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Status of Native Woody Species Diversity and Soil Characteristics in an Exclosure and in Plantations of *Eucalyptus globulus* and *Cupressus lusitanica* in Northern Ethiopia

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Exclusion of grazing animals and tree plantations are 2 methods that have been used for restoration of degraded lands in tropical semiarid areas. These 2 options can foster secondary forest succession by improving soil conditions, attracting seed-dispersal agents, and modifying microclimate for understory growth. We compared native woody plant diversity and soil chemical and physical attributes under exclosure and on Eucalyptus globulus *(EGP) and* Cupressus lusitanica *(CLP) plantations. Vegetation data were collected by an inventory of stands with circular plots of 5.64 m radius, and soil samples were collected from the 4 corners and center of 20 × 20 m plots. As a result, 15 native woody plant species belonging to 13 families were recorded. Importance value index (IVI), Shannon-Wiener, Simpson's diversity, and species richness were higher in the exclosure, followed by EGP and CLP. Contents of soil organic carbon and total nitrogen showed significance difference and were highest in the exclosure, followed by CLP, EGP, and grazing land. Although the difference was not significant, an increasing trend was observed for cation exchange capacity and K^+. Bulk density was highest on the grazing land, followed by EGP, CLP, and exclosure. Our results suggest that degraded land reclamation can be achieved with plantation of rapidly growing tree species as well as exclosure. However, native woody species diversity and improved soil attributes are better achieved with exclosure. Exclosures can be established interspersed strategically with single- or mixed-species plantations to facilitate restoration of native vegetation. However, it is important to conduct further research on the comparative advantage of enrichment planting of exclosures with preferred tree species or exclosures interspersed within blocks of plantation.*

Keywords: *Restoration; regeneration; succession; woody species; soil attributes; Afromontane; Ethiopia.*

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Introduction

Land degradation, which impairs land productivity in the Ethiopian Highlands, may lead to desertification if unabated. Especially in northern Ethiopia, land degradation has been accelerated by long-standing human impact through changing land use and deforestation (Hurni 1988; Nyssen et al 2009) and strong biomass demand for the still-increasing human and livestock populations (Tekle 1999). The most important countermeasures taken to halt this process have been plantation of trees and assisted natural regeneration by excluding human and animal interference (exclosure) (Pohjonen and Pukkala 1990; Tekle 2001).

Plantations of rapidly growing exotic tree species are good options for increased biomass productivity per given time and area (Pohjonen and Pukkala 1990). However, in terms of restoration of degraded lands, this option may fail to address the concerns of productivity and diversity, and it may not be feasible and compatible with specific local environmental, socioeconomic, and technological realities, which all may force tree plantations to be replaced or augmented with different restoration strategies, such as exclosure. Exclosures have been reported to be effective for native plant restoration (Mengistu et al 2005; Aerts et al 2007), improving soil attributes, and reducing soil erosion (Descheemaeker et al 2006a, 2006b). Similarly, plantations have been used to catalyze forest succession in the understory to restore native vegetation (Parrotta 1999; Lee et al 2005; Brockerhoff et al 2008) and improve soil physical and chemical attributes (Mishra et al 2003).

The 2 options considered here can foster secondary forest succession by improving soil conditions, attracting seed-dispersal agents, and modifying microclimate for understory growth; however, there might be differences with regard to speed in restoring native vegetation and soil close to their original condition. Findings show that seedlings of late successional tree species are especially impacted by environmental modifications following restoration (Farwig et al 2009). Thus, the diversity and density of late successional species can be used as proxies for the potential of different reclamation techniques to develop into more natural forests (Babaasa et al 2004).

Several studies have been conducted that compare pure and mixed-species plantation and natural forest (Lisanework and Michelsen 1994; Lugo 1997; Lemenih et al 2004a; Piotto et al 2004; Zamora and Montagnini 2007) to determine their impact on naturally regenerated native woody species (NRNWS) and soil. Few studies, however, have compared exclosure and plantation of exotic species on degraded lands in the dry Afromontane forests of Ethiopia. In this study, we compared exclosure, *Cupressus lusitanica* (CLP), and *Eucalyptus globulus* (EGP) plantations with respect to their impact on naturally regenerated native woody species (NRNWS) as well as on soil attributes.

Material and methods

Study area

The study area is located in Tehuledere district, South Wello, on the eastern edge of the northeastern highlands of Ethiopia (11°12′30.56″N; 39°40′44.51″E). The great Ethiopian Rift system is found within an ~25 km radius. The topography is rugged, with a dissected and degraded plateau. The average altitude is 2350 m, mean annual temperature is 21°C, and the average annual precipitation is 1030 mm. The potential natural vegetation of the area is dry Afromontane forest dominated by *Juniperus procera* and *Olea europaea* ssp *cuspidata*. Broad-leaved species are dominant (Aalbaek 1993). The valley floors are settled by subsistence farmers engaged in mixed-crop production and livestock rearing. The average population density is estimated to be 285 persons per km^2 (Tesfahun et al 2002). The study plots were established on the east-facing slope (20–45%) of a ridge that stretches through the political boundary of the district and that was rehabilitated by the efforts of donors and local partners following the Sahel drought of the 1970s (some of the reports related to the rehabilitation efforts are: Tekle et al 1997; Tekle 1999, 2001; Tekle and Bekele 2000; Tekle and Hedlund 2000). On this ridge, we purposely selected an area where an exclosure had been established between a block of *E. globulus* and *C. lusitanica* plantations on former grazing land. According to reports, it has been protected since establishment from human and domestic animal interference by paid guards as well as by the local population (Tesfahun et al 2002). This area was selected because it is one of the few forests that survived destruction in 1991 during the change of government. The exclosure and plantations were established in close proximity, creating a good opportunity to compare their effects, and they were also easily accessible.

Data collection

Vegetation sampling was done on transect lines perpendicular to the contours. The spacing between transects was 100 m. Circular sampling plots with a 5.64 m radius (~100 m^2) at 75 m intervals (adjusted for slope) were used on a transect. The maximum number of plots per transect was 3 in the exclosure and 2 in the plantations. The total number of plots per habitat was 6. Inside each plot, every woody plant greater than 3 cm diameter at breast height (DBH) was identified and measured. Identification of species and nomenclature follow *Flora of Ethiopia and Eritrea* (Edwards et al 1995; Hedberg and Edwards 1995; Edwards et al 1997).

Little is known about soil conditions before intervention; therefore, the grazing land was used as a reference. Sampling plots were located based on their representativeness by using available field methods such as similarity in soil color, structure, and cohesiveness when wet, developed by the first and second authors. Soil samples were then collected in 5 replicates per habitat from a pit dug from the 4 corners and center of square 20 m × 20 m plots, including on the grazing land. Samples were obtained from depths of 0–10 and 10–20 cm.

Soil analysis was carried out at the soil laboratory at the Sirinka Agricultural Research Center (Ethiopia). Soil pH was measured in water and 1 M KCl suspension at 1:2.5 soil:liquid ratio potentiometrically using glass-calomel combination electrodes. Soil organic C (SOC) and total N were determined using a LECO-1000 CHN analyzer. Available P was analyzed according to standard methods (Olsen et al 954). Potassium was analyzed by flame photometer (Black et al 1965). Cation exchange capacity (CEC) was determined following Chapman (1965). Bulk density was determined following Brady and Weil (2002).

Data analysis

The relative dominance or importance of a species in a given habitat can be expressed by the Importance value index (IVI). IVI is calculated as the sum of relative dominance, relative abundance, and relative frequency of species. Dominance is calculated as the sum of basal area (BA) in square meters per hectare of each species (BA= $\pi[DBH^2/4]$). Relative dominance is the percentage of the total basal area of a given species out of the total measured stem basal areas for all species, relative abundance is the percentage of the abundance (the number of stems of individuals of a species per ha) of each species compared to the total stem numbers for all species

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per hectare, and relative frequency is the percentage of frequency (the percentage of the total number of plots containing the species to all plots) of a species compared to the total frequencies of all the species added up. Plot-level species diversity statistics were calculated using the Shannon-Wiener index and Simpson's diversity index. The effects of habitats (created by each intervention) on the diversity statistics were determined with 1-way analysis of variance (ANOVA). The frequency of DBH (cm) size classes was used to compare population structure. The data obtained from the soil analyses were subjected to 1-way ANOVA for each sample depth separately.

Results

Woody species diversity

In total, 15 NRNWS from 13 families were recorded. All NRNWS were represented in the exclosure, but only 2 were found in CLP and 4 in EGP. About 75% of the species had more than 50% frequency in the exclosure. The most dominant species were *Juniperus procera* Hochst. ex Endl., *Acacia abyssinica* Hochst. ex Benth., *Olea europaea* ssp. *cuspidata*, *Carissa edulis* (Forssk.) Vahl, *Nuxia congesta* R.Br. ex Fresen., and *Maytenus senegalensis* (Lam.) Excell. The dominance, density, and frequency values for each species were higher in the exclosure than the plantation (Table 1). The IVI values for *J. procera*, *A. abyssinica*, and *O. europaea* in the exclosure were higher than the 2 plantations (Table 1).

Species richness was significantly higher in the exclosure than in the 2 plantations ($p < 0.001$). There was no significant difference in species richness between the 2 plantations, although EGP had greater mean species richness value than CLP. Shannon-Wiener and Simpson's diversity indices also showed significant differences, where the exclosure was more diverse than the 2 plantations (Table 2). Stem diameter size distribution for the most dominant NRNWS was higher in the exclosure (Figure 1A) than in CLP (Figure 1B) and EGP (Figure 1C) for all size classes. Rather, smaller-sized individuals dominated in the plantations.

Soil physical and chemical attributes

Significant ($p < 0.05$) differences in soil pH were found at the lower (10–20 cm) soil depth among habitats. In the case of SOC and N, the exclosure exhibited significantly higher ($p < 0.001$) values, and the order was exclosure > CLP > EGP > grazing land, except for EGP > CLP in SOC for the lower layer (Table 3). Mean values of CEC, K, and P were not significantly different ($p > 0.05$).

Bulk density (g cm^{-3}) was also significantly ($p < 0.001$) different. The grazing land exhibited significantly ($p < 0.00$) higher mean value of soil bulk density, followed by EGP, CLP, and the exclosure (Table 3).

Discussion

Our results show, 30 years after establishment, that exclosure increased diversity of NRNWS more than the plantations. DBH for most of the encountered NRNWS was less than 15 cm, except in the population of *A. abyssinica* and *J. procera*, where 99% are less than 30 cm DBH, and more than 95% are less than 19 cm DBH. This difference may be explained by the regeneration strategy of NRNWS and can be discussed in relation to the facilitative or inhibitive processes created by postintervention environmental conditions (Connell and Slatyer 1977).

Reports have shown that succession achieves successful seedling recruitment in dry Afromontane forests either from seed rain or advance regeneration (Teketay 1997a, 1997b, 1997c, 2005). However, these regeneration pathways are reportedly impeded by several limitations. Seed limitation has been reported due to diminished natural vegetation from long-standing deforestation and the confinement of mother trees in churches and remote groves (Wassie and Teketay 2006; Wassie et al 2009), absence of soil seed banks and their depletion by cultivation (Teketay and Granström 1995; Teketay and Granström 1997a, 1997b; Teketay 1998; Lemenih and Teketay 2005), and insufficient disperser activity because the seeds of late successional native plants are large, short-lived, and dependent on frugivorous animals for dispersal (Aerts et al 2006, 2008a). Similar studies also have shown that light, moisture, seed dormancy, and other biotic and abiotic factors limit establishment of late successional tree species.

Our results showed higher frequency of NRNWS for all stem diameter size classes in the exclosure than on the plantations (Figure 1A, B, and C). This suggests that the exclosure created a postintervention environment that facilitated succession, either from seed rain or advance regeneration. Regeneration from seed rain might have been facilitated in the exclosure by increased seed influx, forest structural diversity, attraction of animal seed dispersers (Zanne and Chapman 2001), and creation of light, moisture, and other resource gradients favorable for germination and establishment of diverse NRNWS (Yirdaw 2001; Yirdaw and Leinonen 2002; Yirdaw and Luukkanen 2004).

The positive role of soil seed bank (SSB) against establishment and seed limitations might have contributed to the observed differences. Although we did not measure SSB, and there have been reports of little similarity between SSB and standing flora, and SSB mostly composed of annual plants (Teketay and Granström 1995), pioneer plants from the SSB have strong effects in modifying the environment to facilitate secondary succession (Tekle and Bekele 2000). In addition, some light-demanding trees that have a strong effect on secondary succession might originate from the SSB. For

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TABLE 1 Frequency, abundance, dominance, relative dominance (%), and Importance value index (IVI) of the main naturally regenerated native woody species (NRNWS) under exclosure, *C. lusitanica* plantation (CLP), and *E. globulus* plantation (EGP). (Table extended on next page.)

Family	Tree species	Frequency			Abundance		
		Excl	CLP	EGP	Excl	CLP	EGP
Cupressaceae	*Juniperus procera* Hochst. ex Endl.	100.00	66.67	83.33	1896.00	84.00	495.83
Fabaceae	*Acacia abyssinica* Hochst. ex Benth.	83.33	16.67	83.33	75.00	4.00	29.17
Oleaceae	*Olea europaea* L. ssp. *cuspidata* (Wall. ex G. Don) Cif.	100.00	0.00	33.33	104.17	0.00	16.67
Apocynaceae	*Carissa edulis* (Forssk.) Vahl	83.33	0.00	0.00	583.33	0.00	0.00
Loganiaceae	*Nuxia congesta* R.Br. ex Fresen.	83.33	0.00	0.00	91.67	0.00	0.00
Celastraceae	*Maytenus senegalensis* (Lam.) Excell.	83.33	0.00	16.67	316.67	0.00	4.17
Oleaceae	*Jasminum abyssinicum* Hochst. ex DC.	50.00	0.00	0.00	37.50	0.00	0.00
Melianthaceae	*Bersama abyssinica* Fresen.	16.67	0.00	0.00	8.33	0.00	0.00
Sterculiaceae	*Dombeya torrida* (J.F. Gmel) P. Bamps	50.00	0.00	0.00	25.00	0.00	0.00
Fabaceae	*Calpurnia aurea* (Ait.) Benth.	50.00	0.00	0.00	25.00	0.00	0.00
Anacardiaceae	*Rhus glutinosa* A. Rich.	16.67	0.00	0.00	8.33	0.00	0.00
Sapindaceae	*Allophylus abyssinicus* (Hochst.) Radlkofer	50.00	0.00	0.00	16.67	0.00	0.00
Apiaceae	*Heteromorpha trifoliata* (Wendel) Eckl. & Zeyher	66.67	0.00	0.00	45.83	0.00	0.00
Pittosporaceae	*Pittosporum viridiflorum* Sims	16.67	0.00	0.00	4.17	0.00	0.00
Santalaceae	*Osyris quadripartita* Decn.	16.67	0.00	0.00	8.33	0.00	0.00

instance, *A. abyssinica* and *J. procera* are represented by larger-sized individuals in irregular patterns in the plantations and in almost every size class in the exclosure (Figure 1A–C). Although some of the extremely large trees (<2%; not shown in Figure 1A–C) may be remnants of the original vegetation, the majority are likely to have established from the SSB before the habitat changed much in the plantations. Previous studies have shown that seeds from these 2 species have longer viability and different dormancy mechanisms (Teketay 1998; Wassie et al 2009). Disturbance during plantation-site preparation may break dormancy and trigger germination, and protection from human and livestock would ensure successful recruitment. However, this recruitment does not seem to have occurred continuously; rather, it likely fluctuated with time and affected canopy characteristics, which would have indirectly determined germination (Yirdaw and Leinonen 2002; Yirdaw and Luukkanen 2004).

Succession through the pathway of advance regeneration might have improved NRNWS diversity under exclosure. Site clearance and weeding, which are important activities in plantation forest management, especially impede advance regeneration, as noted by

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TABLE 1 Extended. (First part of Table 1 on previous page.)

Family	Tree species (short name)	Dominance			Relative dominance (%)			IVI		
		Excl	CLP	EGP	Excl	CLP	EGP	Excl	CLP	EGP
Cupressaceae	*Juniperus*	17.12	0.07	2.80	59.08	0.31	9.67	110.54	8.19	27.58
Fabaceae	*Acacia*	1.38	0.10	1.00	4.75	0.41	3.47	12.97	1.95	10.63
Oleaceae	*Olea*	0.36	0.00	0.00	1.23	0.00	0.01	11.42	0.00	2.99
Apocynaceae	*Carissa*	0.23	0.00	0.00	0.80	0.00	0.00	20.73	0.00	0.00
Loganiaceae	*Nuxia*	0.12	0.00	0.00	0.41	0.00	0.00	9.01	0.00	0.00
Celastraceae	*Maytenus*	0.12	0.00	0.00	0.40	0.00	0.01	14.19	0.00	1.40
Oleaceae	*Jasminum*	0.04	0.00	0.00	0.15	0.00	0.00	4.91	0.00	0.00
Melianthaceae	*Bersama*	0.03	0.00	0.00	0.11	0.00	0.00	1.60	0.00	0.00
Sterculiaceae	*Dombeya*	0.03	0.00	0.00	0.09	0.00	0.00	4.57	0.00	0.00
Fabaceae	*Calpurnia*	0.02	0.00	0.00	0.07	0.00	0.00	4.54	0.00	0.00
Anacardiaceae	*Rhus*	0.02	0.00	0.00	0.06	0.00	0.00	1.55	0.00	0.00
Sapindaceae	*Allophylus*	0.02	0.00	0.00	0.06	0.00	0.00	4.34	0.00	0.00
Apiaceae	*Heteromorpha*	0.01	0.00	0.00	0.03	0.00	0.00	6.28	0.00	0.00
Pittosporaceae	*Pittosporum*	0.00	0.00	0.00	0.01	0.00	0.00	1.40	0.00	0.00
Santalaceae	*Osyris*	0.00	0.00	0.00	0.01	0.00	0.00	1.50	0.00	0.00

TABLE 2 Mean ± SE for species richness, Shannon-Wiener, and Simpson's diversity values under exclosure, *C. lusitanica* plantation (CLP), and *E. globulus* plantation (EGP).

Index	Exclosure	CLP	EGP	F	*P*
Shannon-Wiener	1.13 ± 0.17[a)]	0.12 ± 0.11[b)]	0.39 ± 0.11[b)]	14.84	0.00
Simpson's	0.51 ± 0.19[a)]	0.08 ± 0.20[b)]	0.22 ± 0.18[b)]	7.44	0.01
Species richness	9.00 ± 2.81[a)]	1 ± 0.75[b)]	2 ± 1.33[b)]	31.00	0.00

[a)]Different letters indicate significant differences between groups according to Tukey's honestly significant difference (HSD) test.

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FIGURE 1 Frequency of the number of trees per ha according to stem diameter size. (A) Exclosure; (B) *C. lusitanica* plantation (CLP); (C) *E. globulus* plantation (EGP). Note: for reasons of scale, the number of trees per ha has been log transformed.

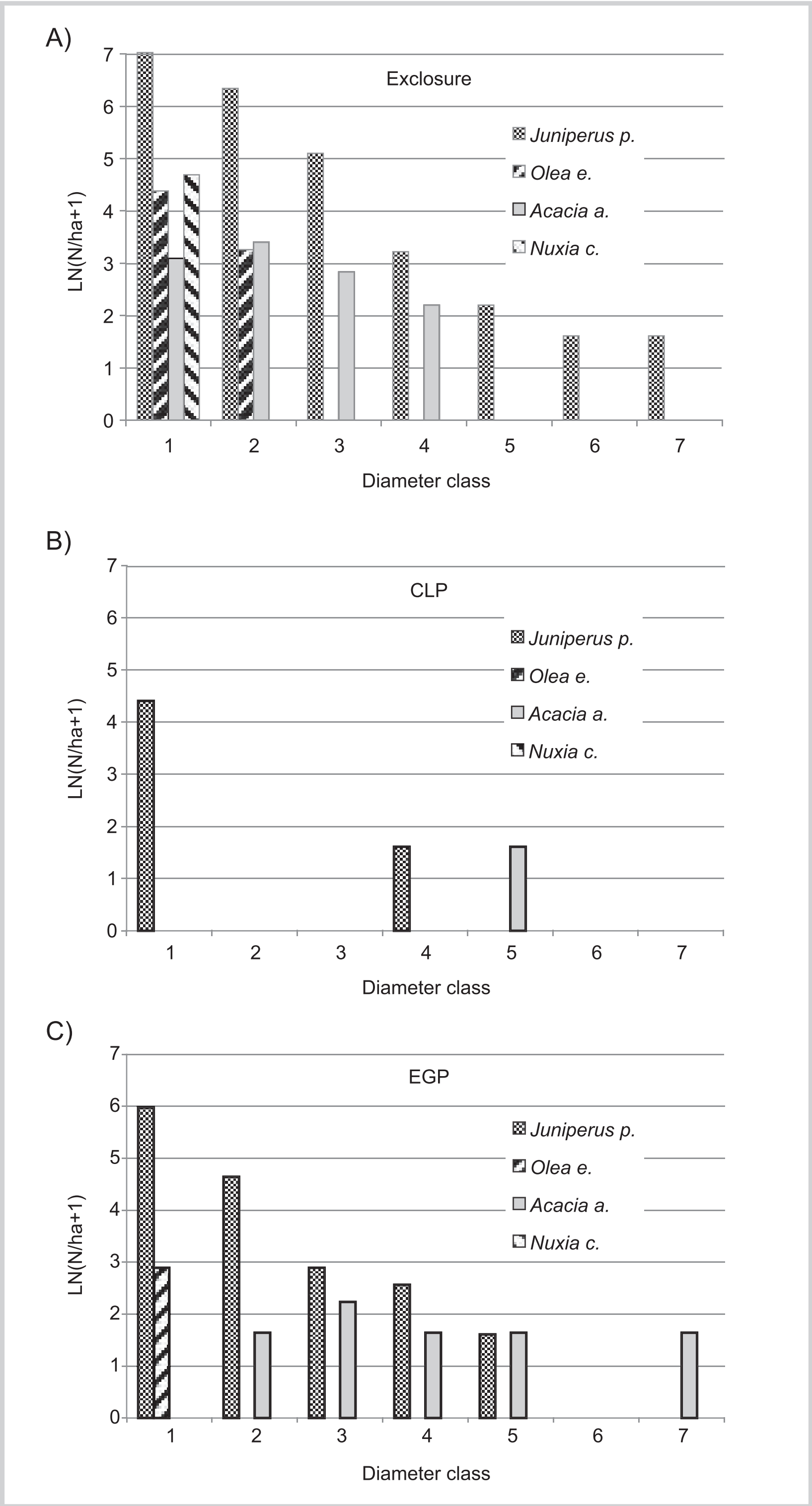

TABLE 3 Mean ± SE result of soil pH, soil organic carbon (SOC), total nitrogen (N), available potassium (K), available phosphorus (P), and bulk density (BD) for depths of 0–10 cm and 10–20 cm for the exclosure, *C. lusitanica* plantation (CLP), grazing land (GL), and *E. globulus* plantation (EGP), and corresponding F and *P* values from ANOVA.

Soil properties	Depth (cm)	Exclosure	CLP	GL	EGP	F	*P*
pH	0–10	5.9 ± 0.1	5.8 ± 0.1	5.9 ± 0.02	5.6 ± 0.2	1.96	0.16
	10–20	5.8 ± 0.1[a)b)]	5.8 ± 0.1[a)b)]	5.9 ± 0.04[a)]	5.6 ± 0.02[b)]	**4.05***	**0.03**
SOC ($g\ kg^{-1}$)	0–10	36.0 ± 3.2[a)]	25.5 ± 1.9[b)]	11.9 ± 1.5[c)]	23.7 ± 2.7[b)]	**16.57**	**0.00**
	10–20	27.1 ± 1.2[a)]	18.7 ± 2.8[b)c)]	11.7 ± 1.2[c)]	19.5 ± 1.5[b)]	**12.52**	**0.00**
N ($g\ kg^{-1}$)	0–10	3.9 ± 0.6[a)]	2.9 ± 0.6[a)]	0.8 ± 0.2[b)]	2.7 ± 0.3[a)]	**8.59**	**0.00**
	10–20	3.8 ± 0.8[a)]	2.0 ± 0.3[b)]	0.9 ± 0.1[b)c)]	1.9 ± 0.2[b)]	**7.41**	**0.00**
K ($g\ kg^{-1}$)	0–10	700.2 ± 63.9	571.6 ± 67.7	414.3 ± 114.3	539.6 ± 109	2.84	0.22
	10–20	413.6 ± 55.3	411.5 ± 33.7	327.2 ± 14.4	431.3 ± 56.2	2.49	0.36
P ($mg\ kg^{-1}$)	0–10	8.0 ± 0.4	7.8 ± 0.9	6.9 ± 0.7	8.2 ± 0.6	1.64	0.58
	10–20	9.6 ± 1.2	7.2 ± 0.1	9.2 ± 0.3	8.1 ± 0.5	1.15	0.07
Clay (%)	0–10	31.8 ± 2.4	32.3 ± 3.1	26.3 ± 1.7	33.3 ± 1.7	1.89	0.17
	10–20	32.3 ± 2.5[a)b)]	34.3 ± 2.9[a)]	24.3 ± 2.0[b)]	34.8 ± 2.1[a)]	**4.13**	**0.02**
Sand (%)	0–10	34.3 ± 3.7[b)]	32.8 ± 3.3[b)]	49.8 ± 2.7[a)]	32.8 ± 1.9[b)]	**7.84**	**0.00**
	10–20	32.8 ± 2.2[b)]	30.3 ± 3.5[b)]	48.3 ± 4.6[a)]	34.0 ± 2.8[b)]	**5.70**	**0.01**
BD ($g\ cm^{-3}$)	0–10	0.7 ± 0.02[c)]	0.9 ± 0.02[b)]	1.1 ± 0.03[a)]	0.9 ± 0.02[b)]	**66.37**	**0.00**
	10–20	0.8 ± 0.01[c)]	0.9 ± 0.03[b)c)]	1.1 ± 0.03[a)]	0.9 ± 0.03[b)]	**28.77**	**0.00**

[a)]Different letters indicate significant differences between groups according to Tukey's HSD test.
**P* values in bold face show statistically significant difference at $P < 0.05$.

Hartley (2002). Some NRNWS in particular, which are exposed to different stresses of herbivory, fire, and cutting, show highly modified morphology. However, when left in situ and relieved from stress with the establishment of exclosures, they can play a remarkable role in the recovery of tree canopy and forest microclimate and forest succession by resprouting. For instance, in situ persistence, the ability to produce vegetative shoots and hence modified morphology, is an important addition to other recruitment pathways such as recruitment via seed rain for *Olea europaea* ssp. *cuspidate* (Aerts et al 2008b).

According to studies from other different areas, tree plantations increase the diversity of understory woody vegetation, which varies with species (eg Kuusipalo et al 1996; Slocum 2000; Ashton et al 2001; Cusack and Montagnini 2004; Butler et al 2008). Similarly, among plantation species, the broad-leaved *Eucalyptus* sp. encouraged higher understory plant recruitment than the conifer (*Cupressus* sp.), which conforms to results from previous studies in Ethiopia (Yirdaw 2001; Lemenih et al 2004a; Yirdaw and Luukkanen 2004). Such variations are attributed to stand canopy characteristics that determine the amount of canopy gaps available for solar radiation, which influences the environmental conditions at the forest floor such as light and air and soil temperatures.

Our results also suggest that exclosure affected the soil chemical attributes desirably. This is consistent with previous studies (eg Descheemaeker et al 2009). Similarly, Mekuria et al (2007) found higher soil organic matter content, total nitrogen, available phosphorus, exchangeable bases, and CEC values in an exclosure (10 years old) than on the adjacent grazing land.

The plantations improved soil features associated with chemical characteristics better than the grazing land. This also conforms to previous reports (Mishra et al 2003; Lemenih et al 2004b; Lemma et al 2006; Boley et al 2009). For instance, Lemenih et al (2004b) reported lower bulk density and higher soil C, total N, CEC, base saturation, K, Ca, and Mg after 15 years of *C. lusitanica* plantation than in soils under cultivation.

The bulk density results from the soil in the exclosure are in agreement with previous reports (Descheemaeker et al 2006b; Castellano and Valone 2007; Jeddi and Chaieb 2010), which showed that grazing increased soil compaction, bulk density, and runoff.

Implications for practice

Recruitment of NRNWS and improved soil attributes can be achieved with the establishment of exclosures, given enough time. The major practical implications are: First,

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exclosures can be established interspersed strategically with single- or mixed-species plantations to facilitate restoration of native vegetation. Second, future tree plantation activities should consider maintaining original vegetation to foster recruitment of seedlings/saplings either from seed rain or soil seed bank through recolonization or advance regeneration through resprouting. However, further research will be required to gain insights into the comparative advantage of either enrichment planting of exclosures with the desired tree species or interspersing exclosures within blocks of single- or mixed-species plantations.

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