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Vegetation Dynamics of Area Enclosure Practices: A Case of Gonder Zuria District, Amhara Region, Ethiopia

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Abstract
Land degradation is one of the major critical challenges facing human beings in agricultural production and sustainable development in many parts of Ethiopia. Strategies for the rehabilitation of those degraded areas are urgently needed before conditions become irreversible. Area Enclosures has been the commonly practiced strategy for the rehabilitation and restoration of degraded lands and other environmental problems. The objective of this study was to investigate woody vegetation changes after area enclosure intervention in one of the highly degraded area North Gondar, Gondar Zuria District, Das-dinzaz kebele. The main purpose of the study was to analyze changes of woody species composition and diversity. Totally 64 circular sample plots, having 314m^2 area each were systematically sampled using transect lines laid along altitudinal gradient on both enclosures and adjacent open areas. The result revealed that altogether 46 species belonging to 24 families were identified in the enclosure site. A total of 43 and 22 woody species belonging to 24 and 14 families were recorded among different enclosures and adjacent open sites, respectively. Compared to the adjacent open areas, enclosed areas hosted larger species richness. Relatively higher Shannon diversity indices in the enclosures indicate the better species diversity in the enclosures than in the open site. The result of the study suggests that area enclosure practices can rehabilitate and restore woody species of degraded lands if adequately protected from interferences.
Keywords: enclosure practices, woody species, composition, diversity, Ethiopia.

INTRODUCTION

The major critical challenges facing human beings in agricultural production and sustainable development in many parts of the Ethiopia is depletion of natural resources. Population growth and its demands are increasingly threatening the sustainable management and use of natural resources in the tropics. Ethiopia relies on its diverse biological resources mainly on forests for its socioeconomic development. However, these resources are now under severe pressure. Its forest has shrunk from covering 65% of the country and 90% of the highlands to 2.2% and 5.6%, respectively (Berry, 2003; *EEPFE, 2005).* As a result, land degradation in the form of soil erosion and loss of soil fertility is a typical phenomenon in many areas of Ethiopia (EARO 2000; Demel Teketay 2001; Asefa *et al.,* 2003). Available data indicate that out of the 60 million ha of agriculturally productive land, about 27 million ha are significantly eroded, 14 million ha are seriously eroded, and over 2 million ha beyond reclamation (FAO 1999). Like other parts of Ethiopia, forest degradation problems are most severe and a high percentage of the land has already been severely degraded and become out of production in many parts of the Amhara region (USAID, 2000) including the present study area. Sustainable and renewed resource management practices need to address the widespread land degradation, declining soil fertility, unreliable rainfall, and even desertification, in a context of global climate change (FAO & World Bank, 2001). Therefore, rehabilitation of those degraded areas needs urgent attention before conditions become irreversible.

In response to the problem of land degradation and other environmental problems, different natural resource conservation and rehabilitation interventions have been carried out in Ethiopia. Among the various rehabilitation techniques used, the predominant is probably area enclosure (Mulugeta Lemenih, 2004) and establishment of fast growing plantations of exotic species & physical conservation measures such as terracing. The idea of area enclosure involves a protection system, exclusion of the degrading agent, to allow the lands to restore itself through natural succession process.

Thus, area enclosures can be defined as degraded lands that have been excluded from human and livestock interference for rehabilitation (Betru Nedessa *et al*., 2005; Mekuria *et al*., 2007, Tesfaye Mebratu, 2002). Degraded lands that almost lost their production potentials are set aside for nature based rehabilitation. These areas, if properly managed and rehabilitated through enclosure system, allow native vegetation to regenerate (Kebrom Tekle, 1998; Tesfaye Bekele, 2000; Emiru Birhane, 2002; Tefera Mengistu, 2002).

Moreover, the rate and extent of vegetation dynamics on enclosures are influenced by several biophysical conditions such as pre-enclosure site history, vegetation status in the vicinity of enclosures, and management of the enclosures, climatic and edaphic conditions prevailing around the sites. These conditions have not yet been studied in Amhara region, Gondar zuria district of Ethiopia where enclosure measures have been taking in place. The objectives were to assess the changes of woody species composition and diversity.

MATERIALS AND METHODS

Description of the study area

Location

This study was carried out in Gondar zuria district, Das Dinzaz kebele in three PAs namely Fana, Belewseged and Wonbergie, Amhara Region of Ethiopia during 2010/2011. The district is located at 37°24'24"E-37°45'43"E and 12°7'23"N-12°39'24"N and its total area is 1286.76 km^2. Being part of the Semien Gondar Zone, Gondar Zuria district is bordered on the south by the Debub Gondar Zone, on the southwest by Lake Tana, to the west by Dembiya, to the north by Lay Armachiho, to the northeast by Wegera, and to the southeast by Belessa. Towns and cities in Gondar zuria woreda include Degoma, Emfraz, Maksegnit and Teda. The city and district of Gondar surround this district in the northern part (CSA, 2005).

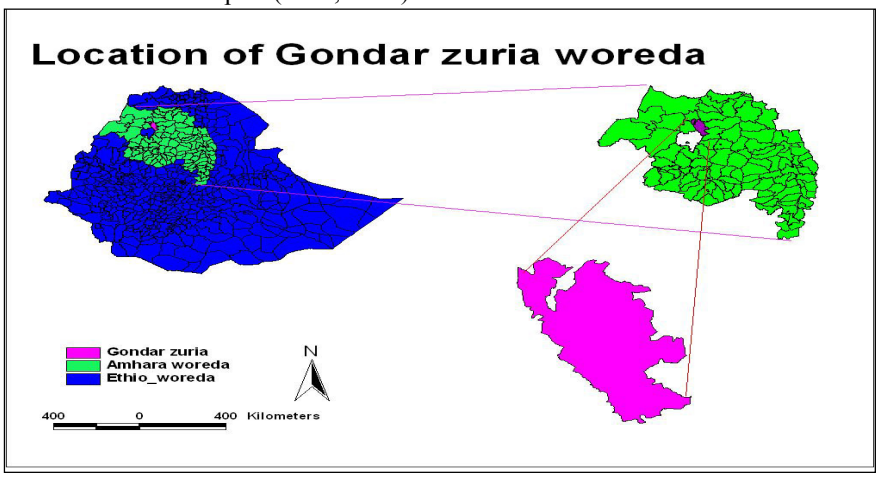

Figure 1. Location of the study area

Population

The district has an estimated total population of 264,920 (of whom 130,796 were males and 134,124 were females). About 10.24% of its population is urban dweller, which is less than the zone average of 14.1%. The rural area constitutes 40,551 households. With an estimated area of 1,286.76 square kilometers, Gondar zuria has an estimated population density of 205.9 people per square kilometer as compared to the zone average of 60.23 (CSA, 2005).

Agro ecology

Gondar Zuria District is located at 1107-3022 m a.s.l, and falls in to three agroecological zones. The two agro-ecology zones, Weynadega (1500-2300 m a.s.l) and Dega (2300-3200 m a.s.l.) constitute the largest area coverage as compared to the Kolla that falls in the range of 500-1500 ma.s.l. In the district, temperature ranges between 14-20°C with the mean annual temperature of 17.9°C. Rainfall ranges between 1030-1223 mm with the mean annual rainfall of 1100 mm.

Land use

Crops cover 56.5% the area, pasture 14.7%, forests and shrubs 10%, settlements 5.3% and the rest 13.5% is a miscellaneous land (GZOARD, 2007 cited in Endege Dress, 2008).

Livestock

Livestock production is important in the farming system of the woreda. The need for draught power, source of food and income has made the mixed farming of animals with other agricultural activities inevitable. However, animal husbandry is largely constrained by feed quality and availability due to an imbalance between animal population and pasture size and productivity (Endege Dress, 2008). The availability of browse to animals, especially in the dry seasons is essential when grass and herbaceous legume forages are scarce

Sampling design and procedure

The general sampling design was employed for the vegetation census. In the first stage, primary sampling units (enclosure areas) were selected from the district purposively based on accessibility and the presence of artificially planted woody species. In the second stage, secondary units (referred to as working units) were selected within each primary sampling unit (selected enclosures and its adjacent open sites). The working units for the vegetation sampling were circular plots in the enclosure and adjacent open areas.

Prior to site selection and launching of the research work, all secondary information was collected from the district agriculture and rural development office. The research work started after the Development Agent office was well informed about the objectives of the study and the activities to be carried out. A reconnaissance tour was conducted before the actual survey operation in order to obtain a general overview about the enclosures and adjacent open sites. Vegetation data was collected and analyzed with the help of various statistical packages.

Vegetation data collection technique

On both enclosed and adjacent open sites, parallel line transects of 100 m apart were laid-out systematically based on the site conditions in the east-west direction, and plots established at 50 m intervals along each transect. To avoid the effect of vegetation disturbances, the first and the last transects line was laid at a distance of 50 m from the edges. On each line transect, circular plots having 10 m radii (working plot) was laid at every 50 m along the line transect.

Species identification was done by referring to the *Honey bee flora of Ethiopia* (Admassu and Reinhard, 1994), *Useful trees and shrubs for Ethiopia* (Azene Bekele, 1993 and 2007). In addition, collection of local names using experienced person from the local community and personal experience was used to identify the woody species encountered. The altitude and global position (longitude and latitude) at each sample plot was recorded using a GPS.

Vegetation data analysis

Species diversity

The species diversities in enclosures and open sites were calculated using Shannon-Wiener index (H') (Magurran, 1988). Diversity, comprised species richness and evenness. Indices that combine both richness and evenness in to a single value are diversity indices. Species richness is expressed as the total number of species in a community or per unit area while species evenness or equitability explains as to how species abundance is distributed among species. Diversity has emerged as the most widely used criterion to assess the conservation potential and ecological value of a site (Magurran, 1988 as cited in Ambachew Worku, 2006).

A.Species Richness

As a measure of species richness, the number of species in a community or sample, S and also two nonparametric estimators of species richness, the Chao1 and the first order jackknife were used (Gimaret-Carpentier *et al*., 1998; Krebs 1999 as cited in Alemayehu Wassie, 2002).

The first Chao index (C) is given by: $C = S + \frac{a^2}{2b}$ ..... (1)

The first order Jackknife index (J) is given by: $J = S + k\frac{[(P-1)]}{P}$ .....(2)

Where, S is the number of species found when all sample plots are pooled; a is the number of species that are represented by a single individual (singletons); b is the number of species that are represented by two individuals (doubletons); k is the number of species that occur in only one sample plot (unique); and P is the number of plots sampled.

B. Species Evenness

Equitability or evenness: $J = H'/H'_{max} = \Sigma\, p_i \ln(p_i / \ln (s)) = H'/\ln S$ .....(3)

Where, H' is Shannon-Wiener Diversity Index; *S* is the number of species found when all sample plots are pooled; *Pi* is the proportion of total individuals in the i^{th} species.

Species Evenness (measure of species balance) is a measure of the relative abundance of the different species making up the richness of an area. Species evenness; as a measure of species diversity which is the relative abundance in which each species is represented in an area. An ecosystem where all the species are represented by the same number of individuals has high species evenness. An ecosystem where some species are represented by many individuals, and other species are represented by very few individuals has low species evenness (Lecointre and Guyader, 2001; Harrison *et al*., 2004 cited in Kibret Mamo, 2008). Evenness compares the similarity of the population size of each of the species present that means it is a measure of the relative abundance of the different species making up the richness of an area.

Complete evenness, only when the same number of individuals represents all the species, always equal to one that means. On the other hand, zero only and only if there is one species in the samples. A high value of evenness indicates that all the species in the community have rather similar abundance (Wilson *et al*., 1996 cited in Kibret Mamo, 2008).

A low equitability value means that there is dominance of one or more species in the community. While high equitability means that there is a uniform distribution among the species in samples, demonstrating that individuals are well-distributed (Cavalcanti and Larrazabal, 2004 cited in Kibret Mamo, 2008).

Diversity

Shannon diversity index accounts for both the diversity and evenness of the species present in a community. This index takes in to consideration of species composition and evenness within the given land or community.

Shannon diversity index (H') $= -\sum_{i=1}^{s} p_i \ln p_i$,.....(4)

Where, *H'* is the Index of Species Diversity; *S* is the number of species; *Pi*=n/N is the proportion of individuals found in the i^{th} species (ranges 0 to 1); n=number of individuals of a given species; N = total number of individuals found (Shannon and Wiener, 1949).

Shannon diversity index (H') is taking in to account the number of individuals as well as the number of species. Shannon diversity Varies from 0 for a community with only a single species to a high value for a community with many species, each with few individuals. It increases with number of species in a community and in theory can reach very large values. But in practice for biological communities H does not exceed 5.0 (Krebs, 1999 as cited in Alemayehu Wassie, 2002). The results are summed across the species and multiply by -1. Shannon diversity index is high when it is above 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 smaller than 1.0 (Cavalcanti and Larrazabal, 2004).

RESULTS

A total of 46 woody species representing 24 families were recorded in the three enclosures and adjacent open sites studied (Table 1). The total number of species and families found in the enclosures were 43 and 24(Table 1) respectively. Among the 43 species recorded, 36 were naturally regenerated indigenous and 7 of them were planted exotics (4) and indigenous (3) woody species. Similarly, in the adjacent open sites the number of species and families encountered were 22 and 14 respectively (Table 1). Furthermore, of the total of 46 woody species recorded, 19 of them were common to both enclosures and the open areas (Table 1).

Table 1. List of species encountered in the enclosures and open access by life form

Species name	**Open access**	**Enclosure**	**Life form**
Acacia seyal	-	+	Tree
*Acacia decurrens***	-	+	Tree
Acacia spps	-	+	Tree
Acacia sieberiana	-	+	Tree
Acacia saligna **	-	+	Tree
Acanthus eminens	-	+	Shrub
Ackocanthera schimperi	+	+	Tree
Allophylus abyssinica	+	+	Tree
Aloe spps	+	+	Shrub
Calpurnia aurea	+	+	Shrub
Capparis tomentosa	-	+	Shrub
Carssia edulis	+	+	Shrub
Clemmatis hirsuta	-	+	Climber
Clerodendron myricoides	-	+	Shrub/tree
Clutia abyssinica	+	+	Shrub
Combretum molle	+	+	Tree
Cordia africana *	-	+	Tree
Croton macrostachyus	+	+	Tree
Dodonaea angustifolia	+	+	Shrub
Continued			
Entada abyssinica	+	+	Climber
Euclea racemosa	+	+	Shrub
Euphorbia tirucalli	+	-	Tree
Euphorbia abyssinica	+	-	Tree
Faidherbia albida	-	+	Tree
Grewia ferruginea	-	+	Shrub
Jasminum abyssinicum	-	+	Climber/shrub
Maytenus arbutifolia	+	+	Shrub/tree
Phytolacca dodecandra	-	+	Climber
Premna schimperia	-	+	Tree/shrub
*Prunus africana**	-	+	Tree
Ocimum urticifolium	-	+	Shrub
Olea europaea	+	+	Tree
Osyris compressa	-	+	Shrub
Otostegia integrifolia.	+	+	Shrub
Rosa abyssinica	-	+	Climber
Rumex nervosus	+	+	Climbing shrub

Rhus vulgaris	+	+	Tree
Schinus molle **	-	+	Tree
*Sesbania sesban**	-	+	Tree
Senna didymobotrya	+	-	Shrub
Solanum indicum	+	+	Shrub
Senna singueana	+	+	Shrub
*Spathodea nilotica***	-	+	Tree
Vernonia amygdalina	+	+	Tree
Ximenia americana	-	+	shrub/tree
Esta abred	-	+	shrub/tree
Total	**22**	**43**	

+ denotes presence of species * denotes planted indigenous species
- denotes absence of species ** denotes planted exotic species

In terms of life form, shrubs outnumbered the trees in both sites. Trees and shrubs constituted 42%, 58% and 40%, 60% of the woody species in the enclosure and open areas respectively.

More specifically, the total number of species in Fana, Belewseged and Wonbergie enclosures and their adjacent open sites were found to be 39, 27, 20 and 19, 10, 8, respectively (Table 2). Generally higher number of species (43) was observed in the enclosures as compared to open access (22). Similarly higher number of families was also recorded in the enclosures (24) than open adjacent sites (14). The families with the highest number of species were Leguminoacae (11) and Oleaceae (3) in the enclosure while Euphorbiaceous (4), Leguminoacae (4) in the open access.

Table 2. Number of species and their families in the enclosures and adjacent open sites

Area	**Species**		**Family**	
enclosures sites	Open	Enclosure	Open	Enclosure
Fana	19	39	13	23
Belewsged	10	27	7	15
Wonbergie	8	20	6	13

The species richness which refers the number of species per site was the highest in all the three enclosures than their adjacent open sites (Table 2). This confirmed that more species were severely affected by interferences in the open site as compared to enclosure, but it can be restored when interferences trim down (Table 2). Higher numbers of woody plant species (43) were encountered in the enclosures than in the open sites (22) (Table 1; 2). Fana enclosure was found to be the highest in terms of species richness followed by Belewseged. In the contrary lower species richness was recorded in enclosure Wonbergie which indicates the presence of interferences in this enclosure.

Jackknife Indices overestimated the species richness for all enclosures and adjacent open sites as compared to the observed number of species whereas Chao's estimated higher number of species both in the Fana enclosure & open sites as well as Wonbergie enclosure only (Table 3). According to Chao's estimate, relatively the highest number of species was expected at Wonbergie enclosure (24), which had the lowest number of observed species (20) among enclosures; While Jackknife estimated the highest number of species at Fana (49) and Belewseged (34) and lowest at Wonbergie (25) (Table 3).

The Shannon diversity value for all the woody species encountered ranged from 2.46 to 1.89 for Fana and Wonbergie enclosure respectively (Table 3). Relatively the higher Shannon diversity indices in the enclosures indicate that there is better species diversity in the enclosures than in the adjacent open site. Shannon evenness indices were low in all sites indicating lack of uniform distribution of species over the sites (Table 3). Relatively the higher evenness was encountered in the Wonbergie open area (0.79), which indicated the occurrence of few (8) but evenly distributed species as compared to other enclosures and adjacent open sites. In the enclosures, species richness is higher but due to the dominance by few species evenness was low.

Table 3. Comparisons of various diversity indices of woody plant species in the different enclosures and adjacent open sites

Diversity indices	Fana		Belewseged		Wonbergie	
	Open	Enclosure	Open	Enclosure	Open	Enclosure
Species Richness						
Observed species (S)	19	39	10	27	8	20
Chao 1 (C)	20	40	10	27	8	24
Jackknife 1 (J)	27	49	13	34	10	25
Species evenness						
Shannon's Equitability (J)	0.73	0.67	0.65	0.53	0.79	0.63
Heterogeneity						
Shannon-Wiener Diversity (H')	2.14	2.46	1.49	2.14	1.66	1.89

DISCUSSION

Restoration of plant species diversity is an important management tool for rehabilitating landscapes, which have lost vegetation cover (Ormerod, 2003). The comparison made between the enclosures and open grazing areas showed that the composition, diversity and density of woody species were higher in the enclosures. Thus suggested, that the rehabilitation of the degraded areas was in relatively short periods of time when interferences is minimized or avoided (Zerihun and Backeus, 1991). Similar encouraging results have been reported from studies made on enclosures in Wello by Tesfaye Bekele (2000); Tefera Mengistu (2002); Kibret Mamo (2008) and in Shewa by Ambachew Worku (2006); all pointed out that establishment of enclosure were improved composition, density, richness, and diversity of woody species in comparison to open adjacent sites.

In similar manner the present study also revealed that compared to the adjacent open sites the composition, richness and diversity of woody species were found to be higher in the enclosed areas. This verified that more species were rigorously affected by interferences in the open site as compared to enclosure, but it can be restored when disturbances getting down. Woody species were substantially richer in enclosures than in open areas, indicating the importance of enclosures for the conservation of biological diversity (Tefera Mengistu *et al.,* 2005b).

Diversity is the most widely used criterion to assess the conservation potential and ecological value of a site (Magurran, 1988). Moreover, it is an important element in resource management planning. This especially holds true for rare and endangered species (Jama and Zeila, 2005). Enclosure has been trusted to contribute to the conservation of biological diversity. The Shannon diversity value for all the woody species encountered were 2.46 for Fana enclosure and 1.49 for Belewseged open sites (Table 3). Relatively higher Shannon diversity indices in the enclosures indicate the better species diversity in the enclosures than in the open site. The relatively high diversity values of enclosures compared with that of the open areas in turn indicates the importance of enclosure practices for the conservation of genetic resources of the woody species, particularly rare and unique species that are under heavy threat of extinction.

Generally higher number of species (43) was observed in the enclosures as compared to open accesses (22). This means that the number of species observed in the enclosures was almost twice of the species in the open sites. Among the different enclosures in the study area Belewseged and Fana were found in better condition as well as better species richness, composition and diversity than Wonbergie enclosure. It is also interesting to indicate that the number of recorded woody species in Wonbergie enclosure (20) was almost the same as the number of recorded species in Fana open access (19) (Table 2; 3). The low degree of success in Wonbergie enclosure was attributed by the presence of relatively high degree of human and animal interferences. The realistic experience of this study revealed that enclosures can only be effective in rehabilitating degraded site if and only if adequate protection from interferences was provided. To achieve this active participation of the community was very crucial.

Jackknife Indices overestimated the species richness for all enclosures whereas Chao's estimated higher number of species in the Fana and Wonbergie enclosure than observed species (Table 3). This indicated that there were some species represented by single individuals (rare species) and also many species found only in single plots (unique species). The presence of rare and unique species implied the need for better protection and management of enclosed areas. The possible explanation for the presence of rare and unique species could be attributed to the continuous reduction of forest area and poor dispensability of the species (Alemayehu wassie, 2007).

CONCLUSION AND RECOMMENDETION

In this study the vegetation changes of area enclosure practices were analyzed. In view of the serious land degradation problems in Ethiopia, enclosure practices can play a paramount role in rehabilitating degraded lands. This study was carried out in Gondar zuria district; Das-Dinzaz kebele verified that area enclosure practices can

change the vegetation coverage of degraded areas in a relatively short period of time. The evaluation made between area enclosures and adjacent open sites in the study area indicated that vegetation parameters such as composition, richness and diversity of woody species were improved in the enclosure. A total of 43 and 22 woody species belonging to 24 and 14 families were recorded among different enclosures and adjacent open sites, respectively. However, differences in species composition, richness and diversity of species vary among enclosures. This could be mainly due to the variation in management and presence of interferences. Hence, As clearly observed in this study, enclosures can only be successful in rehabilitating degraded areas if they are well managed and protected from human and animal disturbances. However, among the artificially planted woody species in the enclosures, the establishment status of *Acacia saligna* found to be in better condition than others. Hence, this species can be used and recommended for degraded land rehabilitation.

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