SOIL SEED BANK ANALYSIS OF WOODY PLANTS ALONG NATURAL FOREST LANDSCAPES OF NORTHERN ETHIOPIA: THE CASE OF DESA’A AND HUGUMBURDA NATURAL FORESTS.

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In Ethiopia, the Afromontane forests have experienced severe deforestation and forest degradation and loss of biodiversity. Hence, there is a need for soil seed bank to play a great role in rehabilitation and restoration of degraded areas. However, assessment of soil seed bank has not been of research interest. Therefore, this study was conducted to determine the soil seed bank status in the dry ever green Afromontane forests of Northern Ethiopia. We collected soil samples from sites spanning seven elevations (1900, 2000, 2100, 2200, 2300, 2400 and 2500) and transported them to a glasshouse for germination trials for species identification. Aboveground vegetation was also identified. The study was covered by locating transect lines across altitudinal gradients at 100 m elevation difference. About 8 and 10 woody species were recorded in Hugumburda and Desa’a forest respectively. Combretum aculeatum, Snowdend polystach, Pennisetum thunbergii, Arthaxoxon pinodes, Aychrannerthes aspen and Sonclus oleracous dominated the soil seed bank. Olea europacea subsp. Cuspidata and Juniperus procera were frequent in aboveground. The Jaccard similary coefficients (JSC) between soil seed bank and abovegrounds were ranged between 0.0377 and 0.156 in both sites. The JSC between the two sites was 0.275. Soil depth and altitude showed no significant effect on seed density and diversity (P > 0.05). Interventions such as reduction of anthropogenic effects, afforestation, site manipulation to improve environmental conditions for seedling establishment and growth should also be considered. In addition, protection of the remaining trees on the aboveground is urgent to maintain ecological balance.

Key words: Soil seed bank, Remnant forests, Biodiversity, Altitudinal gradients, native woody species

INTRODUCTION

Owing to the multidimensional services they provide, forests have been receiving much pressure to the extent that future sustainability falls under threat (Senbeta and Teketay 2002). Occurrence of intensive pressure on forests is especially magnified for sub-Saharan African countries (Blay 2004) and Eastern Africa (Amente 2006). In Ethiopia, the Afromontane forests have experienced severe deforestation and forest degradation (Kindu et al 2013, Teketay et al 2010). According to Reusing (2000), who used satellite imagery to monitor forest cover change, the natural high forest cover of Ethiopia drastically reduced to 4.75% between 1973 and 1976, and then, lessened to 3.93% between 1986 and 1990 with the annual forest loss growing to about 39,000 ha. In the 1990s, the forest cover further went down roughly to around 3% (Bishaw 2001). The forest cover of Tigray had risen by 1.22% from 1985 to 2000, and then, declined by 1.24% in 2012 (Jarno 2015). In Tigray, forests remained to only inaccessible areas and around holy places (Darbyshire et al 2003) in a fragmented (Ermas et al 2006) and heavily disturbed state which led to the local extinction of some important tree species (Ermas et al 2006). Land use and land cover change (Nyssen et al 2004, Solomon et al 2018), fuelwood collection (Fitsum et al 1999, Zenebe 2007) and free grazing (Solomon et al 2018) are the major causes of forest degradation in northern Ethiopia. The frequency and severity of the ongoing disturbance influences the density, biodiversity and regenerative processes of a forest stand and it may lead to species extinction or heavy fragmentation that negatively affects restoration possibilities (Lemenih and Teketay 2006). This may also cause to the modification of soil seed bank.
Soil seed bank plays a great role in plant diversity and arrangement of plant communities (Santos et al. 2010). In degraded tropical forest lands, restoration relies on natural regeneration. Therefore, understanding of regeneration mechanisms is essential towards a successful implementation of forest rehabilitation. Soil seed bank is one of the major sources of natural regeneration (Tessema et al 2012). Assessing the extent and level of diversity of soil seed banks is essential for planning conservation and restoration programs because soil seed banks can provide significantly to the composition of future plant communities (Teketay 2005, Zaghoul 2008). Actually, the composition and diversity of soil seed banks are the main factors for the success of restoring degraded ecosystems (Bossuyt and Hemy 2003, Luzuriaga et al. 2005). Therefore, to ascertain the potential for adequate regeneration, the availability of viable soil seed banks must be known (Teketay 2005).

In Ethiopia, several studies have been carried out aiming at regeneration and soil seed banks in Afromontane forests (Teketay 1997a, Tekle and Bekele 2000, Lemenih and Teketay 2006, Kebede et al 2012, Tessema et al 2012). However, Hugumburda and Des’a’a national forest priority areas have not been studied to date; in addition, Asefa et al (2003) suggested soil seed bank study in the area. Hence, this research tried to quantify the soil seed bank reserve along altitudinal gradients of Hugumburda and Des’a’a natural forest remnants as a means for rehabilitation of degraded forest landscapes. Specifically, the study (i) quantified the soil seed bank abundance and diversity of the two forests; (ii) analyzed the similarity between soil seed bank and the aboveground vegetation; and (iii) assessed the soil seed bank potential for possible future rehabilitation efforts.

MATERIALS AND METHODS

Study area

The study site includes two natural forest reserves, namely Des’a’a and Hugumburda forests. Des’a’a forest is located between 13°20’ and 14°10’N latitude and 39°32’ and 39°55’E longitude, having an area of 120,026 ha at an altitude of between 1500 and 2500 m.a.s.l (BLI 2007). The forest area extends from Atsbi-wonberta Woreda of Tigray down to the lowlands of Afar region. Hugumburda forest is located between 12°33’ and 12°42’N latitude and 39°30’ and 39°39’E longitude at an altitude ranging between 1600 and 2600 m.a.s.l (BLI 2007). The forest comprises an area of 6842 ha; in Offla woreda.

The annual average rainfall of Des’a’a forest is between 406 and 692.5 mm. The mean annual temperature is 17 °C. The mean annual temperature for Hugumburda lies between 14.6 °C and 22.4 °C and its mean monthly rainfall ranges between 800 and 1000 mm. The topography of the study sites is varied and includes some flatter areas and gentle slopes as well as steep escarpments. The soil is shallow in inclined surfaces and deep and fertile in the valley bottoms (BLI 2007). The dominant soil types in the study areas are Leptosols, Cambisols, Vertisols, Regosols and Arenosols (Aynekulu 2011). On the Des’a’a part, the dominant tree species are Juniperus procera, Olea europaea sub species cuspidate and Acacia spp. including A. origena, a species only found on the eastern escarpment of Ethiopia and Eritrea, and in Yemen (BLI 2007). In addition, a range of small understory trees and bushes are found. The plateau above the escarpment is heavily cultivated and the forest provides valuable grazing, particularly in the dry season for the Afar people. In Hugumburda, the forest is dry evergreen/coniferous with Juniperus procera, Olea europaea sub spp. cuspidata and some Podocarpus falcatus in the higher sections. On lower slope, Millettia ferruginea, Croton macrostachyus, Celtis africana, Ekebergia capensis, Prunus africana, Cordia africana and Ficus spp. are more common (BLI 2007).

Sampling of soil seed bank and aboveground vegetation

We employed a systematic random sampling technique. A topographic map of Korem and Aguale areas (20 m contour interval) were first digitized with ILWIS software. Then, after the boundaries of these forests are located on the digitized map, transects were laid, based on the latitudinal ranges running east-west of the map. For each of Des’a’a and Hugumburda forest, we laid out four parallel line transects, covering altitudinal gradients “1900 m.a.s.l” to “2500 m.a.s.l”. The distance between each line transect was kept at 1 km. In both sites, on average, 5 sampling lots were located at 100 m elevation difference each along the transects (Wassie and Teketay 2006). In total, 41 plots (20 in Des’a’a and 21 in Hugumburda) were located. The respective spatial coordinates of each plot were read from geo-referenced topographic map (20 m contour interval) after uploaded to a GPS.

Above-ground vegetation identification were conducted using a 20 m × 20 m quadrat. In each of the selected plots, all vascular plants encountered were identified and the number of individuals for the woody species was recorded. Five 15 m × 15 m subplots within the main plot were designated for soil seed sampling. Soil samples for the determination of
seed abundance and diversity were collected from 0-3 cm, 3-6 cm and 6-9 cm. The soil samples were collected using a core sampler. A composite soil sample was placed in a cotton sampling bags and taken to a glass house found in Mekelle University for germination trail. The soil sample collection was conducted between December and January 2008, when seed persisting from the previous growing season could still germinate and seed dispersal in the current season was peaking.

To remove the smallest soil particles, bigger stones and rough organic material, and to divide samples in a rough and a fine fraction, soil samples were sieved using four mesh sizes of respectively 4 mm, 3 mm, 2 mm and 1 mm. The soil samples were taken to the glass house for six-month germination trial (Teketay and Granström 1995). Germinated individuals were marked with toothpicks using different colors of markers (red, blue and green) to differentiate levels of growth. Seedling germination was checked every week and seedlings readily identified were recorded and discarded. Unidentified species were left to grow more until they were identified. Species found difficult to identify were further identified in Addis Ababa university herbarium collection.

Data analysis
Normality of the data was checked using Shapiro-Wilk W test. Then, two-way ANOVA was used to test for significances of spatial distribution of seed banks with the help of JMP-5 at 95 % confidence interval. Least significant difference (LSD) was used for mean separation for those variables found to differ significantly between the treatments. Species diversities both for the soil seed bank and aboveground vegetation were calculated using Shannon-Wiener diversity index, equation below:

\[ H = - \sum p_i \ln p_i \]

Where, \( p_i \) is the proportion of individuals found in the \( i \)th species and \( \ln \) is the natural logarithm.

Similarities between the two study sites of corresponding altitudinal gradients as well as aboveground vegetation and the soil seed bank of corresponding altitudes were analyzed using Jaccard index of similarity as follows:

\[ JCS = \frac{a}{a + b + c} \]

Where:
- \( JCS \) = Jaccard’s Similarity Coefficient
- \( a \) = species common to quadrat 1 and 2
- \( b \) = species present in quadrat 1 but absent in 2
- \( c \) = species present in 2 but absent in 1

RESULTS
Species composition, abundance, diversity and similarity of seeds in the soil
A total of 975 from Hugumburda and 723 from Desa’a seeds were germinated. The seed bank was dominated by herbs contributing 75% for Hugumburda and 87.2% for Desa’a. The average seed bank densities per plot for Hugumburda and Desa’a were 1845.5 m\(^{-2}\) and 1310.9 m\(^{-2}\) respectively. There were 179 individual seeds recovered from sieving for Hugumburda forest. These were from three species of different families, namely: Dodonaea angustifolia, Juniperus procera and Olea europaea. Juniperus procera and Olea europaea represent 51.4 % of the total species recovered. About 50.8 % from the total number of recovered seeds were finally found to be non-viable mostly dead. Seed recovery and intern viability test revealed that 189 individual seeds were recovered from Juniperus procera, Olea europaea and Dodonaea angustifolia respectively from Desa’a forest. About 63.5 % of all recovered individual seeds lost their viability. About 56.5 % viable seeds belong to Juniperus procera (43.5 %) and Olea europaea (13 %). Most of the non-viable seeds were from Juniperus procera and Olea europaea of which Olea europaea accounted for most.

In Hugumburda, the three species with the highest soil seed densities in descending order include Combretum aculeatum 461.25 m\(^{-2}\), Snowdenig polystache 139.5 m\(^{2}\), Pennisetum thunbergii 112.5 m\(^{2}\). In Desa’a, 35.5% of the composition consisted of only three species, namely: Arthraxon prionodes 10.9%, Achyranthes aspera 14.2% and Sonchus oleraceus 10.4%. The total number of woody species recorded was 8 from Hugumburda and 10 from Desa’a forest (Table 1 and 2).
Table 1. Abundance (AB), composition (COMP), density (D) and frequency (Fr) of woody species for Hugumburda seed bank.

<table>
<thead>
<tr>
<th>Species name</th>
<th>AB</th>
<th>COMP (%)</th>
<th>D (m²)</th>
<th>Fr %</th>
<th>Fr class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berberis holistii engl.</td>
<td>6</td>
<td>0.7</td>
<td>13.5</td>
<td>7.9</td>
<td>1</td>
</tr>
<tr>
<td>Combretum aculeatum</td>
<td>205</td>
<td>23.5</td>
<td>461.3</td>
<td>58.7</td>
<td>6</td>
</tr>
<tr>
<td>Cupressus Lusitanica</td>
<td>1</td>
<td>0.11</td>
<td>2.25</td>
<td>1.6</td>
<td>1</td>
</tr>
<tr>
<td>Dodonaea angustifolia</td>
<td>5</td>
<td>0.57</td>
<td>11.25</td>
<td>3.1</td>
<td>1</td>
</tr>
<tr>
<td>Echinops macrochaetus, Fresen.</td>
<td>3</td>
<td>0.3</td>
<td>6.75</td>
<td>3.1</td>
<td>1</td>
</tr>
<tr>
<td>Lawsonia inermis</td>
<td>5</td>
<td>0.57</td>
<td>11.25</td>
<td>3.1</td>
<td>1</td>
</tr>
<tr>
<td>Leucas glabrata (vahl.) Smith.</td>
<td>5</td>
<td>0.57</td>
<td>11.25</td>
<td>3.2</td>
<td>1</td>
</tr>
<tr>
<td>Withania somnifera</td>
<td>4</td>
<td>0.45</td>
<td>9</td>
<td>4.8</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Abundance (AB), composition (COMP), density (D) and frequency (Fr) of woody species for Desa’a seed bank.

<table>
<thead>
<tr>
<th>Species</th>
<th>AB</th>
<th>COMP (%)</th>
<th>D (m²)</th>
<th>Fr (%)</th>
<th>Fr class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anogeisus leiocapus</td>
<td>1</td>
<td>0.7</td>
<td>40</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>Cadia purpurea</td>
<td>1</td>
<td>0.7</td>
<td>28.9</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>Euclea shimperi</td>
<td>6</td>
<td>1</td>
<td>13.3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Grewia ferruginea</td>
<td>3</td>
<td>0.5</td>
<td>4.4</td>
<td>3.3</td>
<td>1</td>
</tr>
<tr>
<td>Lawsonia inermis</td>
<td>4</td>
<td>0.7</td>
<td>6.7</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Maytenus senegalensis</td>
<td>2</td>
<td>0.3</td>
<td>17.8</td>
<td>3.3</td>
<td>1</td>
</tr>
<tr>
<td>Sapium ellipticum</td>
<td>5</td>
<td>0.8</td>
<td>4.4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Tarchonanthus camphoratus</td>
<td>4</td>
<td>0.7</td>
<td>4.4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Withania somnifera</td>
<td>13</td>
<td>2.2</td>
<td>6.7</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

In Hugumburda, seed density generally increased with altitude. 2500 m elevation was found to have higher density m² followed by 2300 m and 2400 m elevation (Fig. 2). The least seed density was recorded in 2100 m elevation. The highest Shannon diversity value was H’=3.13 recorded at 2400 m elevation and lowest was H’=1.895 recorded at 1900 m elevation for Hugumburda (Fig. 1). In Desa’a forest, there was no distinct type of seed bank distribution across the elevation levels. The middle altitudes (2300 m, 2200 m and 2100 m) were found to have better density/m² (Fig. 2) and the highest Shannon diversity was obtained from 2200 m (H’=2.6356) and the lowest were at 2500 m (H’=2.416) (Fig. 2).
Figure 1. Density and diversity along altitudinal gradient for Hugumburda.

Figure 2. Density and diversity along altitudinal gradient for Desa’a.

In Hugumburda forest, the top layer of the soil (0-3 cm) contains 441.54 seeds m$^{-2}$, followed by the subsequent layer 320.29 m$^2$ and bottom layers 243.67 m$^2$ (Fig. 3).

Figure 3. Layer abundance for Hugumburda.
Similarly, in Desa’a forest, highest seed abundance was recorded in the top soil layer and the lowest was recorded in the bottom layer (Fig. 4).

![Layer A.](image)

**Figure 4.** Layer abundance for Desa’a.

In Hugumburda forest, H’ increased from 0-3 cm (top) to 3-6 cm (middle) and 6-9 cm (bottom) with 3.047, 3.15 and 3.28 values respectively (Table 3). On the other hand, Shannon diversity decreased from top (0-3 cm) to bottom (6-9 cm) soil layers in Desa’a forest (Table 3). In Hugumburda, Shannon evenness value ranged from 0.783 to 0.882, with the highest value recorded in 3-6 cm soil layer and the lowest recorded in 0-3 cm soil layer. In Desa’a forest, Shannon evenness value ranged between 0.078 and 0.878, with the highest recorded in the 3-6 cm soil layer (Table 3).

<table>
<thead>
<tr>
<th>Soil Layer</th>
<th>Site</th>
<th>Species richness (average total)</th>
<th>A</th>
<th>H’</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 1</td>
<td>Hugumburda</td>
<td>49</td>
<td>417</td>
<td>3.047</td>
<td>0.783</td>
</tr>
<tr>
<td></td>
<td>Dessea</td>
<td>35</td>
<td>324</td>
<td>2.83</td>
<td>0.7965</td>
</tr>
<tr>
<td>Layer 2</td>
<td>Hugumburda</td>
<td>46</td>
<td>286</td>
<td>3.15</td>
<td>0.882</td>
</tr>
<tr>
<td></td>
<td>Dessea</td>
<td>26</td>
<td>189</td>
<td>2.79</td>
<td>0.8575</td>
</tr>
<tr>
<td>Layer 3</td>
<td>Hugumburda</td>
<td>42</td>
<td>169</td>
<td>3.28</td>
<td>0.8788</td>
</tr>
<tr>
<td></td>
<td>Dessea</td>
<td>22</td>
<td>88</td>
<td>2.71</td>
<td>0.078</td>
</tr>
</tbody>
</table>

Table 3. Comparison of ecological parameters between Hugumburda and Desa’a forests.

Where: A is Abundance, H’ is diversity and E is evenness

Jaccard similarity between soil seed bank and aboveground vegetation for Hugumburda was recorded at 0.11. Similarly, in Desa’a 0.093 Jaccard similarity was recorded for the soil seed bank and aboveground vegetation. In Hugumburda, similarities between corresponding altitudes of seed bank and aboveground were also ranging between 0.03774 (at 2500 m and 2300 m) and 0.09434 (2400 m). Corresponding altitudes of soil seed bank and aboveground vegetation had values ranging between 0.08 (2000 m) and 0.156 (2300 m) in Desa’a forest. The total types of species encountered from both Hugumburda and Desa’a seed banks amount 79, 22 of which was common to both sites. About 37 of the 79 species belong to Hugumburda only, while the rest 21 belong to Desa’a only. The Jaccard similarity value between the forest sites was 0.275.

Species composition, abundance, diversity and similarity for aboveground vegetation

A total of 6,043 and 3,892 individual plants were identified from the abovegrounds of Hugumburda and Desa’a forest respectively. Average numbers of individuals were 7,250 ha⁻¹ and 4,865 ha⁻¹ for Hugumburda and Desa’a respectively. In Hugumburda, species were composed of 44.12 % trees, 47.06 % shrubs and the rest 8.82 % herbs. In Desa’a, the species consists of 38.7 % trees, 41.93 % shrubs and 19.35 % herbs.
The total number of woody species recorded was 40 from Hugumburda and 29 from Desa’a. In Hugumburda, the three most abundant species composing 17.5%, 11.2% and 10.97% respectively were Monotheicum glandulosum, Combretum aculeatum and Cadia purpurea. Similarly, in Desa’a, the most abundant species was Monotheicum glandulosum 17.5% followed by Combretum aculeatum (11.2%) and Cadia purpurea (11%). The important tree species Olea europaea subsp. Cuspidata, Juniperus procera and Podocarpus falcatus comprised 10.3% for Hugumburda and 8.3% for Desa’a.

Highest abundance of Juniperus procera and Podocarpus falcatus was recorded in 2200 m elevation, while highest abundance of Olea europaea subsp. Cuspidata was recorded in 2300 m elevation. Abundance for Olea europaea subsp. Cuspidata and Juniperus procera increased with altitude in Desa’a forest. Olea europaea subsp. Cuspidata is more abundant than Juniperus procera in Desa’a forest.

The heterogeneity measure Shannon diversity index was H’ = 2.935 for Hugumburda and H’ = 3.075 for Desa’a. The Shannon evenness value was E= 0.736 and E = 0.771 for Hugumburda and Desa’a forest respectively. Species altitudinal distribution was also supported by Jaccard similarity values. The highest similarity index (0.72) was recorded between 2300 m and 2100 m for Hugumburda, while the lowest value was 0.42 between 2400 m and 1900 m and 2300 m and 1900 m. In Desa’a, the highest similarity index was recorded between 2300 m and 2200 m that was 0.57.

DISCUSSIONS

The results from the soil seed bank analysis revealed that viable seeds of native woody species were generally few in the soil seed bank as compared to the aboveground flora found. Consequently, there was low overall similarity between the species recovered from soil seed bank taken from both the sites with the aboveground vegetation. However, this finding does not rule out the occurrence of the eight and ten woody species found in Hugumburda and Desa’a respectively. In line with this study, Lemenih and Teketay (2005) found that a rare viable seeds of native woody species in the soil of Ethiopian highlands. The occurrence of few woody species seeds in the soil banks might be attributed to the short-lived nature of the seeds of most woody species in the dry Afromontane forests of Ethiopia (Teketay and Granström 1995, Teketay 2005).

Some dry Afromontane forest species such as Juniperus procera and Olea europaea subsp. Cuspidata had low germination in the seed bank. The result was in agreement with previous studies (Aerts et al 2006, Khurana and Singh 2001, Teketay 1997b) who stated Afromontane forest species lack persistent seed reserve. This might be partially contributed by the short germination period nature of the species after dispersal (Teketay 1993, Teketay 2005). Predation is the other factor that could significantly change the situation; this was proved by the non-viability of most of the recovered seeds in this study. Similarly, Teketay and Granström (1995) found that rodents ate Juniperus procera, Olea europaea subsp. cuspidata and Podocarpus falcatus seeds after seed rain. Moreover, the loss of seeds by erosion due to high degradation in Northern Ethiopia might also be a reason for the low seed bank (Birhane et al 2006). Those species lacks long distance dispersal ability (Teketay and Granström 1995) and prefer seedling-sapling route (Bekele 2000).

The dominance of herbaceous species was reported in both sites of this study. In fact, this is consistent with various studies carried out on soil seed bank (Birhane et al 2006, Senbeta et al 2002, Teketay 2005, Tesfaye et al 2004, Argaw et al 1999). The domination of herbaceous species might be due to the ability of gap colonizing as Teketay and Granström (1995) discussed. Other reason supported by Teketay and Granström (1995) for the phenomenon was the ability of herbs to recruit by minor disturbances and in turn incorporation of seeds into the soil. Species traits also affect density of herbaceous seeds in the seed bank. Previous studies revealed that herbaceous seeds in the soil remain viable for longer than other seed types (Ghersa and Martinez-Ghersa 2000).

In Hugumburda, seed density generally increased with altitude. However, the difference in seed density across altitude was not significant (P = 0.2144). Similarly, in Desa’a forest, there was no distinct type of seed bank distribution across the elevation levels. In line with this study, Lippok et al (2013) revealed that altitude had no effects on seed density. Previous studies found that the seed density of soil seed bank peaked at an intermediate elevation (Erfanzadeh et al 2013, Luo et al 2017). This seems to be true for the Desa’a forest in our study. In the present study, both study sites recorded highest species diversity at an intermediate altitudes. In agreement with this study, Luo et al (2017) also found higher species diversity of soil seed bank at an intermediate elevation. However, Lippok et al (2013) reported that altitude had no effects on species richness.

Though, the difference in seed density across the soil layers was not significant, highest seed density was recorded in the top layer of the soil in both sites.
The total seed bank density decreases as the soil layer depth increases. This observation is consistent with some earlier studies in Ethiopia (Senbeta and Teketay 2001, Silesshi and Abraha 2014). Similarly, Tessema et al (2012) indicated that seed density decreased with increasing soil depth. Seeds of tropical vegetation are generally more abundant near the surface as stated by Young (1985). Furthermore, in Hugumburda forest, species diversity increased from top layer to the lower soil layer. Similarly, Wang et al (2009) found that there was lower species richness and seed density in the lower soil layer than in the upper soil layer in four 22 year old plantations. This pattern may be attributed to seed size (Decocq et al 2004) and the vertical movement of seeds (Guo et al 1998), an explanation supported by the current study’s finding that large-seeded species such as Podocarpus falcatus only appear in the upper soil layer while the smaller seeds of herbaceous species dominate in the lower soil layer. However, the case of Desa’a is different from Hugumburda. In Desa’a, species diversity did not show any pattern.

A Jaccard similarity between soil seed bank and aboveground vegetation for both sites were relatively low, but was higher for Hugumburda than Desa’a forest. Many dominant species, including some overstory species, are absent from the soil seed banks. Low similarity in species composition between the soil seed banks and aboveground vegetation was also reported in a semi-arid Savanna of Ethiopia (Tessema et al 2012), natural forests (Lemenih and Teketay 2006) and church forest (Wassie and Teketay 2006). The low similarity between the soil seed banks and aboveground vegetation might be due to seed production and intrinsic attributes of seeds (Luzuriaga et al 2005). The scarcity of some species in the seed banks probably reflects the short persistence of their seeds in the soils (Hill and Stevens 1981). The scarcity of many aboveground species in the seed banks might also be affected by seed size, because seed size and seed longevity are often negatively correlated (Bossuyt et al 2002). In our study, the large-seeded woody species are among the least abundant species in the seed banks, while the small-seeded herbaceous species are the most abundant species in the seed banks. Furthermore, the Jaccard similarity value between the forest sites was also relatively low (27%). This might be due to the difference in disturbance level and variation in some biophysical characteristics between the two sites.

In the current study, the soil seed banks of the natural forests contain relatively few species and are dominated by herbaceous species. Furthermore, seed density decrease with soil depth, indicating a transient soil seed bank under these natural forests. Furthermore, most of the woody species identified in the seed banks are also found in the aboveground vegetation, and few viable seeds of woody species are observed. These results indicated that the soil seed banks in the study area play a minor role in forest regeneration and rehabilitation. Therefore, forest rehabilitation should not depend on such existing soil seed banks as also stated by Decocq et al (2004) and Wang et al (2009). Managed primary forests may serve as major seed sources for indigenous tree species, and seed dispersal from adjacent natural forests plays a major role in the recolonization of native species (Lemenih and Teketay 2005).

CONCLUSIONS

The aim of this study was to generate knowledge that could support efforts to improve the rehabilitation of degraded areas in the two natural forests and similar environment. The results revealed that there is low diversity of woody species in the two study areas. The seed banks were dominated by herbaceous species. Soil depth and altitude had not a significant effect on seed density and diversity. Woody species regarded as important for the forest structure were in general poorly represented in the soil seed bank, while aboveground vegetation importantly represents ecologically valuable tree and shrub species that were not found in the seed bank composition. Although abundances of Juniperus procera and Olea europaea ssp. cuspidata were generally low, they were frequent in the aboveground, which indicates that the two species have wide altitudinal ranges and are still dominant in the two sites. Shrub species such as Combretum spp. and Cadia purpurea were found to be dominant in this study. The similarity between the aboveground vegetation and soil seed bank was very low. This can lead to poor natural regeneration of important species from soil seed bank and hence affects further development of the forests. Therefore, the role of seed bank in maintaining and developing the forests in this regard is very low, so human intervention is probably needed to speed up forest rehabilitation. Interventions such as reduction of anthropogenic impacts in the forest area, enrichment planting, site manipulation to improve environmental conditions for seedling establishment and growth should be considered. Furthermore, studies should continue in other similar areas to understand the contribution of the soil seed bank in the rehabilitation of degraded areas. Moreover, soil seed bank dynamics should be studied using data from different seasons, since seed bank sampling on a single period may miss transient species.
REFERENCES


Tessema ZK, de Boer WF, Baars RMT and Prins HHT (2012): Influence of Grazing on Soil Seed