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Vegetation Restoration in Area Closures: The Case of Douga Tembein, Central Tigray, Ethiopia

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Abstract

Since 1991, communities in Tigray region have started to establish area closures (exclosures) to deal with shortage of biomass and land degradation. Although the need of scientific information is clear, studies made to assess vegetation restoration in exclosures are very limited. This study assesses the population structure and biomass of two dominant woody species: *Acacia etbaica* and *Euclea racemosa* subsp.schimperi and compare with communities fuel wood demand. For this study contrasting age of exclosures (5 and 10) were selected. Vegetation assessment was done using systematic line plot sampling in an area of 3600 m^2. One way analysis of variance and regression analyses were used to analyse the data. A strong relationship was not found between the diameter and height of the two woody species in both exclosures. However, with the increase in year of protection, the relationship for A. etbaica gets better (R^2 =15.4 - 22.8%). This shows the improvement of sites with an increase in age of protection. The frequency distribution of woody species showed almost an inverted J-shape with few or no individuals at higher diameter classes. This could be due to selective removal of bigger woody species for fuel wood and construction. Mean density of the two woody species within treatments varied between 194 and 1078 trees ha^{-1}; basal area 1.74 and 8.7 m^2 ha^{-1}; volume 1.98 - 13.98 m^3 ha^{-1}; live above ground biomass 3014.40 - 5268.30 kg ha^{-1}; and dry above ground biomass 359.98 - 462 kg ha^{-1}. The result showed that there is a significant difference ($p<0.05$) in vegetation parameters investigated between the two wood species within treatments. The result also indicated that from the total of 114. 6 ha of exclosures investigated, 51 tons of dry above ground biomass could be harvested. Given the estimated firewood consumption of 1-1.2 t yr^{-1} per household and taking the number of households (200), the amount of dry aboveground biomass produced from the two dominant woody species would cover around 25% of their yearly consumption. Thus, exclosures have considerable contribution in solving shortage of biomass for fuel. Vegetation management such as pruning could help to increase vegetation growth and biomass produced.

Key words: Area closure, biomass, Ethiopia, fuel wood, population structure, Tigray

Introduction

Exclosures which are a type of land management, implemented on degraded, generally open access land are a mechanism for environmental rehabilitation with a clear biophysical impact on large parts of the formerly degraded commons (Tucker and Murphy, 1997). Studies indicated that land use change affects the composition, structure, diversity and landscape pattern of vegetation (e.g. MatejkovaIvona *et al*, 2003; Walters *et al*., 2006), and biomass accumulation (e.g. Ray *et al*., 2003).

For a country like Ethiopia where sustainable land management is a priority for the overall development, availability of relevant land management information at all levels is very crucial (Million, 2000). However, there are limited studies in the region dealing how the conversion of free grazing lands into exclosures restoring native vegetation (e.g. Emiru, 2002; Mastewal *et al*., 2006) and increasing biomass accumulation (Kidane, 2002; Ermias *et al*., 2006). Considering, the diverse agro-ecological condition of Tigray, these studies are not enough to conclude about the effectiveness of exclosures to restore degraded vegetation and biomass increment. This calls for systematic research and developmental activities on restoration of degraded land (Mishra *et al*., 2004). Therefore, this research project is initiated to assess the population structure and biomass accumulation of two dominant woody species in exclosures. It is hypothesised that the effectiveness of exclosures to restore degraded native vegetation and biomass increment varies with age of conversion.

Materials and Methods

The study was conducted in Douga Tembein Woreda located in Tigray, northern Ethiopia (Fig. 1). For the study, 5- and 10-year-old exclosures were selected to examine the influence of age of protection on the structure and biomass accumulation of two dominant woody species. For each of the investigated exclosure categories three replicates were selected which were all located on hill slopes. In total, 6 sites with similar lithology, soils, climate, and land use and areas ranging from 5.4 to 40.8 ha were selected. Each of the study sites was divided into three slope positions: upper slope (US), middle slope (MS), and foot slope (FS, Mekuria *et al*., 2007), bringing the total number of plots to 18.

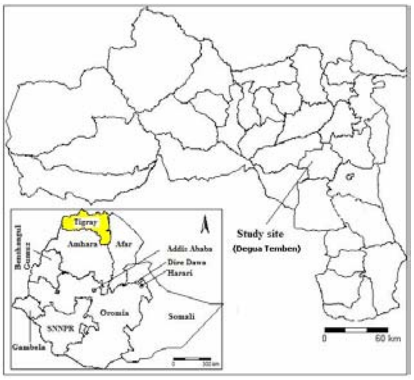

Figure 1 Location of the study area

The parameters set for the vegetation assessment were DBH (diameter at breast height), DSH (diameter at stamp height), crown diameter and total height. DBH and DSH were measured by using calipers. Total height was measured by using clinometers or meter tapes depending on the suitability. Meter tape was used to measure crown diameter. The DSH of each tree is measured at 30cm from the ground. Crown diameter was measured in two directions (west- east and north -

south) and average value was taken. To estimate aboveground biomass, destructive weighing study of the two dominant woody species was conducted. Only one tree per plot per species was felled making a total of 18 trees per species from each category (5- and 10-year old exclosures) for the weighing study because tree felling is restricted. Fresh weight of the trees was measured using a spring balance of 0.1g precision. Sample discs were taken from each tree and shrub for the determination of the oven dried weight in the laboratory.

A frequency distribution for each site and for each species was estimated through the determination of diameter classes. The number of the diameter class of each species was determined using the formula: $K = \sqrt{n}$ where: K = the number of diameter classes; n = the number of trees in all plots ($600m^2$). The basal area (BA), Volume (V) and density per hectare per slope class (D) were calculated using the following formulas:

$$BA = \sum \frac{\pi D^2}{4} \text{ ; V} = \sum (\pi D^2 / 4) \times H \times f \text{ ; D} = \frac{10^4 (m^2/ha) \times N}{600\ (m^2)}$$

Where: D = diameter at stamp height; H = total height; f = form factor; N = the total number of trees per slope class. Conversion factors: $\frac{10^4 (m^2/ha)}{600\ (m^2)}$ was used to determine per hectare basal area and volume per each slope class.

Average live aboveground biomass (LB) and dry aboveground biomass (DB) per tree for each slope class (SC) was calculated using the formula:

$$\text{LB} = \frac{\sum SW\ (kg) + CW\ (kg)}{6}$$

$$DB = \frac{\sum ODW}{6}$$ where: SW = stem weight; CW = crown weight; ODW = oven dry weight.

To calculate the aboveground biomass per hectare basis for each slope class, the average values are multiplied by the number of tree/ha/SC. Finally the average of these three figures was considered as the estimated value for each category of exclosures. Regression analysis was used to determine the strength of the relationship between diameter at stamp height and total height of each species under each category. One way analysis of variance (ANOVA) was also used to test the significance of the difference between the mean values of D, BA, V and aboveground biomass of the two species in the two categories.

Results and Discussion

Biomass production

Significant differences ($p < 0.05$) were observed between density, basal area, volume, and live aboveground biomass of the woody species in the two exclosure categories (Table 1). The result also indicated that from the total of 114. 6 ha of exclosures investigated, a total of 51 tons of dry aboveground biomass could be harvested. Given the estimated firewood consumption of 1 kg d^{-1} per person (De Montalembert and Clement, 1983; Bhagavan, 1984) and taking the number of beneficiaries (600, or 200 households), the amount of dry aboveground biomass produced from the two dominant woody species would cover around 25% of their yearly consumption of the local community. The increase in biomass with age of exclosures could be explained by the positive effect of exclosure to improve site quality. A study conducted by Mekuria et al. (2007) indicated that the soil organic matter, soil nutrients as well as soil physical and chemical properties of exclosures are significantly different compared to the adjacent free grazing lands. The improvement in soil properties and nutrients is a key factor for the enhancement of biomass production in exclosures.

Table 1 Average biomass production (n=3) of woody species in exclosures

Treatment	Woody Species	Density (No/ha)	Basal area (m^2/ha)	Volume (m^3/ha)	Biomass (kg/ha)	
					Live	Dry
5 yr AC	*A. etbaica*	905^{b}	$5{,}82^{ab}$	$7{,}78^{ab}$	$3014{,}40^{a}$	$359{,}98^{a}$
	E. schimperi	194^{a}	$3{,}21^{a}$	$4{,}19^{ab}$	$550{,}14^{c}$	$64{,}48^{b}$
10 yr AC	*A. etbaica*	1078^{b}	$8{,}70^{b}$	$13{,}98^{b}$	$5268{,}30^{b}$	$462{,}64^{a}$
	E. schimperi	233^{a}	$1{,}74^{a}$	$1{,}98^{a}$	$980{,}35^{c}$	$85{,}31^{b}$
F-value		$24{,}5^{**}$	$7{,}6^{**}$	$4{,}6^{*}$	$29{,}2^{**}$	$11{,}1^{**}$
P-value		0,00022	0,009	0,038	0,0001	0,003

Different letters in the same column indicates significant difference ($p < 0.05$)

Population structure of wood species

The frequency distribution of the two woody species showed almost an inverted J – shape (Figure 2a-2d). Differences in life history strategies and site preferences may explain the coexistence of these species (Miyadokoro *et al.*, 2003). However, the study revealed that the number of woody species decreases at higher diameter classes. This could be due to the selective removal of woody species for fuel wood and construction.

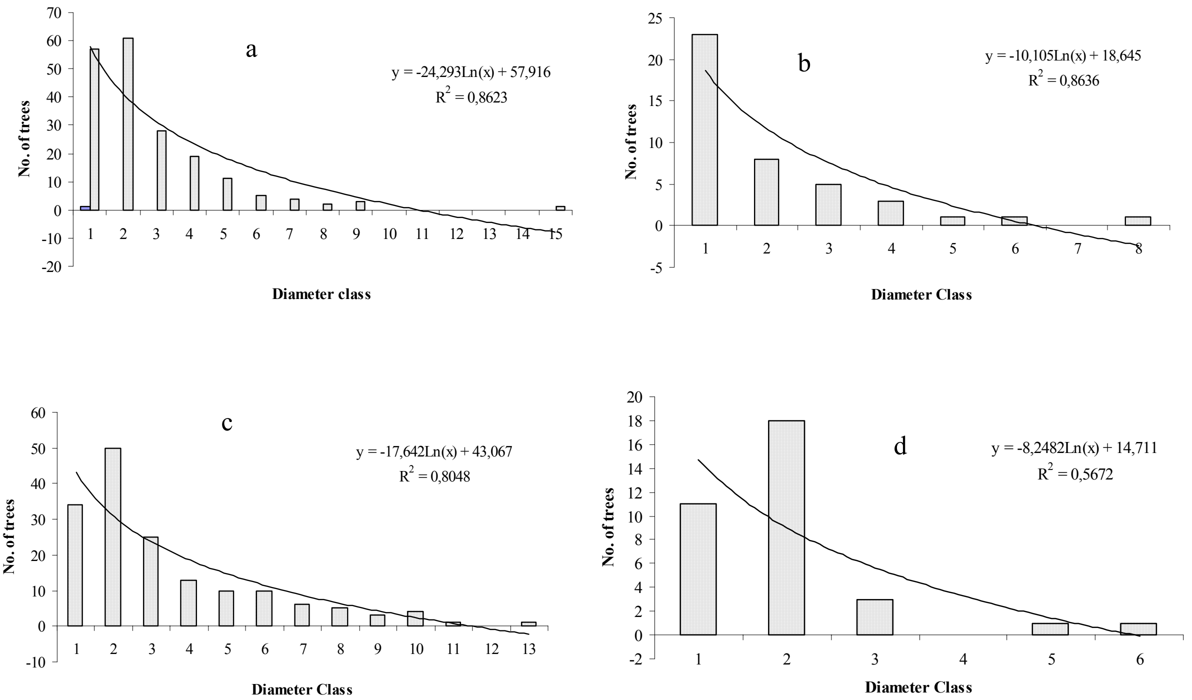

Figure 2 Frequency distribution of *Acacia etbaica* (a, 10 years old, c, 5 years old exclosure) and *Euclea racemosa subsp.schimperi* (b, 10 years old, d, 5 years old exclosure)

The high number of woody species at lower diameter classes shows the potential of exclosures to restore degraded lands. However, unmanaged selective removal of big trees could also interrupt the continuous replacement of woody species (Mastewal *et al.*, 2006). This is due to: (1) with the depletion of big trees, communities will be forced to use young trees which in turn lead to destruction of woody species, (2) loss of big trees means loss of seeds and flowering plants which in turn damage the continuity of the generation.

The study showed that there was no strong relationship between the diameter at stamp height and total height (Figure 3a-3d). However, with the increase in year of protection, the relationship for *A. etbaica* gets better (R^2 =15.4-22.8%). This is an indication of the improvement of site due to exclosures establishment. The relatively weak relationship (R^2 = 6.4%) between diameter and height of *Euclea racemosa subsp.schimperi* could be explained by the significantly ($p < 0.05$) high number of *A. etbaica* in 10-years old exclosure which could suppress the proportional growth of *Euclea racemosa subsp.schimperi*. Competition appears to be important in the determination of community structure. Competition usually determines the absence, or presence and abundance of species in a community and their spatial arrangement (Fowler, 1986).

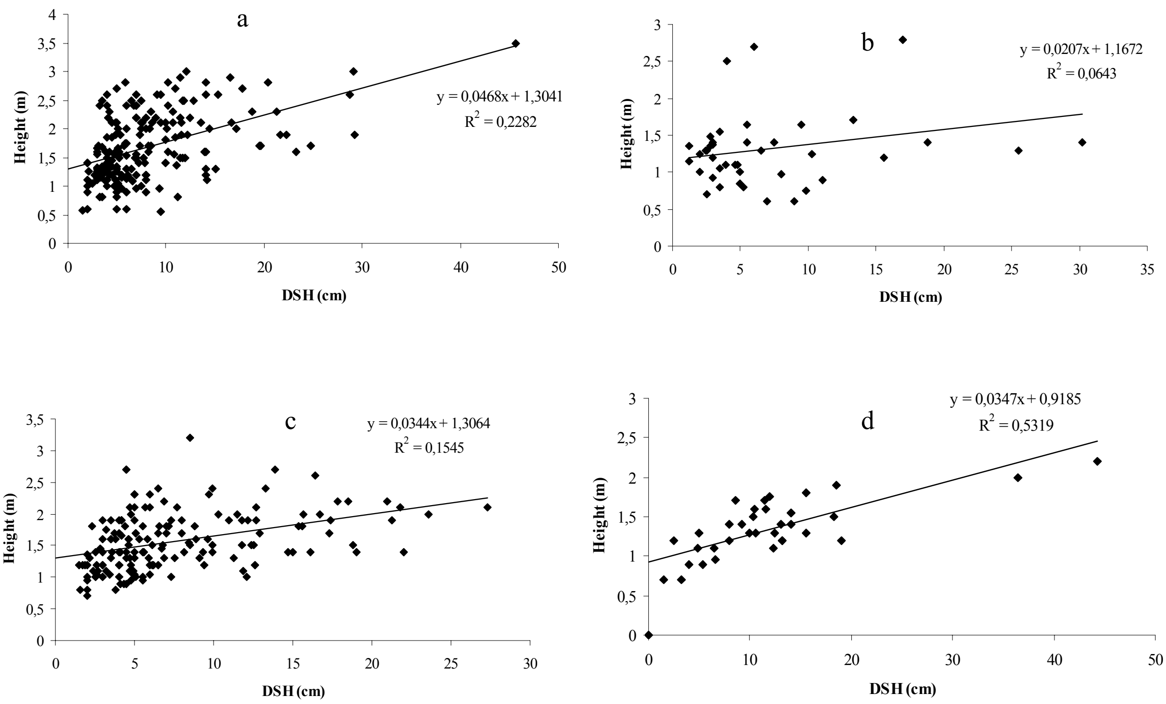

Figure 3 diametr height relathionship of *Acacia etbaica* (a, 10 years old, c, 5 years old exclosure) and *Euclea racemosa subsp.schimperi* (b, 10 years old, d, 5 years old exclosure)

Conclusions

The study revealed that there was an increase in the biomass of woody species investigated with age of conversion. The increase in biomass could be explained by the positive effect of exclosure to improve site quality. Given the estimated firewood consumption of 1 kg d^{-1}per person and taking the number of beneficiaries (600), the amount of dry aboveground biomass produced from the two dominant woody species would cover around 25% of their yearly consumption of the local community. This shows the great contribution of exclosures to solve the problem of fuel wood. However, unmanaged selective removal of big trees which is clearly seen from the population structure could also interrupt the continuity of replenishment of woody species. Thus, vegetation management and awareness creation concerning the sustainable utilization of the existing woody species is urgently needed.

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