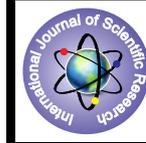


Re-Vegetation of Degraded Hillsides Through Household Tree Planting in Northern Highlands of Ethiopia



Environment

KEYWORDS: Hillside, Landless, Tree planting, Woody species,

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ABSTRACT

Degraded hillsides have been allocated for tree planting to find land for farmers while improving their lives. We assessed the contribution of tree growing on re-vegetation of degraded hillsides. Vegetation inventories were carried out from randomly fixed sample plots. Independent samples t-test was run on density, richness, diversity indices and volume of woody species between managed and disturbed hillsides. ANOVA was also used to examine age and site effects among hillsides. The study showed that management increased tree density by a factor of 4.1 over disturbed hillsides ($p < 0.00$). Species richness was higher in the managed ($675 \pm 59 \text{ ha}^{-1}$) than disturbed ($267 \pm 12 \text{ ha}^{-1}$) hillsides ($p < 0.001$). Age of managed plots brought significant variation on species richness ($p < 0.00$) and density ($p < 0.00$). Location of the hillside plots, on other hand, brought difference on density ($p < 0.02$) and volume of woody species ($p < 0.00$) among hillsides. Our study indicates that tree planting on degraded hillsides brought positive impact on vegetation cover. Therefore, redistribution of wastelands for tree planting should be scaled-up to other areas where land scarcity and forest degradation persists

Introduction

Forests play an important role in Ethiopian culture, traditions, economy, employment and livelihoods. They are the base of biodiversity and pull the foreign exchange through the ecotourism (Senbeta et al., 2002). But the rate of depletion of forest is alarming in the highlands of northern Ethiopia. Many plans were formulated to save forests and adopt policy reforestation but due to increasing population, expansion of cultivable land, lack of awareness a great chunk of northern highlands of Ethiopia were changed in bare rocks from 40% (before human settlement took place) to 3%. Consequently, the region has suffered from lack of woody biomass, water shortage and crop failure (Reubens et al., 2010).

Comprehensive plantation through woodlots and agro-forestry improved vegetation cover of Ethiopia to about 9% (Gebremedhin et al., 2003). The promotion of vegetation restoration with active planting of high value multi-purpose, woody species has been needed to reverse land degradation and to provide livelihoods. Consequently, Acacia and Eucalyptus tree species have been preferred due to their compatibility with climatic and adapted parameters of the site, fast-growing, ability to coppice vigorously and to provide fuel wood for the poor farmers (Jagger & Ponder, 2003). Unlike Lemenih et al. (2004), Eucalyptus species is considered a boon to check land degradation at the northern Ethiopian Highlands.

However, there was low survival rate of plants and poor tree establishment in the community woodlots (Gebremedhin et al., 2003). Moreover, increasing population and limited supply of land increased landlessness, thus steeper and more marginal lands were brought into cultivation to feed the increasing population (Hurni et al., 2005). In exclosures, population interference was restricted to encourage natural regeneration with less emphasis for local farmers. There was also no institutional mechanism to deal with sharing of grasses and dead trees from exclosures. As a response of these problems, the community proposed that degraded hillsides allocation for tree planting to enhance land rehabilitation while improving the lives of landless farmers. The innovation has been promoted to other districts with technical assistance (Hooton & Hagos, 2007).

Allocated degraded hillsides have improved livelihoods of small holder farmers by promoted plantation (Hailemariam, 2010). Comparing changes with key ecological indicators between managed and adjacent disturbed hillsides could contribute for further improvement of the hillside plantation. However, vegetation status of the hillside plantations was not scientifically assessed to show their impact on re-vegetation of degraded

landscape. Thus, the study was conducted to assess the woody species condition by asking the following questions: (1) Did tree planting change the composition, density, richness, diversity and regenerative of woody species? (2) Did age and site of hillside plots affect woody species performance?

Materials and Methods

Study area

The study was carried out in Tigray, located at the northern limit of Ethiopia. After Hurni et al. (2005), 58% of the Tigray area is lowland ("Kolla"—less than 1500 m), 41% is medium highland ("Woina Degua"—1500 to 2300 m), and 1% is upper highland ("Degua"—2300 to 3000 m). Hawzen (Mingirgar Adigi) and Negash sub-watershed of Tigray region (Fig. 1) are located at $13^{\circ} 58' 39'' \text{N}$ and $39^{\circ} 25' 45'' \text{E}$. The study area is under cover of flat (40%), slopes (15%) and hillsides (45%) consisting with sandy loam and clay loamy soil textures. It has an average daily temperature of 21°C with mean annual rainfall of 519 mm. The study villages have limited cultivable land and farming is practiced on steep slopes (Hailemariam, 2010).

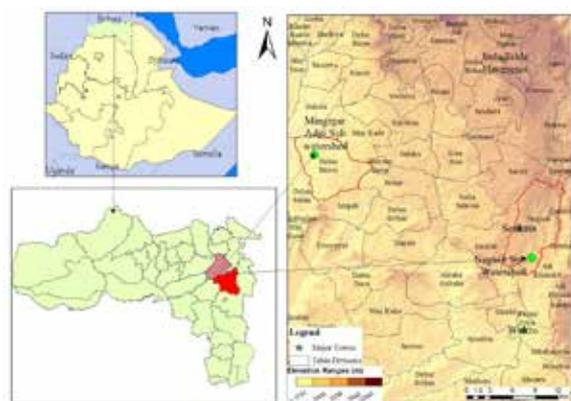


Figure 1: Map showing the study areas

Data collection

Data were obtained from hilltops, plains and gullies of similar landscape position by using random sampling. Based on relative variability, more plots were considered at managed ($N=12$) than disturbed hillsides ($N=6$) at an area of 100 m^2 (Senbeta et al., 2002). In each plot, all woody species were listed. Height was measured using meter and graduated stick. Diameter of woody species was measured at diameter at breast height (Dbh) and diameter at stem height (Dsh) using a caliper and diameter

tape. Interview and transect walks along the hillsides were also carried out to observe intensity of geomorphic processes and management system.

Data analysis

Density of each woody species was estimated by converting the total number of the species encountered to a hectare (No/ha). The frequency of each woody species was also calculated. Basal area (BA) was calculated by the following equation that used by Aynekulu et al.(2009).

Where,

d = diameter of each tree in sample plots

n = number of trees in sample

Coefficient similarity of the land uses was estimated following equation of Sørensen (1948)BA= -----Equation 1

Where,

Ks = Sorensen's coefficient of similarity

x = number of species managed and disturbed land uses

y = number of species uniquely in managed hillside

z = number of species exclusively in disturbed hillsides

-----Equation 2

Analysis on height and diameter of woody species give insights on structure, regeneration status and condition of woody species. Measuring the number and abundance of the tree species per plots makes the use of diversity indices. Dominance (D), Shannon (H), Simpson (1-D), Evenness (E^H/S) were manipulated using PAST software package, version 1.91. Independent samples t-test was used for pair wise comparison of diversity indices between the treated and untreated sub-watersheds. A one-way ANOVA was used to detect variations caused by age and site effects on woody species performance across the study areas.

Volume (V) of Eucalyptus, Acacia and Dodonaea was calculated using equation 3:

V= BA*H*0.45 -----Equation 3

Where,

BA= i basal area

H = height of the stand woody species

*0.45 was used as a factor to reduce range of errors during height measurement

Moreover, effect of age management (by the years 3, 6, 9, 10 and 12) since establishment on species richness, density and diversity was considered during analysis of woody species.

Results and Discussion

Effect of private tree planting on composition, richness and diversity of woody species

Eucalyptus, Dodonaea, Becium and Acacia were the most abundant woody species in the private managed hillsides (Table 1 and Figure 2). The result reveals that higher preference was given to tree species of multiple uses, economic returns, resistance to water stress and ecological agents. In the disturbed hillsides, Acacia and Becium were dominant species due to their advantage of primary succession and less palatability for browsers. The species having height less than 1.5 m are affected by browsing, free grazing and households use lead to less probability of regeneration. Moreover, random removal of seedlings, saplings and trees interrupted the continuous replacement of the species in the disturbed hillsides.

Table 1 Numbers of individual (NI), relative abundance (RA, %), relative frequency (RF, %) and basal area (BA, m3) of woody species in managed (8*100 m2) versus disturbed (3*100 m2) hillside of Mingirgar Adigi.

Scientific name	Vernacular name	Managed hillsides				Disturbed hillsides			
		NI	RA	RF	BA	NI	RA	RF	BA

Acacia abyssinica	Chea'	3	8	25	0.01	0	0	0	0.00
Acacia etbalca	Seraw	73	20	100	0.14	24	73	100	0.11
Aloe macrocarpa	Ere	3	8	25	0.00	0	0	0	0.00
Becium grandiflorum	Tabeb	22	6	62.5	0.00	6	18	66.5	0.00
Capparis tomentosa	Andel	1	3	12.5	0.00	0	0	0	0.00
Cassia singuana	Tahses	18	4.9	87.5	0.10	1	3	33.3	0.00
Dichrostachys cinerea	Gonok	4	10.1	25	0.00	0	0	0	0.00
Dodonaea angustifolia	Tahses	76	20.9	62.5	0.06	0	0	0	0.00
Ficus carica	Beles talian	3	8	37.5	0.00	1	3	33.3	0.00
Eucalyptus camaldulensis	Bahrizaf	146	40.1	100	5.37	0	0	0	0.00
Euphorbia abyssinica	Qolqal	1	3	12.5	0.00	0	0	0	0.00
Jasminum abyssinicum	Tselim habi	2	5	25	0.00	0	0	0	0.00
Maytenus senegalensis	Kebkeb	2	5	25	0.00	0	0	0	0.00
Olea africana	Awlie'	6	1.6	37.5	0.00	1	3	33.3	0.21
Cardiulus nyassanus	Dander	2	0.5	25	0.00	0	0	0	0.00
Faidherbia albida	Momona	2	0.5	12.5	0.00	0	0	0	0.00
Maytenus senegalensis	Kebkeb	2	5	25	0.00	0	0	0	0.00
Total		364			5.68	33			0.32

Woody species encountered in the managed and disturbed hillsides of Mingirgar Adigi, Hawzen were 4550 and 1100 count ha⁻¹, respectively. This indicates that planting trees brought species density by a factor of 4.1 was over disturbed hillsides. Similarly, the trees/shrubs density ranged from 3000 counts ha⁻¹ in the managed hillside to 2166 counts ha⁻¹ in disturbed hillsides of Negash sub-watershed. Species richness was ranged from 675±59ha⁻¹ in managed to 267±12 ha⁻¹ in disturbed hillsides of Mingirgar Adigi (p<0.001) similarly in managed and disturbed Negash hillsides (p<0.59), woody species ranged from 575±11ha⁻¹ to 400±57ha⁻¹, respectively. Direct seeding from matured trees and pollinating actors improved species richness in the managed hillsides. This result is consistent with the finding of Lugo (1992) revealing rural tree planting on degraded hillsides increased species richness in managed site and thereby enhances ecosystem function and conservation of forest genetic forest resources. However, Dominance, Evenness, Simpsons and Shannon did not show significant difference between managed and disturbed hillsides (Table 3). Disturbed hillsides usually had rarer and few dominant species.

Table 2: Numbers of individual (NI), relative abundance (RA, %), relative frequency (RF, %) and basal area (BA m³) of woody species in managed (4*100 m²) and disturbed (3*100 m²) hillsides of Negash, Wukro Kilde-Awulaelo.

Scientific name	Local name	Managed gully/hillside				Disturbed gully/hillside			
		NI	RA	RF	BA	NI	RA	RF	BA
<i>Acacia abyssinica</i>	Chea'	1	1.25	25	0.20	0	0	0	0.00
<i>Acacia etbaica</i>	Seraw	1	1.25	25	0.01	0	0	0	0.00
<i>Becium grandiflorum</i>	Tabeb	22	27.5	100	0.00	39	60	100	0.00
<i>Dodonaea angustifolia</i>	Tahses	1	1.25	25	0.00	0	0	0	0.00
<i>Ficus carica</i>	Beles tali	1	1.25	25	0.00	5	7.7	100	0.00
<i>E. camaldulensis</i>	Bahrizaf	39	48.6	100	0.31	0	0	0	0.00
<i>Euphorbia abyssinica</i>	Qolqual	5	6.3	25	2.60	2	3.1	25	0.02
<i>Maytenus senegalensis</i>	Kebekeb	6	7.5	5	0.00	0	0	0	0.00
<i>Rumex nervosus</i>	Hohot	3	3.8	50	0.00	12	18	50	0.00
<i>Cardulus nyassanus</i>	Dander	1	1.25	25	0.00	0	0	0	0.00
<i>Calpurnia aurea</i>	Hitsawuts	0	0	0	0.00	1	1.0	25	0.00
<i>Carissa edulis</i>	Egam	0	0	0	0.00	3	4.5	25	0.00
<i>Barbeya oleoides</i>	Hirmi teli	0	0	0	0.00	2	3	25	0.00
<i>Olea europaea</i>	Awule'	0	0	0	0.00	1	1.3	25	0.00
Total		80			3.12	65			0.02

Up to five woody species were commonly found in Mingirgar Adigi and Negash hillsides (Table 1 & 2). Based on the absence and presence criterion, the land uses plantations were qualitatively dissimilar by 35.7 % and 40 %, respectively. In Negash hillsides, the dissimilarity gap was not significant (p<0.08) as smaller species were shared by managed and disturbed hillsides. The aggregation of the woody species changed the power of Sørensen's coefficient of similarity to 58.3% due to the increased number of species shared by both land uses while the species uniquely found in disturbed and managed areas were less. Many native woody species were regenerated in the hillsides. Herbaceous species were also observed as fast colonizers in the treated gullies due to siltation of fertile soil and spring development. In agreement with Emiru et al. (2006), this indicates that tree planting encouraged the regeneration of native species across hillsides. Those species disappeared before due to natural and anthropogenic calamities were re-appeared with judicious exotic plantation species.



Figure 2: Partial view of private hillside plantation, previously degraded hillsides in Tigray.

Better height class was documented in Mingirgar Adgi (6.80±0.47 m) than Negash (5.06±0.73 m). Height and diameter classes varied between the managed and disturbed hillsides with "L" shape as the species were under lower diameter (p<0.00). Unlike in the disturbed sites, large diameter and height in the managed hillsides shows new rising species that grow up to tree which in turn could ensure productive ecosystem over time. Similarly, Yirdaw (2002) reported that tree planting served as "nurse-trees" for native species whereas exotic tree planting was foster the regeneration of native species. Management has greatly improved the seedlings survivals as saved from livestock trampling. Moreover, basal area had significant variation between managed (73.3m²ha⁻¹) and disturbed hillsides (0.83m²ha⁻¹) as a function of better coppicing system, seedling propagation and under-story management (p<0.00) application.

Table 3: Means (±SE) and test of significance for diversity parameters at plot level (10*10 m²) in managed and disturbed hillside in Mingirgar Adigi and Negash

Diversity indices	Mingirgar Adigi (a)		Negash hillsides(b)		P-value (a, b)
	Managed (n=8)	Disturbed (n=3)	Managed (n=4)	Disturbed (n=3)	
Taxa_S	6.75±0.59	2.67±1.20	5.75±1.11	4.00±0.57	0.02
Individual	45.50±6.82	11.67±1.0	20.0±7.16	21.0±7.0	0.04
Dominance_D	0.36±0.03	0.64±0.19	0.36±0.03	0.46±0.1	0.29
Shannon_H	0.31±0.08	0.62±0.36	0.24±0.13	1.02±0.23	0.24
Simpson_1-D	0.63±0.03	0.35±0.18	0.63±0.03	0.54±0.1	0.29
Evenness_e^H/S	0.56±0.02	0.87±0.08	0.65±0.06	0.72±0.08	0.23
Equitability_J	0.69±0.02	0.55±0.28	0.74 ±0.3	0.73±0.09	0.01

Time-duration and site effects on woody species performance

Time-duration of establishment brought significant variation on richness (p<0.00; R²=60%) and density (p<0.00; R²=79%) across hillside plantation (Table 4). However, Dominance (p<0.09), Simpsons (p<0.15) and Shannon (p<0.06) did not show variation by age categories. Moving from six to twelve year old hillside regeneration of herbaceous species declined while Eucalyptus becomes dominant with homogenous stands due to the suppression of native woody species by allelopathic effects of dominant species. The intensities affected species structure and composition among plots and between sites (Lemenih et al., 2004). Unlike species richness (p<0.85), tree density varied significantly between Mingirgar Adigi and Negash sites (p<0.02).

Table 4: The impact of Time duration and site on indices of tree species

Diversity indices	Mingirgar Adigi				Negash	
	3 years	6 years	9 years	12 years	6years	10 years

Taxa_S	6.5±1.50	7.67±0.88	6.5±1.5	5.0±0.0	7.5±0.5	4.0±1.0
Individual	62.67±16	48.3±11.1	28.5±8.5	29.0±8.0	48.67±12	32.0±6
Dominance_D	0.34±0.04	0.29±0.01	0.46±0.05	0.48±0.03	0.32±0.0	0.40±0.02
Shannon_H	1.28±0.18	1.51±0.08	1.18±0.17	1.0±0.0	1.44±0.32	1.04±0.36
Simpson_1-D	0.65±0.04	0.70±0.0	0.67±0.9	0.51±0.03	0.68±0.0	0.59±0.02
Evenness_e^H/S	0.56±0.03	0.6±0.03	0.57±0.8	0.55±0.0	0.57±0.02	0.73±0.09
Equitability_J	0.69±0.01	0.75±0.01	0.64±0.01	0.63±0.0	0.71±0.01	0.77±0.5

There was significant variation on volume ($p < 0.001$) of woody species due to good guarding system, pruning and watering in Mingirgar Adigi as compared to Negash. Eucalyptus had 134 m³h⁻¹ in Mingirgar Adigi and 1±0.56 m³h⁻¹ in Negash. On average, *A. etbaica* and *D. angustifolia* had a volume of 0.85m³ha⁻¹ and 0.65m³ha⁻¹ respectively. In line to this, Reubens (2010) reported that tree planting increases tree volume and the economic value of forests.

Conclusion and implication for landscape management

Composition, density and richness of woody species were better in managed than disturbed hillsides. But they vary with ages and sites. Planting trees on degraded area associated with better management encourage native trees to re-emerge and contributed to natural regeneration of important trees. Private tree planting on degraded hillsides whose opportunity cost was zero improved vegetation cover regardless of the magnitude. Local efforts are often limited to a small pool of known species, thus more attention should be given to valuable alternatives, performing a range of socio-economic, ecological and cultural functions. Allocation of degraded hillsides for tree planting is beneficial from environmental rehabilitation and ecosystem maintenance perspectives. Therefore, there is a great opportunity that the efforts made in the study area could be scaled-up to other highland regions of Ethiopia.

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