

Dynamics of woody Species Composition and diversity as a Result of Conversion of open grazing land to an enclosure in Northern Ethiopia, The case of Tigray lowlands

Abstract

Exclosures have been established on open grazing lands to tackle environmental degradation in Ethiopia, particularly in Tigray region. However, little has been known with regard to the effect of establishing exclosures on open grazing lands especially in Lowlands of Tigray region, northern Ethiopia. Hence, this study was conducted to explore the effect of conversion of grazing lands to an enclosure on woody species composition and diversity in Tselemti district, which was taken as testing site to represent the lowlands of Tigray). To collect data on vegetation, three line transects, parallel to each other and across the slope were laid in the enclosure and open grazing lands systematically at 150 meters interval. Along each transect line, six sample plots measuring 20m×20m were laid down at 100 meters intervals from each other. So, a total of 36 plots (18 from grazing land and 18 from enclosure), measuring 20m*20m, were established along 6 transects for vegetation sampling. 41 woody species were recorded in the enclosure and grazing land respectively. Shannon diversity, richness, evenness and density were found to be significantly higher ($P < 0.05$) in enclosure than grazing land. It can be concluded that conversion of open grazing lands to exclosures is a viable option to restore degraded vegetation. For this reason, additional exclosures have to be established on previously degraded open grazing lands in the area and areas with similar biophysical setup.

Comment [U1]: Remove parenthesis

Keywords: Exclosure, grazing land, dynamics, conversion

1. Introduction

In response to environmental problems, communities in the Northern highlands of Ethiopia started to establish exclosures about three decades ago (Mekuria and Aynekulu, 2011). Exclosures are areas closed off from the interference of human and domestic animals with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands. Exclosures are usually established in steep, eroded and areas that have

been used for grazing in the past (Descheemaeker et al., 2006). Tigray, northern Ethiopia, is one of the most environmentally degraded regions in Ethiopia, characterized by erratic rainfall, overgrazing, deforestation, soil erosion, soil moisture stress, loss of biodiversity and soil fertility decline (Tadesse, 2014).

To overcome the challenges of land degradation exclosures were established in Tigray region the region in the last 30 and more years (Nedessa et al., 2005). Exclosures are areas exempted from the interference of human and domestic animals with the goal of reducing land degradation and promoting natural regeneration of plants of formerly degraded grazing lands.

Studies conducted by authors (Birhane et al., 2006; Mamo, 2008; Mekuria et al., 2011; Getseselassie, 2012; Mekuria and Yami, 2013; Mebrat et al. 2014; Mulugeta 2014; Manaye et al., 2019) have shown the positive role of exclosures on biodiversity enhancement and degraded soil restorations in the region. However, most of these studies focused in the mid (1500 – 2300 meter above sea level) and highlands (> 2300 meter above sea level) with limited attention to the lowlands (< 1500 meter above sea level) such as the study area, Tselemti district. The effectiveness of restoration options can be affected by the differences in ecological and socio-economic conditions, political and historical contexts and level of management (Munie, 2013). The effect of land use conversion on environmental restoration is variable and it depends on soil type, land use history, vegetation type, climate, topography and current land use and land cover (Marland, 2004) and according to Mekuria et al. (2017), the effectiveness of establishing exclosures to restore degraded open grazing lands varies across different localities due to heterogeneity of exclosure management, soil, slopes, climate and topography. Therefore, studies which investigate the role of exclosures under different agro-ecologies, socio-economic conditions, soil types and level of management are crucial. Hence, this study was conducted to explore the effect of establishing exclosures in previously degraded communal grazing lands on woody species composition diversity in Tselemti district, Northern Ethiopia representing the lowlands of Tigray region.

2. Materials and Methods

2.1. Study area

The study was conducted at Mai-Saba enclosure and its adjacent grazing land, Sekota-Mariam Kebelle (the smallest political administration units in Ethiopia) in Tselemti district, Tigray, Northern Ethiopia (Figure 1), which is 380 km far from Mekelle, capital city of Tigray region, towards North West. The study site is located at 13°05' latitude and 38°18' longitude at an altitude of 1350 meter above sea level (m a.s.l.) (Darcha et al., 2018). Areas characterized at an elevation of <1500, but >500 m a.s.l. are classified as lowland or locally called 'Kolla' (Hurni et al., 2016).

Comment [U2]: Indicated total area of the study site in hectares/acres

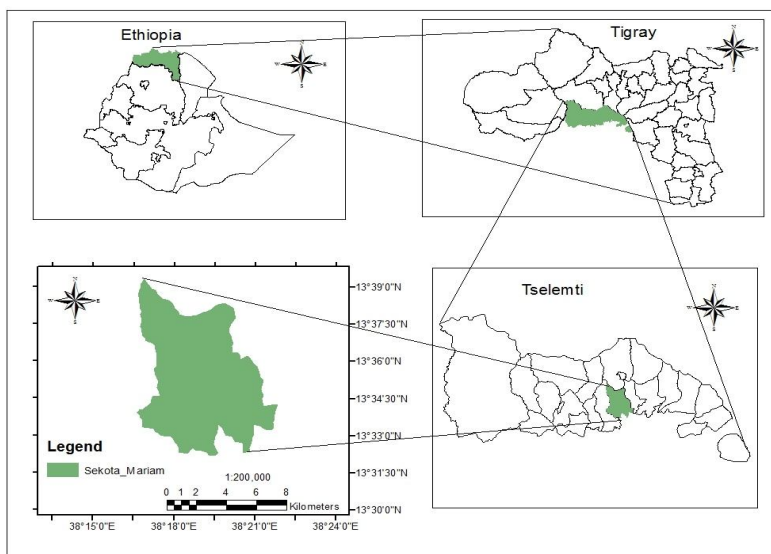


Figure 1. Location map of the study area

The study area is characterized by hot to dry semi-arid lowland plain with a very hot temperature. Five years (2012-2016) temperature data show that the temperature in the study area varies from 15.6°C in January to 38.6°C in April. The dry season occurs between November and April while the rainy season occurs between June and September (Figure 2).

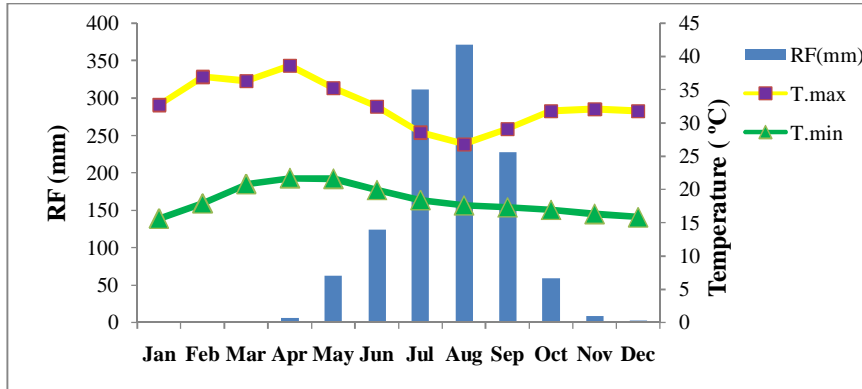


Figure 2. Five years (2012–2016) mean monthly rainfall (mm) and maximum and minimum mean monthly temperatures of the study area (Source: Tigray meteorological services center).

Nitolsols, cambisols and Vertisols are the most dominant soil types of the study area. *Anogeisus l eiocarpus*, *Balanites aegyptica*, *Cordia africana*, *Croton macrostachyus*, *Ficus sycomorus*, *Ficus thonningii*, *Ficus vasta*, *Stereospermum kunthianum*, *Ziziphus spinachristi*, *Boswellia papyrifera*, *Vanguria edulis*, *Dodonea angustifolia* and *Acacia abysinica* are some of the dominant plant species in the district. The community mainly depends on mixed agriculture (both crop and animal husbandry) for livelihood. The dominant crops grown are *Sorghum bicolour* L., *Zea mays* L. and *Eleusine coracana* L (Darcha et al., 2018) and the major livestock herds are donkeys, cattle, chicken and goats.

2.2. Experimental design, Data collections and Analysis

2.2.1. Experimental design and vegetation data collection

Space for time substitution approach was used for data collection. The assumption of this approach is that exclosures and adjacent grazing lands had similar initial conditions before the establishment of exclosures (Mekuria et al., 2009). To collect data on vegetation, three line transects, parallel to each other and across the slope were laid in the exclosure and open grazing lands systematically at 150 meters interval. Along each transect line, six sample plots measuring 20m×20m (Mekuria and Yami, 2013) were laid down at 100 meters intervals from each other (Figure 3). The first plot was laid down randomly and the other plots systematically at

equal interval in each of the transects. To avoid the effect of disturbances, the first and the last line transects and plots were laid at a distance of at least 30m from the edges.

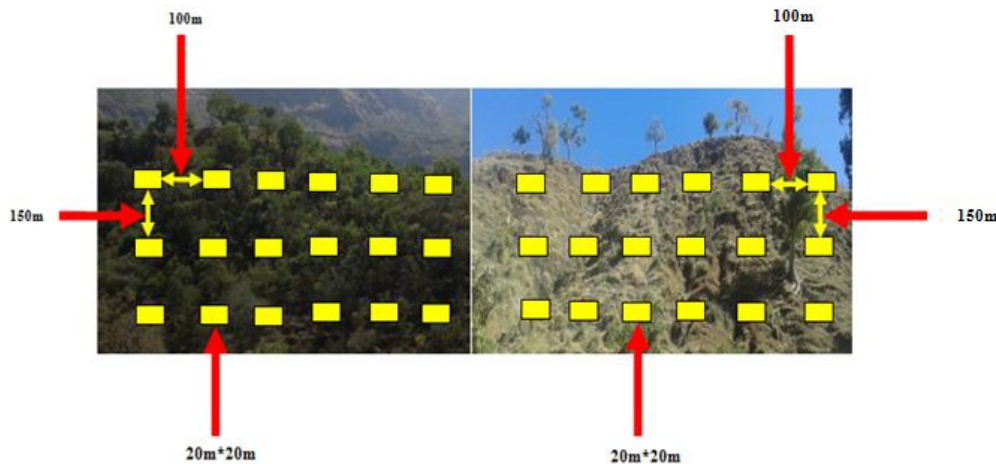


Figure 3. Experimental design for exclosures (left) and its adjacent open grazing land (right)

Thus, a total of 36 plots (18 plots from each land use type) were used to collect data on vegetation. All woody species were identified, counted and recorded by their local name and measured in each plot in both land uses. The plots were marked using strings and wooden pegs and the counted and recorded woody species were marked using a chalk not to miss or count an individual twice. The woody species encountered in the plots were identified supported by the local residents. The scientific name of the species was identified from: i) useful trees and shrubs for Ethiopia (Bekelle-Tesemma, 2007); ii) useful trees and shrubs in Eritrea (Bein et al., 1996).

2.2.2. Vegetation Data analysis

The vegetation data were analyzed by computing the density, frequency, dominance, diversity indices, importance value index (IVI) and coefficient of floristic similarity.

Density: was computed by summing up all the individuals from all sample plots and translated to hectare base for all the species. Two sets of density were calculated: density/ha of each species and relative density, which was calculated as the ratio of the density of a given species to the sum total of the density of all species:

$$\text{Relativedensity} = \frac{\text{Density of species A in hectare base}}{\text{Density of all species in hectare base}} * 100 \dots \text{Eq (1)}$$

Comment [U3]: Instead of using experimental design please use the word "Field Layout"

Comment [U4]: Indicate the extent of minimum qualification for a woody species that was included in the study (e.g. All woody species with at least 5cm dbh were included...) If not, please justify

Comment [U5]: Indicate the program/application that was used in the analysis of data (e.g. excel, spss, etc.)

Frequency: It shows the presence or absence of a given species in each sample quadrant. Two sets of frequency were calculated, absolute frequency, which refers to the number of plots in which the woody species encountered and relative frequency, calculated as the ratio of the absolute frequency of a given species to the sum total of the frequency of all species:

$$\text{Relative frequency} = \frac{\text{Frequency of species A}}{\text{Frequency of all species}} * 100 \dots\dots\dots \text{Eq (2)}$$

Dominance: It refers to the degree of coverage of a given species expressed by a space it occupied in a given area. Two sets of dominance were calculated: absolute dominance (the sum of basal areas of the stems in m²/ha), and relative dominance: ratio of the total basal area of a given species to the sum of total stem basal areas of all species. Dominance was calculated for individual stems with diameter > 2.5cm (Worku, 2006):

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Dominance of all species}} * 100 \dots\dots \text{Eq (3)}$$

Basal area (BA) was computed using the formula:-

$$BA = \frac{\pi d^2}{4} \dots\dots\dots \text{Eq (4)}$$

Where BA= basal area in m²; π=3.14; D=diameter

Importance Value Index (IVI):

It refers to the relative ecological importance of each species in a given area. It was calculated by summing up the relative dominance, relative density and relative frequency of the species as follows:

$$IVI = Rd + RD + RF \dots\dots\dots \text{(Eq 5) (Mata et al., 2011)}$$

Where Rd is relative density, RD is relative dominance and RF is relative frequency.

Diversity indices

Species diversity was estimated using Shannon Wiener Diversity Index and evenness (Kent & Coker 1992):

$$H' = - \sum_{i=1}^s p_i \ln p_i \dots\dots\dots \text{(eq. 6)}$$

Where:

H' = Shannon diversity index

s = number of species

Pi=the proportion of individuals or the abundance of the ith species expressed as a proportion of the total

ln= natural logarithm

Evenness: was calculated using the formula:

$$\text{Evenness (J')} = - \sum_{i=1}^s p_i \ln p_i / \ln s \dots \dots \dots \text{Eq (7)}.$$

Where: S = number of species and ln is a natural log.

Coefficient of floristic similarity

Sorensen's similarity index (Ks) (Sorensen, 1948) was used to determine the similarity of woody species between exclosure and grazing land using the following formula:

$$\text{Similarity(Ks)} = \frac{2c}{(a+b)} * 100 \dots \dots \dots \text{Eq (8)}$$

Where, Ks=Sorensen's similarity coefficient

a= number of species in exclosure

b= number of species in grazing land

c= number of species common to both land use systems

2.2.2. Statistical analysis

Data were first checked for normality. Those data which were not normally distributed were log transformed. All variables were subjected to paired samples t-test statistics at 5% level of significance using SPSS version 20 to compare the land uses.

3. Result and Discussions

3.1. Woody species composition

A total of 41 woody plant species which belong to 22 families were recorded at the exclosure (Table 2), while 16 species which belong to 12 families (Table 3) were encountered at the grazing land. This shows that the exclosure had 25 more species and 10 more families as compared to the grazing area. This could be related to the high chance for emergence and survival of new seedlings from the seed bank in exclosures while the continuous removal of seedlings by livestock grazing, browsing and trampling at the open grazing land (Tesfay et al., 20

09; Mebrat et al., 2014). The soil fertility enhancement due to litter fall in exclosures could also be another reason for the increment of species and families in the exclosures as it provides suitable media for plant growth and re-growth (Mekuria et al., 2007). The finding of this study concurs to a finding of Manaye (2019), who reported that the number of species in closed areas was almost twice that of adjacent grazing land in Endamekoni district, Southern Tigray. Similar results were also reported by other authors from different parts of Ethiopia (Getseselassie, 2012; Mekuria and Yami, 2013; Gebremedihin et al., 2018; Shimelse et al., 2017).

Fabaceae and Moraceae were families with relatively higher number of species in the exclosure, represented by five and four species respectively. These two families contributed to 22% of the species composition. The dominance of Fabaceae was reported from similar prior studies (Mebrat et al., 2014; Asmare and Gure, 2019; Fikadu and Argaw, 2021). This could be attributed to successful seed dispersal mechanism of the family (Kelbessa and Soromessa, 2008). Combretaceae, Celastraceae, Moraceae and Rhamnaceae were relatively the four most diverse families in grazing land each represented by 2 species and constituting 50% of the species composition.

Table 1. Comparison of Shannon diversity index, richness, evenness and density between enclosure and grazing land (Mean \pm SEM).

Land use	Density(stems/ha)	Shannon diversity index	Evenness	Richness
EX (n=18)	1301.4 \pm 180.83 ^a	1.24 \pm 0.13 ^a	0.69 \pm 0.05 ^b	6.89 \pm 0.87 ^a
GL (n=18)	152.8 \pm 9.01 ^b	0.91 \pm 0.08 ^b	0.84 \pm 0.03 ^a	3 \pm 0.21 ^b
<i>P</i> -values	0.000	0.027	0.004	0.001

Means followed by the same letter across each column do not differ significantly at $p < 0.05$. n indicates number of plots. EX= enclosure, GL Grazing land.

Table 2. Abundance (Ab), relative abundance (RA %), density per hectare (den./ha), relative density (R.den(%), dominance per hectare (Dom(m²/ha), relative dominance (R.Dom(%), frequency (Fre.), relative frequency (R. Fre (%), importance value index (IVI%) of woody species sampled in enclosure

Species name	scientific Local name	Ab	RA %	den./ha	R. (%)	den	Dom(m ² /ha)	R. Dom(%)	Fre	R. (%)	Fre	IVI %
<i>Anogeisus leiocarpus</i>	Hanse HamboHamb	19 6	20.9	272.2	20.9	5.9	36.2	12	9.7		66.8	
<i>Cassia singueanea</i>	o	10	1.1	13.9	1.1	0.0	0.1	8	6.5		7.7	
<i>Vangueria edulis</i>	Guramayle	11 8	12.6	163.9	12.6	4.0	25	15	12.1		49.7	
<i>Ficus sycomorus</i>	Sagla	1	0.1	1.4	0.1	0.1	0.7	1	0.8		1.6	
<i>Ziziphus jujube</i>	Abetere	3	0.3	4.2	0.3	0.1	0.5	2	1.6		2.4	
<i>Dovyalis abyssinica</i>	Ayahada	41	4.4	56.9	4.4	0.6	3.6	7	5.6		13.6	
<i>Dichrostachys cinerea</i>	Gonoq	6	0.6	8.3	0.6	0.2	1.3	3	2.4		4.3	
<i>Lannea fruticosa</i>	Dugdugugni	1	0.1	1.4	0.1	0.0	0.1	1	0.8		1	
<i>Ziziphus spina-christi</i>	Gaba	2	0.2	2.8	0.2	0.2	1.1	2	1.6		3	
<i>Ficus hochstettelri</i>	Afekemo	1	0.1	1.4	0.1	0.00	0.0	1	0.8		0.9	
<i>Gardenia lutea</i>	Hatsinay	1	0.1	1.4	0.1	0.00	0.0	1	0.8		0.9	
<i>Acacia polyacantha</i>	Gomoro	1	0.1	1.4	0.1	0.00	0.0	1	0.8		0.9	
<i>Cordia africana</i>	Awhi	1	0.1	1.4	0.1	0.0	0.2	1	0.8		1.2	
<i>Maytenus arbutifolia</i>	Atat	21	2.2	29.2	2.2	0.6	3.4	8	6.5		12.1	
<i>Diospyros mespiliformis</i>	Aye	5	0.5	6.9	0.5	0.2	0.9	2	1.6		3.1	
<i>Acokanthera schimperi</i>	Mebtie	6	0.6	8.3	0.6	0.3	1.8	4	3.2		5.6	
<i>Rhus natalensis</i>	Tetialo Tahses	24 46	2.6	33.3	2.6	0.6	3.9	7	5.6		12.1	
<i>Dodonaea angustifolia</i>		0	49.1	638.9	49.1	2.4	14.9	16	12.9		76.9	
<i>Acacia persiciflora</i>	Trmi	6	0.6	8.3	0.6	0.0	0.0	2	1.6		2.3	

Species scientific name	Local name	Ab	RA	den./ha	R.	den	Dom(m ² /ha)	R.	Dom(%)	Fre	R.	Fre	IVI
		.	%	a	(%))		(%)		.	(%)		%
<i>Carissa edulis</i>	Agam	2	0.2	2.8	0.2	0.0	0.2	0.2	2	1.6	2		
<i>Boswellia papyrifera</i>	Meker	1	0.1	1.4	0.1	0.0	0.3	0.3	1	0.8	1.2		
<i>Ficus vasta</i>	Daero	1	0.1	1.4	0.1	0.2	1.1	1.1	1	0.8	2		
<i>Acacia albida</i>	Momona	1	0.1	1.4	0.1	0.1	0.3	0.3	1	0.8	1.2		
<i>Maytenus senegalensis</i>	Argudi	5	0.5	6.9	0.5	0.0	0.2	0.2	3	2.4	3.1		
<i>Diospyros abyssinica</i>	Tselimo	1	0.1	1.4	0.1	0.0	0.3	0.3	1	0.8	1.2		
<i>Ficusingens</i>	Tsekente	1	0.1	1.4	0.1	0.1	0.5	0.5	1	0.8	1.4		

Table 2. Cont.

Species scientific name	Local name	Ab	RA	den./ha	R.	den	Dom(m ² /ha)	R.	Dom	Fre	R.	Fre	IVI
		.	%	a	(%))		(%)		.	(%)		%
<i>Acacia seyal</i>	Chea	1	0.1	1.4	0.1	0.0	0.0	0.0	1	0.8	0.9		
<i>Trichiliaaemetic</i>	Gume	1	0.1	1.4	0.1	0.0	0.3	0.3	1	0.8	1.2		
<i>Capparis micrantha</i>	Andel	3	0.3	4.2	0.3	0.1	0.3	0.3	3	2.4	3		
<i>Jacaranda mimosifolia</i>	Bus	2	0.2	2.8	0.2	0.0	0.3	0.3	2	1.6	2.1		
<i>Sterospermum kunthianum</i>	Adgizana	1	0.1	1.4	0.1	0.1	0.4	0.4	1	0.8	1.3		
<i>Grewia ferruginea</i>	Tsnquya	1	0.1	1.4	0.1	0.0	0.1	0.1	1	0.8	1		
<i>Euclea schimperi</i>	Kilio	1	0.1	1.4	0.1	0.0	0.0	0.0	1	0.8	0.9		
<i>Otostegia integrifolia</i>	Chindog	1	0.1	1.4	0.1	0.0	0.0	0.0	1	0.8	0.9		
<i>Grewia flavescens</i>	Mesoqua	1	0.1	1.4	0.1	0.0	0.0	0.0	1	0.8	0.9		
<i>Calpurnia aurea</i>	Hitsawts	2	0.2	2.8	0.2	0.0	0.0	0.0	2	1.6	1.8		
<i>Ximenia americana</i>	Milio	2	0.2	2.8	0.2	0.0	0.0	0.0	1	0.8	1		
<i>Ehretia cymosa</i>	Kirah	2	0.2	2.8	0.2	0.1	0.6	0.6	2	1.6	2.4		
<i>Boscia angustifolia</i>	Kermed	1	0.1	1.4	0.1	0.1	0.7	0.7	1	0.8	1.7		
<i>Croton macrostachyus</i>	Tambook	1	0.1	1.4	0.1	0.1	0.7	0.7	1	0.8	1.6		
<i>Terminalia brownii</i>	Weiba	1	0.1	1.4	0.1	0.0	0.1	0.1	1	0.8	1		

Total	937	1301.4	16.3	124
--------------	------------	---------------	-------------	------------

Table3. Abundance (Ab), relative abundance (RA %), density per hectare (den./ha), relative density (R.den (%), dominance per hectare (Dom (m²/ha), relative dominance (R.Dom(%), frequency (Fre.), relative frequency (R.Fre(%), importance value index (IVI%) of woody species sampled in grazing land

Species name	scientific name	Local name	Ab .	RA %	den./ha	R. (%)	den	Dom(m²/ha)	R.Dom (%)	Fre .	R.Fre (%)	IVI %
<i>Anogeisus leiocarpus</i>		Hanse	60	54.5	83.3	54.5	3.5	52.8	16	30.2	137.5	
<i>Maytenus senegalensis</i>		Argudi	1	0.9	1.4	0.9	0.1	1.3	1	1.9	4.1	
<i>Vangueria edulis</i>		Guramayle	3	2.7	4.2	2.7	0.1	1.6	2	3.8	8.1	
<i>Ficus sycomorus</i>		Sagla	3	2.7	4.2	2.7	0.4	6.1	2	3.8	12.6	
<i>Boswellia papyrifera</i>		Meker	5	4.5	6.9	4.5	0.4	5.8	4	7.5	17.9	
<i>Terminalia brownii</i>		Weiba	5	4.5	6.9	4.5	0.1	2.3	4	7.5	14.3	
<i>Dodonaea angustifolia</i>		Tahses	1	0.9	1.4	0.9	0.0	0.2	1	1.9	3	
<i>Acacia polyacantha</i>		Gomoro	5	4.5	6.9	4.5	0.4	5.6	4	7.5	17.7	
<i>Diospyros mespiliformis</i>		Aye	6	5.5	8.3	5.5	0.6	9.1	3	5.7	20.2	
<i>Ficus vasta</i>		Daero	3	2.7	4.2	2.7	0.5	6.9	2	3.8	13.4	

<i>Ziziphus spina-christi</i>	Gaba	5	4.5	6.9	4.5	0.1	1.1	5	9.4	15.1
<i>Maytenus arbutifolia</i>	Atat	1	0.9	1.4	0.9	0.1	1.2	1	1.9	4
	HamboHamb									
<i>Cassia singueanea</i>	o	7	6.4	9.7	6.4	0.0	0.7	4	7.5	14.6
<i>Cordia africana</i>	Awhi	2	1.8	2.8	1.8	0.2	2.5	2	3.8	8.1
<i>Ziziphus jujube</i>	Abetere	1	0.9	1.4	0.9	0.1	1.2	1	1.9	4
<i>Lannea fruticosa</i>	Dugudugugni	2	1.8	2.8	1.8	0.1	1.7	1	1.9	5.4
		11								
Total		0		152.8		6.6		53		

UNDER PEER REVIEW

3.2. Density, Diversity indices and Similarity of woody species

The woody species density was significantly ($p < 0.001$) higher at the enclosure (1301.4 trees ha^{-1}) than the grazing land (152.8 trees ha^{-1}), indicating more than eightfold higher in the enclosure than the grazing land (Table 1), which is related to continuous disturbances by human and livestock in the grazing land. This finding is in line with the findings of Tekalign (2010); Mekuria et al. (2017); and Asmare and Gure (2019). The study also revealed the existence of variation in density among the woody species. Few species such as *Dodonaea angustifolia* (638.9 stems ha^{-1}), *Anogeisus leiocarpus* (272.2 stems ha^{-1}) and *Vanguria edulis* (163.9 stems ha^{-1}) were dominant at the enclosure (Table 2). These three species contributed to 83% of the total density. Likewise, *Anogeisus leiocarpus* was found to be the densest species at grazing land with 83.3 stems ha^{-1} contributing to 54.5% of the total plant density (Table 3). In contrast, 21 species in the enclosure and 4 species in the grazing land were found to be the least abundant with 1 stem ha^{-1} each. The dominance of some species could be due to overharvesting of some selective plant species.

The Shannon diversity index was also significantly ($p < 0.05$) higher at the enclosure (1.24 ± 0.13) as compared to the grazing land (0.91 ± 0.08) (Table 1). Similarly, the species richness at the enclosure (6.89 ± 0.87) was significantly ($p < 0.05$) higher than that of the grazing land (3 ± 0.21).

The higher diversity at the enclosures might be due to increased litter accumulation which leads to an increase in organic matter and other nutrients content (Hiernaux, 1998). Similar trend was reported by Mengistu et al. (2005); Bahiru (2008); Asmamaw (2011); and Mekuria et al. (2017) from different locations of Ethiopia. However, the species evenness was significantly ($p < 0.05$) higher at the grazing land (0.84 ± 0.03) as compared to the enclosure (0.69 ± 0.05). This might be due to the uneven distribution of species in the enclosure as a result of high heterogeneity, whereas, even the small numbers of species in grazing land were found to be distributed evenly. The same result was reported by Gebremedihin et al (2018), from four highland districts of Tigray region, who indicated high Shannon diversity and richness, but less evenly distributed species in enclosures, while grazing land had low species richness with high species evenness value.

The Sorenson's similarity of species encountered at the enclosure and grazing land was 56.1%, indicating a difference of 43.9% in woody species composition between the land use

types. Worku (2006), indicated that 56.25% similarity index is low, whereas 80% is high. Accordingly, the result in this study revealed that the land uses had low similarity. This is because among the 41 encountered woody species, only 16 were found in common, as a result of protection of woody species in the enclosure which leads to a restoration of species that were lost in the grazing land, while continuous human and livestock disturbance in the grazing land.

3.3. Frequency, Dominance and Importance value index (IVI)

Frequency analyses in the present study showed that most of the woody species had low distribution across the plots and few species in high distribution which revealed that there was an existence of high variation among species. For instance, *Dodonaea angustifolia* and *Vanguria edulis* were the most frequent species in the enclosure recorded in 16 and 15 out of 18 sample plots respectively followed by *Anogeisus leiocarpus*. In contrast, 22 species were encountered only in one plot (Table 2). Likewise, *Anogeisus leiocarpus* and *Ziziphus spina-christi* were the most frequent species in grazing land recorded in 16 and 5 plots respectively out of the 18 plots, while 5 species were recorded only in one plot (Table 3).

A high variation was also observed among species in their dominance. The three top dominant species in the enclosure were *Anogeisus leiocarpus* (36.2%), *Vanguria edulis* (25%) and *Dodonaea angustifolia* (14.9%) with 5.9 m²/ha, 4 m²/ha and 2.4 m²/ha respectively (Table 2). *Anogeisus leiocarpus* was the most dominant species with 3.5 m²/ha and it alone contributed to more than half (52.8%) of the total basal area in grazing land (Table 3).

Based on the result of the comparison of individual species in terms of their importance value index (IVI), *Dodonaea angustifolia* (76.9%), *Anogeisus leiocarpus* (66.8%), *Vanguria edulis* (49.7%) in the enclosure (Table 2) and *Anogeisus leiocarpus* (137.5%) in the grazing land (Table 3) were the most important woody species, indicating that these species are more ecologically significant and plays a significant role in the restoration of the degraded ecosystem, due to their higher relative abundance, frequency and basal area. The dominance of *Anogeisus leiocarpus* in the grazing land might be due to rapid propagation of the species by wildings and its ability to coppice (personal observation while conducting the study). On the other hand, 33 species in the enclosure and 4 species species in the grazing land had an IVI value of less than 5% (Table 2 and 3), indicating that they must be prioritized for conservation.

4. Conclusion

The present study revealed that establishment of exclosures on degraded communal grazing lands is a viable option to enhance woody species richness, density, Shannon diversity index. The analyses of woody vegetation composition revealed that low woody species similarity was observed between the two land use types. Alternative livestock management systems such as tethering should also be introduced so as to minimize the negative effects of free grazing by livestock. As the present study only consider vegetation, further studies on the fauna and micro-organisms, erosion control, hydrology, downstream agricultural production and socio-economic factors analysis that determine the sustainability of the land use systems need to be undertaken.

References

- Asmamaw, M.M. (2011). The role of area closures for soil and Woody Vegetation Rehabilitation in Kewot District, North Shewa. MSc Thesis. Addis Ababa University, Ethiopia.
- Asmare, M. T., & Gure, A. (2019). Effect of exclosure on woody species diversity and population structure in comparison with adjacent open grazing land: the case of JabiTehnan district north western Ethiopia. *Ecosystem Health and Sustainability*, 5(1), 98-109.
- Bahiru, K. M. (2008). Enclosure as a viable option for rehabilitation of degraded lands and biodiversity conservation: the case of kallu woreda, Southern wello. *Addis ababa university school of graduate studies, Ethiopia*, 1-99.
- Bein, E., Habte, B., Jaber, A., Birnie, A., and Tengnas, B. (1996). Useful Trees and Shrubs in Eritrea. Identification, Propagation and Management for Agricultural and Pastoral Communities. Regional soil conservation unit, RSCU/SIDA, Nairobi.
- Bekele-Tesemma, A. (2007). Useful trees of Ethiopia: Identification, propagation and management in 17 agroecological zones. Nairobi: RELMA in ICRAF Project, 552 p.
- Birhane, E., Teketay, D., and Barklund, P. (2006). Actual and potential contribution of exclosures to enhance biodiversity of woody species in the dry lands of Eastern Tigray. *Journal of Dry lands*, 1(2), 134-147.

- Darcha G, Abay K, Birhane N (2018) Evaluation of Awir (*Ipomoea carnea*) for Gully Rehabilitation through Different Propagation Techniques in North Western Zone of Tigray. *Journal of Agriculture and Ecology Research International* 1-8. DOI: 10.9734/JAERI/2018/39723.
- Descheemaeker, K., Nyssen, J., Rossi, J., Poesen, J., Haile, M., Raes, D., ... & Deckers, S. (2006). Sediment deposition and pedogenesis in exclosures in the Tigray Highlands, Ethiopia. *Geoderma*, 132(3-4), 291-314.
- Fikadu, A., & Argaw, M. (2021). Impact of exclosures on woody species diversity in degraded lands: the case of Lemo in Southwestern Ethiopia. *Heliyon*, 7(4).
- Gebremedihin KM, Birhane E, Tadesse T, Gbrewahid, H. (2018) Restoration of degraded drylands through exclosures enhancing woody species diversity and soil nutrients in the highlands of Tigray, Northern Ethiopia. *Nature Conservation Research* 3(1): 1-20. DOI: 10.24189/ncr.2018.001.
- Getseselassie, H.A. (2012). Effects of Exclosure on Environment and its Socioeconomic Contributions to Local People: In the case of Hallaexclosure, Tigray, Ethiopia. Msc thesis. Norwegian University of Life Science. Norway.
- Hiernaux, P. (1998). Effects of grazing on plant species composition and spatial distribution in range lands of the Sahel. *Plant Ecology*, 138(2), 191-202.
- Hurni H, Berhe WA, Chadhokar P, Daniel D, Gete Z, Grunder M, Kassaye G (2016) Soil and Water Conservation in Ethiopia: Guidelines for Development Agents. Second revised edition. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, with Bern Open Publishing (BOP). 134 pp. https://boris.unibe.ch/80013/1/Guidelines_Soil_and_Water_Conservation_in_Ethiopia_2016.pdf
- Kelbessa, E., & Soromessa, T. (2008). Interfaces of regeneration, structure, diversity and uses of some plant species in Bonga Forest: A reservoir for wild coffee gene pool. *SINET: Ethiopian Journal of Science*, 31(2), 121-134.

- Mamo, K.B. (2008). Enclosure as a viable option for rehabilitation of degraded lands and biodiversity conservation: The case of Kallu Woreda, southern Wello. MSc Thesis. Addis Ababa University.
- Manaye, A., Negash, M., & Alebachew, M. (2019). Effect of degraded land rehabilitation on carbon stocks and biodiversity in semi-arid region of Northern Ethiopia. *Forest science and technology*, 15(2), 70-79.
- Marland, G., Garten, C.T., Post, W.M., and West, T.O. (2004). Studies on enhancing carbon sequestration in soils. *Energy*, 29(9), 1643-1650.
- Mata, I.D., Moreno-Casasola, P., Madero-Vega, C., Castillo-Campos, G., and Warner, B.G. (2011). Floristic composition and soil characteristics of tropical fresh water forested wetlands of Veracruz on the coastal plain of the Gulf of Mexico. *Forest Ecology and Management*, 262(8), 1514-1531.
- Mebrat, W., Molla, E., and Gashaw, T. (2014). A Comparative Study of Woody Plant Species Diversity at Adey Amba Enclosed Forest and Nearby Open Site in West Belessa District, North western Ethiopia. *Journal of Biology, Agriculture and Health care*, 4, 74-80
- Mekuria W, Langan S, Noble A, Johnston R (2017) Soil restoration after seven years of enclosure management in northwestern Ethiopia. *Land degradation & development* 28(4): 1287-1297. <https://doi.org/10.1002/ldr.2527>.
- Mekuria, W., and Aynekulu, E. (2011). Exclosure land management for restoration of the soils in degraded communal grazing lands in northern Ethiopia. *Land Degrad. Develop.* DOI:10.1002/ldr.1146.
- Mekuria, W., and Yami, M. (2013). Changes in woody species composition following establishing exclosures on grazing lands in the lowlands of Northern Ethiopia. *African Journal of Environmental Science and Technology*, 7(1), 30-40.
- Mekuria, W., Veldkamp, E., and Haile, M. (2009). Carbon stock changes with relation to land use conversion in the low lands of Tigray, Ethiopia. Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg, Germany.

- Mekuria, W., Veldkamp, E., Corre, M.D., and Haile, M. (2011). Restoration of ecosystem carbon stocks following exclosure establishment in communal grazing lands in Tigray, Ethiopia. *Soil Science Society of America Journal*, 75(1), 246-256.
- Mekuria, W., Veldkamp, E., Haile, M., Nyssen, J., Muys, B., and Gebrehiwot, K. (2007). Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. *Journal of arid environments*, 69 (2), 270-284.
- Mengistu, T., Teketay, D., Hulten, H., and Yemshaw, Y. (2005). The role of exclosures in the recovery of woody vegetation in degraded dry land hillsides of central and northern Ethiopia. *Journal of Arid Environments*, 60(2), 259-281.
- Mulugeta, G. (2014). Vegetation Dynamics of Area Enclosure Practices: A Case of Gonder Zuria District, Amhara Region, Ethiopia. *Journal of Natural Sciences Research*, 4(7), 75-82
- Munie SA (2013) Effect of plantation forests on soil chemical properties, Soil temperature and regeneration of woody plants: A Comparative analysis. PhD Dissertation. Mendel University in Brno, Czech Republic. Pp. 1-111.
- Shimelse, S., Bekele, T., & Nemomissa, S. (2017). Effect of exclosure age on carbon sequestration potential of restorations in Tigray Region, N. Ethiopia. *American Journal of Biological and Environmental Statistics*, 3(4), 65-80.
- Sørensen, T. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. *Biol.Skr.*, 5, 1-34.
- Tadesse, D. (2014). Impacts and impediments of community participation on soil and water conservation to sustainable land resource management in LaelayMaychew Woreda, Tigray, Ethiopia. M.Sc .thesis. Addis Ababa University. Addis Ababa, Ethiopia.
- Tekalign, M., (2010). The Role of Area Exclosures for Biodiversity Conservation and its Contribution to Local Livelihoods: The case of Biyo-Kelala Area Exclosures in Ada`a woreda. M.Sc Thesis. Addis Ababa University, Addis Ababa. Ethiopia.

Tesfay, Y., Eik, L.O., and Moe, S.R. (2009). The effects of exclosures in restoring degraded semi-arid vegetation in communal grazing lands in northern Ethiopia. *Journal of Arid Environments*, 73(4), 542-549.

Worku, A.G. (2006). Population Status and Socio-economic Importance of Gum and Resin Bearing Species in Borana Low lands, southern Ethiopia. M.Sc thesis. Addis. Ababa University, Addis Ababa, Ethiopia.

UNDER PEER REVIEW