grazing pressure (Sisay and Baars 2002; Desalew 2008; Angassa et al. 2010); and heavy grazing, trampling and inappropriate management interventions (Amaha 2006), might lead to a reduction in herbaceous species diversity. In addition, continuous grazing affects the amount of plant litter at the soil surface and exerts indirect pressures on the germination and seedling establishment patterns (Lishan 2007; Desalew 2008). The high diversity measured in the AE might be explained by increased litter accumulation, improved soil organic matter and other nutrients inside the AE that eventually lead to increased species richness (Hiernaux 1998). However, the results contrast with other studies that reported species richness to be considerably increased under moderate grazing compared to no or heavy grazing treatments (Loeser, Sisk, and Crews 2007; Dorrough et al. 2007).

There is a global perception that heavy livestock grazing reduces biodiversity and that biodiversity is maximized in primary vegetation (Alkemade et al. 2000). A well-known contemporary grazing-diversity model indicates a decline in diversity with heavy grazing intensity, at least outside areas of high resources (Cingolani, Noy-Meir, and Díaz 2005). The decline in the proportion of herbaceous species abundance due to the effect of grazing pressure is consistent with other studies (Angassa and Oba 2010; Sisay and Baars 2002; Terefe, Ebro, and Tessema 2010). Under continuous and increased grazing pressure, palatable plants (decreasers) would die and with the death of decreasers less palatable plants (increasers) become dominant (Mengistu, Angassa, and Abebe 2015). This may be related to the presence of high animal grazing pressures due to the presence of a high number of livestock and human activities which is to the damage of palatable herbaceous species. Hence, the palatable herbaceous species dominate the AE and this result agrees with the research findings of Teshome (2006), Lishan (2007), Ketama (2007), and Tesfaye (2008). The major reason for the low number of palatable herbaceous species in the CGL is the lack of adequate protection from disturbance by livestock and other related human activities. The “extinction” of most valuable herbaceous species and their replacement by less important annuals was also reported on the work of Abdulatife (2009) and Ibrahim (2016).

### Herbaceous species similarity

The estimated Sørensen similarity index of herbaceous species in terms of species richness of the two land-use systems was about 0.37%; which means there was 0.63 (63%) difference in herbaceous species composition between two land-use systems. This indicated a higher dissimilarity of herbaceous species between the two land use systems. Again, the difference in species composition is due to the reappearance of species that were lost from the adjacent communal grazing land over time. This dissimilarity difference to some extent might have resulted from the management role provided by AE in the restoration of fast-growing plants in
degraded grazing lands. The extent of species similarity and difference between the land uses might be related to the level of disturbance in the composition of species between the sites (Melkamu and Abdella 2019).

**Herbaceous biomass production**

Aboveground biomass of herbaceous plant species is significantly higher (P ≤ 0.05) in the AE than in the CGL areas. The results are in line with Lazim (2009), Angassa et al. (2010), Lazim, Babo, and Elsheikh (2012), Eltalib, Lazim, and Dawelbait (2018), and Ombega et al. (2017) who reported that protection, gradually increased plant forage biomass of herbaceous plants. Higher biomass production of herbaceous plant species in the AE could be as a result of improved land management due to the establishment of soil and water conservation (Ruto 2015). Proper grazing management through livestock exclusion has been found to enhance above ground biomass in areas that are severely degraded (Wasonga, Nyariki, and Ngugi 2011). Moreover, lower biomass production of perennial grasses in the CGL could be a result of year-round grazing which could not allow quick vegetation recovery in the study area (Verdoodt, Mureithi, and Van Ranst 2010). These findings corroborate with those of Singh et al. (2011) and Mekuria and Aynekulu (2013) who reported higher biomass production in AE. Grazing throughout the year has consistently reduced the herbaceous aboveground biomass production capability of the grazed areas (Yayneshet, Elk, and Moe 2009). Improved above ground biomass in the rehabilitated area could be due to reduced grazing pressure in the rehabilitated sites (Ombega et al. 2017).

The biomass production in the AE better than the CGL areas this might be due to better rangeland management practices in the AE, but the CGL areas have deteriorated through continuous overgrazing and the mismanagement system of the community (Ahmed 2006; Ibrahim 2016). On the other hand, the highest scores for biomass were recorded at enclosed sites reflecting the benefits of reduced disturbance such as the effects of heavy grazing, trampling, and inappropriate management interventions (Ahmed 2006). Similarly, Angassa and Oba (2010) show that the biomass of herbaceous species was significantly greater in enclosures than in the free grazed areas. Van Der Westhuizen et al. (2001) argued that in arid and semiarid rangelands, biomass production of herbaceous is greatly influenced by the effects of grazing pressure. Heavy grazing leads to excessive defoliation of herbaceous vegetation, reducing standing biomass, often triggered by a decline in net primary productivity, as the intensity of grazing increases (Cingolani et al. 2003; Friedel et al. 2003; Bilotta, Brazier, and Haygarth 2007; Stephen et al. 2014).

The dry matter yield of grass species was higher in AE than in the CGL. The impact of management factors may be the main reason for the significant difference in terms of herbaceous dry matter yield between the AE and CGL (Mengistu, Angassa, and Abebe 2015). The low dry matter yields of forage in the CGL as compared to AE corresponded with the reports of Amsalu (2000); Amaha (2006); Gemede, Maass, and Isselstein (2006); Teklu, Negessa, and Angassa (2010); Shenkute et al. (2011); Teshome et al. (2012). The dry matter yield of forb species in the CGL site was found to be higher than in the AE site. The increase in forbs in pasture lands threatens livestock production because encroaching forbs species suppress palatable grasses and herbs through competition for soil moisture and nutrients (Scholes and Archer 1997). The increase in the dry matter yield of forbs in the CGL might be evidence for poor range conditions (Gemede, Maass, and Isselstein 2006). This might point out that such low dry matter yield herbaceous in the CGL could directly affect livestock production and sustainability of the rangeland over time (Ahmed 2006). Area enclosures are effective in restoring dry matter yield of herbaceous species than the CGL areas. The results of the current study suggest that with continuous grazing pressure on communal lands, the above ground biomass grass production is low, both because of heavy utilization and destruction of grassroots by trampling livestock (Quinfeng, Phillip, and David 1999). Consequently, the production capacity of grasses and their ultimate contribution to the total dry matter yield were reduced (Mapako 2011).

**Conclusions and recommendation**

This study showed that the establishment of area enclosures on degraded free grazing lands in the Southern zone of Tigray is a viable option to restore herbaceous vegetation composition, richness, diversity, and aboveground biomass. This is particularly important to consider when planning activities aimed at the responsible management, sustainable utilization, and conservation of the herbaceous plant species at the study sites. Moreover, the study concluded that AE is the potential option for future herbaceous palatable plant species improvement and conservation of key forage species. Area enclosure from a land rehabilitation point of view is expressed through increasing biomass production, species diversity and composition of herbaceous species in the study area. Therefore, based on the present results, the authors recommend the following points: AE is an advisable strategy of herbaceous species rehabilitation, the need for further studies on temporal and spatial herbaceous species biomass should be thoroughly examined under various regimes of grazing exclusions. Although the current study will contribute towards the thoughtful of AE on the herbaceous plant...
species restoration, further studies that aim to integrate feeds that have higher nutritive values within the feeding system are needed to further appraise feed intake, digestibility, animal’s responses, and anti-nutritional factors for sustainable animal production.

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List of abbreviations

AE= area exclosure; CGL= communal grazing land

Authors’ contributions

All authors contributed to the development of the concept and implementation of the study, TA, NG, TGe, and TGi carried out field data collection and data analysis and drafted the manuscript.

Competing interests

We declare that we do not have competing interests.

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