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Woody species diversity, population structure, and regeneration status in the Gra-Kahsu natural vegetation, southern Tigray of Ethiopia

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Abstract

The study was conducted at Gra-Kahsu protected natural vegetation (PNV) and communal grazing land (CGL), in order to evaluate the conservation impact level. The diversity of plant species, population structure of woody species, and regeneration status were analysed from 62 quadrats, each with 20 m × 20 m for trees and 5 m × 5 m for shrubs, using systematic sampling methods. A total of 64 vascular plant species belonging to 52 genera and 37 families from PNV and 43 plant species belonging to 34 genera and 25 families from CGL was identified. Shannon diversity index values of PNV and CGL were 2.29 and 1.84, respectively. The mean basal area of PNV and CGL were 8.29 and 5.32 m²/ha, respectively. Three community types from PNV and two from CGL were identified. The population structure of woody species based on diameter and height class distribution showed reflected reversed J-shape for PNV however, bell-shaped, and interrupted inverted J-shape for CGL. The regeneration status of PNV and CGL were considered as good (sapling > seedling > matures) and fair (mature > sapling > seedling), respectively. Therefore, the floristic analysis of

these two adjacent land use systems located in similar landscape showed distinctive variation in floristic composition, diversity, and regeneration status, which could be taken as the best practice of restoration and rehabilitation programs like, area enclosure.

Keywords: Ecology, Environmental science

1. Introduction

The decline of vegetation cover is one of the most serious challenges facing human-kind today (Reynolds et al., 2007). Ethiopia is also facing severe land degradation. The natural vegetation of the country was highly affected by several factors such as, agricultural expansion, settlement, deforestation, land degradation, and invasive species (Teshome et al., 2009; Solomon, 2015). In order to minimize such threats, the country was striving for different conservation strategies like, watershed management, afforestation, and reforestation, restoration, and rehabilitation programs. These practices were found crucial to achieve better vegetation cover and contribute to improve livelihoods of local communities (Mengistu et al., 2005; Wondie, 2015). The northern part of Ethiopia, Tigray Regional State, was practicing well-recognized conservation strategies on severely degraded landscapes for decades, where area enclosure was the most common conservation strategy. So far, two major types of area enclosures were practiced in Ethiopia. The most common type involves closing off an area from livestock and people so that natural regeneration of the vegetation can take place. The second option comprises closing of degraded land while simultaneously implementing additional measures such as establishing soil and water harvesting structures to enhance the regeneration process (Wondie, 2015).

Enclosures are areas closed from human and domestic animals interference, with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands (Wolde et al., 2011c). In the Northern part of Ethiopia, establishment of area enclosure has been taken as an important strategy for rehabilitation or restoration of degraded hillsides (Yayneshet, 2011). Forest restoration in protected enclosure has become a common practice to fight land degradation in the highlands of Tigray. Restoration of degraded communal grazing lands through establishing enclosures has become increasingly important in the Tigray regional, state, northern Ethiopia (Wolde et al., 2011b; Yayneshet, 2011; Gebrehiwot and Van Der, 2014). A number of studies reported on ecosystem services delivered due to a wide-scale enclosures activities of the northern Ethiopia, which are considered as best practices of ecosystem restoration (Tefera et al., 2005; Wolde et al., 2007; Wolde and Aynekulu, 2011; Wolde et al., 2011a; Wolde et al., 2011b; Yayneshet, 2011; Gebrehiwot and Van Der, 2014). Nevertheless, there is still limited information on ecosystem services delivered by long-time

protected natural vegetation's as compared to communal grazing land (unrestricted open vegetation sites).

The unique landscape of Gra-Kahsu natural vegetation have two kinds of land use system, protected natural vegetation (PNV) through enclosures for more than three decades and communal grazing land (CGL). Therefore, the objectives of this study were to determine the contribution of conservation strategy implemented in the study area on woody plant species diversity and restoration potentials after long term grazing exclusions in Northern Ethiopia. Comparative floristic analysis was conducted in these two land use systems, i.e. protected natural vegetation (PNV) and communal grazing land (CGL), to evaluate the conservation impact levels through a comprehensive floristic analysis of plant species diversity, community types, woody plant population structure, and regeneration status.

2. Materials and methods

2.1. Description of study area

Gra-Kahsu *having* unique scenery with natural vegetation is located in Alamata District known as Wereda of the Tigray Regional State, Northern Ethiopia. It is situated about 600 km north of Addis Ababa (Capital of Ethiopia) and about 180 km south of Mekelle (capital of the Tigray Regional State). It is geographically located between $12^{\circ}19'21''$ to $12^{\circ}24'28.5''$ North latitude and $39^{\circ}14'52''$ to $39^{\circ}45'47.8''$ East longitude (Fig. 1).

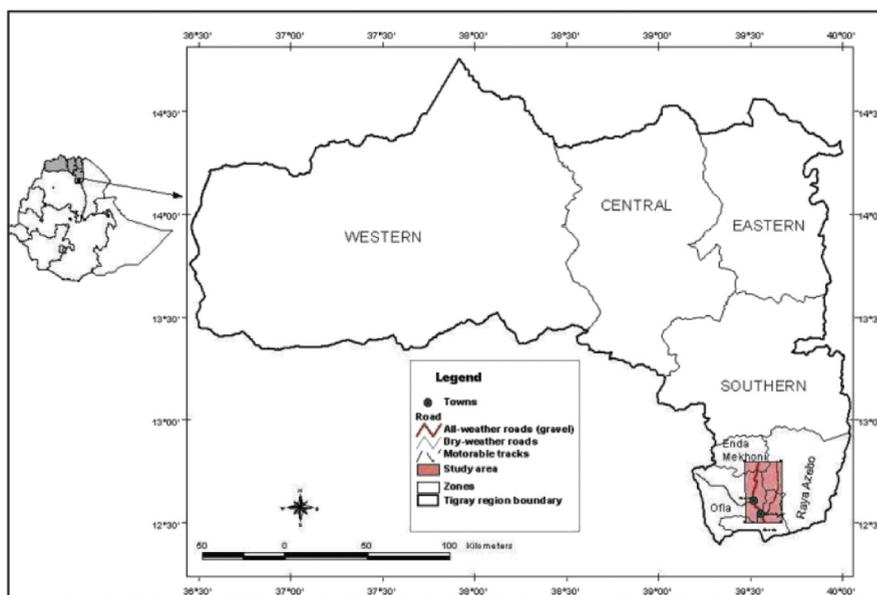


Fig. 1. Location map of the study area.

The altitude of the Wereda ranges from 1,178 to 2,300 meters above sea level (m.a.s.l). Seventy five percent (75%) of the Wereda can be described as lowland (1,500 m.a.s.l or less), and the remaining 25% is in the mid-highlands (range between 1,500—2,300 m.a.s.l). The annual mean precipitation ranges from 615-900 mm, with maximum and minimum temperatures of 23 °C and 14 °C, respectively (Girmay et al., 2014).

Gra-Kahsu natural vegetation accounts the major vegetation cover of the Wereda, which was designed to conserve long lasted unique natural features, unique scenery, historical interests and other natural values with legal and administrative supports on the upper part of Alamata town. The protected part of Gra-Kahsu natural vegetation endowed with different types of wildlife and considered as an important pillar for future local development (WAOARD, 2016). Adjacent to the protected natural vegetation (PNV) in a similar scenario of Gra-Kahsu natural vegetation, there is communal grazing land (CGL) used by the local community with no restriction to access resource.

2.2. Sampling and data collection methods

Following the reconnaissance survey, protected natural vegetation (PNV) and communal grazing lands (CGL) were classified into three strata based on homogeneity in floristic composition and distributional pattern. Then a systematic transect sampling technique was used in the three strata, which are different in their vegetation type and distributional pattern. In each of the sites, a parallel line transects were laid at 500 m interval that lie with parallel to the slope of the stand. To avoid the effect of disturbances the first and the last line transects were laid at a distance of 70 m from the edges. The locations of the quadrats were marked by GPS and slope along transects were measured using clinometers. Along the transect lines, a total of 62 quadrats (35 from PNV and 27 from CGL) measuring 20 m × 20 m for trees and 5 m × 5 m sub-quadrats for shrubs was laid down at a 0.5 Km interval.

Data on woody plant species were collection from September–October 2016 following the main rainy season of the locality. In both land use systems, data on species identity, density, and frequency, diameter at breast height and diameter at stump height were recorded for tree, tree/shrub, and shrub species. Basal area was measured using calliper and height of woody species was measured using a measuring stick having 5 m in height graduated with 10 cm markings. Yet, trees greater than 5 m in height were measured using clinometers. Mature tree is defined as woody plants with DBH/DSH \geq 2.5 cm and height \geq 1.5 m (Negash et al., 2013). The sapling and seedling population was counted from five sub-quadrats (5 m × 5 m) established at the four corners and one in the centre within the main quadrat. Saplings are young woody plants with DBH/DSH < 2.5 cm and height form 50–150 cm, whereas seedlings are woody plants with DSH < 2.5 cm and height form

1–50 cm (Gemedo, 2004). During counting or measuring of woody species, double counting and missing were avoided using marking system. Plant species identification was done in the field in addition, specimens were collected for herbarium identification in Haramaya University supported by voucher specimens by referring to Hedberg and Edwards (1989); Hedberg and Edwards (1995); Edwards et al. (1995); Edwards et al. (1997); Edwards et al. (2000); Hedberg et al. (2006).

3. Analysis

Species richness, evenness and Shannon-Weiner Diversity Index (H') were analyzed using R software program (version 3.3.4.) using permute, lattice, and vegan packages (R Core Team, 2018). Basal area (BA) is the cross-sectional area of woody stems diameter at breast height (DBH). It is a measure of dominance and calculated by using the following formula (Kent and Coker, 1992): $BA = \Pi d^2/4$, where d is diameter at breast height.

Importance Value Indices (IVI) were analyzed for woody species based on relative dominance, relative density, and relative frequency. The similarity coefficient between community types were assessed using Sorensen's similarity index as recommended by Kent and Coker (1992). To assess the population structure of woody plants, all individuals encounter in the quadrats were grouped into height classes and diameter classes (Emiru et al., 2002). The population structure of woody species in both land use systems was assessed through a bar graph constructed by using the density of individuals of each species (Y-axis) categorized into seven diameters classes (X-axis). Regeneration status of the two land use systems was analysed by comparing saplings and seedling total count with that of mature trees according to Khumbongmayum et al. (2006); Dhaukhhandi et al. (2008); Tiwari et al. (2010).

In addition, T-test unequal variance was employed to test the significance of differences of species richness, diversity index, species evenness, and basal area of the two land use systems. Differences were considered significant at $P < 0.05$. For the cluster analysis, abundance data of the 64 species for PNV and 43 species for CGL were used. In the clustering analysis, the Ward's method and Euclidean distance were used in order to minimize the total within the group mean of squares or residual sum of squares (McCune et al., 2002).

4. Results and discussion

4.1. Woody species composition

In the floristic analysis, 64 woody plant species belonging to 52 genera and 37 families were identified in protected natural vegetation (PNV), which lies in the altitudinal range between 1655 and 2298 m. a.s.l. The life form distribution of these

species was 22 (34.38 %) trees, 25 (39.06 %) shrubs, 13 (20.31 %) tree/shrubs, and 4 (6.25%) climbers. On the other hand, 43 woody plant species belonging to 34 genera and 25 families were identified in communal grazing land (CGL) in the altitudinal range between 1620 and 1930 m.a.s.l. The life form distributions of these species were 16 (37.21 %) trees, 17 (39.53 %) shrubs, 9 (20.93 %) tree/shrubs and 1 (2.33%) climbers. Fabaceae was found the most species-rich family comprising 12 (18.75 %) and 12 (27.91 %) of the total plant species identified in PNV and CGL, respectively, followed by Anacardiaceae by four (6.25 %) species from PNV but Rhamnaceae with three (6.97 %) species from CGL. Similar studies at Tara-Gedam forest (Haileab et al., 2005); Belete forest (Kitessa and Tsegay, 2008), Hulgumburda forest (Aynekulu, 2011) and Babile Elephant Sanctuary (Anteneh et al., 2011) reported the dominance of the Fabaceae in the vegetation stands. This dominance could be attributed to the adaptation potential of leguminous species (Fabaceae) to diverse ecologies of the country.

The abundance and distribution of plant species were found higher in PNV than CGL. In addition, the entire site at the CGL was dominated by *Euclea racemosa*, *Acacia tortilis*, *Gomphocarpus fruticosus*, and *Carissa spinarum* that accounted 56.65% of the total plant cover/density of the 43 plant species identified. An expansion of species like, *Euclea racemosa* in the mountainous landscape of Ethiopia became an indicator of land degradation. On the other hand, in the PNV the same species constituted about 28.89% the total plant cover/density, relatively lower invasion by *Euclea racemosa*. Rather, multipurpose woody species are increasing in the PNV as compared to the CGL. The study showed that few woody species dominated (those species recorded as indicators of degraded land) in the CGL whereas a relatively good proportion of valuable woody species were found in PNV.

The observed difference in woody species composition between the two land use systems showed the positive effect of vegetation protection through proper conservation strategies like area exclosures and restoration practices. Similarly, encouraging results have been reported from studies made on exclosures established in Tigray, Ethiopia (Emiru et al., 2002; Tefera et al., 2005). According to Kibret (2008), the reduction of species diversity in the CGL could be an indication of the increased vulnerability of the plant species by animals and/or human intervention at maturity or early stage of regeneration. This might indicate that individuals in the CGL either harvested at an early growth stage by the local inhabitants and/or their domestic animals (Wondie et al., 2014). Similarly, Sisay et al. (2001); Tessema et al. (2011) suggested that heavy grazing/browsing might cause a reduction of plant species density and diversity over time.

Out of the total 64 woody species recorded from PNV, 36 woody species were found common for both land use systems and the rest 28 woody species were not found in the CGL. Endemic, indigenous, and multipurpose plant species like, *Acacia*

abyssinica, *Celtis africana*, *Clusia abyssinica*, *Cynanchum abyssinicum*, *Dovyalis abyssinica*, *Hagenia abyssinica*, *Maytenus undata*, *Myrsine africana*, *Osyris quadripartita*, *Phytolacca dodecandra*, *Pittosporum viridiflorum*, *Rosa abyssinica*, *Rhus glutinosa* and *Teclea simplicifolia* were found increasing in the PNV. These plant species were not recorded from the CGL. Whereas, woody species, which are commonly known as bush encroachers, invaders, and indicators of land degradation like, *Balanites aegyptiaca*, *Carissa spinarum*, *Euclea racemosa*, *Gomphocarpus fruticosus*, *Grewia villosa*, and *Opuntia ficus-indica* were found increasing in the CGL.

The Sorensen's similarity coefficients of woody species in terms of species richness, genera, and families of the two land use systems were about 40.22%, 39.43% and 42.59%, respectively. This indicated an increasing dissimilarity of woody species between the two adjacent land use systems. Because, the conservation strategy, area enclosure, applied in the PNV was contributed much in the restoration of valuable woody plant species as compared to CGL of Gra-Kahsu natural vegetation. Similar studies were reported that area enclosures and open-grazed lands differed in floristic composition due to the variation of management practices applied (Tefera et al., 2005; Emiru et al., 2007).

4.2. Density and frequency of woody species

The density of a given species is expressed as a number of stems per hectare. Species were classified into five density classes, A – E as follows: A ≥ 100.1 ; B = 50.1–100; C = 10.1–50; D = 1.1–10 and E ≤ 1 . The density of woody species in each class at PNV was relatively higher than CGL (Fig. 2). Forty-nine species and 36 species exhibited density classes A at PNV and CGL, respectively, whereas, 7 species and 4 species exhibited density class C at PNV and CGL, correspondingly. However, there were no woody plant species recorded in the lower density class distribution (D and E) in both land use types (Fig. 2).

In the Gra-Kahsu protected natural vegetation, the highest density of species was recorded for multipurpose woody species like, *Acacia abyssinica*, *Celtis africana*,

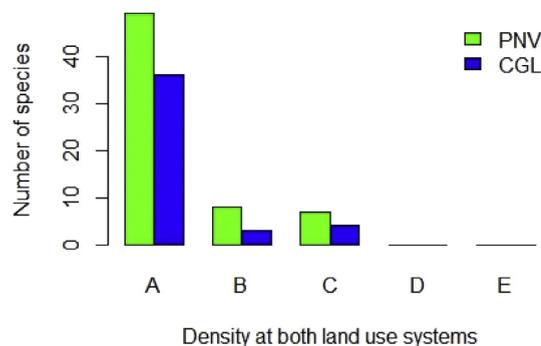


Fig. 2. Density class distribution of woody species at both land use systems: (Density classes: A ≥ 100.1 ; B = 50.1–100; C = 10.1–50; D = 1.1–10; E ≤ 1).

Clusia abyssinica, *Dodonaea angustifolia*, *Hagenia abyssinica*, *Maytenus undata*, *Myrsine africana*, *Phytolacca dodecandra*, *Rosa abyssinica*, and *Rhus glutinosa* that accounted a total of 1838.10 individuals per hectare. Among these, a single species *Euclea racemosa* accounted 1795.24 individuals per hectare for CGL. A single woody species of *Cupressus lusitanica* accounted 1284.38 individuals per hectare in the PNV whereas, *Opuntia ficus-indica* accounted 1608.33 individuals per hectare in the CGL. In addition to the difference in densities of woody species, the type (endemic, indigenous, invasive, etc) and quality (use value) of woody species showed much variation in the two land use systems.

The stand density of seedling and sapling in the PNV was 2334.29 ha⁻¹ and 3114.29 ha⁻¹, respectively. However, in the respective open grazing area the densities were 1320.37 ha⁻¹ (seedling) and 1644.44 ha⁻¹ (sapling). This might be indicated that, fair or poor regeneration status of the CGL and improvement of the regeneration status of PNV due to proper application of management practices. The constant and frequent grazing in the open grazing land might have inhibited the propagation of seedlings from shoots, root suckers, and seeds. In addition, the available species in the open grazing land sustained probably because they had a tolerance to disturbance and hence, are very important in the recovery of degraded vegetation in the area. Similar research work also reported that open-grazed lands had a less seedling density as compared to area enclosures that were adjacent to them and tolerance to disturbance are very important in the recovery of degraded vegetation in the area (Tefera et al., 2005; Emiru et al., 2007; Teshome et al., 2009; Yayneshet, 2011).

Frequency is the number of quadrats (expressed as a percentage) in which a given species occurred in the study area. Species were grouped into five frequency classes: A = ≥81; B = 61–80.9%; C = 41–60.9%; D = 21–40.9%; E = ≤20%. Two species were recorded in frequency class A and B at both land use systems. Therefore, those species were the most frequent species recorded in the study area. Only four species, was recorded in frequency class C at both land use system (Fig. 3). The frequency gives an approximate indication of the homogeneity and heterogeneity of

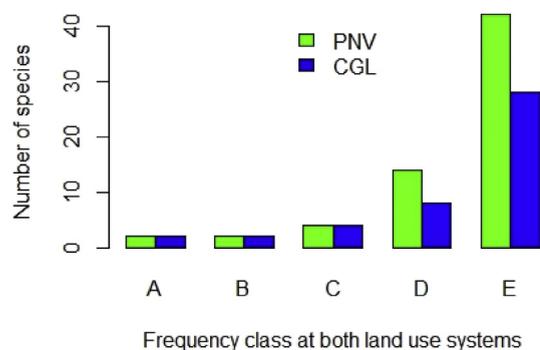


Fig. 3. Frequency class distribution of woody species at both land use systems (Frequency classes: A = ≥80, B = 61–80.9; C = 41–60.9; D = 21–40.9%; E = ≤20%).

species (Haileab et al., 2005). Lamprecht (1989) pointed out that high values in higher frequency classes (classes A and B) and low values in lower frequency classes (classes E and D) indicate constant or similar species composition (homogeneity). High values in lower frequency classes and low values in higher frequency classes on the other hand indicate a high degree of florists heterogeneity (Shibru and Balcha, 2004; Abyot et al., 2014). In this study, high values were obtained in lower frequency classes (classes E and D) (Fig. 3). This shows that high degree of floristic heterogeneity exists in both land use systems.

Acacia abyssinica, *Acacia tortilis*, *Cupressus lusitanica*, *Gomphocarpus fruticosus*, *Hagenia abyssinica*, and *Carissa spinarum* have been the most frequently recorded woody plant species in PNV, whereas *Euclea racemosa*, *Carissa spinarum*, *Opuntia ficus-indica*, *Rhus natalensis*, *Dichrostachys cinerea*, and *Dodonaea angustifolia* were frequently recorded in the CGL. Therefore, as a result of conservation strategy, area exclosures, highly preferred (use value) and multipurpose woody species frequency were increasing in the PNV while decreasing from the adjacent CGL.

4.3. Species diversity, richness and evenness

The value of the Shannon diversity index and evenness in the PNV were 2.29 and 0.80, respectively (Table 2). However, the Shannon diversity index and evenness indices in CGL were 1.84 and 0.64 respectively, indicating significantly lower species diversity and dominance of few species in the CGL than the PNV ($t = 1.67$, $DF = 57$, $p < 0.001$). This could result from repeated habitat disturbances in the CGL due to frequent and intensive interference of both humans and livestock for grazing and other communal uses. Decline in species diversity in the grazing land could be a result of the loss of seedling of some species unable to establish at an early stage of development, and selective defoliation and trampling by grazing herbivores (Belaynesh, 2006). The species evenness also showed significant differences ($t = 1.67$, $DF = 60$, $p < 0.001$) between the two land use systems. A low equitability/evenness value means that there is the dominance of one or few species in the community. While high equitability/evenness means that, there are uniform distributions among the species in a given ecological setting (Wilson et al., 1996; Cavalcanti and Larrazabal, 2004).

Shannon diversity index considered as high when the calculated value is ≥ 3.0 , medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is ≤ 1.0 (Cavalcanti and Larrazabal, 2004). In this respect, in Gra-Kahsu the PNV and CGL sites had medium and low Shannon diversity index, respectively. On the other hand, the species richness in the PNV was significantly higher than CGL ($t = 1.68$, $DF = 42$, $P < 0.001$). The average number of species per quadrat was also higher in the PNV (14.23) than in the CGL (10.30), indicating more diversity in the PNV of Gra-Kahsu natural vegetation (Table 1).

Table 1. Species composition and diversity (mean \pm SD) of protected natural vegetation and adjacent communal grazing land.

Land use system	N	Species richness	Shannon diversity index (H')	Evenness (H'/H _{max})
PNV	35	14.23	2.29 (\pm 0.35)	0.80 (\pm 0.06)
CGL	27	10.30	1.84 (\pm 0.34)	0.64 (\pm 0.10)
P value		<0.001	<0.001	<0.001

N= Number of quadrats.

This indicated that the type of management practices influenced both species richness and diversity. Studies done in Ethiopia also indicated the impact of different management practices on the vegetation status (Mulbrhan et al. 2006; Yayneshet, 2011; and Gebrewahd, 2014). It was also suggested by Oba et al. (2000); Tessema et al. (2011) that species richness declines in heavy grazing grassland.

4.4. Basal area

Basal area (BA) is the cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level). Basal area is used to explain the crowdedness of a stand of natural vegetation. A stand of large trees is more stacked than with the same number of trees of smaller diameter (Shambel, 2010). The mean basal area (expressed as the basal area of stems per hectare) of PNV and CGL woody species with DBH \geq 2.5 cm were 8.29 and 5.32 m²/ha, respectively. BA was significantly larger in the PNV compared to the CGL ($t = 1.67$, $DF = 54$, $P < 0.05$). The highest proportion of the mean BA at the PNV was covered by *Ficus sycomorosa* (33.31 m²/ha), followed by *Eucalyptus camaldulensis* (26.68 m²/ha). While, *Acacia tortilis* (18.6 m²/ha) and *Balanites aegyptiaca* (16.4 m²/ha) were accounted the highest proportion of the mean BA at CGL. The greater difference in basal area between the PNV and CGL could be due to the high number of multi-stemmed trees in the PNV, leading to bigger diameters.

4.5. Importance value index

The IVI values have been helped to understand the ecological significance of the tree species in community structure (Premavani et al., 2014). In this respect, the IVI of woody species of the PNV, which was calculated from relative density, relative dominance, and relative frequency (Shambel, 2011) for *Acacia abyssinica* (18.23), *Cupressus lusitanica* (14.87), *Dodonaea angustifolia* (22.15), *Ficus sycomorosa* (18.67), and *Ficus sycomorosa* (14.87) were found to have relatively higher values. These woody species might be ecologically important in PNV of Gra-Kahsu. Whereas, woody species like, *Teclea simplicifolia* (0.25), *Clematis*

hirsuta (0.25), *Cynanchum abyssinicum* (0.29), and *Rumex nervosus* (0.58) were found with lower IVI (Table 2).

Among other factors, their lower IVI may indicate that these woody species are threatened and need immediate conservation measure (Anteneh et al., 2011; Temesgen et al., 2015). On the other hand, *Cupressus lusitanica* (14.62), *Eucalyptus camaldulensis* (11.71) and *Carissa spinarum* (6.19) were species with the highest relative dominance species in the PNV. About 12.5% and 16.28% of the woody species in the PNV and CGL, respectively, had IVI ≤ 1 that can indicate the significance of initiating conservation measure in the study areas.

Woody species like, *Euclea racemosa* (27.13), *Acacia tortilis* (27.62), *Gomphocarpus fruticosus* (18.97) and *Carissa spinarum* (14.56) with the highest IVI at the CGL may not be necessarily ecologically important rather could be due to an invasive nature of the species, which had been found dominant. Woody species like, *Pavetta oliveriana* (0.82), *Grewia ferruginea* (0.63) and *Clerodendron myricoides* (0.45) had lower value of IVI at the CGL that attract conservation action depending on the social and ecological values of the species (Table 3).

Table 2. Relative frequency, Density, Relative Density, Basal area, Relative Dominance and important value index of same woody species of the protected natural vegetation.

Scientific name	RF	D	RD	BA	Rdom	IVI
<i>Carissa spinarum</i>	2.01	322.50	1.41	14.10	6.19	9.60
<i>Euclea racemosa</i>	1.61	1284.38	4.49	8.77	3.85	9.94
<i>Dodonaea angustifolia</i>	4.22	1102.86	17.44	1.13	0.49	22.15
<i>Ficus sycomorus</i>	6.83	707.86	11.20	1.48	0.65	18.67
<i>Acacia abyssinica</i>	6.22	709.29	11.22	1.80	0.79	18.23
<i>Cupressus lusitanica</i>	0.20	2.86	0.05	33.33	14.62	14.87
<i>Eucalyptus camaldulensis</i>	2.01	32.86	0.52	26.68	11.71	14.23
<i>Rhus natalensis</i>	5.62	432.86	6.85	1.92	0.84	13.31
<i>Dichrostachys cinerea</i>	5.22	425.00	6.72	1.04	0.46	12.40
<i>Cupressus lusitanica</i>	1.61	293.57	4.64	8.77	3.85	10.10
<i>Solanum schimperianum</i>	0.40	9.29	0.15	0.71	0.31	0.86
<i>Clusia abyssinica</i>	0.40	14.29	0.23	0	0.00	0.63
<i>Rumex nervosus</i>	0.40	11.43	0.18	0	0.00	0.58
<i>Cynanchum abyssinicum</i>	0.20	5.71	0.09	0	0.00	0.29
<i>Clematis hirsuta</i>	0.20	2.86	0.05	0	0.00	0.25
<i>Teclea simplicifolia</i>	0.20	2.86	0.05	0	0.00	0.25

RF-Relative Frequency; D-Density; RD-Relative Density; BA-Basal Area; Rdom-Relative Dominancy; IVI- important value index.

Table 3. Relative frequency, Density, Relative Density, Basal area, Relative Dominancy and Important value index of same woody species of the communal grazing land.

SPP	RF	D	RD	BA	Rdom	IVI
<i>Euclea racemosa</i>	7.45	1396.3	17.47	5.53	2.21	27.13
<i>Acacia tortilis</i>	9.57	849.07	10.63	18.56	7.42	27.62
<i>Gomphocarpus fruticosus</i>	9.22	663.89	8.31	3.62	1.45	18.97
<i>Carissa spinarum</i>	6.03	499.07	6.25	5.73	2.29	14.56
<i>Acacia albida</i>	3.55	399.07	4.99	5.44	2.17	10.71
<i>Balanites aegyptiaca</i>	2.48	43.52	0.54	16.43	6.56	9.59
<i>Pavetta oliveriana</i>	0.35	37.04	0.46	0.00	0.00	0.82
<i>Grewia ferruginea</i>	0.35	22.22	0.28	0.00	0.00	0.63
<i>Dombeya torrida</i>	0.35	7.41	0.09	0.00	0.00	0.45
<i>Acokanthera schimperi</i>	0.35	7.41	0.09	0.00	0.00	0.45
<i>Clerodendron myricoides</i>	0.35	7.41	0.09	0.00	0.00	0.45

RF-Relative Frequency;- D-Density; RD-Relative Density; BA-Basal Area; Rdom-Relative Dominancy; IVI- important value index.

4.6. Population structure of woody plant species

The diameter and height class distribution of woody species in the PNV reflected reversed J-shape (L-shape). This means, where species frequency distribution had the highest frequency in the lower diameter and height classes and a gradual decrease towards the higher classes. In this respect, 80.93% of the total frequency lies between the first and second diameter classes, whereas, about 16.49 % of the frequency were found to be in the middle diameter classes (9.1–21 cm) in PNV (Fig. 4a). This indicated that there was selective removal of middle and high diameter class trees for various purposes by local people like for, fencing, farm implementing, house construction, and fuel wood when allowed by the community leaders. The number of

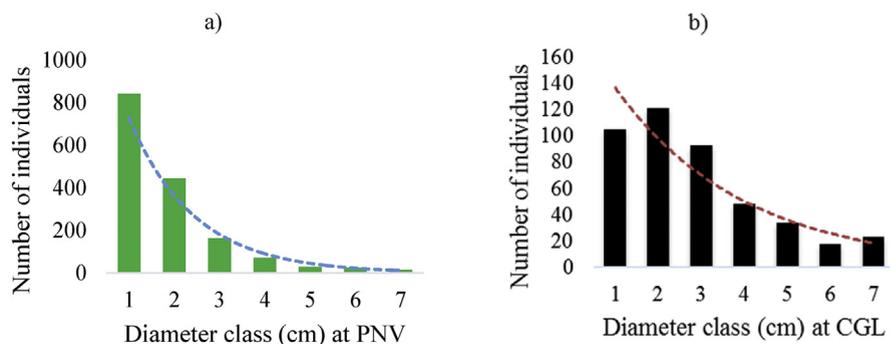


Fig. 4. Diameter class frequency distribution of woody species at both land use systems. DBH class: (1 = ≤ 5 cm; 2 = 5.1–9 cm; 3 = 9.1–13 cm; 4 = 13.1–17 cm; 5 = 17.1–21 cm; 6 = 21.1–25 cm; 7 = ≥ 25.1 cm).

individuals within the larger diameter class (≥ 25.1 cm) accounted for only 2.58 and 9.27% in the PNV and CGL, respectively.

The possible reason for decreasing percentage of the number of individual woody species within the largest diameter class (≥ 25.1 cm) might be due to illegal cutting used by the local people for construction materials and fuel wood consumption. Similar reports indicated that woody species with $DBH > 30$ cm were harvested by the local people for construction and charcoal making (Getaneh, 2007; Tefera et al., 2005). The diameter classes distributions in the CGL shows a bell-shape, which showed there was a higher number of individuals in the middle diameter classes, but decrease towards the lower and higher diameter classes (Fig. 4b). According to Feyera et al. (2007), the bell - shaped pattern indicates a poor reproduction and recruitment of species.

The density distribution of woody individuals in different height classes also showed a similar pattern with diameter classes at the PNV. The height distribution for the CGL and PNV showed an interrupted inverted J shape and inverted J shape, respectively. There was high decrease in the density of classes of three, four, five, six, seven, and eight at PNV. While, in the CGL there were no individuals with height classes of six, seven, and eight. Generally, it showed a decrease in density with increase in height classes of both land use systems (Fig. 5).

A reversed J-shape distribution of height/diameter classes indicated a continuous and good regeneration and/or a stable population of woody species. In contrast, bell-shape and interrupted reversed J-shape distribution of woody species in the communal grazing lands indicated a hampered regeneration status due to several disturbance factors, including deforestation by local people in addition to frequent browsing and trimming by livestock.

4.7. Regeneration status

The density of seedlings and saplings for woody species were analysed to know the regeneration status in both land use systems. A total of 7628 individual seedling and

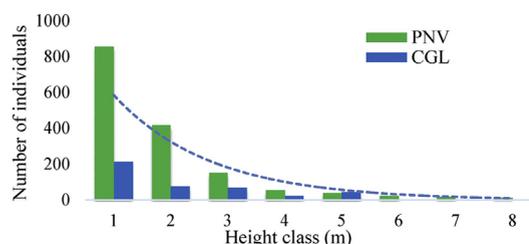


Fig. 5. Height class frequency distribution of woody species at PNV and CGL. Height class (1 = ≤ 4 m; 2 = 4.1–6 m; 3 = 6.1–8 m; 4 = 8.1–10 m; 5 = 10.1–12 m; 6 = 12.1–14 m; 7 = 14.1–16 m; 8 = ≥ 16 m).

saplings belonging to 64 species were counted among all quadrats from the PNV. Woody species like, *Euclea racemosa* (43.41%), *Carissa spinarum* (38.06%), *Rhus natalensis* (37.62%), *Dichrostachys cinerea* (33.39%) and *Dodonaea angustifolia* (30.83%) showed relatively better regeneration in the PNV. Woody species like, *Euclea racemosa* (41.93%), *Carissa spinarum* (47.47%), *Rhus natalensis* (48.18%), *Dodonaea angustifolia* (50.52%) and *Cupressus lusitanica* (61.31%) were contributed higher to the sapling counts. Of course, it was reported that species like, *Euclea racemosa*, *Carissa spinarum*, and *Dodonaea angustifolia* were known to produce a lot of litter and accumulate organic matter in a thick humus profile that enhance the restoration process (Wendwessen, 2009). However, the current increasing level of regeneration status of woody species like *Euclea racemosa* known to have least use value calls for immediate attention in this unique scenery protected natural vegetation.

In the PNV, 43.75% woody species exhibited good regeneration status, 17.19% fair regeneration, and 18.75% showed poor regeneration status. Nevertheless, 12.5% woody species were not found at the seedling stage and 7.81% woody plant species were not found in both seedling and sapling stages. According to Taye et al. (2002), a tree species with no seedling and sapling in a natural vegetation is under risky condition and it is suggested that these species are under threat of local extinction. There were no seedlings or saplings for woody species such as, *Maytenus senegalensis*, *Ficus sycomorou*s, *Cassipourea malosana*, and *Cordia ovals*. The relatively better/lower regeneration of trees might be attributed to the density of their mature trees, which determine the presence/absence of viable seeds amount in the soil (Anteneh et al., 2011).

The regeneration status of the PNV is considered as good since sapling (47.62%) > seedling (35.69%) > matures (17.34%) (Fig. 6). Because, the regeneration status of a given natural vegetation is considered as good if sapling > seedling > matures (Khumbongmayum et al., 2006; Dhaukhhandi et al., 2008; Tiwari et al., 2010). This was revealed in the PNV where better level of protection in the area helped the regeneration of woody species. However, about 53.6% regeneration was

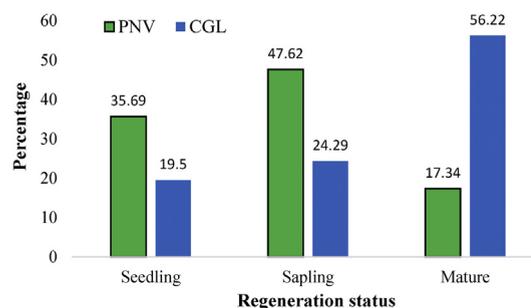


Fig. 6. Regeneration status of woody tree species at both land use systems.

recorded for shrubs, which may indicate the gradual move of the natural vegetation towards shrub land in the PNV that call-up proper planning in its conservation practices.

On the other hand, a total of 3202 individual seedling and saplings belonging to 43 species were counted among all quadrats from the CGL. Woody species like, *Aca-cacia albida* (136), *Carissa spinarum* (120), *Gomphocarpus fruticosus* (248) and *Euclea racemosa* (376) showed relatively better regeneration. In addition, *Euclea racemosa* (478), *Carissa spinarum* (160) and *Gomphocarpus fruticosus* (56) species were the highest sapling counts.

In this area, 72.09% tree species exhibited fair regeneration status and 18.60% showed poor regeneration. A total of 9.30 % woody species was not found regenerating. It was stated that the regeneration status of the given natural vegetation is considered as fair if mature > sapling > seedling (Khumbongmayum et al., 2006; Dhaukhandi et al., 2008; Tiwari et al., 2010). Therefore, the regeneration status of the CGL was considered as a fair since mature (58.59%) > sapling (25.31%) > seedling (20.32%) (Fig. 6). The lower seedling count in the CGL showed its least restoration potential that could be due to unlimited free grazing and vegetation exploitation by the local community. Though, there are some germination of seeds due to few remnant mother trees, most of these seedlings were perishing off before reaching sapling and mature stages for various reasons including grazers and browsers pressure (Teshome et al., 2015).

The major factors contributed for lack of regeneration for some woody species could be a result of existing disturbance in the study areas like, free grazing, firewood collection, and poor biotic potential of tree species. These could either affect the fruiting or seed germination or successful conversion of seedling to sapling stage. Moreover, individuals in young stages of any species are more vulnerable to any kind of environmental stress and anthropogenic disturbance (Iqbal et al., 2012; Moumita and Ashalata, 2014). In addition, decline in species diversity in the communal grazing land could be a result of the loss of seedling of some species unable to establish at an early stage of development, and selective defoliation and trampling by grazing herbivores (Belaynesh, 2006).

4.8. Plant community types

Based on a hierarchical cluster analysis using Ward's method and Euclidean distance, three clusters were identified in the PNV: community type I (lower altitude), community type II (middle altitude), and community type III (higher altitude) (Fig. 7).

I. Community type I was formed from aggregate of quadrats from the lower altitude, which was represented by 22 species and 5 quadrats. The altitudinal range of this

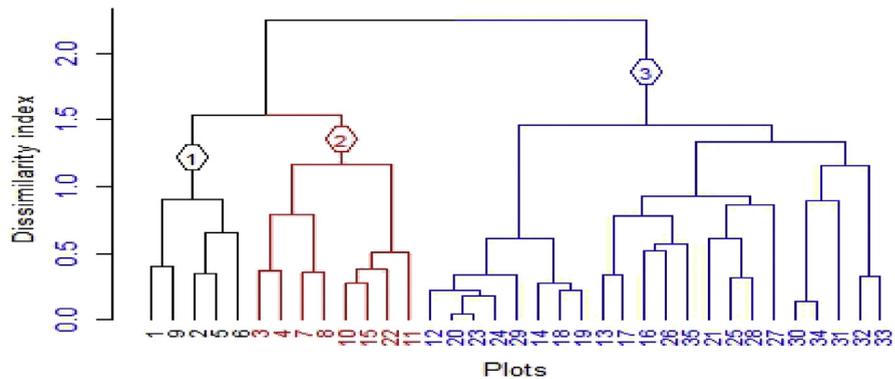


Fig. 7. Dendrogram representing plant community types of the protected natural vegetation (Agglomerative coefficient: 0.84).

community was from 1655 to 1691 m a.s.l and at a slope of 15–30%. Woody species (trees, shrub and woody climbers) associated with this community, such as *Dichrostachys cinerea*, *Laggera tomentosa* and *Acacia tortilis* are the dominant species of this community.

II. Community type II was formed from aggregate of quadrats from the middle altitude, which was represented by 58 species and 22 quadrats. This community type was distributed and was situated at altitudinal ranges from 1828 to 2298 meters above sea level and at a slope of 30–60%. Furthermore, this community type is mainly comprised of *Dodonaea angustifolia*, *Cupressus lusitanica*, *Rhus natalensis*, *Celtis africana*, and *Myrsine africana*.

III. Community type III was formed from aggregate of quadrats from the higher altitude, which was represented by 58 species, and 22 quadrats. This community type was distributed and was situated at altitudinal ranges from 1828 to 2298 meters above sea level and at a slope of 30–60%. The dominant woody species represented were *Euclea racemosa*, *Pterolobium stellatum*, *Acacia abyssinica*, and *Myrsine africana*.

Community type III was the highest in total count of shrubs and trees (7763.64 individuals per hectare). This is because of the location of the quadrats in this community, which were not suitable for grazing and browsing by animals due its difficulty in topography. In addition, this community is far away from most populated areas. On the other hand, community types I was found to have the least average counts of woody species with an average 4190.63 individuals per hectare. This could be due to the relative disturbance of the area by peripheral free grazing and browsing of livestock.

Species diversity across the community at PNV: Of the three community types, community type three (III) had highest woody species diversity (2.38) and species richness (16.22) followed by community type two (II) which has 2.25 and 12

diversity and species richness, respectively. The least species diversity and species richness was recorded in community type one (I) which has (2.01) and (10.13), respectively (Table 4). The low species richness of community type I may be due to anthropogenic disturbance since located towards the community side.

The Sorenson's similarity coefficient was used to detect similarities among the plant community types. The overall similarity values in species composition between the communities ranged from 41.15 to 50%. High similarity coefficient ($Sc = 50\%$) was observed between community II and III and low similarity ($Sc = 41.15\%$) was observed between community I and community III. Community II and III had better levels of similarities located relatively at higher altitudes than Community I. In addition, the lower level of similarity between lower and higher altitudes could be due to the less number of common species between them and the lower altitude might be exposed to human interference. Generally, the three plant community types had different in species diversity, species richness, species composition and species density. Moreover, application of management strategies contributed for the formation of complex communities (Ganatsas et al., 2012).

Based on a hierarchical cluster analysis using Ward's method and Euclidean distance in R-software, two clusters were identified in the CGL: community type I (lower altitude), and community type II (higher altitude) (Fig. 8).

I. Community type I was formed from aggregate of quadrats from the lower altitude, which was represented by 32 species and 15 quadrats. The altitudinal range of this community was from 1620 to 1748 m a.s.l and at a slope of 5–40%. Woody species dominant in this community were like, *Acacia tortilis*, *Acacia asak*, *Eucalyptus camaldulensis* and *Gomphocarpus fruticosus*.

II. Community type II was formed from aggregate of quadrats from the higher altitude, which was represented by 33 species and 12 quadrats. This community type was distributed and is situated at altitudinal ranges from 1631 to 1930 m.a.s.l and at a slope of 10–45%. This community was mainly comprised of *Euclea racemosa*, *Carissa spinarum*, *Acacia tortilis*, *Gomphocarpus fruticosus* and *Dichrostachys cinerea*.

Table 4. Shannon diversity indices, species richness and evenness of the plant communities at protected natural vegetation.

	Community type		
	I	II	III
Species Diversity (H')	2.01	2.25	2.38
Species evenness (E)	0.80	0.80	0.83
Species richness (S)	10.13	12	16.22

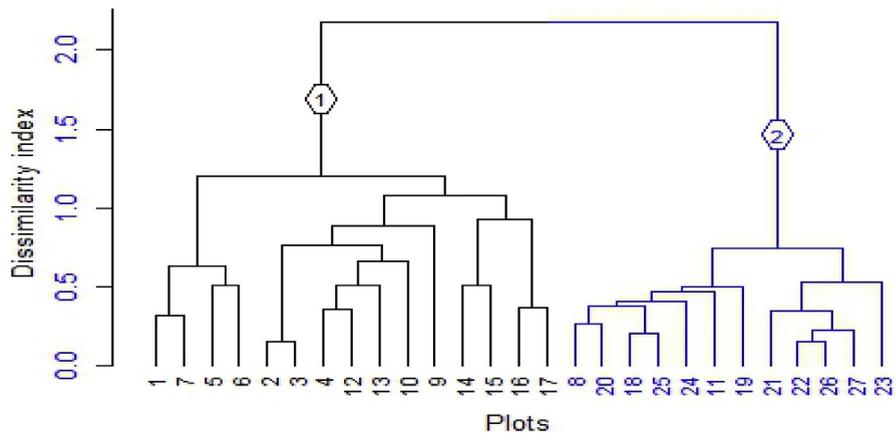


Fig. 8. Dendrogram representing plant community types of the communal grazing land (Agglomerative coefficient: 0.83).

Woody species density across the community at CGL indicated that community type II was the highest in total count of shrubs and trees (4618.75 individuals per hectare). On the other hand, community types I was found to have the least average counts of woody species with an average 3465 individuals per hectare. This was associated with the area where there is relative disturbance due to higher grazing and browsing by livestock and it was located towards the most populated villages.

Species diversity across the community at CGL indicated that community type two (II) had highest woody species diversity (1.87) and species richness (10.83) (Table 5). The least species diversity and species richness was recorded in community type one (I) which has (1.82) and (9.87), respectively.

The low species richness of community type one may be due to anthropogenic disturbance. However, community type one had more evenness than the community type two.

The Sorenson's similarity coefficient was used to detect similarities among the plant community types. The overall similarity values in species composition between the two communities of CGL were 70.77% indicating the entire vegetation is moving to homogenous type.

Table 5. Shannon diversity indices, species richness and evenness of the plant communities at communal grazing land.

	Community type	
	I	II
Species Diversity (H')	1.82	1.87
Species evenness (E)	0.63	0.65
Species richness (S)	9.87	10.83

5. Conclusions

This comparative analysis, which has been done between PNV and the adjacent CGL of Gra-Kahsu natural vegetation showed the impacts of conservation strategies like, area exclosures. Following this conservation strategy an improvement in the floristic composition, density, richness, diversity indices, BA, IVI, population structure, and regeneration of woody species were observed in the PNV of Gra-Kahsu. In addition, the type and quality of woody species showed variation in the two land use systems. Highly preferred and multipurpose woody species frequencies were increasing in the PNV whereas decreasing from the adjacent CGL with similar scenery. Though the PNV, which was under better conservation practices, still the values indicated that least valuable species like, *Euclea racemosa* and *Carissa spinarum* were found increasing that urge further attention in addition to the existing conservation practices. The population structure analysis showed more irregularities in which the regeneration of most important tree species was hampered, suggesting an urgent need for a conservation plan to promote sustainability of the woody vegetation resources. Moreover, the relative higher regeneration status recorded for shrubs could be indicator of the gradual move of the natural vegetation towards shrub land in the PNV that call-up timely attention in its conservation practices. Therefore, to maximize the benefit coming out of the natural vegetation, it is not only the greening, density, and biomass that matter, rather need proper floristic analyses on the types and qualities of existing and emerging species that leads to informed planning in order to implement proper conservation strategies and practices.

This comparative analysis of the natural vegetation in the two land use systems could be taken as a benchmark and lessons for enhancing the existing wide-scale conservation practices in-line with Climate Resilient Green Economy (CRGE) mainstreamed development plan of the country. In addition, the findings provide basic information for local decision making, which could enhance establishment and management of the natural vegetation in the complex mountains and unique landscapes in the southern part of Tigray, North Ethiopia. In conclusion, these types of comprehensive floristic analysis and comparative analysis contribute to see the impact of conservation practices on the natural vegetations for countries like Ethiopia, intensively practicing wide-scale conservation activities in the degraded landscapes.

Declarations

Author contribution statement

Tesfay Atsbha: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Anteneh Belayneh Desta, Tessema Zewdu: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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