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# Effects of *Eucalyptus camaldulensis* Tree Plantation on Indigenous Trees and Soil Properties in North Western Ethiopia

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## ABSTRACT

Widespread deforestation demanded proportional restoration initiative either through an active plantation of fast-growing tree species or passive restoration, which depend on natural regeneration of the land. This study aimed at characterizing the impacts of *Eucalyptus* plantation on woody plant species and selected soil physicochemical properties, the adjacent natural forest was considered as a reference. Data was collected by using plots established on transect lines inside the plantation and adjacent forests. Diversity indices were used for the analysis of vegetation data. Seventy-one woody plant species (33 *Eucalyptus* and 63 natural forests) were determined with a density of 404/ha in plantation and 635/ha in the natural forests. The basal area was 4.9 $m^2$/ha in plantation and 24.5 $m^2$/ha in natural. The regeneration status in the plantation was 699 seedlings and 344 saplings/ha while the natural forest had 1117 seedlings and 390 saplings/ha. Fourteen plant species were recovered from the soil seed bank, 12 in natural and 7 in plantation. Soil seed bank was not similar in the two forests with Sorenson's similarity values of 0.208. There were 11,022 seeds/$m^2$ in natural forest and 10,667 seeds/$m^2$ in plantation forests in the soil seed bank. The soil carbon, nitrogen, and potassium were significantly higher in natural forests as compared to plantation. The Cation exchange capacity and soil available phosphorus were found to be statistically similar. The pH of plantation forest was significantly lower than the natural forest. Furthermore, fostering effect of *Eucalyptus* plantation on native woody species and increase the biodiversity in northwestern Ethiopia.

***Keywords:*** *Eucalyptus*, Florstic diversity, Fostering effect, Natural forest, Soil seed bank.

## INTRODUCTION

Forest, inherited resources with an economic, environmental and biological value which supply's lumber, play wood, various hand tools, source of fuel (Reusing, 2000) providing watersheds protection, carbon sink and habitats for animals and plant life (Nune et al., 2012). Over the last centuries, about 30 % of global forest cover has been cleared and a further 20% has been degraded. Since 1990 up to 2015, the global forest area declined by 129 million hectares (FAO, 2001), and more than two billion degraded forests and landscapes across the globe are suitable for restoration, either through mosaic restoration, wide-scale restoration or remote restoration (Abiyu et al., 2011).

Ethiopia is the most populous landlocked country situated in East Africa covering an area of about 1.2 million $Km^3$ (Bobe & Behrensmeyer, 2004). It is a mountainous, with topographic features dominated by rugged mountains cut by river valleys and deep gorges, flat-topped plateau, undulating hills and lowland plains. The vegetation types are highly diverse, ranging from afro-alpine to desert vegetation (Zegeye et al., 2005) which was estimated to include> 6,500 species of which 12% are endemic. About 35-40% of the landmass was covered by climax vegetation, which was, either coniferous or broad-leaved (Yirdaw, 1996). However, over the last 3,000 years, there has been progressive deforestation, loss of biodiversity and impoverishment of ecosystems by rapid population growth, extensive forest clearing for cultivation, overgrazing, movement of political centers, and exploitation of forests for fuel wood and construction materials drastically reduced the forest cover (FAO, 2001). Recent reports showed it reached about 14.7% (Mengestu, 2018).

Due to severe forest clearing and deforestation, the country's forest resource becomes dwindling and

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*Eucalyptus* tree was introduced to relieve the shortage of construction and fuel wood (Pohjonen & Pukkala, 1990) during Emperor Menelik regime (1894−1895). Nowadays it is the most successful tree species, adopted by farmers for its fast growth, coppicing ability, the un-palatability of leaves, and wide range adaptability (FAO, 1981). Tree plantations mainly used for economic purposes such as timber production and firewood. Nowadays, tree plantations as an alternative site for the regeneration of native plant species (Senbetu et al., 2002). It enhance the regeneration by suppressing competitive grass species, other light-demanding species (Parrotta et al., 1997; Koonkhunthod et al., 2007), and creating a micro-climate that favor colonization and as “stepping stones” between remnant natural forests and agricultural matrix enhancing seed dispersal (Parrotta, 1995; Hartley, 2002; Carnus et al., 2006; Ashton et al., 2014), conservation of biodiversity by providing an environment not only for native woody plants but also for the forest herb species (Boothroyd-Roberts et al., 2013) and habitat for a wide range of wild animals (Parrotta et al., 1997; Oberhauser, 1997; Senbeta et al., 2002; Carnus et al., 2006 and Koonkhunthod et al., 2007). *Eucalyptus* plantation occasionally promotes the recruitment, establishment and succession of native woody species (Lugo et al., 1993; Parrotta et al., 1997) particularly on sites where soil seed banks of native forest species are lacking (Senbetu & Teketay, 2001). Some regeneration studies on plantations of *Eucalyptus globulus*, *Eucalyptus saligna*, *Eucalyptus grandis*, *Pinus patula*, *Pinus radiata*, *Cupressus lusitanica* and *Grevillea robusta* were done in different locations of Ethiopia, which also proved a surprising catalytic role of these monocultures with regard to habitat recolonization by native woody plants (Alem et al., 2012).

However, intensive monocultures of *Eucalyptus* plantations have attracted much criticism because these species have been considered to deplete soil nutrients, decrease available water resources, suppressing ground vegetation by secretion of allopathic chemicals (Jagger & Pender, 2003). In addition, it contributes positively to biodiversity conservation by fostering native woody species (Da-Silva et al., 1995; Senbeta & Teketay, 2001; Tesfaye et al., 2004; Parrotta, 1995). Regarding their productive importance, it have been given huge attention on the protection of the local ecosystem by giving fostering effect to the soil seed bank flora and minimize the loss of natural forest by replacing as a fuel-wood source. Different studies was reported on the nursing effect of *Eucalyptus* plantation including Yirdaw (2001), Senbeta and Teketay (2001), Hundera (2010) and Alem et al. (2012).

Monitoring the composition, densities and the role of seed rain, soil seed banks and the regeneration potential of indigenous woody species following plantation establishment is of paramount importance. There is no scientific study about the woody composition, diversity, vegetation structure, soil seed bank and soil physicochemical properties of Qimbaba *Eucalyptus* plantation forest and the adjacent natural forest. Therefore, development of effective management approaches for conservation and sustainable utilization of the plantation and the natural forest resource needs empirical information on composition, diversity, vegetation structure, soil seed bank and soil properties of the forest. Therefore, the present study was carried out and tried to fill part of the information gap on the composition, diversity, structure, soil seed bank and selected soil properties of the Qimbaba Eucalypts plantation and natural forests located in North West Ethiopia.

## MATERIALS AND METHODS

### Study site:

The study area was located in Bahir Dar zuria district Amhara region, Ethiopia (Fig 1) at $12^0$62’37”m and $12^0$65’31.6”m N latitude and $32^0$50’20”m and $32^0$78’76” m E longitude 20 km south-west of Bahir Dar. Qimbaba state forest has a land area of 967.50 ha, consisting of about 60.58% is plantation (19.53% are government and 41.05% private) 39.32% were natural forest. The climate was characterized as hot and wet in the rainy season and dry periods in the winter from March to May. The mean annual rainfall is 1272-1397 mm/year and the mean monthly temperature ranges from 19ºC-21ºC (Kibret & Tulu, 2014). The natural forest harbors a significant number of large and small mammals, birds, and plant species, which was primarily dominated by shrub species of *Acokanthera schimperi*, *Calpurnia aurea*, *Capparis tomentosa* and *Maytenus arbutifolia*. Whereas, trees like *Ficus ovata*, *Sapium ellipticum* and *Syzygium guineense* were found along small streams.

### Plant data collection:

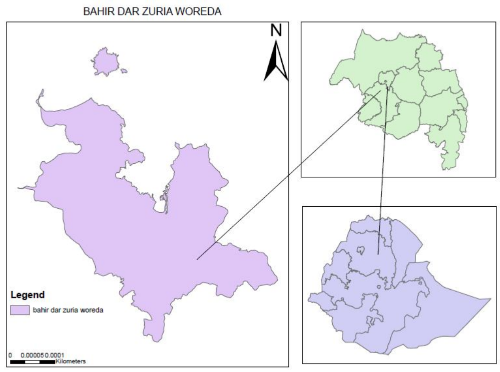


**Fig. 1: Map of Bahir Dar Zuria woreda**

Vegetation assessment was conducted using a line transect survey with a circular plot of 314 $m^2$ established at 200 m intervals along in the east-west direction (Fig 2). The plots ware laid at every 200 m distance on each transect and the first plot was located at least 50 m away from the forest edges. In each plot, all naturally regenerated woody species were identified and counted. The plants were categorized as a seedling (height ≤ 1.0 m), sapling (height between 1 and 3 m) and tree (height > 3 m). For specimens found difficult to identify in the field, voucher samples were collected, pressed and identified in the National Herbarium of Ethiopia, Addis Ababa University. For each plot (Fig 2) number regenerated species, the number of individual trees, diameter at breast height (DBH) and height were measured according to methods reported in literature (Yirdaw, 2001). Tree regeneration was measured in each plot. 40 sampling plots (20 in the natural and 20 in the plantation forest) were taken across the study area.

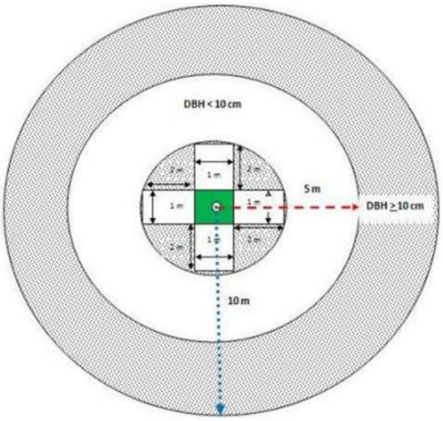


**Fig. 2: A schematic illustration of plot area**

All woody species in each quadrant were recorded and identified.

**Soil sampling for soil seed bank:**

The Soil seed bank samples were collected from the plots used for vegetation sampling. At the center of each plot, a small plot of 10 cm x 10 cm was marked and four separate soil layers consisting of litter layer, each 3 cm thick with 160 soil samples were collected (Teketay, 2001). All soil samples were sieved using a 0.5 mm mesh to recover large-seeded woody species before the soil samples were incubated to stimulate germination of seeds in the glasshouse for four months to stimulate germination of seeds. The emerging seedlings were identified, recorded and discarded once every two weeks. Those seedlings difficult to identify were transplanted and grown to a larger stage to make identification easier and accurate (Senbeta & Teketay, 2001).

**Soil sampling for physicochemical properties study:**

Five representative soil sampling sites were selected randomly per each forest using available field methods (similarity in soil color, structure, and cohesiveness when wet). Soil samples were collected from 20 m x 20 m plots in five replicates per habitat from a pit dug four corners and center of the square. Samples were obtained from depths of 0–15 and 15–30 cm. The soil bulk density was determined following methods reported by (Kolay, 2000). The soil pH was measured using a pH meter in 1:2.5 soils: water ratio suspension (Anderson & Ingram, 1993). The soil organic carbon content was determined following (Walkley & Black, 1934) and percentage organic matter was obtained by multiplying percent organic carbon by 1.72. Available Phosphorous was determined using the standard method (Watanabe & Olsen, 1965) and total Nitrogen was determined according to a report by (Neuendorf et al., 2005). Potassium was determined using Morgan solution by film photometer. Cation exchange capacity was determined following (Chapman, 1965).

**Data analysis:**

The Shannon-Wiener Diversity Index (H′) was used to determine diversity of species in both the natural forest and plantation.

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

Where $k$ is the number of species, $pi$ proportion of individual species to the total.

Shannon evenness index (Peet, 1974).

$$J = H'/H'_{max} \quad \text{------------------------------(2)}$$

Where, J=evenness, H'=Shannon-wiener diversity index and $H'_{max}$=maximum Shannon-wiener diversity indexes,

Importance value index (IVI) was calculated as the sum of relative dominance, relative abundance, and relative frequency of species. Relative dominance: the area occupied by a given species relative to the total area occupied by all species, Relative frequency (RF): is the distribution of one species in a sample relative to the distribution of all species. Relative density (RD): is defined as the number of all individuals of a given species divide by the total number of all individuals of all species (DBH ≥ 2 cm) times 100. To analyze the population structure of woody species, all individuals of each species encountered in the quadrats were grouped into arbitrary diameter classes and histograms were developed using the diameter classes versus the number of individuals categorized in each of the classes using Microsoft Excel Computer Software. The seedling data was also analyzed in a hectare base. Similarity index of understory re-generated native woody species was calculated using Sorensen similarity coefficient. The data obtained from the soil analyses were subjected to one-way analysis of variance (ANOVA) for each sample depth separately for statistical significance.

## RESULTS

### Floristic composition and diversity of species:

Seventy-one tree species belonging to 34 families were recorded, 63 species in the natural forest and 33 species in the plantation forest. Of the total, two species (*i.e. Cupressus lusitanica* and *Grevillea robusta*) were exotics. Therefore, the number of species recorded in this study is greater as compared which was reported elsewhere in Ethiopia. The dominant families occurring in the natural forest were Fabaceae represented by five (8%) species followed by Euphorbiaceae, Moraceae and Oleaceae represented by four (6%) species. Others such as Rubiaceae, Anacardiaceae and Sapindaceae represented by two (3%) species each. Similarly, in the plantation forest Fabaceae and Euphorbiaceae were represented by four (12%) species each, whereas Oleaceae was represented by three (9%) species as shown in (Table 1).The result indicated that there was an increasing number of species per plot from 5.32 ± 2.92 to 15.8 ± 3.21 with increasing order from plantation to the natural forest (Table 2). The Shannon diversity index of Qimbaba forest was found to be 2.08 and 3.19 for the plantation and natural forest, respectively. The species encountered in the two forest types were distributed evenly as indicated by the Shannon evenness value of 0.59 and 0.77 for plantation and natural forest respectively. There were 699 seedlings and 344 saplings/ha, and 1117 seedlings and 390/ha saplings were recorded in plantation and natural forest, respectively. There were 21 and 38 tree species in the seedling stage from the plantation and natural forest were recorded respectively, with *Acokanthera schimperi* (301 individuals/ha) were the most dominant species.

### Vegetation Structure and Density of Species:

A total of 404 and 635 individual tree per ha from *Eucalyptus* plantation and natural forest, respectively were recorded, 69 % of trees in the natural forest were in the diameter at breast height (DBH) class of 0-6 cm followed by 19% trees in DBH class 6-12 cm and >12 cm shares only 12%.

### Basal area and important value index:

The basal areas of the forests were 4.9 $m^2$/ha and 24.5 $m^2$/ha for the plantation forest and adjacent natural forest, respectively. In the plantation forest, more than 75% of the basal area was shared by six species (*Ficus sycomorus* 26%, *Grevillea robusta*11.7%, *Cupressus lusitanica* 11.1%, *Croton macrostachyus* 8.8 % and *Sapium ellipticum* 7.6 %) whereas, in the natural forest *Sapium ellipticum* (11.6%), *Ficus ovata* (8.7%), *Bersama abyssinica* (6.3%), *Croton macrostachyus* (6.3%), *Mimusops kummel* (6.05%), *Ficus vasta* (4.9%), contributes the largest basal area. In terms of the IVI value *Acokanthera schimperi* (26.4), in natural forest and *Calpurnia aurea* (68.3) in the plantation were the most important species in the forest.

### Species composition and diversity of soil seed banks:

Fourteen plant species representing 11 families were recorded in the soil seed bank (12 species in the natural forest and 7-plantation forest). Trees were the dominant group, 8 species, followed by shrubs and climbers (5 and 1 species, respectively). *Acokanthera schimperi,* which was the dominant species, accounting to more than 80 % of the seed bank flora. The Shannon diversity index for the diversity of soil seed bank in Qimbaba natural and *Eucalyptus* plantation forests were (H'=0.94 and H'=0.706), respectively (Table 3). In the two forests there is relatively higher diversity of all studied forest sites was found on the litter layer followed by 0-3 cm, 3-6 cm and 6-9 cm, respectively. Generally, species richness decreased down the soil layers (Table 3). The Shannon

**Table 1. Plant families with their number of species in each forest types**

| Forest type | Family | Number of species | % | Forest type | Family | Number of species | % |
|---|---|---|---|---|---|---|---|
| Natural forest | Fabaceae | 5 | 8 | Plantation forest | Fabaceae | 4 | 12 |
| | Euphorbiaceae | 4 | 6 | | Euphorbiaceae | 4 | 12 |
| | Moraceae | 4 | 6 | | Oleaceae | 3 | 9 |
| | Apocynaceae | 2 | 3 | | Apocynaceae | 2 | 6 |
| | Oleaceae | 4 | 6 | | Ebenaceae | 1 | 3 |
| | Rubiaceae | 2 | 3 | | Celastraceae | 1 | 3 |
| | Anacardiaceae | 2 | 3 | | Myrtaceae | 1 | 3 |
| | Sapindaceae | 2 | 3 | | Melianthaceae | 1 | 3 |
| | Others | 38 | 60 | | Rutaceae | 1 | 3 |
| | | | | | Others | 15 | 45 |

evenness index (E) had no consistence value among the soil layers of each forest site; but totally viewed as litter layer>0-3 cm>6-9 cm>3-6 cm. The overall soil seed bank evenness of the plantation forest was 0.36, which is less than the adjacent natural forest (0.38). The similarity in soil seed bank between the two forests were low with Sorenson's coefficient of Similarity values of 0.208.

**Species density in the soil seed bank:**

The total seed density value from seed emergence and seed counting method was 11,022 seeds/m$^2$ (10,844.44 seeds/m$^2$ viable and 177.56 seeds/m$^2$ non-viable) in the natural forest and 10,667 seeds/m$^2$ (10311.11 seeds/m$^2$ viable and 355.89 seeds/m$^2$ non-viable) in plantation forest were recorded.

**Effects of plantation forest on selected soil physicochemical properties:**

The bulk density did not show significant difference (P>0.05) between the two forests and with soil depth. The pH ranges from 6.28 in plantation forest to 6.61 in the natural forest. The pH in plantation was significantly lower (P<0.05)

**Table 2. Woody species along different forest area.**

| Forest type | Mean ±std | Min | Max | S$^2$ | Cof. Of var. | SE (%) | Number of plots |
|---|---|---|---|---|---|---|---|
| Plantation forest | 5.32 ± 2.92 | 0 | 11 | 8.54 | 0.55 | 0.65 | 20 |
| Natural forest | 15.8 ± 3.21 | 11 | 22 | 10.27 | 0.20 | 1.6 | 20 |

**Table 3. Soil seed bank species richness, diversity and evenness of Qimbaba forest.**

| **Forest site** | **Soil layers (cm)** | **S** | **H'** | **E** | **Forest site** | **Soil layers (cm)** | **S** | **H'** | **E** |
|---|---|---|---|---|---|---|---|---|---|
| Natural forest | Litter layer | 8 | 1.17119 | 0.878433 | Plantation forest | Litter layer | 5 | 0.70313 | 0.43688 |
| | 0-3 | 4 | 0.68857 | 0.496696 | | 0-3 | 3 | 0.46341 | 0.42181 |
| | 3-6 | 2 | 0.34883 | 0.503258 | | 3-6 | 2 | 0.34883 | 0.50355 |
| | 6-9 | 2 | 0.27119 | 0.391244 | | 6-9 | 2 | 0.27119 | 0.39124 |

**Table 4. Soil physical and chemical property in plantation and natural forest**

| Soil property | Depth (cm) | EP(Mean ± SE) | NF(Mean ± SE) | T-value | P-value |
|---|---|---|---|---|---|
| Bulk density | Overall | 0.995±0.03 | 1.005±0.056 | | 0.8847$^{ns}$ |
| | 0-15 | 0.966±0.0643 | 0.914±0.058 | | 0.567$^{ns}$ |
| | 15-30 | 1.026±0.026 | 1.097±0.085 | | 0.46$^{ns}$ |
| Soil pH(No) | Overall | 6.28±0.08 | 6.61±0.079 | **2.101*** | **0.01** |
| | 0-15 | 6.31±0.12 | 6.54±0.1 | 2.3 | 0.2 |
| | 15-30 | 6.25±0.13 | 6.69±0.12 | **2.3*** | **0.04** |
| SOC (%) | Overall | 1.83±0.144 | 3.45±0.27 | **2.14*** | **0.0001** |
| | 0-15 | 2.1±0.13 | 3.8±0.38 | **2.57*** | **0.008** |
| | 15-30 | 1.56±0.2 | 3.08±0.35 | **2.44*** | **0.009** |
| OM (%) | Overall | 3.16±0.24 | 5.94±0.47 | **2.14*** | **0.001** |
| | 0-15 | 3.62±0.22 | 6.56±0.67 | **2.57*** | **0.009** |
| | 15-30 | 2.69±0.34 | 5.32±0.61 | **2.44*** | **0.009** |
| N (%) | Overall | 0.18±0.02 | 0.31±0.04 | **2.14*** | **0.02** |
| | 0-15 | 0.201±0.03 | 0.292±0.05 | 2.36 | 0.2 |
| | 15-30 | 0.16±0.03 | 0.32±0.08 | 2.57 | 0.12 |
| Available P (ppm) | Overall | 0.92±0.25 | 2.00±3.89 | 2.20 | 0.21 |
| | 0-15 | 0.79±0.4 | 3.1±7.4 | 2.57 | 0.18 |
| | 15-30 | 1.06±0.33 | 0.93±2.85 | 2.57 | 0.66 |
| K(mg/kg) | Overall | 187.8±15.7 | 251.05±20.99 | **2.11*** | **0.02** |
| | 0-15 | 201.05±26.8 | 261.6±23.1 | 2.3 | 0.12 |
| | 15-30 | 174.44±17.4 | 240.5±37.3 | 2.44 | 0.16 |
| CEC (meq/100g) | Overall | 50.01±2.07 | 55.45±3.42 | 2.13 | 0.19 |
| | 0-15 | 50.3±2.52 | 56.7±4.02 | 2.36 | 0.21 |
| | 15-30 | 49.7±3.6 | 54.1±5.9 | 2.36 | 0.54 |

** Statistically significant (P < 0.05). EP (eucalyptus plantation), NF (natural forest), SE (standard error), CEC (cation exchange capacity), K (potassium), P (phosphorous), N (nitrogen), SOC (soil organic carbon), ppm (parts per million) and meq/100g (milli equivalent per 100g)*

**Table 5: Average plot values of Shannon-Wiener diversity, Evenness and density of naturally regenerated woody species in each**

| Stand | Species richness | Diversity (H′) | Evenness (H/lns) | Density (no. $ha^{-1}$) |
|---|---|---|---|---|
| Natural forest | 63 | 3.19 | 0.77 | 2142 |
| Plantation forest | 33 | 2.08 | 0.59 | 1447 |

than natural forest (Table 4). Nutrients occur in available forms at a soil pH of 5.5 to 6.5 (Hazelton & Murphy, 2016). Therefore, the natural forest soil is likely to be more fertile with a greater availability of plant nutrients. Soil organic carbon was significantly lower (t (5) = 2.14, P = 0.00013) than natural forest. When the soil depth increases, the soil organic carbon content decreased in the two adjacent forests. Available phosphorus in the plantation forest was not significant (t (5) =2.2, P = 0.18) compared to natural forest. The Nitrogen concentration in plantation was significantly lower (t (5) = -2.14, $P_{value}$ = 0.02) (Table 4) than the natural forest. The $K^+$ content that was observed in plantation forest was significantly lower than the natural forest (t (5) = 2.11, $P_{value} < 0.05$). The Change in $K^+$ content under plantation and natural forest across the soil depth mostly showed regular reduction rate (Table 2). Although the Cation exchange capacity recorded in the plantation forest (50.01) soil was lower than in the natural forest soil (55.45) (Table 2), but not significant.

## DISCUSSION

### Floristic composition and diversity of species:

In terms of species richness, from the natural and plantation forest, Qimbaba has a higher number of woody species compared with similar dry Afromountain forests in Ethiopia. For instance, 20 and 22 tree species in Chancho and Menagesha, respectively (Yirdaw, 2001). Abiyu et al. (2011) also reported two and four tree species in *Cupressus* and *Eucalyptus* plantation forests, respectively in Tehuldere district. On the other hand, it was lower than the one recorded in Munessa-Shashemene (55 species) by Senbetu et al. (2002). The diversity of natural forest was high compared to the plantation one and the result indicated that there was an increasing number of species per plot from plantation to the natural forest. Similar results reported by Alem et al. (2012) in the Belete state forest and (Abiyu et al., 2011) in Tehuledere district also showed an increase in number of species from *Eucalyptus* plantation to natural forest. On the other hand, other studies from dry afro mountain forest, reported that species diversity increases in the plantation forest than the natural forest (Senbeta & Teketay, 2001; Hundera, 2010; Alem et al., 2012). The species encountered in the two forest types were distributed evenly as indicated by the Shannon evenness value with a good share of diversity among all quadrants. According to Kent (2011), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Table 5). Lower Shannon evenness is an indication of the existence of unbalanced distribution of individual’s species encountered at a given study area. Therefore, based on the Shannon-Weiner diversity index it can be concluded that the study area is with good diversity and more or less has evenly distributed individual of all species in the quadrates.

Regarding the number of plant life forms it was much lower than other forest reported by Ambachew et al. (2018) (2916 Seedlings/ha in Wanzaye forest), Teketay (1997) (16290 and 32650 seedlings/ha in Menageshasuba and gera-ades forests), Kflay and Hundera (2014) (4500 seedlings/ha in Belete forest), Mekonene et al. (2014) (1068 seedlings/ha in Gedo dry montane forest) and Haile et al. (2012) (120 seedlings/ha in Metema dry forest). There were 21 tree species in the seedling stage (plantation forest) were recorded, which was lower than other forests of GaraAdes forest 40 and 41 species of Mengesha forest (Teketay, 1997) and Belete forest 60 species (Hundera, 2010). In the natural forest, 38 seedling stage trees were recorded, which was higher than Metema dry forest 26 species (Hail et al., 2012) and wanzaye forest 37 species (Ambachew, 2018). *Acokanthera schimperi*(301 individuals/ha) were the most dominant species.

### Vegetation Structure, Density and Basal area of Species

In Qimbaba forest there is a higher number of individuals in the lower diameter class than the higher diameter class. This is a general pattern of normal distribution (Didita et al., 2010). Generally, this pattern indicated good regeneration status of the forest (Tektay, 1997). Yineger et al. (2008) reported similar results in Bale mountain national park, Zegeye et al. (2010) in Tara Gedam and Abebaye forests and Ambachew et al. (2018) in Wanzaye natural forest. The basal area distribution is important for determining and classifying forest type based on maturity of the stand (Sokpon & Biaou, 2001). In the plantation forest the highest shareholders were *Ficus sycomorus* 26%, *Grevillea robusta*11.7%, *Cupressus lusitanica* 11.1%, *Croton macrostachyus* 8.8 % and *Sapium ellipticum* 7.6 %) whereas, in the natural forest *Sapium ellipticum* (11.6%), *Ficus ovata* (8.7%), *Bersama abyssinica* (6.3%), *Croton macrostachyus* (6.3%), *Mimusops kummel* (6.05%), *Ficus vasta* (4.9%).However, it was very low compared to tropical forest 35 $m^2$/ha (Midgley and Niklas, 2004), Boda dry evergreen mountain forest (114.6 $m^2$/ha) (Erenso et al., 2014); Belete moist evergreen mountain forest (103.5 $m^2$/ha) (Kflay & Hundera, 2014); Metema woodland vegetation (42.54 $m^2$/ha) (Haile et al., 2012) and vegetation of Nechisar national park (49.45 $m^2$/ha) (Shimelse et al., 2010).

**Species composition, diversity and density of soil seed banks:**

Fourteen plant species in the soil seed bank were in line with Tekle & Bekele (2000), reported five tree species, in Bezawit revirian forest. The lower number of seeds in seed bank could also be the result of short residence time of most woody species (Teketay, 2005) except *Acokanthera schimperi*, which was the dominant species, accounting to more than 80 % of the seed bank flora. The Shannon diversity index value shows lower value than Hgumbirda National Forest Priority Area (H'=1.763154) (Sileshi & Abraha, 2014) and Harenna forest (Tesfaye et al., 2004). Generally, species richness decreased down the soil layers (Table 3). The Shannon evenness index (E) had no consistence value among the soil layers of each forest site; but totally viewed as litter layer >0-3 cm >6-9 cm >3-6 cm. The similarity in soil seed bank between the two forests were low with Sorenson's coefficient of Similarity values of 0.208. Which is similar to other studies, Amente et al. (2006) in Dodola forest and Sileshi and Abraha (2014) in Hgumbirda Forest of Ethiopia. The species density in soil seed bank was considerably lower density than Hgumbirda National forest Priority area (12,611.1 seeds/$m^2$) by Sileshi and Abraha (2014), Dodola Dry Afromontane Forest (30,267 seeds/$m^2$) by Amente et al. (2006), Menagesha-Suba and Munessa-Shashemene forest sites (ranged from 27,200 seeds/$m^2$ to 82,600 seeds/$m^2$) by Senbetu et al. (2002) and Gera Ades moist evergreen Afromontane forest (10,333 - 93,293 seeds/$m^2$) by Kassahun et al. (2009).

**Effects of plantation forest on selected soil physicochemical properties:**

The bulk density shows compaction of the soil and directly shows the infiltration rate of the soil, Abiyu et al. (2011) found 0.9 g $cm^{-3}$ in 0-10 cm and 0.9 g $cm^{-3}$ in 10-20 cm soil depths of *Eucalyptus* plantation forest in Tehuledere district Northern Ethiopia. However, Balieiro et al. (2008) showed a higher soil bulk density of 1.24 g $cm^{-3}$ under *Eucalyptus* Plantation forest than native forests (0.66 g $cm^{-3}$) in a Brazilian soil at a soil depth of 0-15 cm. Nutrients occur in available forms at a soil pH of 5.5 to 6.5 (Jones, 1993). Therefore, the natural forest soil is likely to be more fertile with a greater availability of plant nutrients. The result was in line with Abiyu et al. (2011) who reported soil pH: exclosure> *Cupresses lustanica* >*Eucalyptus* plantation forest. When the soil depth increases, the soil organic content decreased in the two adjacent natural forest. This result is in line with Abiyu et al. (2011) in Tehuledere district, Behera (2003) in Kenya, and Kidanu et al. (2005) in Jufi plantation forest, Ethiopia. Phosphorous concentration falls below the medium sufficiency range, the relatively lower available phosphorus in plantation forest may be due to the low pH (higher amount of soil available phosphorus fixed/adsorbed Albert (2016). Aweto and Moleele (2005) reported that *Eucalyptus* species have a higher capacity of immobilizing phosphorus, and make them inaccessible for plant use. Berendse (1998) adds that at soil pH of below 5.5, soil trace nutrients like Aluminum availability increases to levels that are unsuitable for most plant growth and soil soluble phosphorus tends to form insoluble compounds with Aluminum and iron in acidic soils, which are inaccessible to native plants. The result was in line with Polglase et al. (1992) who found lower phosphorous in the 0–5 cm depth soil under *Eucalyptus* Plantation forest. Furthermore, Tilashworki et al. (2009) reported that phosphorus concentration in *Eucalyptus* plantation within 2 cm depth soil was in the very low range (< 5 mg $kg^{-1}$) in Ethiopia. But Abiyu et al. (2011), reported that available phosphorus concentration; *Eucalyptus glubules* > enclosure > *Cupresses lustanica* plantation with the depth of 0-10 cm. The Nitrogen concentration was high in the natural forest, which were in line with Abiyu et al. (2011) in Tehuledere district and Kidanu et al. (2005) in Jufi plantation, Tilashworki et al. (2009) reported lower soil Nitogen in koga, Ethiopia. Nitrogen in the soil is partly reflected by rate of decomposition (Cao et al., 2010). As a result, *Eucalyptus* produce litter with low nutrient concentrations, which decomposes slowly to release low concentrations of nutrients (Aweto & Moleele, 2005; Cao et al., 2010; Demessie et al., 2012), coupled with low soil pH and nitrogen mineralization. The potassium content was high from plantation to natural forest, which was in line with Abiyu et al. (2011). Kidanu et al. (2005) in Jufi plantation also reported there is a reduction in $K^+$ concentration with increasing in depth. Although the CEC were high in the natural forest, which was the same as jufi, plantation forest reported by Kidanu et al. (2005).

In conclusion, our results indicate that tree plantations can be useful to foster natural regeneration of native woody species, particularly on sites where soil seed banks of native forest species are lacking. However, the need to have seed sources in the vicinity to facilitate the regeneration of native woody species under the canopies of tree plantations is a pre-requisite.

Therefore, it is very important to keep enough natural forests not only to maintain seed sources in the vicinity but also habitats for seed-dispersing animals. Many of these trees are important for their timber production capacity, bees forage, medicinal or soil conservation potential, also found at neighboring native woodland or under *Eucalyptus* plantation forest. Thus, *Eucalyptus camaldulensis* plantation forest, when it is established with wider spacing, can allow more light to reach the understory, and serve as a nurse tree, intern, it plays a role in biodiversity conservation and to rehabilitate degraded lands. But the costs and benefits of planting *Eucalyptus* need careful assessment based on detailed site studies with due consideration to both environmental and socio-economic needs.

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