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Effects of exotic plantation expansion and management intervention on woody plant species diversity, regeneration and soil seed bank in *Tarmaber* district, Ethiopia

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Abstract

This study was carried out to determine the effect of plantation forest with management intervention on woody plant species diversity in Tarmaber district north shewa zone Ethiopia, regeneration and soil seed bank species composition in five different forest types. A total of 75 circular sample plots of 314 m^2 were established along a transect lines. Soil seed bank analysis was done from soil samples collected in each of the plots (225 samples). Different diversity index and ANOVA was used in SPSS software for analysis. The result showed that a total of 51 woody plant species was recorded in adjacent natural forest (41), managed *C. lusitanica* (27), not managed *C. lusitanica* (9), managed *E. globules* (22) and not managed *E. globules* (13) species. Regeneration of seedlings were 3538, 5567, 707, 1462 and 2524 mean stems ha^{-1} for natural forest, managed *C. lusitanica*, not managed *C. lusitanica*, managed *E. globules* and not managed *E. globules* respectively. Unmanaged *C. lusitanica* plantations had significantly lower densities of mature tree stems ha^{-1} as compared to managed *C. lusitanica*, managed *E. globules* and adjacent natural forest ($F=14.03$, $p<0.05$). Similarly in terms of sapling density ha^{-1} unmanaged *C. lusitanica* was significantly lower from other forest types ($F=7.37$, $p<0.05$). However managed *C. lusitanica* had significantly higher seedling regeneration (stem density ha^{-1}) than other plantation and adjacent natural forests ($F = 16.11$, $p < 0.05$). Generally mean stem densities including tree, sapling and seedling of woody species among different forest types managed *C. lusitanica* was significantly higher among different forest types ($F= 13.01$, $p<0.05$). From the soil seed bank a total of 22 plant species (20 native and 2 exotic) species were recovered. In different forest types the number of species recorded was in adjacent natural forest (19), managed *C. lusitanica* (11), unmanaged *C. lusitanica* (4), managed E. globules (7) and unmanaged *E. globules* (5). Generally with appropriate management intervention undergrowth vegetation and soil seed bank status in plantation forest had good species composition and diversity.

Keywords*:* Floristic diversity, Management intervention, Natural forest, Plantation forest, Soil seed bank

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Introduction

To overcome the shortage of wood caused by extensive deforestation, plantation forest with exotic tree species like Eucalyptus, Cupressus and pinus were started in Ethiopia since 1894- 1895 (Shiferaw & Jindrich, 2012) and are the most successfully introduced and widely distributed plantation throughout the country (Markus, 2012). The reason to be widespread is attributed to their fast growth, and their adaptability to a wide range of site conditions (Abrham *et al*., 2011).

Even though plantations have many economic and environmental benefits, intensive monoculture exotic plantations are widely viewed negatively mainly in relation to biological diversity conservation, and undergrowth regenerations (Carnus *et al*., 2006). For example, scientific and community stake holders argued that Eucalyptus species do not provide valuable organic matter, deplete soil nutrients, pump up water resources used for agricultural crops, suppress ground vegetation by secretion of allopathic chemicals, and unsuitable soil erosion control because of the less undergrowth vegetation (Becerra *et al*., 2018; Sekaleli, 2012; Tilashwork, 2009).

Although it has criticism on its negative impact for environment, Eucalyptus, Cupressus, and Pinus are the most commonly used species for plantation purpose throughout the world (Sean & Robert, 2003).

A study on the tropical forest plantations indicated that they may rarely promote the recruitment, establishment and succession of native woody species by fostering ecosystems (Parrota, 1992). Different studies on plantations of *Eucalyptus globulus*, *Eucalyptus saligna*, *Eucalyptus grandis*, *Pinus patula*, *Pinus radiata*, *Cupressus lusitanica* and *Grevillea robusta* established in high rainfall and relatively high altitudes of Ethiopia also proved a catalytic role of these monoculture plantation with regard to habitat re-colonization by native woody plants (Shiferaw & Jindrich, 2012; Feyera & Demel, 2003). Management intervention on exotic plantation to foster the undergrowth vegetation and the upper canopy to make productive the harvestable yield and substitute regeneration is important (Gilman *et al*., 2016). Because, the different management interventions avoid competition of light, nutrient and moisture the upper canopy trees and undergrowth vegetation (Williams, 2015).

Most farmers and expert's dealing the negative impact on expansion of exotic plantation forests concerning ecological and environmental issues in the study area.

However, studies on the regeneration of native woody plants under plantation forest with management intervention and feelings of local people about exotic plantation forest in ecological dilemma have limited information in the study area. The general aim of this study is to evaluate the potential effects of exotic plantation with management intervention on the natural regeneration of woody plants and the insight of local people about exotic plantation expansion interaction to the environment in order to synthesize truth information and to verify the dilemma about plantation forest in the highland part of North Shewa Zone, Ethiopia.

Materials and methods

Study area description

The reason behind the selection of Tarmaber district was the existence of huge plantation forests on the study area both state forest and private woodlot plantation as well as an adjacent natural forest in similar agro-ecology. The forest is currently owned by Amhara Forest Enterprise. In Tarmaber plantation forest different management intervention was involved by the government and the community before Amhara Forest Enterprise established to produce quality timber and fuelwood collection from the part of branches. The other management interventions involved was enrichment planting on left lands under the plantation forest stand using different indigenous tree species. Generally this research was conducted under five different forest types such as managed *Cupressus lusitanica* (pruning management involved), unmanaged *Cupressus lusitanica* (no pruning management involved), managed *Eucalyptus globules* (enrichment planting involved by different indigenous tree species like *Juniperus procera*), not managed *Eucalyptus globules* (no enrichment planting involved by indigenous tree species) and adjacent natural forests.

Data collection method

Quantitative approaches were used to address the objective of this research. Quantitative approaches to research are based on formal, objective, and systematic processes in which data are numerically quantified. Quantitative approaches are objective, deductive, and based on numeric quantification and generalization of results. The regeneration, diversity, density and structure of the forest data was collected using quantitative data collection method. Whereas the insight of local people about the trend of plantation expansion, impacts on environment was used qualitative data collection method.

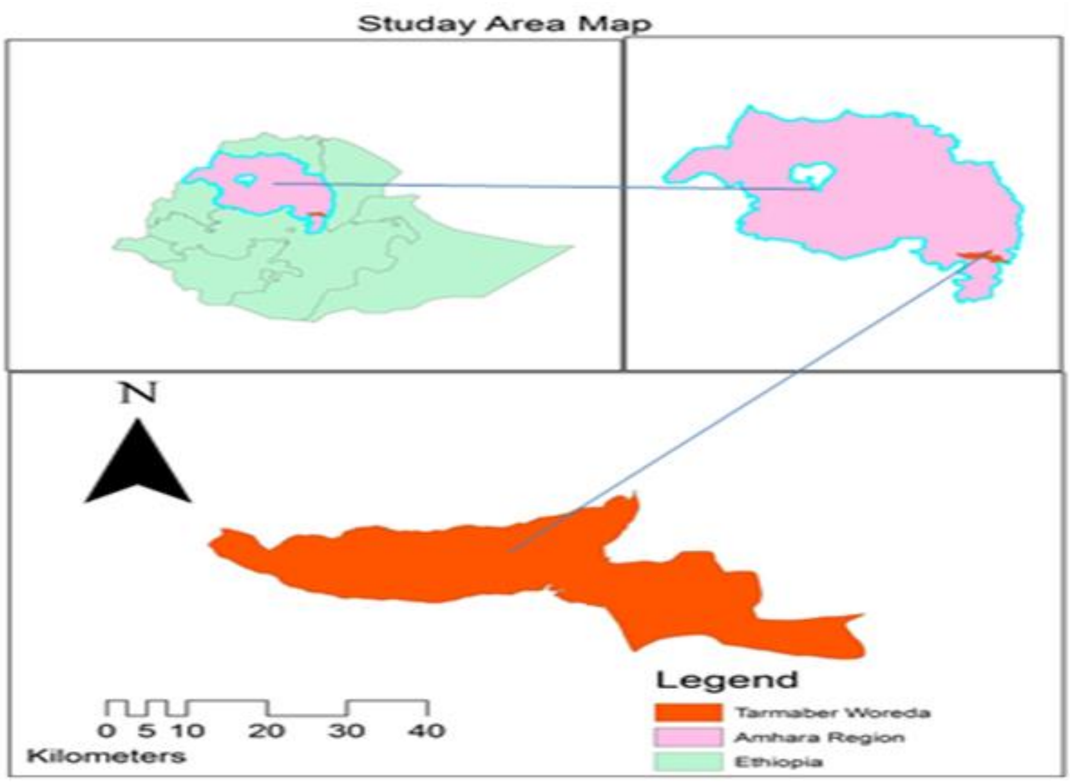

Figure 1. Map of study area

Vegetation data collection

Vegetation inventory was carried out in five forest types, such as adjacent natural forest, managed and unmanaged *Cupressus lusitanica* and *Eucalyptus globulus* plantation forest. The vegetation data collection was conducted by applying a nested plot design using a line transects survey. All sample plots were located at least 10 m far from the forest boundary or roadside to avoid border effect (Yvette & David, 2002). A circular plot was established at specified intervals along the transect line both in natural forest and managed and unmanaged plantation forests, based on using the distance between transect and sample plots for each forest types (Table 1). The first transect and sample plot was placed randomly at one side of each forest types, while the other sample plots laied at specified intervals from each other (Fikadu *et al*., 2014). The trees were measured in the 10 m radius, saplings in 5 m radius sampling plot and seedlings were measured in 3 m radius in a concentric circle (Shiferaw & Jindrich, 2012). The plants was categorized as seedlings (height <1.0 m and DBH <2 cm) saplings (height between 1 and 3 m and DBH <10 cm) and tree (height >3 m and DBH ≥10 cm) (Feyera *et al*., 2002; Feyera & Demel, 2003; Ayanaw & Gemedo, 2018).

Height and diameter were measured by hypsometer and calliper respectively and the tree which had large diameter was measured by tape meter. Additionally, aspect, altitude and slop were recorded on each plot. A total of 75 sampling plots, 15 for each forest types were used along the study area and to increase precision and to make easy for analysis for each forest types equal sample plot was used. In each plot, all of the naturally regenerated woody species were identified and counted. Species identification and verification were done by referring the Flora of Ethiopia and Eritrea (Edwards *et al*.,2000) and natural database for Africa (NDA) on CD-ROM version 2.0, August 2011 (Ermias, 2011). Note: the configuration of the transect was based on the elevation of the area by classifying low (2800 m), medium (3000 m) and highest elevation (3200m) relative to the land feature (Gillison & Brewer, 2014).

Soil sampling for soil seed bank

In order to determine species composition, diversity, the vertical distribution as well as the similarity of aboveground flora in the soil seed bank soil samples was collected. A total of 225 soil samples were collected from the above surface layer and the soil depth of 0-5 cm and 5-10 cm both from the plantation forests and adjacent natural forests (Maranon, 1998). The soil seed bank samples were collected from the plots used for vegetation sampling. At the centre of each plot, a small plot of 20 cm x 20 cm (400 cm^2) was marked and collected soil seed bank sample from the three separate soil layers to investigate depth distribution of seeds in the soil. The soil samples were put into plastic bags separately and transported to Debre Birhan Agricultural Research Center for analysis. In cases of dissimilarity between soil and aboveground flora, soil depth was used to speculate the seed sources, whether recently dispersed seed or from the soil seed bank.

There are various methods involved in determining soil seed bank which has been adopted by many authors. These are a seedling emergence method, the sieving and floating methods (Eyob, 2006). The seedling emergence method is the most frequently used, and the more reliable method, in soil seed bank studies (Esmailzadeh *et al*., 2011; Gomaa, 2015). The emerging method was best compared to other methods because a seed which is not visible in the mixed soil samples by naked eyes can be observing the physical morphology of the seedlings (Wagner *et al*., 2003). Others identification methods are not commonly used and are time consuming, ineffective at finding small-seeded species and may overestimate the viable seed bank by including non-viable seeds (Savadogo *et al*.,2016; (Colin & Lauren, 1996).

Table 1. Characteristics of the plantation and adjacent natural forest stands and sampling procedures at Tarmaber Amhara forest enterprise forests

Forest types	Forest area (ha)	No. of transects	Sample plot in each transect	No. sample plot	Distance between transect	Age of the forest	Distance between plot (m)
Natural forest	15	3	5	15	200m	unknown	50
Managed *C. lusitanica*	38.5	3	5	15	400m	> 30 yr.	100
Not managed *C.lusitanica*	41	3	5	15	400m	> 30 yr.	100
Managed *E. globules*	23	3	5	15	200m	> 30 yr.	100
Not managed *E.globules*	69	3	5	15	400m	> 30 yr.	150
Total	186.5			75			

After transported the soil sample to the Debre Birhan Agricultural Research Center, all soil samples were sieved using a mesh size of 0.50 mm to recover seeds of woody species and to facilitate the germination process of the seeds, the soil samples were incubated in the glass house for four months (Figure 3) (Teketay, 2005). Then finally seedlings were identified, recorded and discarded once every two weeks using local reference material (Teketay, 2005). Those seedlings emerged from the soil seed bank in the glass house difficult to identify were transplanted and grown to a larger stage to make identification easier and accurate (Teketay, 2005). However, in this study, there were no such problems faced because the identification of seedlings was done by using both combinations of taxonomic experts and local peoples who were lived in the surrounding area.

Data analysis

Descriptive and inferential statistics were used for data presentation and analysis. MS-Excel was used for data organization of the forest tree density, relative abundance, species richness, and evenness. Analysis of

Variance (one way ANOVA) was carried out using SPSS program version 25 to test the effect of plantation forest with and without management intervention and adjacent natural forest on diversity and regeneration status and role of soil seed bank for regeneration. During the ANOVA test, the number of species, stem density and the soil seed bank community was the dependent variables while the study treatments or plantation forest types with management intervention and adjacent forest were considered as the independent variables which were a determinate factor for the above listed dependent variables. Data were checked for homogeneity of variances to assess the equality of variances, while normality was checked in the test and some data parameters are not normal, then, data were log transformed.

Vegetation Data Analysis

Species diversity and richness in Tarmaber plantation with different management intervention and the adjacent natural forest were calculated using the Shannon-Wiener diversity index (H'), Shannon evenness index and Margalef index (R) to evaluate species richness (Peet, 1974).

$$H' = -\sum_{i=1}^{k} pi \ln pi \quad \ldots\ldots\ldots \text{ Eq. (1)}$$

Where, H' is Shannon diversity index, Pi is the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of a total cover, K is the number of species and ln is log basin.

The most common and widely used methods for evenness or equitability is based on Pielou (1966) as follows

$$J = \frac{H}{H'max} \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (2)}$$

Where, J is evenness,

H' is Shannon-wiener diversity index and H'max is the maximum Shannon-wiener diversity indexes

$$R = \frac{S'-1}{LnN} \text{ (Margalef, 1958)}\ldots\text{Eq. (3)}$$

Where, R is Margalef index of species richness, S' is number of species and N is number of individuals

Structural data analysis

The forest structure would describe in terms of frequency, dominance, basal area per hectare, important value index determination in the following formulas:

Density determination: - species density was summarized from a total number of individual abundance in each species. It was calculated as follows,

$$\text{Density} = \frac{\text{Total no. of individuals of the species}}{\text{No.of quadrat per unites studied}} \text{x100 Eq. (4)}$$

Frequency: - the frequency of quadrates occupied by a given species. It was calculated in the following formula

$$\text{Frequency} = \frac{\text{No.of units in which the species occurred}}{\text{Total no.of unit studied}} \text{x100} \quad \text{Eq. (5)}$$

Relative Density (RD): is defined as the number of all individuals of a given species divided by the total number of all individuals of all species times100.

$$\text{Relative Density} = \frac{\text{Density of a given species}}{\text{Total densities of all the species}} x100 \quad \text{Eq. (6)}$$

Relative Dominance: the area occupied by a given species relative to the total area occupied by all species, where dominance is defined as the mean basal area per tree times the number of trees of the species.

$$\text{Relative Dominance} = \frac{\textbf{Basal area of each species}}{\textbf{Area sample}} \mathbf{x}100 \quad \text{Eq. (7)}$$

Relative Frequency (RF): is the distribution of one species in a sample relative to the distribution of all species.

$$\text{Relative frequency} = \frac{\textbf{Frequency of species A}}{\textbf{Total ferquency of all species}} \mathbf{x}100 \quad \text{Eq. (8)}$$

Important Value Index (IVI): It is an index which describes the structural role of a species in a stand and all woody species population was examined by estimating frequency, relative frequency, density, relative density, dominance and relative dominance (Pichette and Gillespie, 1999). It was calculated as follows based on Kent and Coker, 1992).

Important Value Index (IVI) =RD+RF+RDo Eq. (9)

Where, RD is Relative Density, RF is Relative Frequency and RDO is Relative Dominance

Population Structure: Population structure of tree stem diameter distribution was used to infer regeneration patterns and successional trends in tree population. To determine the population structure, individuals of each species encountered were grouped in to a diameter class and structure of the species was shown using frequency class of diameter and height distribution. According to Peters (1996) frequency class was important to interpret the indication of the regeneration status of the forest.

Regeneration Status: the regeneration status of woody species was summarized based on the total count of seedling, saplings and mature tree stem ha^{-1} of each species across all quadrates and presented in tables and frequency histograms.

Similarity index

The similarity analysis is used to identify the highly similar and/or dissimilar stands in their understory plant composition. Most of the time similarity is analyzed using a statistical measure of similarity coefficient of Sorensen and Jaccard's similarity coefficients. But Jaccard's similarity coefficient is most sensitive for extreme error for small sample sizes (Chao *et al*., 2005). Due to this reason Sorensen similarity coefficient was used to compare the similarity between the forest types in their species richness and to test soil seed bank community and above ground flora similarity for this research. The index is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample. The similarity (Ss) index was calculated using the formula according to Kent & Coker, 1992).

$$Ss = \frac{2a}{2a+b+c} \times 100 \qquad \text{........} \qquad \text{Eq.(10)}$$

Where, Ss is Sorenson similarity coefficient b is number of species in sample1 a is number of species common to both samples c is number of species in sample 2

Results and discussion

Woody species diversity

Species Area Curve

Species area curve shows that the relationship between the area and the number of species found within that area and it is very important to determine the sufficiency of the sample plot (Scheiner *et al*., 2000). The species area curve was developed from 75 sample plots, which covered an area of 2.355 ha. In the case of plantation forest with management intervention and adjacent natural forest, the pattern of the curve shows an increasing the number of woody species in the starting phase with increasing areas up to a 2198 m^2, 3454 m^2, 4082 m^2, 3140 m^2 & 3140 m^2 for natural forest, managed *C. lusitanica*, not managed *C. lusitanica*, managed *E. globules* and not managed *E. globules* respectively. And this assumption is scientifically true, when the species diversity increased with the increasing of area (Lawson & Henrik, 2006). Also in this study, the numbers of species become constant after above points for each forest types and made curve flat (Figure 5). Normally based on curve formation, it confirmed that 15 sample plots for each forest types were sufficient and it can represent the entire population and generated good information about the composition, diversity and species richness in the study area (Khaine *et al*., 2017).

Floristic composition

For this study, list of the naturally regenerated woody species in managed and unmanaged plantation forests and the adjacent natural forest stand had a total of 51 woody species with 31 families and 1265 individuals were recorded (Table 2). The present study both in adjacent natural and plantation forest were (i.e. 51 species), which were close to the Munessa-

Shashemene forest (i.e.55 species) reported by Feyera & Demel (2002). And it had higher number of species compared to Menagesha-Suba dry Afromontane forest (i.e. 42 species) reported in central Ethiopia (Feyera & Demel, 2001).

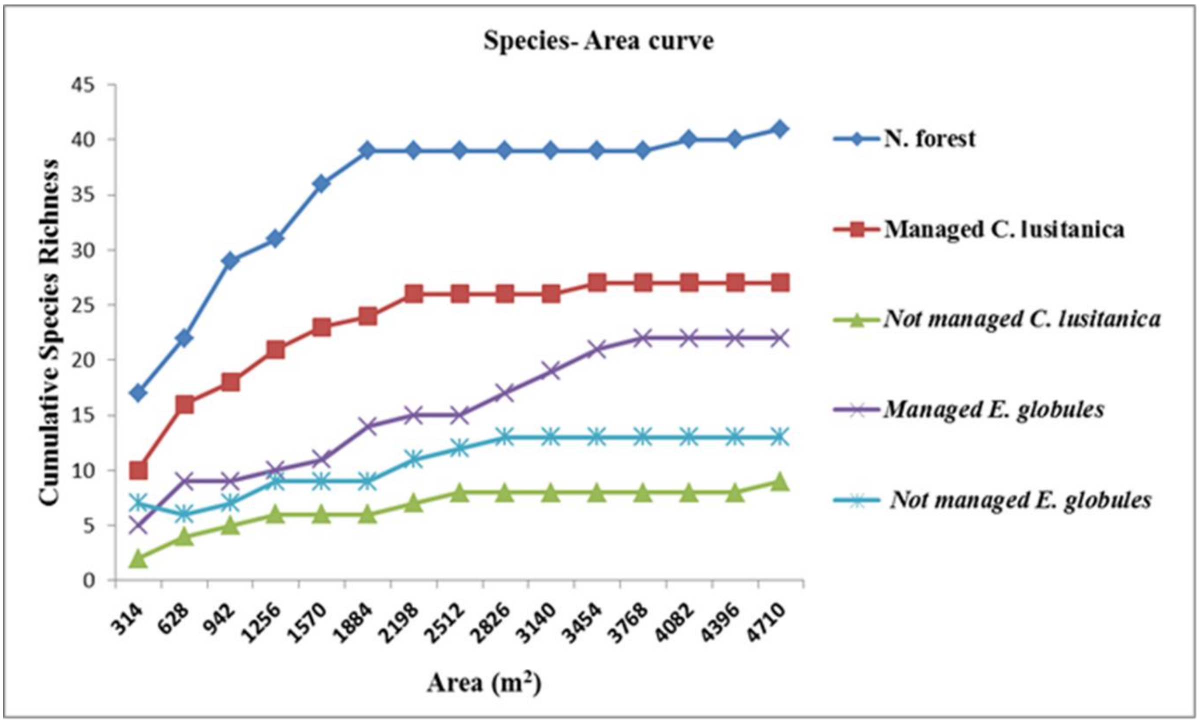

Figure 2. Species-area curve of all species in managed and unmanaged Tarmaber plantation forest and adjacent natural forest.

The higher number of species recorded in this study under plantation forest and natural forest compared to Menagesha-Suba dry Afromontane forest could be due to the reason of environmental difference, human and animal interference, and altitude difference among the forests. Since Munessa-Shashemene and Menagesha-Suba dry Afromontane forest found in the altitude of 2200 to 3000 m. a .s, whereas this study was conducted at 2800 to 3500 m. a.s. The life form of the plants according to the classifications of Getachew & Biruk (2014), among 51 native woody species 17 species were trees, 36 were shrubs, and 6 species were shrub/woody climbers .

The species composition in different forest stands ranged from 9 to 41 species in the study area. The number of species recorded in unmanaged *C. lusitanica* plantation was 9 species, whereas in managed *C. lusitanica* plantation 27 species were recorded. Also in unmanaged E. *globules* plantation (without enrichment planting) and managed *E. globules* (with enrichment planting) had 13 and 22 species respectively. However in adjacent natural forest 41 species was recorded and highest among other plantation forests. The highest number of species was found in the natural forest stand, which confirms to the results from previous studies in Yeraba priority state forest, Amhara Region, Ethiopia (Getachew & Biruk, 2014). Whereas among plantation stands, the highest number of species was recorded in managed *C. lusitanica* (with pruning management intervention) plantation stand and the least numbers of species are recorded in not managed *C. lusitanica* (without pruning management intervention) plantation in the study area. species recording in not managed *C. lusitanica* is in line with the study of Abrham *et al*. (2011) under Cupressus and Eucalyptus species low understory plant recruitments were recorded in cupressus plantation than eucalyptus plantation without any enhancing management interventions. Such variations are attributed to standing canopy characteristics that determine the number of canopy gaps available for solar radiation, which influences the environmental conditions at the forest floor such as light and air and soil temperatures.

Species Frequency Class

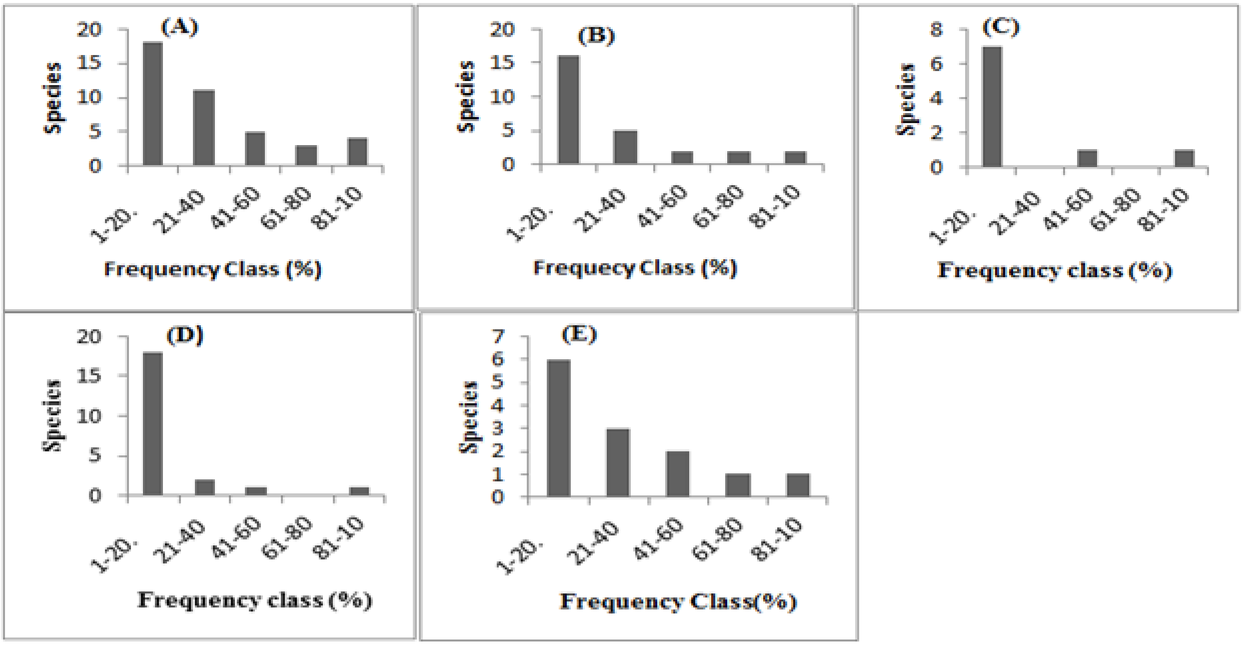

Figure 1 Frequency diagram of woody species in managed and unmanaged plantation forest and adjacent natural forests. A (natural forest), B (Managed C. Lusitanica), C (Not managed C. lusitanica), D (Managed E. globulus) and E (Not managed E. globulus)

This result also confirmed by (Bauhus & Schmerbeck, 2010) the effect of management on diversity. Least number of Frequency expresses how frequently the species is observed in all samples. In other words it explains its distribution over the forest (Kebede *et al.*, 2013). In this study plantation forest with management intervention and adjacent natural forest tree species were categorized under five frequency classes according to Raunkiaer's frequency classes (Robert, 1962) (Figure 6). High number of species were found in frequency class of 1-20%) and 21-40%) and it gradually decreases the number of species in frequency class of 41-60%), 61-80%) and class (81-100%). This result indicated that more than 80 % of the species found in the absolute class of 1-20% and 21-40%, which means that high value in the lower frequency classes and low values in the higher frequency classes indicated that high floristic heterogeneity occurred, but the reverse of this result displayed similar or constant species composition (Abyot *et al*., 2014).

Frequency: The most frequently found species (frequency ≥50%) are described for each forest types. In natural forest (10), managed *C. lusitanica* (5), in not managed *C. lusitanica* (2), managed *E. globules* (2) and in not managed *E. globules* (3) species were recorded in this study (Table 3). The remaining species found less than 50% frequency and the minimum frequency for each forest types in 75 quadrats was 7%. This means out of the 75 sampled quadrates these species were encountered only in seven quadrants. This implies that these particular species are rare relative to the other species and may become nonexistent from the study forest in the future (Getachew & Biruk, 2014).

Table 2. Family of the dominant woody species in Tarmaber plantation forest and adjacent natural forest at Tarmaber North Shewa Zone, Ethiopia

No.	Family	No of Species	No of Individuals
1	Asteraceae	5	73
2	Lamiaceae	3	19
3	Myrsinaceae	3	40
4	Rosaceae	3	36
5	Rubiaceae	3	50
6	Anacardiaceae	2	18
7	Cupressaceae	2	396
8	Melianthaceae	2	15
9	Moraceae	2	33
10	Solanaceae	2	105
	Others 11-31	24	480
	Total	51	1265

Species diversity, richness and density

The highest mean number of species was found in the natural forest (15±0.65) followed by managed *C. lusitanica* (8±1.05) and the least mean number of species was recorded at unmanaged *C. lusitanica* (2±0.18) (Table 4). There was a significant difference between forest types ($F=62.43$, $p< 0.05$). Similar results reported by Shiferaw & Tadesse (2009) in Belete state forest and Abrham *et al*. (2011) in Tehuledere district showed natural forest have more number of species than plantation forest.

Table 3. List of the most frequently found species (F ≥50%) in all sampled stands at Tarmaber plantation forest and in adjacent natural forests in North Shewa Zone, Ethiopia

Forest types	Species name	Local name	Frequency (%)
Natural forest	*Allophylus abyssinicus*	Embus	53
	Discopodium penninervum	Ameraro	80
	Dovyalis abyssinica	Koshem	53
	Galiniera saxifrage	Yetota kula	80
	Juniperus procera	Habesha tisde	93
	Maesa lanceolata	Kelewa	87
	Maytenus arbutifolia	Atate	87
	Morus mesozygia	Injory	60
	Olea africana	Woyera	73
	Vernonia auriculifera	Gujo	93
Managed *C. lusitanica*	*Cupress lusitanica*	Yefereje tisd	87
	Discopodium penninervum	Ameraro	93
	Erica arborea	Aseta	73
	Juniperous procera	Habsha tisd	80
	Vernonia auriculifera	Gujo	60
Not managed *C. lusitanica*	*Erica arborea*	Aseta	87
	Juniperous procera	Habesha tsid	50
Managed *E. globules*	*Discopodium penninervum*	Ameraro	53
	Juniperous procera	Habesha tsid	100
Not managed *E. globules*	*Erica arborea*	Aseta	93
	Lobelia rhynchopetalum	Jibra	67
	Pentas schimperiana	Woyinagifet	60

Depending on this result managed *C. lusitanica* and natural forest was highly significantly differed between them and other unmanaged plantation forests types (F=62.43, p< 0.05 (Table 4). Similar results also reported in Vietnam by Millet *et al.* (2013).

Table 4. Woody species along plantation forest with management intervention and adjacent natural forest (F=62.43, p=0.000; n= 15)

Forest types	Mean ±SE	SD.	Min	Max	CV%
Natural forest	15±0.65[c]	2.52	11	20	17
Managed *C. lusitanica*	8±1.05[b]	4.05	1	14	51
Not managed *C. lusitanica*	2±0.18[a]	0.70	1	4	33
Managed *E. globules*	5±0.38[a]	1.51	2	7	34
Not managed *E. globules*	4±0.53[a]	2.07	1	8	50
Sig (5%)	**				

Table 1: Species richness computation using Margalef index (R) and Shannon diversity index in different forest stands in Tarmaber forest North Shewa Zone, Ethiopia

No.	Treatments	S	N	Diversity (H')	Evenness (H'/lnS)	R (Margalef richness index)
1	Natural forest	41	359	3.32	0.89	6.80
2	Managed *C. lusitanica*	27	409	2.25	0.68	4.32
3	Not managed *C. lusitanica*	11	52	1.29	0.59	2.03
4	Managed *E. globules*	22	211	1.83	0.33	3.92
5	Not managed *E. globules*	13	233	1.8	0.70	2.20

Table 2: Mean stem density ha^{-1} in managed and unmanaged plantation forest and adjacent natural forests (ANOVA, F=13.01, p=0.000, n= 15).

Variables	Forest types	Mean± S.E	SD.	Min	Max
Stem density ha^{-1}	Natural forest	762±83.64[bc]	323.95	414	1465
	Managed *C. lusitanica*	868±99.92[c]	386.99	382	1592
	Not managed *C. lusitanica*	110±11.09[a]	42.94	32	191
	Managed *E. globules*	450±58.05[b]	224.80	191	924
	Not managed *E. globules*	494±115.47[b]	447.23	64	1497
	Sig (5%)	**			

Enrichment planting of native species in a logged tree plantation increases the number of tree species in the understory vegetation. In addition, Jennifer & Alistair (2013) reported that silvicultural activities like pollarding, pruning and coppicing enhance vegetation regeneration plant species composition under exotic plantation forests. This is because silvicultural treatment affects soil and water content and nutrient availability and sunlight penetration that create an opportunity for understory vegetation growth. So from this study, the number of species increases from unmanaged plantation forest to managed plantation forests and to natural forest. Also in comparison of plantation forest and natural forest in woody species regeneration with appropriate management interventions like seed source or planting materials, availability of remnant patch natural forests and dispersing agent made increasing the number of species. But with absence of these management activity clamming plantation forest for negatively on species abundance and composition is a wrong way in scientific and local communities in different parts of the world (Bernes *et al*., 2014).

The Margalef richness indices Table 5 confirmed that the natural forest stand was richer in regenerated species than plantation stands (R=6.8). And among plantation forest stands managed *C. lusitanica* stand was richer than others (R=4.32). Not managed *E. globules* and *C. lusitanica* had the least species richness (R=2.2 and 2.03) respectively (Table 5). The existence of rare species made the richness result higher in the natural forest and 13 species were found in a natural forest and these were not found on the plantation stands. Among plantation stands, the *C. lustanica* and *E. globules* with management intervention contained 10 more species, which were not found in natural forest.

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 and in theory, this can reach very large values. However, in practice for biological communities, H' does not exceed 5.0 (Krebs, 1999 as cited in Alemayehu, 2002). 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 as cited in Temesgen *et al*., 2015). From this study, the natural forest showed high diversity; managed *C. lusitanica* had medium diversity and the unmanaged plantation forest had low diversity (Table 5).

And the species evenness ranges from zero 0 to 1, with zero signifying no evenness and one, a complete evenness (Pielou, 1966). From this study all forest types had high evenness (Table 5) except managed *E. globules* had low evenness (0.33) values, because it might be biased from some important group of species during enrichment planting. This reason was similar in the study of species diversity by artificial restoration for coniferous forests in Southwest China (Qiaoying *et al*., 2006). Generally in this study more or less even representation of individuals of all species encountered in the studied quadrants except a few species are dominant.

There was a significant difference in the mean stem density of woody species among the different forest types (F= 13.01, p<0.05). Not managed *C. lusitanica* forest was significantly lower than other forest types. Whereas the managed C.*lusitanica* plantation is significantly higher than other forest types except the adjacent natural forest (Table 6). From this result with appropriate management intervention in plantation forest can enhance species composition, species diversity and good regeneration as equally as in natural forests (Nagaraja *et al*., 2011). Regeneration in the understory of the managed plantations differed from that of an unmanaged plantation forests. This implies that management intervention like spacing, enrichment planting, pruning and pollarding can offer opportunities for species richness (Bauhus & Schmerbeck, 2010); (Kerr, 2015); (Petit & Montagnini, 2006).

Similarity in species composition between different plantation forests and adjacent natural forest

The similarity in species composition of the plantations to the natural forests could determine the plantations that eventually undergo secondary succession to be replaced by indigenous woody species that closely resemble the floristic composition of the natural forest. The results of the study showed that the not managed *C. lusitanica* plantation exhibited the least similarity in species composition to the natural forest and other managed plantations, while the managed *C. lusitanica* plantation was the most similar to the natural forest (Table 7). The similarity indices determine if the composition of a future secondary forest that replaces the plantation forest would be similar to the natural forest (Pande *et al*., 1988).

The similarity in species composition between the five forest types was ranged from the similarity index values of 0.312 (between managed *E. globule*s forest and not managed C. *lusitanica* plantation forest) to 0.653 (between managed *C. lusitanica* and managed *E. globule*s plantation forests) (Table 7). Generally, natural forest and managed plantation forest have high similarities which, most of the forest types had a score of a similarity index value between 0.407-0.653. This result also is inline with Shiferaw & Tadesse (2009) in the study of a comparative assessment on regeneration status of indigenous woody plants in *Eucalyptus grandis* plantation and adjacent natural forest in Belete state forest. From the total similarity index values, the better similarity was observed between managed *C. lusitanica* and managed *E. globule*s plantation forests because these forests were located close to each other or there were either similar seed dispersal mechanisms or the forests could have similar soil seed banks (Omoro & Luukkanen, 2011).

Table 3: Sorenson's similarity index and the number of common woody species composition between the different forest types (* the lowest similarity, ** the highest similarity).

Forest types	Natural forest	Managed *C. lusitanica*	Not managed *C. lusitanica*	Managed *E. globule*s	Not managed *E. globules*
Natural forest		0.588	0.320	0.590	0.407
Managed *C. lusitanica*			0.444	0.653**	0.55
Not managed *C.lusitanica*				0.312*	0.545
Managed *E. globules*					0.388
Not managed *E. globules*					

Basal Area: The basal area distribution is very important criteria for determining and classifying forest types and often important for forest management decisions such as estimating forest regeneration (Hökkä *et al*., 1997). Total woody species basal area among the forest types of the study area was high in the natural forest (27.56 m^2 ha^{-1}) and low in an unmanaged *C. lusitanica* plantation forest (0.18 m^2 ha^{-1}) (Figure 7). The comparison of the total basal area of the adjacent natural forest had a higher basal area to plantation forest.

Generally, in this study, the basal area of adjacent natural forest was very low even when it compared to the basal area of tropical forests 35 m^2 ha^{-1} (Midgley & Niklas, 2004). However, it had a greater basal area, which reported from Bale Mountain National park, Boditi Forest (23 m^2 ha^{-1}) (Yineger *et al*.,2008); Zengena Forest (22.3 m^2 ha^{-1}) (Tadele *et al*.,2014) and Hugumburda forest (9.23 m^2 ha^{-1}) (Aynekulu, 2011). Among plantation forests, the managed stands of plantation forests had a higher basal area with relative to an unmanaged plantation forest (Figure 7). The management effect on the basal area among plantation forest had good indication of natural regeneration in terms of basal area and number of species compared to unmanaged plantation stands. Similar studies conducted in Britain showed that the use of silvicultural systems like pruning, pollarding and coppicing enhance the biological diversity of indigenous tree species basal area and good regeneration under plantation forest (Kerr, 2015). Other studies conducted enrichment planting of indigenous tree species in plantations forest in Costa Rica was found to be more successful in tree stem regeneration and good basal area under the forest plantations (Petit & Montagnini, 2006).

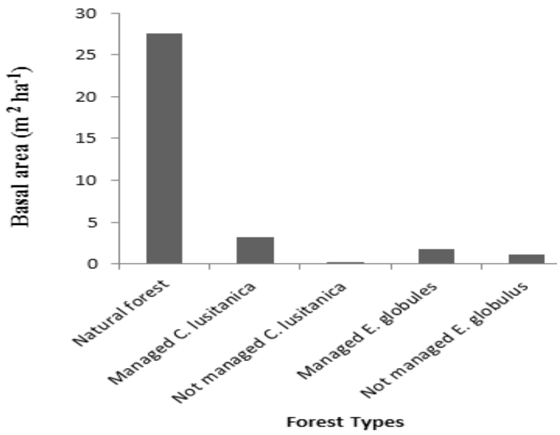

Figure 2. Basal area of plantation forest with and without management intervention and adjacent natural forest

The basal area of natural regenerated plants under plantation forest with and without management intervention and adjacent natural forest was classed in to five classes (Figure 8). The number of species found in an unmanaged plantation forest had only basal area <1 m^2 ha^{-1} and the managed plantation forest and adjacent natural forest some species had above 1 m^2 ha^{-1} basal area and most species had <1 m^2 ha^{-1}. This is the reason behind the management effect that made basal area difference across all forest types in a similar environment and agroecology situations. Also the number of species in each forest types laid in the lower basal area class, the managed plantation stand and natural forests showed good regeneration capacity. Nenninger *et al*. (2012) also confirmed that appropriate silvicultural treatments in plantation forests enable to increase the productivity of the harvestable stand in terms of mass values and it converts plantation forests of exotic tree species into natural forests by enhancing of undergrowth native trees regeneration.

Importance value index (IVI)

It provides the measure of the relative importance of the species than simple count and species with the largest value in dominance could be considered as the most important species in the study area (Ajayi & Obi, 2016).

In this study ten most important woody species in the adjacent natural forest with the highest import value index are *Juniperus procera Olea eurpeana*, *Ficus sur*, *Vernonia auriculifera*, *Prunus africana*, *Discopodium penninervum*, *Maesa lanceolata*, *Rhus glutinosa*, *Maytenus arbutifolia* and *Allophylus abyssinicus*. These species contributed to over 64 % of the total import value index. Whereas in the managed C. *lusitanica* plantation stand more than 61 % of the IVI is dominated by 6 species which, are *Juniperous procera*, *Discopodium penninervum*, *Erica arborea* , *Vernonia auriculifera*, *Myrica salicifolia* and *Hagenia abyssinica* (appendix 3). In not managed C. *lusitanica* plantation stand, more than 80% of the IVI was covered by *Erica arborea* and *Juniperous procera.* In managed *E. globules* more than 64% of the IVI was occupied by *Juniperous procera* and *Discopodium penninervum*, and in not

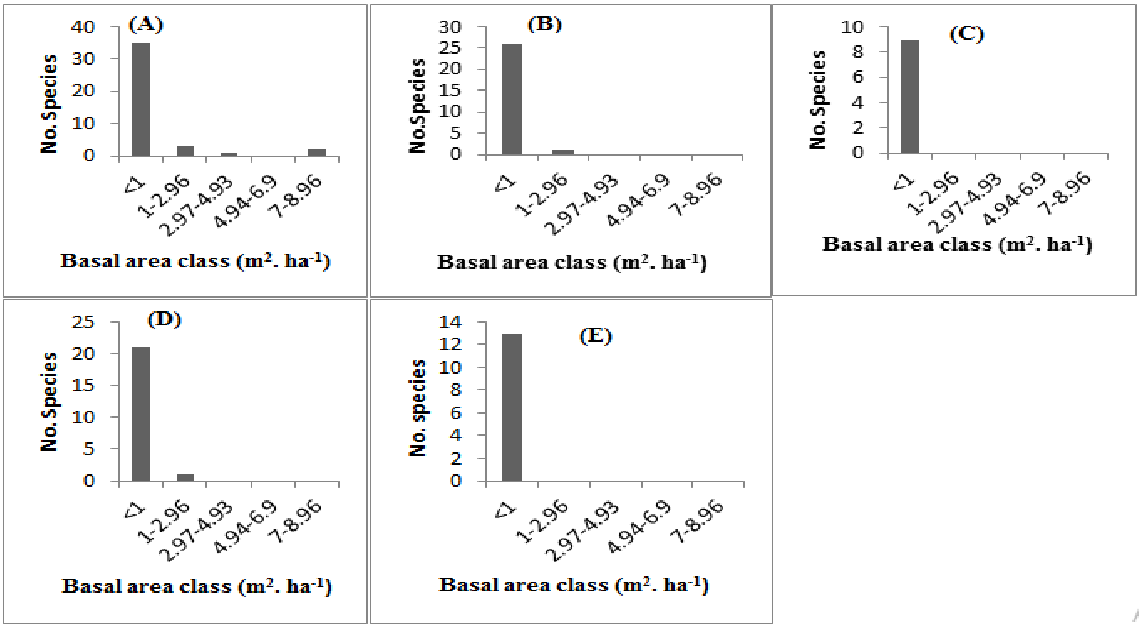

Figure 3. Number of woody species in different forest types of plantation forest and adjacent natural forests. A (natural forest), B (Managed C. Lusitanica), C (Not managed C. lusitanica), D (Managed E. globulus) and E (Not managed E. globulus)

managed *E. globules* plantation *Erica arborea*, *Juniperus procera* and *Hagenia abyssinca* was the most important species in the study area. Generally, in plantation forest with and without management intervention and adjacent natural forest the most important species was *Juniperus procera*. Similar results were reported in the study of Ethiopian highland forests *Juniperous procera* tree species was existed under the canopy of plantation forest (Getachew & Biruk, 2014; Hundera, 2011; Shiferaw, 2006). Also in this study the focus group discussion and key informants 'confirmed that *Juniperous procera* can exist in exotic plantation forest without inferior to the existed exotic plantation forest stand. Because in this study area before converting to plantation forest scattered *Juniperus procera* trees was found. And the tree had wider agroecology (1750-3500 m) and mostly the plant existed rocky basalt soil types (Hall, 2009).

Mean diameter and height

The mean Diameter at Breast Height (DBH) and mean height of Tarmaber plantation forest with and without management intervention and adjacent natural forest was illustrated in (Table 8). The result indicated that the mean DBH and height of woody species both in plantation and adjacent natural forest had varied results due to management effects in the plantation forest (Table 8). The standard deviation of diameter and height were higher because of the variation of individual trees. This results was confirmed by (Karlsson, 2013) on his dessiretation in Swedish University of Agricultural Sciences on silvicultural regimes and early biomass thinning in young, dense pine stands.

Diameter distribution plays a significant role in forest science and used to determine the optimum selective cutting that improves the stand structure (Linares *et al*., 2011). The overall distribution of diameter classes of individuals of all the species in the study area (Figure 9) in natural forest, managed *C. lusitanica* and in managed E. *globules* indicated a relatively high proportion of individuals in the lowest diameter class (seedlings), which ensures the potential of recruitment of sustained future regeneration of the forest. However, the decline of number of individuals in the higher diameter classes considerably suggesting that there is unplanned and unsustainable exploitation of woody species in the forest by the local people for domestic consumption and generating income. This result is similar to the study of Zegie, north western Ethiopia (Alelign *et al*., 2007). In an unmanaged *C. lusitanica* and *E. globules* a bell shaped distribution skewed to the right which is normal in plantation forests (Varga., 2015). From here, the overall distribution of diameter classes of individuals of all the species are dominated by a relatively high proportion of individuals in the lowest diameter class (seedlings) that ensure sustained

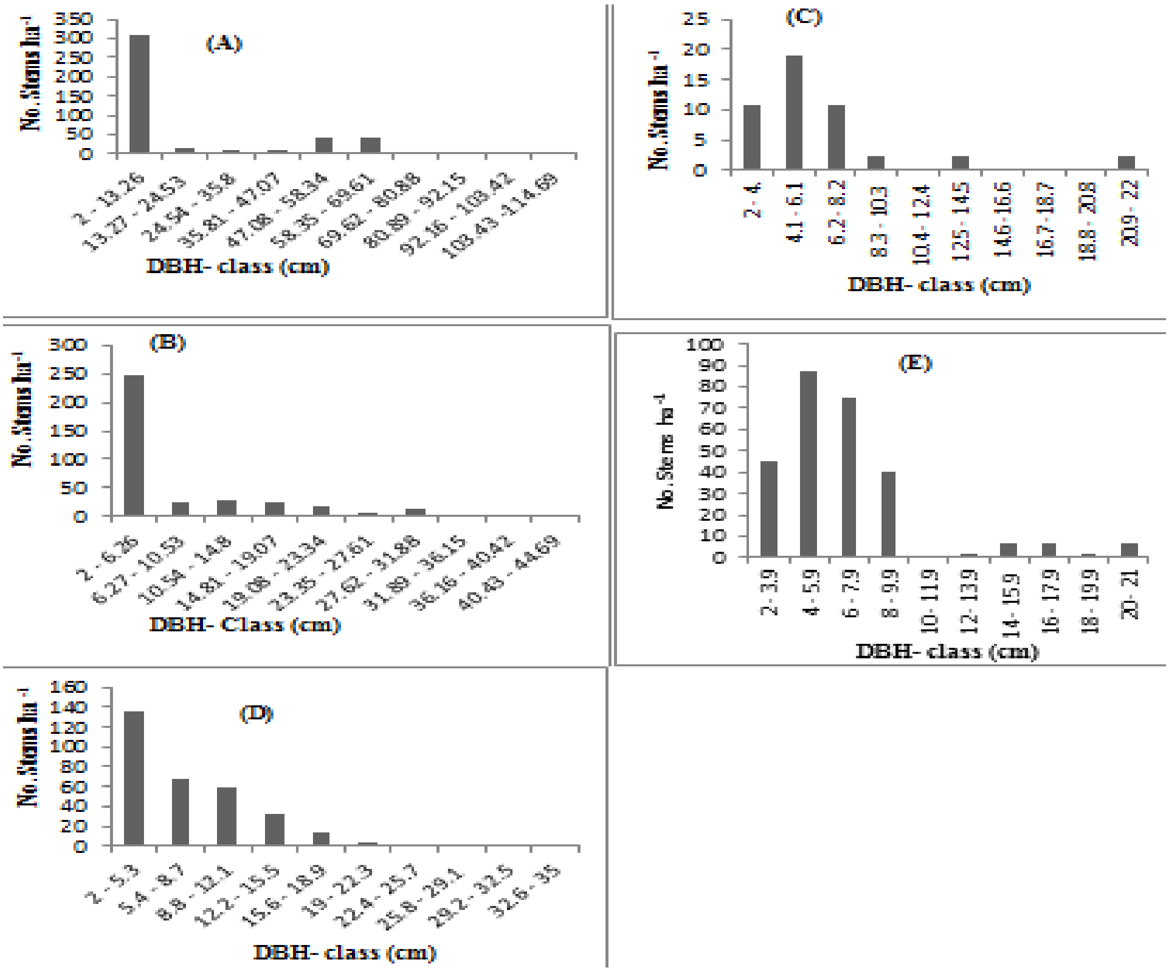

Figure 4. Diameter frequency distribution of Woody species of in managed and unmanaged plantation forest and adjacent natural forests. A (natural forest), B (Managed C. lusitanica), C (Not managed C. lusitanica), D (Managed E. globulus) and E (Not managed E. glo

regeneration of forests.

Like diameter distribution, the height distributions of the study area were performed. The height distribution in each study forest types showed an inverse -J shaped curve (Figure 10). The number of stems ha^{-1} declined with increasing size (height), that is, more number of individuals at lower size classes and very few numbers of individuals in the high height classes. Generally this pattern of height distribution indicated that good regeneration status of the Forest (Tadele, 2004).

Natural regeneration

The highest regeneration mean density of mature tree woody species was higher in the natural forest followed by the managed C. *lusitanica* and least regenerate mean density of mature tree stem ha^{-1} was recorded in not managed *C. lusitanica* adjacent natural forest (F=14.03, p<0.05). This can possibly be attributed to the lack of nutrient availability, sun-light and moisture stress due to competition. for example, other studies carried out in *Cupressus lusitanica* plantations in Kibale,

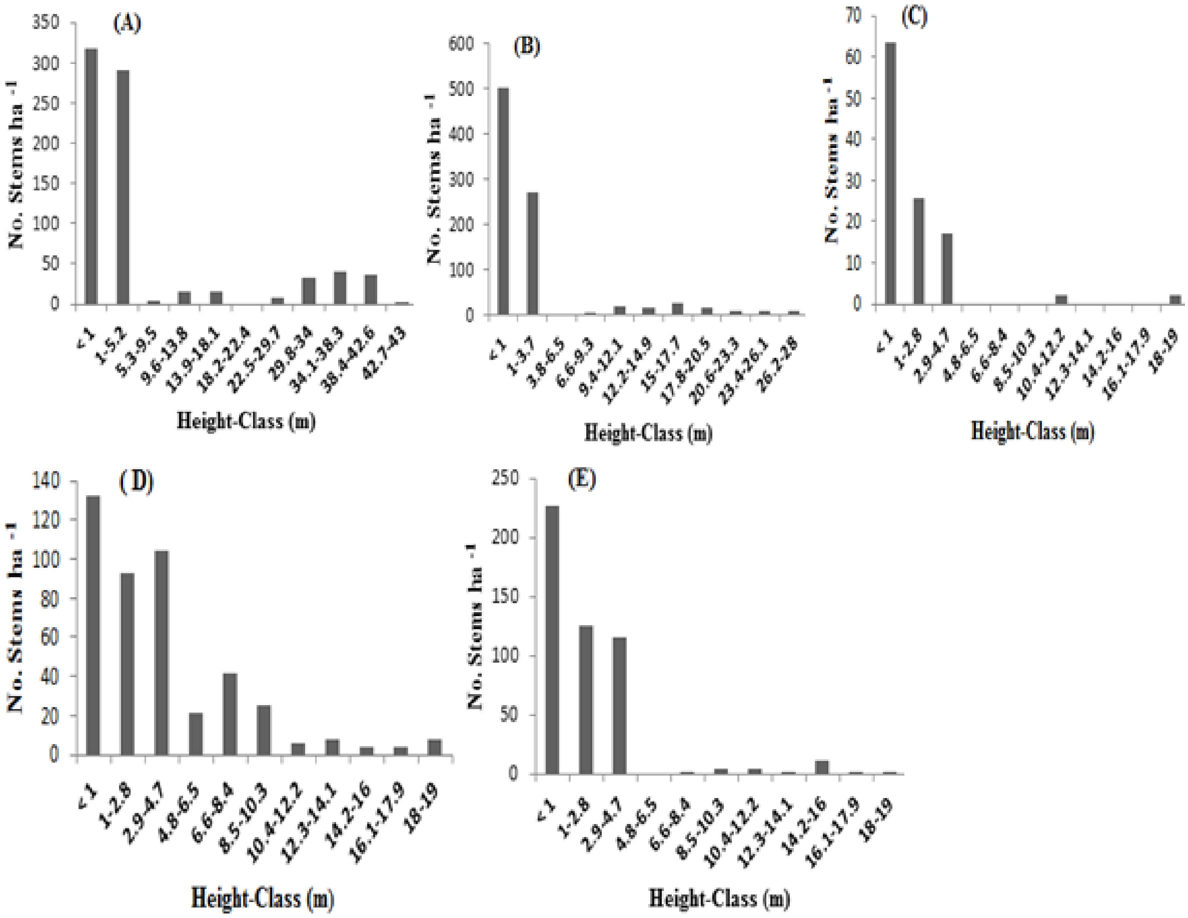

Figure 5. Height frequency distribution of Woody species in managed and unmanaged plantation forest and adjacent natural forests. A (natural forest), B (Managed C. Lusitanica), C (Not managed C. lusitanica), D (Managed E. globulus) and E (Not managed)

plantation stand among different forest types.

Tukey's post hoc analysis showed that the mature tree regenerate mean density in not managed C. *lusitanica* and *E. globules* had significantly lower from the mean density of the other managed plantation forest and Uganda found that the managed Cypress plantations had high species diversity and stem density ha^{-1} indigenous trees under the canopy of plantation forest stand (Colin & Lauren, 1996). Saplings of woody tree species are one of the parameters to evaluate the regeneration performance of the plantation and adjacent natural forests (Dupuy & Chazdon, 2006). The natural forest had the highest regenerate mean density of saplings (Table 9) followed by managed *C. lusitanica* and *E. globules* stems ha^{-1}. The lowest regenerate mean density of saplings was recorded in the not managed *C. lusitanica* stem ha^{-1}. There were significant differences in regeneration between the not managed *C. lusitanica* plantation forest with that of managed plantation forest and unmanaged *E. globules* and adjacent natural forest (F=7.37, p <0.05).

Table 4: Mean diameter and mean height of Tarmaber plantation forest with management intervention and adjacent natural forest at Tarmaber North Shewa Zone Ethiopia

Forest types	N (sample tree population)	Variables	Mean ± SE	Min	Max	SD.
Natural Forest	209	DBH (cm)	20.51±1.86	2	115	26.83
	209	Height (m)	12.54±1.02	2	43	14.73
Managed *C. lusitanica*	173	DBH (cm)	8.53±0.65	2	44.6	8.55
	173	Height (m)	6.55±0.51	2	28	6.71
Not managed *C. lusitanica*	22	DBH(cm)	6.22±0.92	2	22	4.33
	22	Height (m)	3.92±0.83	2	19	3.90
Managed *E. globulus*	150	DBH (cm)	7.86±0.44	2	35	5.38
	150	Height (m)	5.36±0.33	2	19	4.01
Not managed *E. globulus*	127	DBH (cm)	6.58±0.47	2	18	3.58
	127	Height (m)	3.85±0.30	2	19	3.40

Also seedling is the most critical phase to express regeneration performance among different growth stage of trees (Balliu *et al.*, 2017). The managed *C. lusitanica* plantation forest had the highest regeneration of seedlings followed by adjacent natural forest and not managed *E. globules* stems ha^{-1} and the lowest regenerate of seedlings was recorded in not managed *C. lusitanica* stand. This regeneration of seedlings showed significantly different among the different forest types (F = 16.11, p < 0.05).

Table 5. Regeneration of mean densities of mature tree, sapling and seedling in managed and unmanaged plantation forest and adjacent natural forests (ANOVA, F=14.03, F=7.37, F=16.11, p=0.000, n=15)

Variables	Forest types	Mean± S.E	SD.	Min	Max
Tree Density ha^{-1}					
	Natural forest	$154±19.88^{b}$	77.01	0	287
	Managed *C. lusitanica*	$97±19.75^{b}$	76.51	0	223
	Not managed *C. lusitanica*	$4±2.91^{a}$	11.26	0	32
	Managed *E. globules*	$121±24.28^{b}$	94.04	0	350
	Not managed *E. globules*	$21±10.62^{a}$	41.13	0	127
	Sig (5%)	**			
Sapling Density ha^{-1}	Natural forest	$1163±138.93^{b}$	538.09	382	2548
	Managed *C. lusitanica*	$1078±150.68^{b}$	583.59	0	1911
	Not managed *C. lusitanica*	$169±42.45^{a}$	164.42	0	382
	Managed *E. globules*	$789±119.36^{b}$	462.29	0	1656
	Not managed *E. globules*	$985±222.54^{b}$	861.89	0	3057
	Sig (5%)	**			
Seedling Density ha^{-1}	Natural forest	$3538±390.7^{b}$	1513.22	1769	7431
	Managed *C. lusitanica*	$5567±663.80^{c}$	2570.87	1415	9908
	Not managed *C. lusitanica*	$707±109.19^{a}$	422.87	354	1415
	Managed *E. globules*	$1462±302.76^{a}$	1172.60	0	3185
	Not managed *E. globules*	$2524±650.55^{ab}$	2519.56	0	8139
	Sig (5%)	**			

**=significant at 1% level, *=significant at 5% level, ns= not significant

In managed *C. lusitanica* plantation forest, mean seedlings regeneration strongly higher than all other plantation forest types and adjacent natural forest whereas unmanaged *E. globules* and *C. lusitanica* and *managed E. globules* not significantly differed seedling regeneration between them. This result also inline to the study of diversity of native woody regeneration in exotic tree plantations and natural forest in Southern Philippines (Tulod *et al*., 2017). The result in Table 9 confirmed that managed *C. lusitanica* have the highest number of seedlings among other forest types and the number of seedlings regeneration under plantation forest with and without management intervention and the adjacent natural forest was important to indicate the management effect on regeneration.

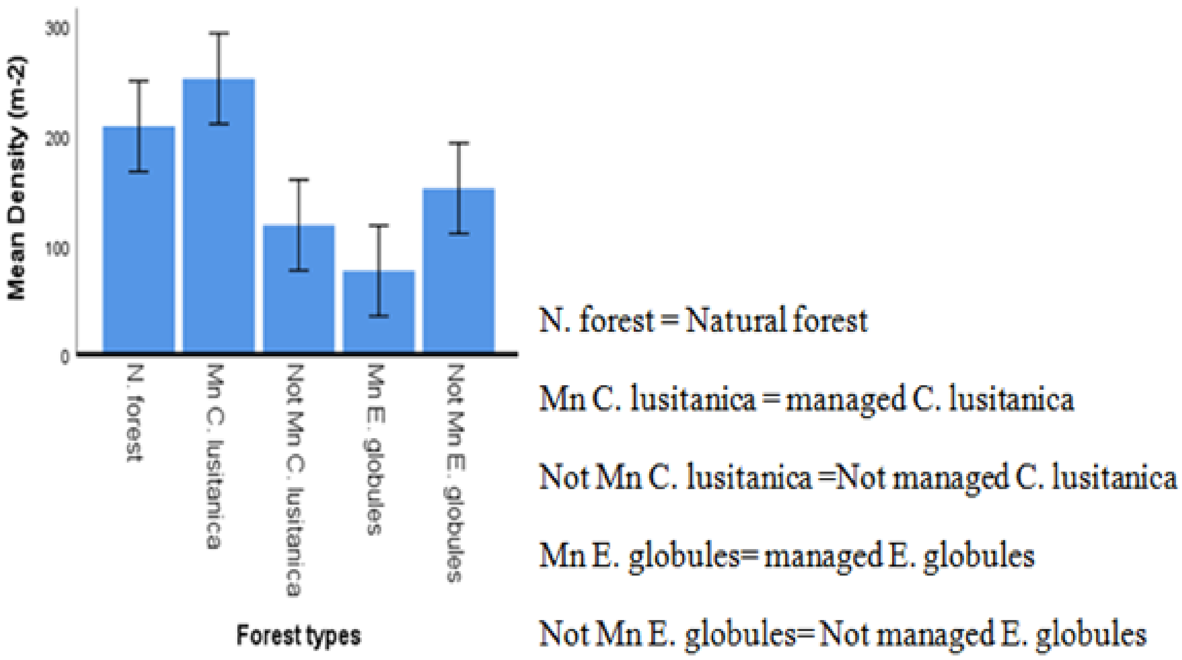

Figure 6. Mean density of seeds in the soil seed bank in different forest types from above surface layer to 10 cm soil depth

When this study result compared to assumption of the regeneration status using the categories had good regeneration status in all forest types that implies the number of stems of seedling density > sapling density> tree density (Table 9).

1. ‘Good’, if presence of seedling > sapling > mature strata,
2. ‘Fair’, if presence of seedling > sapling < mature strata;
3. ‘Poor’, if a species survives only in the sapling stage, but not as seedlings (even though saplings may be <,> or = matured trees;

4. 'None', if a species is absent both in sapling and seedling stages, but present as mature; and
5. 'New', if a species has no mature, but only sapling and/ or seedling stages (Fisaha *et al*., 2013).

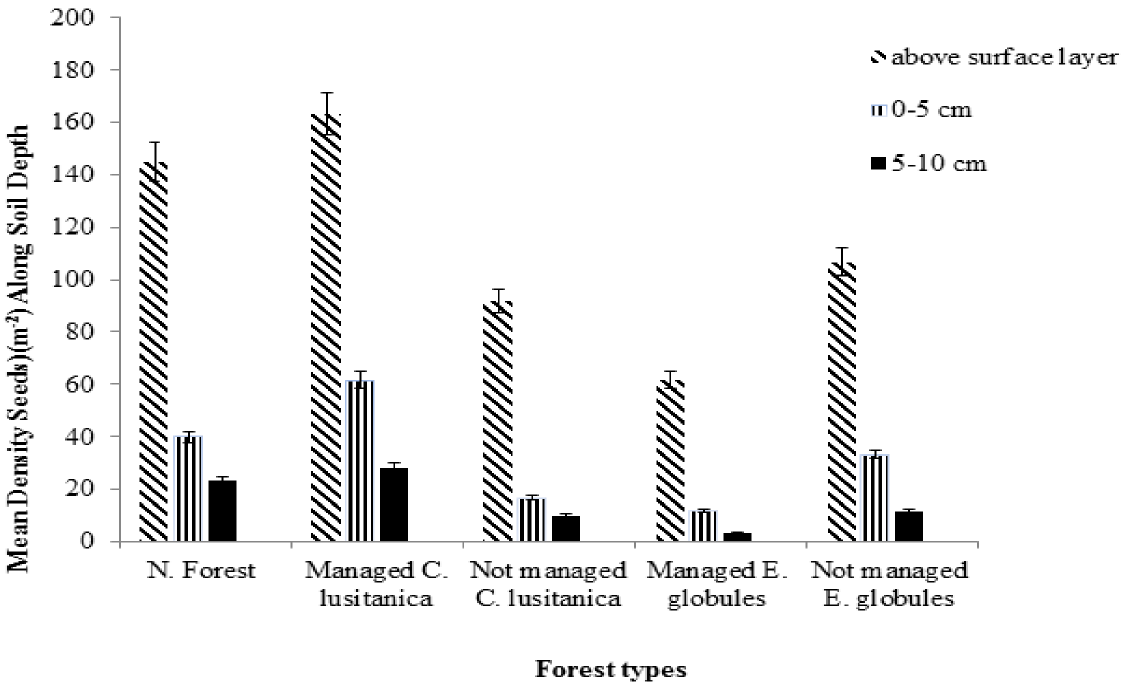

Figure 7. Vertical distribution of viable seeds in soil depth for all forest types.

Soil seed bank and seedling emergence

The mean abundance of seeds in the study area in different forest types from the above surface layer to 10 cm soil depth ranged from 77±19.13 to 252±63.92 seeds per m^2 (Figure 11). The managed *C. lusitanica* had the highest density of seeds followed by adjacent natural forest, while *E. globulus* plantation with enrichment plantation had the least mean seed abundance (Figure 11). This might be due to the different environmental factors that affect regeneration, such as temperature, light; pH, burial depth, and soil moisture are known to affect seed germination (Lu *et al*., 2006). And the lowest seed density recorded in managed *E.globulus* was the reason behind the information obtained from secondary data, the site was before converting to plantation forest it was the cultivated land and used for cropping purpose that is why the plantation forest needed enrichment planting on the left lands. Similar studies conducted at Karei Deshe in northeastern Israel farm and grazing lands previously before converting grass lands and other land uses type, the high intensity and timing of cattle grazing and cultivation changes the size and composition of the soil seed bank, even if after changing the land use type (Sternberg *et al*.,2003).

Table 6. Densities of seedlings in the soils of the different forest types along soil depth above surface (F=2.493, p=0.051), 0-5 cm (F=2.98, p=0.024) and 5-10 cm (F=2.38, p=0.059, n=15)

Emerging seedling in the soil seed bank per m^2	Forest types	Mean± S.E	SD.	Min	Max
Above the surface layer of the soil	Natural forest	145±30.88^a	119.59	0	450
	Managed *C. lusitanica*	163±37.70^a	146.03	0	425
	Not managed *C. lusitanica*	91±15.74^a	60.99	0	225
	Managed *E. globules*	61±13.77^a	53.34	0	175
	Not managed *E. globules*	106±23.20^a	89.87	0	275
	Sig (5%)	**ns**			
0-5 cm soil depth	Natural forest	40±14.80^{ab}	57.32	0	175
	Managed *C. lusitanica*	61±17.40^b	67.39	0	225
	Not managed *C. lusitanica*	16±5.27^{ab}	20.41	0	50
	Managed *E. globules*	11±5.90^a	22.88	0	75
	Not managed *E. globules*	33±9.01^{ab}	34.93	0	100
	Sig (5%)	**			
5-10 cm soil depth	Natural forest	23±7.09^a	27.49	0	100
	Managed *C. lusitanica*	28±11.40^a	44.18	0	150
	Not managed *C. lusitanica*	10±4.08^a	15.81	0	50
	Managed *E. globules*	3±2.27^a	8.79	0	25
	Not managed *E. globules*	11±4.13^a	15.99	0	50
	Sig (5%)	**ns**			

The vertical distribution of soil seed banks in different forest types was assessed. The density of seeds in the soil showed similar vertical distribution in all forest types in a gradual decreasing along increasing soil depth (Figure 12). Similar studies done by Teketay & Granström (1995) in dry Afromontane forests of Ethiopia showed density of soil seed bank decreased when the soil depth is increased. The burial depth of seeds may affect the distribution along soil depth (Lu *et al*., 2006).

Table 7. Soil seed bank species richness, diversity and evenness of Tarmaber plantation forest with management intervention and adjacent natural forest

Forest type	Soil layers	S	H'	E
Natural forest	Above litter layer	19	2.59	0.88
	0-5 cm	11	2.22	0.93
	5-10 cm	7	1.57	0.81
Managed *C.lustanica*	Above litter layer	9	1.47	0.67
	0-5 cm	7	1.16	0.60
	5-10 cm	5	1.3	0.81
Managed *E.globulus*	Above litter layer	7	1.42	0.73
	0-5 cm	4	1.15	0.83
	5-10 cm	1	0	0.00
Not managed *C.lustanica*	Above litter layer	4	0.62	0.45
	0-5 cm	1	0	0.00
	5-10 cm	1	0	0.00
Not managed *E.globulus*	Above litter layer	5	1.14	0.71
	0-5 cm	4	1.14	0.82
	5-10 cm	3	0.8	0.72

Table 8. Similarity between soil seed bank and above ground flora (* the lowest similarity, ** the highest similarity)

Forest types	Common species both in above ground flora & soil seed bank	Species exclusive to aboveground flora	Species exclusive to soil seed bank	Sorenson's coefficient similarity values
Natural forest	19	22	0	0.633**
Managed *C. lusitanica*	9	18	2	0.473
Not managed *C. lusitanica*	3	19	1	0.230*
Managed *E. globules*	6	16	1	0.413
Not managed *E. globules*	4	9	1	0.444

Other environmental factors such as light sensitivity, chemical inhibitors, pH and differences in seed longevity may affect seed distribution with depth (Eyob, 2006). Other study showed that woody species seeds tend to accumulate due to their longlived seeds in the soil seed bank (Teketay & Granström, 1995). However, emerging seedlings from the soil seed bank from 5-10 cm was lower compared to the above surface layer of the soil and 0-5 cm soil depth, even though emerging seedlings in different forest types were not significantly differed among each forest types (F=2386, p > 0.05 (Table 10).

The mean densities of emerging seedlings in the above surface layer of the soil were not significant among the different forest types (F = 2.493, p > 0.05) (Table 10). And the emerging seedlings from soil seed bank in the soil depth of 0-5 cm was minimum relative to the emerging seedlings from the above soil surface layer and the results of one way ANOVA analysis in managed *E. globules* was significantly lower than other forest types (F=2.989, P <0.05).

Species richness, diversity and evenness of soil seed bank

The Shannon diversity index for the diversity and evenness of soil seed bank in adjacent natural forest, managed *C.lustanica* and *E.globulus* plantation forests were good as compared to unmanaged plantation forests (Table 11). In the five forests, there was relatively higher diversity on the surface layer of soils followed by 0-5 cm and 5-10 cm soil depth. Generally, species richness decreased down the soil layers (Table 11). Similar studies in Mongolia China (Qian *et al*., 2016) showed species richness decreased down the soil depth.

Similarity between Soil Seed Bank and Aboveground Flora

The similarity between the soil seed bank and aboveground flora was ranged from similarity index values from 0.230 for not managed *C. lusitanica* plantation forest to 0.633 for natural forest (Table 13). Totally twenty two species (20 native and 2 exotic) woody species out of 51 species (*Allophylus abyssinicus*, *Bersama abyssinica*, *Cupressus lusitanica*, *Discopodium penninervum*, *Dovyalis abyssinica*, *Eucalyptus globulus*, *Embelia schimperi*, *Erica arborea*, *Galiniera saxifrage*, *Juniperus procera*, *Laggera pterodonata*, *Maesa lanceolata*, *Maytenus arbutifolia*, *Morus mesozygia*, *Olea africana*, *Phytolacca dodecandra*, *Prunus africa*, *Rhnmnus prinoides*, *Rumex nervosus*, *solanum dasyphyllum*, *Vernonia amygdalina* and *Vernonia auriculifera)* were represented both in the aboveground vegetation and in the soil seed bank.

This implies that the soil seed bank contributed for the aboveground flora or vice versa (Looney & Gibson, 1995). This is because, most woody species do not accumulate seeds in the soil and only few woody species tend to produce recalcitrant seeds (Teketay & Granström, 1995).

The similarity between the different soil layers was also important. Generally, the similarity between the above surface layer and 0-5 cm and 5-10 soil depth was relatively higher (Table 13) however; unmanaged plantations and managed *E. globules* plantation forest had low similarity in some soil depth layers.

Conclusion

The plantations studied were mainly monocultures and it is suggested that management intervention could possibly improve the regeneration of indigenous tree species. Different species of exotic tree plantations with management intervention showed variability in their understory woody species regeneration. In comparison managed plantations and the natural forests to unmanaged plantations stands the exotic tree plantations had limited effectiveness in facilitating regeneration of indigenous woody vegetation. The managed *C. lusitanica* (pruning of branches) creates a good opportunity for light penetration found to be effective in facilitating woody species regeneration as compared to the unmanaged plantations forests.

The different species of plantation forest varied in woody species composition, diversity and soil attributes showing that the over-story species affected regeneration. The various factors that influence regeneration such as canopy cover, limitation of seed dispersal agents, seed source natural forests near to plantation forest and soil seed bank limitation and management intervention can be linked to the species of tree regeneration. Enrichment planting of indigenous tree species in plantations would enhance conservation efforts as well as providing alternative sources of forest resources. The soil seed bank of the studied sites was dominated by 20 native and 2 exotic woody species and this is the inverse of the understory vegetation which was dominated by woody vegetation. The proximity of natural forests to plantations forests has been shown to enhance the floristic diversity in plantations and could perhaps enhance the viability of the woody species populations in the plantation forests.

Plantations can play an important role in restoring the productivity, ecosystem stability, and biodiversity of degraded tropical lands as well as providing economically and socially valued forest products and services. Through careful selection of appropriate management, the negative effects of the plantations can be offset while facilitating indigenous forest regeneration. The local people perception about plantation forest expansion in environmental and ecological issues was positive concerning soil conservation, biodiversity, water flow and rehabilitation

Conflict of interest

The authors declare that there is no conflict of interest

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