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Impact of Exclosure on Species Diversity, Population Structure and Regeneration Status of Woody Plants in Lowland Northern Tigray, Ethiopia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aim: This study was conducted to assessing woody plant composition, population structure and regeneration status in lowland exclosure (EX) of Northern Ethiopia.
Study Design: Investigation of parameters was undertaken from 71 plots with size of 20 m x 10 m laid systematically along transect lines for vegetation data. These 200 m^2 plots were used for assessment of trees with DBH >5 cm. Small quadrats of 4 m*4 m (16 m^2) nested within the bigger plots was laid at the four corners and center of each plots. These were used for measuring seedling and sapling individuals. To analyze species diversity, population structure and regeneration status of woody plants were by computing abundance, density, basal area, Importance value index (IVI) and using Shannon-Weiner diversity and evenness indices.
Results: According to vegetation survey result, a total of 23, 17 and 26 woody species were recorded, at Kara, Erba and Shektekli exclosures (EXs), respectively. While 8, 7 and 5 species of woody plant were in open grazing land (OGL). The total mean densities of all woody plants were found to be 1530, 1480 and 2999 individual's ha^{-1} at Kara, Erba and Shektekli in EXs.
Conclusion: The study suggested that the regional government have to considering EXs as useful for restoration or rehabitation strategy in the region, the vegetation in all the EXs in the study sites have a higher species composition, diversity, density, increment of basal area and regeneration woody plants than OGL, as a result of management differences in EXs. However, there are also

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variation on species composition, diversity, density increment of basal area and regeneration woody plants among exclosures having similar age and altitude for instance the species recorded in Erba site is lower than with other of EXs, This could be due to among local site characteristic variation and high grazing happen before Ex establishment exists. Therefore, we need to apply soil and water conservation, enrichment planting with indigenous tree species and strengthen local management institution in effectively protect the exclosure.

Keywords: Exclosure; open grazing land; woody species and lowland.

ABBREVIATIONS

EX : Exclosure
OGL : Open Grazing Land

1. INTRODUCTION

Degradation of vegetation has eventually led to desertification in Africa than any other continent [1]. The dry land vegetation in Ethiopia resides in arid and semi-arid lands, which occupy 50% of the land area [2]. The vast dry lands in Ethiopia encompass diverse ecosystems: woodlands, grasslands, shrub lands, bush tickets, wetlands, agro-ecosystems, forests and aquatic ecosystems. These ecosystems intimate in rich biodiversity, some of which are the most valuable and rarest flora and fauna resources [3]. Degradation, deforestation, and land cover/land use changes are perhaps the number one threat to dry land ecosystems today in Ethiopia These processes result in native habitat loss for the rich biodiversity of the dry land ecosystems, both flora and fauna.

Rehabilitation of degraded dry land ecosystems is quintessential for the conservation of the threatened and unique dry land biodiversity. Generally, ecological restoration is regarded as an effective way for the enhancement of both biodiversity and the provision of ecosystem services and consequently contributes also to sustainable development [4]. In fact, in recently rehabilitation works either through exclosures, soil and water conservation and plantation trees and other forms are common in dry lands of Ethiopia. Among the various ways of overcoming environmental degradation, loss of biodiversity and deforestation problem of the country, exclosure is the most crucial one because it is specially the determinant way of rehabilitating severely exploited vegetation and degraded dry land environment in Ethiopia [5]. As indicated by scientific studies [6], protecting areas from livestock intervention i.e., a practice termed exclosure, is one of assisted natural regeneration strategy adopted to restore degraded forests. In several case studies conducted in highland of Tigray, exclosures were found to have higher species richness and diversity than the unclosed lands [7,8]. For instance, exclosures had twice the plant species richness and diversity value compared with grazing lands after 22 years of exclosure establishment [9]. Despite the fact that exclosures have been implemented in Ethiopia for about decades, empirical data on the effectiveness of these area exclosures in restoring ecosystem woody diversity are lacking [10]. However, the corresponding attraction given to adapt woodlands and other ecosystems to climate is negligible. Perhaps, compared to the highland and moist ecosystems, dry land ecosystems in Ethiopia are under researched. Until recently, they were largely considered as little contributor to the national economy and hence were grossly ignored. Potentials in their ecosystems and natural resources for development, adaptation and mitigation were little explored in depth [11]. There is little conclusive study that shows a need for in-depth understanding of the effectiveness of the strategy under diverse biophysical conditions. Such understandings of the vegetation the process of rehabilitation of the degraded areas after exclosure under various settings will contribute to developing ideas for designing management and technical guidelines for other restoration projects in the country. Therefore, the current study was intended to give these information particularly woody species recovery potential in lowland of Tigray. Therefore, the objective of this study was to assess woody plant composition, population structure and regeneration status in the study areas.

2. MATERIALS AND METHODS

2.1 Description of the Study Sites

2.1.1 Exclosure site selection

This study was conducted at three sites, Kara, Erba and Shektekli, in the southern and central lowland parts of the Region Tigray National

Regional State (TNRS). The first two sites are located in the Raya Valley Catchment Area while the third is found in the Tekeze River Catchment Area. Description of each sites are described below.

Site 1: Kara (Raya Azebo district): Kara is located between 13º 86-13º 87 N and 37º57'-37º58 E, with altitudinal range of 1563–1668 m.a.s.l and at distance 7 km away from Mohoniy town in south on the main road Addis Ababa. The topography is classified as level (2-7º slope) bottom land and surrounded by mountain slopes; it has shallow soil and moderately clay loam fine textured and following soil bund structures have been constructed. Kara exclosure is established in the period from 1996 to 1997, in communal area [12]. It is about 16 hectare in total, and managed by Woreda agriculture office in collaboration with the local administration of Kara tabias, are not fenced, guards are hired by the local administration on a productive safety net program (PSNP) projects.

Site 2: Erba (Raya Azebo district): Erba is located between 13º 06-13º 07'N and 37º56'-37º57 E, with altitudinal range of 1627–1707 m a.s.l. and at distance of 43 km away from Mohoniy town in East direction and near to Afar National Regional State (Yalo district). Information by local people is that the exclosure had been closed for 10 year at the time of this study [12]. The total area of this field is approximately 20 ha. The area is generally characterized by undulating mountains and rugged terrain; it has rocky and stony, with the slope ranging between 3% and 15%. The exclosure was completely protected from grazing and human interference under the management of the Woreda agriculture office. Early, before five or four years ago sedentary human and livestock enrichment was happening into exclosure from neighbor Afar Region during dry season.

Site 3: Shektekli (Tanqua Abergelle district): Shektekli is located between 14º 06-14º 07'N and 37º56'- 37º57 E, with altitudinal range of 1565-1608 m a.s.l. and located at a distance of 39 km away from Yechla town in north direction, near Kola Temben District. The exclosure is nearly to 10 year at the time of this study. The total area of this field is approximately 17 ha [13]. The exclosure was administered by Woreda Agriculture office, with the support of food security project. The management plan includes the using soil bund structure, enrichment planting and other activities.

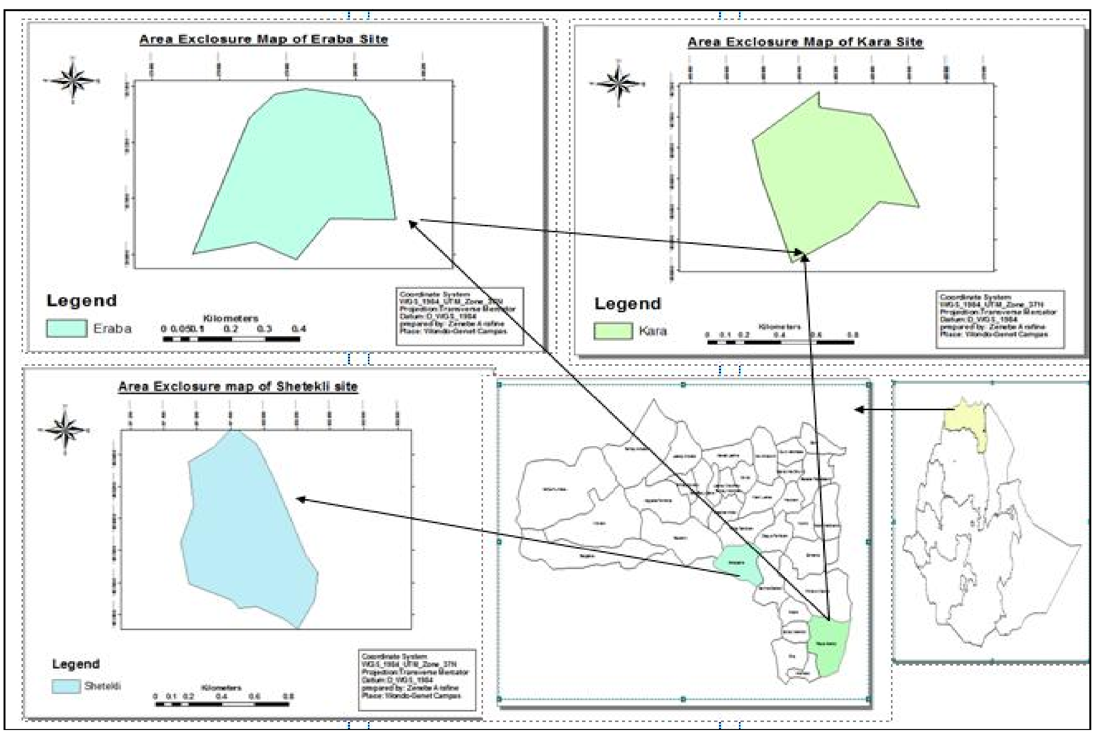

Fig. 1. Map of the study sites (Raya Azebo and Tanqua Abergelle Districts)

As mentioned above, three representative study sites of the EXs and OGL needed to had similar vegetation cover in the past, although there is no much difference in elevation gradients, age and rainfall. On the other hand, the representative study sites represented the varied micro landscape, aspect and slope, and hence the effect of 'site' being accounted on woody diversity, composition and regeneration.

2.2 Study Procedures and Measurement Techniques

2.2.1 Data collection

Systematic transect sampling technique was used in this study where parallel transect lines were laid at 300 meter distance interval in each of the selected exclosures (EXs) and the adjacent open grazing land (OGL). The number of transects per site was based on vegetation density, spatial heterogeneity of vegetation, and area of the site [10]. These transects were laid following altitudinal gradient at appropriate direction. The length of transects varied in both EXs and adjacent OGL, it depending on area of the site. Along each transect, plots of 10 m x 20 m size were laid at distance of 100 meter apart. A total of 71 plots were established for this study sites: 14, 15 and 17 plots at EXs as well as 8, 8 and 9 plots at adjacent OGL in Kara, Erba and Shektekli, respectively. These 200 m^2 plots were used for assessment of trees with DBH >5 cm. Small quadrats of 4 m*4 m (16 m^2) nested within the bigger plots was laid at the four corners and center of each 200 m^2 plot. These were used for measuring seedling and sapling individuals.

2.2.2 Field data collection

In each 200 m^2 plot, all matured individuals of woody species with diameter at breast height (DBH) greater than 5 cm were identified and their height and DBH was measured using measuring stick and/or hypsometer and caliper, respectively. All germinating seedlings (height ≤1 m) and saplings (individuals with DBH < 2.5 cm and 1< height < 2 m) were identified and counted within the five 16m^2 sub-plots [14] and 2.5< DBH <5 shrubs also considered as sapling. Plant species were identified in the field following nomenclature approaches of [15,16].

2.2.3 Analysis of woody vegetation data

The woody vegetation data was analyzed by computing the abundance, density, basal area, and Importance value index (IVI) and population structure. Heterogeneity of the two management types was also determined using Shannon-Weiner diversity and Evenness indices. Abundance: Two sets of abundance value were calculated in this study. (i) Average abundance per quadrats, calculated as the sum of the number of stems of a species from all quadrats divided by the total number of quadrats, (ii) Relative abundance, calculated as the percentage of the abundance of each species divided by the total stem number of all species, following [17]. Species richness: It is defined as the number of species per quadrat, area or community. In this particular case, the number of observed species across the whole sample quadrats was used as a representation of species richness. Density: Which refers to the total number of stem of a species ha^{-1}, and calculated by summing up all the stems across all sample quadrats (abundance) and translated to hectare base for all the species encountered in the study quadrats. Species diversity: To determine species richness of each land use and each sample site, Species index (S), which is simply the total number of tree species on an area can be calculated. This index doesn't indicate the relative proportion or abundance of a particular species. Hence, models that incorporate both richness and the evenness of relative abundance are required.

Shannon index (Shannon and Wiener, 1949) and Simpson's diversity index (D) were calculated.

Shannon diversity index (H') H'= $-\sum pi \ln pi$ and Simpson's diversity index (D) as, and D =1- $\sum pi^2$,

Where pi is the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of the total, and S is the total number of species.

Importance Value Index (IVI): To investigate the structural role of tree in the sampling plots, the Importance Value Index (IVI) was calculated using the percentage of relative density (R.A), relative dominance (R.D) and relative frequency (R.F) equation 1.

$$I.V.I = R.A. + R.D. + R.F - Equation \quad (1)$$

Where: I.V. I = Important value index of each species

$$\text{RA} = \text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} * 100$$

$$RD = \text{Relative dominance} = \frac{\text{Basal area of each species}}{\text{Basal area of all species}} * 100$$

$$RF = Relative\ Frequency = \frac{\text{Chance to find each species}}{\text{Chance to find all of species}} * 100$$

The total basal area was calculated from the sum of the total basal area of immerging stems. Basal area was calculated as: BA= (πDBH^2)/4.

2.3 Statistical Analysis

All statistical analysis was run using SAS. A one-way analysis of variance (ANOVA) and Mean comparisons were made using the Tukey 'Honestly Significantly Different (HSD) test with $p< 0.05$ in order to test for differences between study sites. Whereas, to test woody species Shannon diversity index, Simpson evenness index and species richness significant differences between EXs and OGL, analysis of variances (ANOVA) was performed. Descriptive were used for species composition, density, Basal area and IVI of tree species.

3. RESULTS

3.1 Species Composition, Diversity and Abundance

3.1.1 Floristic composition

A total of 41 species belonging to 24 families and 34 geneses were found, with Fabaceae (10 species), Euphorbiaceae (5) and Burseraceae (3) as dominant families, five of the woody species in the EXs were exotic species, which accounted for (12.2%) woody species recorded in the three study sites both in EXs and OGL. The highest composition of woody plants species was recorded in Shektekli site followed by Kara and Erba study sites (Appendix 1, A-C). With respect to specific sites, the vegetation at Kara site was composed of a total of 24 woody species, distributed across 15 families and 21 geniuses both in the EX and OGL; among the species encountered 23 were recorded in the EX and 8 of them in the OGL. Sixteen species (66.7%) were alone in the EX. The family Fabaceae was represented by seven species (30.4%) followed by Euphorbiaceae and Mimosoideae which had two species (8.7%) for each in the EX. In the OGL, Fabaceae was represented by five species (62.5%) followed by Balanitaceae, Rhamanaceae and Aslcepiadaceae containing only one species for each species (Appendix 1- A).

A total of 20 woody species, belonging to 12 families and 16 genera, was recorded both in the EX and OGL. Among the species encountered, 17 were recorded in the EX and seven of them in the OGL. Twelve species (60%) were alone in the EX. The family with the highest number of species was Fabaceae, represented by six species (35.3%), and followed by Myrtaceae, Euphorbiaceae and Moraceae, which were represented by two species each inside the EX. For OGL, the family with the highest number of species was also Fabaceae, represented by two species, while the remaining five families were represented by only one species each in the Erba site (Appendix 1- B and Table 1).

Similarly, a total of 26 woody species, distributed across 14 families and 21 geniuses both in the EX and OGL, were recorded in Shektekli site of which all were recorded in the EX and five of them in the OGL. Twenty one species (80.8%) were alone in the exclosure, of which two were planted exotic species. Fabaceae was represented by 5 species (19.2%) followed by and Burseraceae and Euphorbiaceae which had 4 each species, were represented in Shektekli site in EX. At the same time, in OGL, the family Fabaceae was represented by two species followed by Caesalpiniodeae, Moraceae and Capparidaceae, which were represented by one species each (Appendix 1-C and Table 1).

3.1.2 Density

The total mean densities of all woody species was found to be 1530, 1480 and 2999 individuals ha^{-1} at, Kara, Erba and Shektekli in both EXs and OGL, respectively (Table 2). The density of all encountered species in the respective study area is summarized in (Appendix 1, A-C). At Kara study site, the total mean densities of woody species were 1136 individuals ha^{-1} at the EX, whereas the density of seedlings, saplings and trees were 511, 396 and 229 individuals' ha^{-1} respectively, Of the total density of all woody species, the proportion of seedlings in EX was 45% and the total mean density of woody species were 394 individuals' ha^{-1} in OGL, on the other hand, the density of seedlings, saplings and trees were 88, 156 and 150 individuals' ha^{-1} respectively (Table 2). The most abundant species in the EX were *Cadia purpurea* 225 stems ha^{-1} (19.8%), *A. abyssinica* 196.43 stems ha^{-1} (17.3%), *B. saegyptiaca* 153.57 stems ha^{-1} (13.5%) and *E. tirucalli* 121.43 stems ha^{-1} (10.7%), and these altogether accounted for 61% of the of woody species density. On the other hand, 60% of woody species density in OGL was occupied by *A. abyssinica* 237.50 stems ha^{-1} (Appendix 1-A). Similarly, the total mean densities of woody species were 930 individuals' ha^{-1} at the EX, and 550 individuals' ha^{-1} at the OGL in Erba site. The percent of seedlings and trees were almost equal share 39% and 40% in the EX respectively (Table 2). The dominant species were *A. etabaica* 216.7 stems ha^{-1} (23.3%) followed by *S. guineense* 213.3 stems ha^{-1} (22.9%) and *A.abyssinica* 163.3 stems ha^{-1} (17.6%) at the EX and *A. etabaica* 150 stems ha^{-1} (27.3%), *A. abyssinica* 143.8 stems ha^{-1} (26.1%) and *S. guineense* 131.3 stems ha^{-1} (23.9%) were at OGL (Appendix 1-B).

At Shektekli site, the total mean densities of woody species were found in the EX 2171 individuals ha^{-1} whereas the density of seedlings, saplings and trees were 994, 503 and 674 individuals' ha^{-1}, respectively. The proportions of seedlings were the highest 46% from the total density of all woody species. On the contrary, the total mean density of woody species were 828 individuals' ha^{-1} in OGL, the density of seedlings, saplings and trees was 278, 311 and 239 individuals' ha^{-1} respectively. Of the total density of all woody species, the proportion of seedlings was 33.6% at OGL (Table 2). With respect to specific woody species, it was found that 54.7% of the woody vegetation at EX of Shektekli study site was covered by *Acacia etbaica*, *Senna Singueana*, and *Acacia abyssinica*, and the highest density was that of *A. etbaica,* 529 stems ha^{-1}, while the lowest was that of *Commiphor habessinica*, *Combretum molle*, *Sida schimperiana* and *Ehretia cymosa*, each with 3 stems ha^{-1}. In case of OGL, *A. etbaica* and *S. singueana* were the most abundant species which covered 772 stems ha^{-1} (93.3%) of the total density (Appendix 1-C).

3.1.3 Basal area

Basal area of all woody plants with diameter >2.5cm was 5.3, 3.1 and 7.4 m^2/ha for EX and 3.5, 1.6 and 1.7 m^2/ha for OGL at Kara, Erba and Shektekli study sites, respectively. With regarding specific sites, almost (51.9%) basal area were shared by *A. abyssinica* followed by *B. aegyptiaca* 0.96 (18%) in the EX and 2.89 (82.1%), 0.31(8.8%) and 0.15(4.3%) shared by *A. abyssinica, B. aegyptiaca* and *A. etabaica* at OGL, respectively at Kara site. Similarly, the highest share of basal area were *A. etbaica* 1.6 (51.6%) followed by *B. aegyptiaca* 0.4 (13%) at the EX and *A. abyssinica,* and *A. etabaica* 0.8 (50%) and 0.6 (37.5%) at OGL at Erba site. The higher share of basal area in Shektekli EX was *A.abyssinica* 2.9 (39.2%) and *A. etabaica* 2.1 (28.4%), in the case of OGL, 1.5 (88.2 %) by *A. etabaica* followed by *S. singueana* 0.2 (11.8%) (Appendix 1, A-C).

3.1.4 Important value index

Importance value index (IVI) indicates the extent of dominancy and level of ecological importance of particular species. In the current study, *A. abyssinica* was the most dominant species both at EXs and OGL in Kara study site, with IVI of (84.2%) and (179.1%), respectively.

Table 1. Summary of floristic composition in two management types at three study sites

Sites	Family			Genus		
	EX	OGL	Total	EX	OGL	Total
Kara	15	4	15	20	6	21
Erba	12	6	12	16	6	16
Shektekli	13	4	14	21	4	21

Where; Exclosure (EX) and Open Grazing land (OGL)

Table 2. Density per hectare of seedlings, saplings and trees in EX and OGL at the three sites

Site	Management types	Seedling	Sapling	Tree	Total
Kara	EX	511	396	229	1136
	OGL	88	156	150	394
Erba	EX	363	193	373	929
	OGL	300	181	69	550
Shektekli	EX	994	503	674	2171
	OGL	278	311	239	828

Where; Exclosure (EX) and Open Grazing land (OGL)

On the other hand, the most dominant species in the EX were *A. etbaica* (94.9%), *S. guineense* (50.5%), and *A. abyssinica* (47.4%), and those in the adjacent OGL were *A. abyssinica* (103.4%) and *A. etbaica* (96.3%) in Erba study site. *Acacia etbaica* (66.7%) *A. abyssinica* (66.6%) and *S. singueana* (29.1%) were those with highest IVI in the EX of Shektekli study site, while it was *A. etbaica* (171.2%), *S. singueana* (94%) and *A. abyssinica* (11.7%) were the highest IVI in the OGL (Appendix 1, A-C).

3.1.5 Diversity and richness of woody species

The study found that EXs had higher mean species richness, Shannon diversity index and Simpson's diversity index than adjacent OGL at all of the three study sites. Average Shannon diversity index for EX and OGL was 2.29 and 1.17 at Kara, 1.89 and 1.45 at Erba and 2.21 and 0.92 at Shektekli site. Similarly, the mean Simpson's evenness was for EX 0.83, 0.68 and 0.91 at Kara, Erba and Shektekli respectively. On the other hand, 0.39, 0.62 and 0.12 at Kara, Erba and Shektekli for OGL. Except Erba study site, Simpson's diversity index significant (p=0.6977) difference between two management types. In addition, mean number of species were statically different between two management types at Erba (p=0.0004), Kara (p=0.0190) and Shektekli (p=0.0007) sites. Such observed differences in mean species richness and species diversity among the two land types were also confirmed by statistical test which revealed the presence of statistically significance variation, at 5% level of significance for all study sites (Table 3).

3.1.6 Population structure of woody species

The diameter distribution of the ranking two woody species shows higher number of individuals in the lower diameter class than the higher diameter class (Fig 2). With specific Kara site seems to have an inverted J shape. Of the total individuals, 82% of the individuals had a diameter distribution of less than 5cm.The most abundant species *A. abyssinica* had also an inverted J distribution. About 53% of its populations had diameter distribution less than 5 cm, but, *Cardia purpurea* was only found in the first diameter class distribution.

There is also relatively higher number of individuals with lower diameter class than higher diameter class in top two dominated species, *A. etbaica* and *Syzgium guineense*, in Erba site. Similarly, in Shektekli, there is higher number of individuals with lower diameter classes, the seedling and sapling were dominated by shrub *A. abyssinica* next to *Anethum graveolens.* Even though, there is relatively higher number of stem with lower diameter classes in Shektekli site.

In the case of the OGL, even though there are high numbers of lower class diameter individuals than higher diameter class in the top two ranked species (Fig 3), the recorded individual are dominated by a shrub *A. etbaica* species followed by *A. abyssinica* in both Kara and Erba sites have an inverted J distribution. The most abundant species for the three open grazing lands *A. etbaica* had an inverted J distribution.

4. DISCUSSION

4.1 Species Composition and Species Diversity

The woody plant species at 23 and 26 in Kara and Shektekli site for EX and 8 and 5 for adjacent OGL were on averagely three times lower than to the EXs sites. This is consistent with results of studies conducted in northern Ethiopia; for instances [18,19,20] in Gonder Zuria

Table 3. Mean (±SE) of plant species richness and diversity of tree species in two management types at the three sites

Variable	Sites	EX	OGL	P-value
Shannon diversity index	kara	2.29 ± 0.08^a	1.17 ± 0.07^b	0.0001
	Erba	1.89 ± 0.06^a	1.45 ± 0.09^b	0.0003
	Shektekli	2.21 ± 0.07^a	0.92 ± 0.01^b	0.0001
Simpson's diversity index	Kara	0.83 ± 0.09^a	0.39 ± 0.08^b	0.0007
	Erba	0.68 ± 0.09^a	0.62 ± 0.14^a	0.6977
	Shektekli	$0.\ 91 \pm 0.12^a$	0.12 ± 0.03^b	0.0001
Richness (Number)	kara	6 ± 0.56^a	3 ± 0.37^b	0.0004
	Erba	5 ± 0.39^a	3 ± 0.57^b	0.0190
	Shektekli	6 ± 0.17^a	3 ± 0.24^b	0.0007

Mean with same later are not significant at P < 0.05

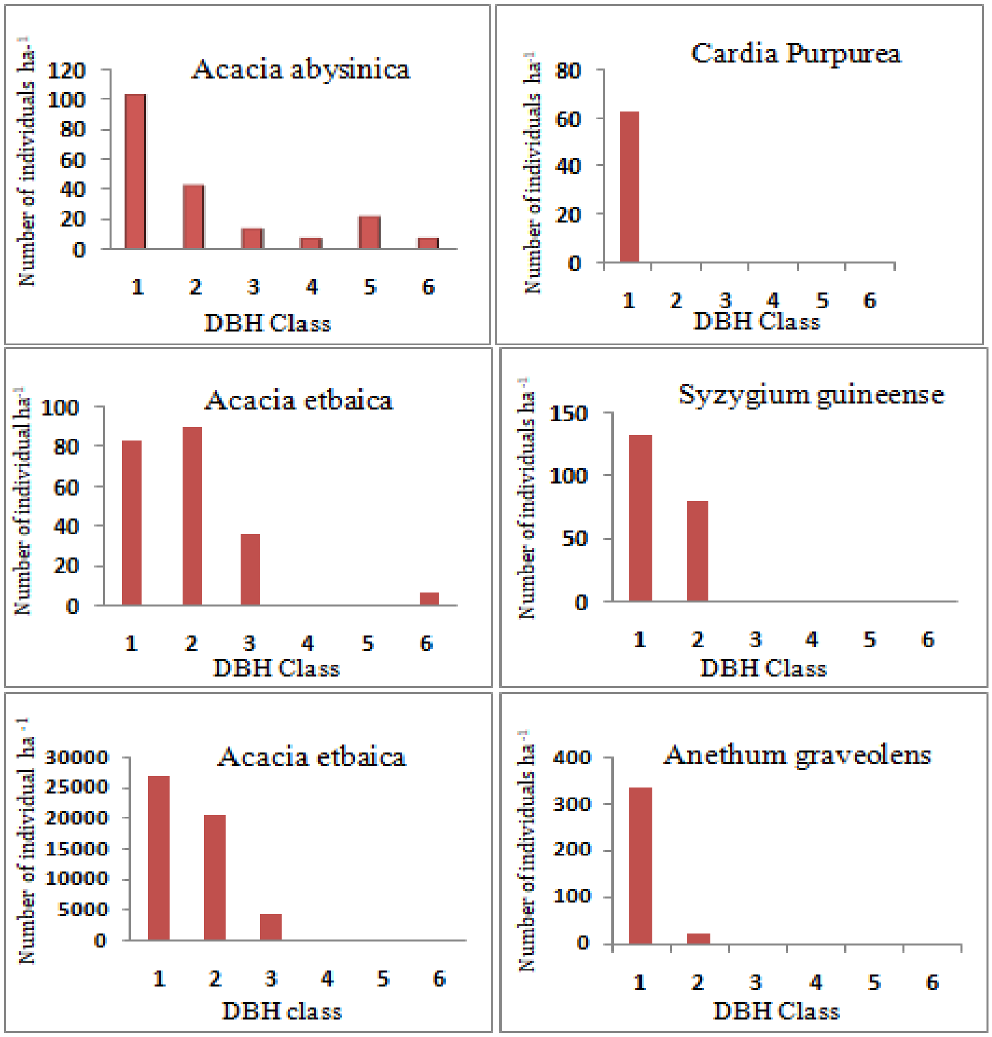

Fig. 2. Diameter distribution of two top dominant woody plants in all plots of the exclosures. Diameter class: 1< 5 cm, 2= 5-10, 3= 10-15, 4= 15-20, 5= 20-25, 6= >25 cm

district, While at Erba sites was below from range of other reported in northern Ethiopia. Because the site is closer to a highly livestock migration from neighboring region when the time of dry season and more susceptible to livestock interference than other two sites. However, the recorded number of species in all EX sites is slightly less than the species number reported by [21] at 5 years, 10 years and 15 years age EX were 46, 37 and 44 woody species composition, respectively, in lowland of northern Ethiopia. Generally, the composition of the woody vegetation in exclosures of degraded land depends largely on the original vegetation and past disturbance history [18].

The Shannon-Wiener diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 [22]. The index increases with the number of species in the community but in practice, for biological communities H' does not exceed 5.0 [23]. However, the results of Shannon diversity indices from all the present study sites were within this range except Shektekli OGL, it could be dominate by single species of *A. etbaica;* 50% abundance covered by it. Even though, there is high density as compared to other OGL. The Shannon diversity index (H') values of woody plants in EX sites were much higher than their adjacent OGL. The highest mean diversity value 2.29 was recorded at Kara site which was more than twice of the OGL (1.17). In general, the diversity of woody species in EXs is almost double to that of OGL. The diversity of this finding is similar with the one conducted by other researchers who did comparison of woody

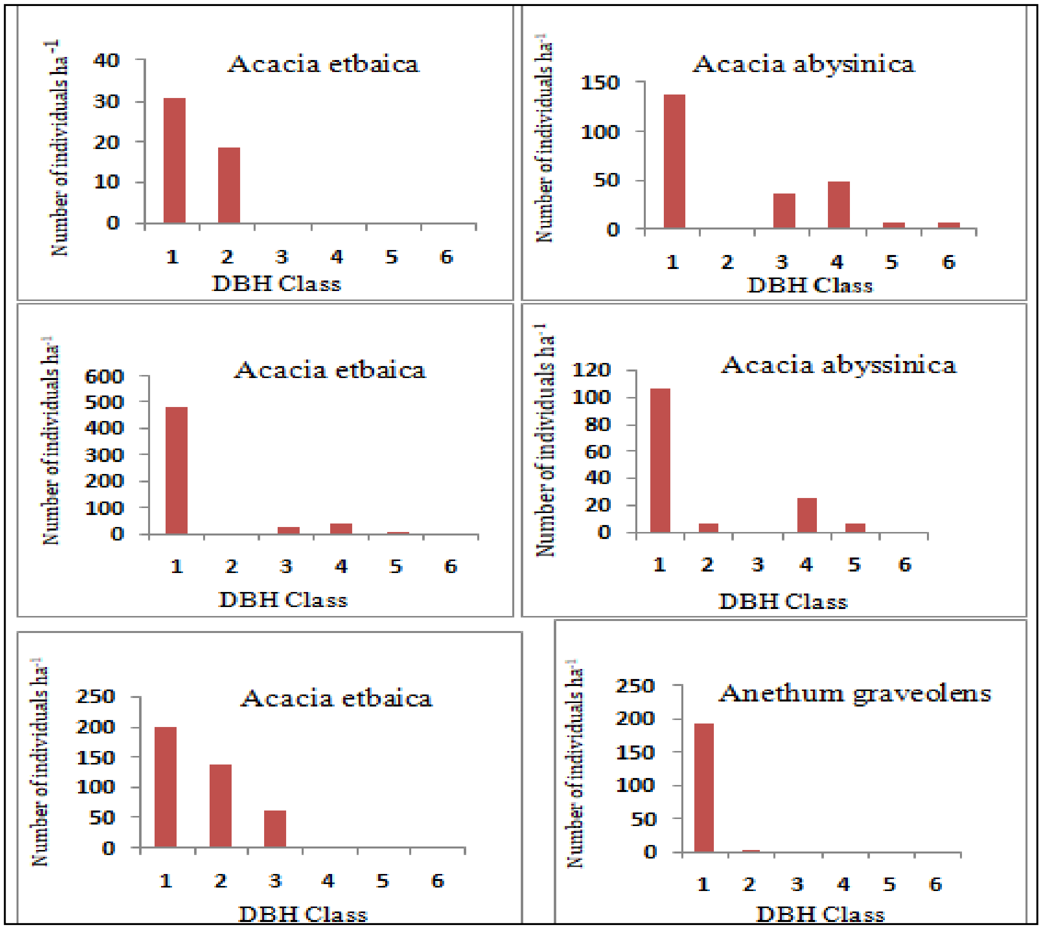

Fig. 3. Diameter distribution of two dominant woody plants in all plots of the open grazing lands. Diameter class: 1< 5cm, 2= 5-10, 3= 10-15, 4= 15-20, 5= 20-25, 6= >25 cm

species diversity between EXs and OGL in Ethiopia; [24] in North Wello and [10] in central and northern Ethiopia.

In Shektekli EX had a higher basal area, which is 7.4 m^2/ha than that of Kara EX 5.3 m^2/ha and Erba EX 3.1 m^2/ha (Appendix A-C). Basal area is influenced by site productivity, density and/or competition between individuals in the EXs. In this regard the difference in basal area of Shektekli EX is higher, due to the existence of relatively higher number of trees with bigger diameter in Kara and Erba EXs. The stand basal area at three EXs ranges of 3.1 -7.23 m^2 ha^{-1}. Similar results were reported from farm exclosure in Tigray, Northern Ethiopia [25] and in semi-arid region of Northern Ethiopia [26]. The total basal area for the three EXs are far less than that within the reported range for dry forests of Ethiopia (e.g. 49.80 m^2/ha for Masha Anderacha [27] and 64 m^2/ha for Gurra Farda [28]. It could be variations due to the nature of plant species which cannot be grown to a high basal area.

Importance Value Index is crucial to compare the ecological significance of species [29]. It was also stated that species with the greatest importance value are the leading dominant of specified vegetation [30]. In this regard, *A. etbaica* and *A. abyssinica* were the three leading dominant and ecologically most significant trees species in entire study sites. The reason why they have higher IVI value is that they have higher relative density, relative frequency and relative abundance relative to other species in the exclosure. Generally, based on density per hectare, and IVI the greater composition of *A. etbaica,* both in the EXs as well as the OGL in Erba and Shektekli sites, indicate that the species was highly favored to germinate and survived with the existing climate than the other species. The same result was also found in

Wukro [18,31]. In most cases, [32] stated that the higher dominant and ecologically most significant species might also be the most successful species in regeneration, pathogen resistance, preference by browsing animals (least preferred), attraction of pollinators and attraction of seed predators that facilitate seed dispersal within the existing environmental conditions.

According to Simon Shibru and Girma Balcha [30], population structures of trees have significant implications to their management, sustainable use and conservation. This study both in the EXs and OGL at all sites, there are normal DBH distribution patterns and the inverted J-shaped. It indicates a pattern where species frequency distribution had the highest frequency in the lower DBH classes and gradually decreases towards the higher diameter. A similar trend was also reported from the semi arid areas of northern Ethiopia [10]. Furthermore, as [19] indicated, the presence of few numbers of large individuals could also interrupt the continuous replacement of woody species. The evaluation of most dominant species releaved that there is also a normal DBH distribution patterns in most species, the inverted J-shaped. Such a pattern was represented by two species in both EXs and OGL, represented by species like *Acacia etbacia* and *Acacia abyssinica* etc (Figs. 1 and 2). It is an indication for healthy regeneration status with good reproduction and recruitment capacity of a given species [33] and considered to be with stable population structure [34].

5. CONCLUSION

Assuming that vegetation of both EX and adjacent OGL was the similar characteristics some years ago, the vegetation in all the EXs have a higher species composition, diversity and regeneration sapling and seedling. This is as a result of management differences of the EXs.

Accordingly, there are also variation on species composition, diversity, density basal area and regeneration sapling and seedling among study sites having similar altitude, age and level of management. This is due to among local site characteristic variation and past vegetation story. However, the species recorded in Erba site is lower than the other area of EXs. This could be due to activities in the area before establishment of EXs. The poor regeneration capacity in EX calls for need to encourage conservation and to strengthen local management institution for effective protection and maintenance of woody species in the area.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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Appendix 1. Density (D), Basal Area (BA), and Important Value Index (IVI) of woody species at Kara (A), Erba (B) and Shektekli (C)

A. Kara

Scientific name	Family	D		BA		IVI	
		EX	OGL	EX	OGL	EX	OGL
Cadia purpurea (Picc.)	*Fabaceae*	225.00	37.50	0.11	0.02	28.85	14.59
Acacia abyssinica Hochst.ex Bak.	*Fabaceae*	196.43	237.50	2.77	2.89	84.16	179.12
Balanites aegyptiaca (L) Del.	*Balanitaceae*	153.57	18.75	0.96	0.31	44.37	22.78
Euphorbia tirucalli (L.)	*Euphorbiaceae*	121.43	0.00	0.06	0.00	18.78	0.00
Acacia etabaica Schlueinf.	*Fabaceae*	64.29	50.00	0.33	0.15	21.16	35.07
Dichrostachys cinerea (L.) Wight	*Mimosoideae*	64.29	0.00	0.03	0.00	10.90	0.00
Capparis tomentosa Lam.	*Capparidaceae*	60.71	0.00	0.03	0.00	8.23	0.00
Dodonea angustifolia L.f.	*Sapindaceae*	42.86	0.00	0.02	0.00	6.49	0.00
Commiphora africana (A.Rich)	*Burseraceae*	25.00	0.00	0.01	0.00	5.92	0.00
Leucaena leucocephala Lam[d]	*Mimosoideae*	25.00	0.00	0.01	0.00	4.76	0.00
Osyris quadripartita Decn.	*Sanatalaceae*	21.43	0.00	0.28	0.00	10.65	0.00
Ziziphus spin-christi (L.)Desf	*Rhamanaceae*	21.43	25.00	0.29	0.01	12.02	20.34
Carissa edulis (Forssk).	*Apocynaceae*	21.43	0.00	0.01	0.00	5.57	0.00
Jatropha curcas L.[d]	*Euphorbiaceae*	17.86	0.00	0.01	0.00	5.22	0.00
Ficus-indica	*Moraceae*	14.29	0.00	0.01	0.00	2.55	0.00
Maytenus senegalensis (Lam.) Exell	*Celastraceae*	10.71	0.00	0.01	0.00	2.20	0.00
Hypericum revolutum Vahl	*Hypericaceae*	10.71	0.00	0.06	0.00	5.49	0.00
Acacia senegal (L.) Wild	*Fabaceae*	7.14	0.00	0.08	0.00	4.49	0.00
Eucalyptus globules Labill [d]	*Myrtaceae*	7.14	0.00	0.01	0.00	3.12	0.00
prosopis juliflora (sw)	*Fabaceae*	7.14	0.00	0.14	0.00	5.49	0.00
Calotropis procera (Ait.)	*Aslcepiadaceae*	7.14	6.25	0.03	0.03	3.42	6.85
Acacia tortolis (Forssk.)Hyyne.	*Fabaceae*	7.14	6.25	0.09	0.09	4.63	8.81
Sesbania sesban (L) [d]	*Fabaceae*	3.57	0.00	0.00	0.00	1.51	0.00
Faidherbia albida Del	*Fabaceae*	0.00	12.50	0.00	0.01	0.00	12.44
Total		**1135.7**	**393.75**	**5.34**	**3.52**	**300.0**	**300.0**

B. Erba

Scientific name	Family	D		BA		IVI	
		EXC	OPEN	EXC	OPEN	EXC	OPEN
Acacia etabaica Schlueinf.	*Fabaceae*	216.7	150.0	1.6	0.6	94.9	96.3
Syzygium guineense	*Myrtaceae*	213.3	131.3	0.4	0.1	50.5	44.5
Acacia abyssinica Hochst.ex Bak.	*Fabaceae*	163.3	143.8	0.3	0.8	47.4	103.4
Dichrostachys cinerea (L.) Wight	*Mimosoideae*	100.0	0.0	0.1	0.0	25.4	0.0
Balanites aegyptiaca (L) Del.	*Balanitaceae*	100.0	62.5	0.1	0.0	25.0	25.8
Sesbania sesban (L) [d]	*Fabaceae*	26.7	0.0	0.0	0.0	7.6	0.0
Jatropha curcas L. [d]	*Euphorbiaceae*	23.3	0.0	0.0	0.0	4.3	0.0
Achyranthes aspera L.	*Amaranthaceae*	20.0	0.0	0.1	0.0	7.7	0.0
Acacia tortolis (Forssk.)Hyyne.	*Fabaceae*	16.7	0.0	0.0	0.0	6.3	0.0
Osyris quadripartita Decn.	*Sanatalaceae*	13.3	0.0	0.0	0.0	5.0	0.0
Ficus-indica	*Moraceae*	10.0	37.5	0.0	0.0	2.7	16.3
Maytenus senegalensis (Lam.) Exell	*Celastraceae*	6.7	0.0	0.0	0.0	2.3	0.0
Eucalyptus globules Labill [d]	*Myrtaceae*	6.7	0.0	0.0	0.0	2.3	0.0
Acacia amythethophylla Steud.ex *A.Rich*	*Fabaceae*	3.3	0.0	0.0	0.0	2.0	0.0
Acacia senegal (L.) Wild.	*Fabaceae*	3.3	0.0	0.0	0.0	2.1	0.0
Carissa edulis (Forssk.)	*Apocynaceae*	3.3	0.0	0.0	0.0	1.8	0.0
Ehretia cymosa Thonn	*Boraginaceae*	3.3	0.0	0.0	0.0	1.8	0.0
Triticum polonicum L.	*Moraceae*	0.0	0.0	0.3	0.0	11.0	0.0
Capparis tomentosa Lam.	*Capparidaceae*	0.0	18.8	0.0	0.0	0.0	8.1
Tragia pungens (Forssk.).	*Euphorbiaceac*	0.0	6.3	0.0	0.0	0.0	5.5
Total		**930.0**	**550.0**	**3.1**	**1.6**	**300.0**	**300.0**

C. Shektekli

Scientific name	Family	D		BA		IVI	
		EX	**OGL**	**EX**	**OGL**	**EX**	**OGL**
Acacia etabaica Schlueinf.	*Fabaceae*	529.4	400.0	2.1	1.5	66.7	171.2
Senna singueana (Del.) Lack**.**	*Caesalpiniodeae*	355.9	372.2	0.3	0.2	29.1	94.0
Acacia abyssinica Hochst.ex Bak.	*Fabaceae*	302.9	22.2	2.9	0.0	66.6	11.7
Commiphora africana (A.Rich)	*Burseraceae*	208.8	0.0	0.3	0.0	21.1	0.0
Maytenus senegalensis (Lam.) Exell	*Burseraceae*	141.2	0.0	0.4	0.0	18.6	0.0
Jatropha curcas L. [d]	*Euphorbiaceae*	135.3	0.0	0.3	0.0	16.1	0.0
Acacia senegal (L.) Wild.	*Fabaceae*	91.2	0.0	0.2	0.0	13.7	0.0
FICUS-indica	*Moraceae*	70.6	5.6	0.1	0.0	6.7	6.5
Dichrostachys cinerea (L.) Wight	*Mimosoideae*	67.6	0.0	0.0	0.0	9.2	0.0
Commiphora samharensis Schweinf	*Burseraceae*	52.9	0.0	0.0	0.0	4.6	0.0
Triticum polonicum L.	*Moraceae*	35.3	0.0	0.0	0.0	3.7	0.0
Capparis tomentosa Lam.	*Capparidaceae*	35.3	27.8	0.0	0.0	7.3	16.7
Boscia angustifolia A.Rich	*Capparidaceae*	35.3	0.0	0.0	0.0	4.8	0.0
Faidherbia albida Del	*Fabaceae*	26.5	0.0	0.0	0.0	4.4	0.0
Euphorbia tirucalli L.	*Euphorbiaceae*	11.8	0.0	0.0	0.0	1.9	0.0
Ziziphus spin-christi (L.)Desf	*Rhamanaceae*	11.8	0.0	0.3	0.0	7.6	0.0
Salix subserrata Willd.	*Salicaceae*	11.8	0.0	0.0	0.0	4.2	0.0
Osyris quadripartita Decn.	*Sanatalaceae*	8.8	0.0	0.0	0.0	1.4	0.0
Balanites aegyptiaca L.	*Balanitaceae*	8.8	0.0	0.0	0.0	3.3	0.0
Acacia amythethophylla Steud.ex.A.Rich	*Fabaceae*	8.8	0.0	0.0	0.0	1.4	0.0
Croton macrostachyus Del.	*Euphorbiaceae*	5.9	0.0	0.0	0.0	1.4	0.0
Sida schimperiana Hochst.ex A,rich	*Malvaceae*	2.9	0.0	0.0	0.0	1.1	0.0
Commiphora habessinica (Berg.)	*Burseraceae*	2.9	0.0	0.0	0.0	1.1	0.0
Combretum molle R.Br.ex.G.Don	*Euphorbiaceae*	2.9	0.0	0.1	0.0	1.8	0.0
Ehretia cymosa Thonn.	*Boraginaceae*	2.9	0.0	0.0	0.0	1.1	0.0
Mangifera indica L [d]	*Boraginaceae*	2.9	0.0	0.0	0.0	1.1	0.0
Total		**2170.6**	**827.8**	**7.4**	**1.7**	**300.0**	**300.0**

[d] *Planted species*

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