

Assessment of Soil Seedbank Composition of Woody Species in Hgumbirda National Forest Priority Area, Northeastern Ethiopia

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ABSTRACT

Detail study on soil seedbank composition and regeneration potential is needed for Ethiopian forests. In present work, soil seedbank assessment of woody plant species was made in Hgumbirda national forest priority area so as to evaluate composition and estimate their regeneration status. A total of 36 quadrates were established in selected four sites of the forest. The quadrates (20 m x 20 m) were laid along line transects. Soil samples were collected from sub-quadrates measuring 10 cm x 10 cm. Composition and status were determined by direct count and seedling emergence technique. Results showed the presence of seeds of 19 plant species in the soil. *Juniperus procera* had the highest viable seed density. Only *Afrocarpus falcatus* seeds were non-viable although very abundant (266.7seeds/m²). Except *Cupressus lusitanica*, no exotic woody species were found. The Shannon diversity index demonstrated low value for soil seedbank in Hgumbirda NFPA ($H' = 1.763$). There was also significant variation of seed distribution between soil layers of the four selected forest sites ($p < 0.05$). Jaccard's coefficient of similarity between the standing vegetation and soil seedbank showed low value (JCS = 0.21 - 0.43). From the results, appropriate management strategies including preparation of nursery sites for selected indigenous plant species is suggested.

Keywords: Soil, Seedbank, Woody species, Viable seeds, Afromontane, Hgumbirda forest, Regeneration, Ethiopia.

1. INTRODUCTION

Deforestation and conversion of land to permanent cultivation is the primary cause for dwindling tropical biodiversity and the practice has already threatened a number of plant species (IBC, 2005). In countries like Ethiopia where a rapidly growing human population is inducing overexploitation of the available productive natural resources, restoration of the vast degraded landscapes will have a valid and important role in harnessing sustainable development. In fact, restoration/rehabilitation of degraded lands is a subject receiving considerable attention in many parts of the world (Mulugeta Lemenih and Demel Teketay, 2006). One widely used option is creating exclosures, i.e. demarcated land areas under strict conservation management where intruders are excluded, often controlled by a local community. In these areas, cultivation, unmanaged collection of fuel wood and grazing are forbidden whereas harvesting of grass is strictly controlled in order to allow spontaneous forest regeneration from soil seedbank (Reubens et al., 2007). Dormant seeds (viable seeds that would germinate after favourable conditions are met) in the soil, collectively known as

the seedbank, play a crucial role in the patterns of vegetation (Hirsch et al, 2012). Seed dormancy or longevity is important parameter for the existence of a seedbank. Seedbanks are formed by seeds, either born and produced on site or carried to the site by dispersal agents and accumulated in the soil (Hirsch et al., 2012; Emiru Brhane et al., 2006, Carlo and Aukema, 2005).

In Ethiopia, as described by Mulugeta Limehah and Demel Teketay (2006), little was known about the survival of seeds of forest species in the below ground vegetation and their ecological implication for biodiversity. To our knowledge, and also as said by Reubens et al. (2007), the studies so far made on dry afro-montane forests including in northern Ethiopia are limited. Therefore, studies on soil seedbank in Ethiopian forests are necessary to draw the attention of forest policy makers and other concerned bodies.

From the above aspects, this investigation was focused on assessment of soil seedbank composition of woody species in Hgumbirda National Forest Priority Area (NFPA), which is being encroached. Scattered individual household settlements, small patches of farmlands and open pasture fields at the forest edges are common. North western part of the Hgumbirda forest was being used by the Maichew Particle Board, about 20 km far north. A study on underground vegetation (the soil seedbank) is very important to evaluate the regeneration status of the vegetation. This enables policy makers and the community to make appropriate interventions in managing this ecologically important afro-montane forest. But, to our knowledge there is no documented study on soil seedbank of Hgumbirda vegetation. Hence this study was designed to abridge the prevailing gap on the seedbank flora and relate it with the above ground vegetation.

2. MATERIALS AND METHODS

2.1. Description of Study Site

Hgumbirda National Forest Priority Area (NFPA) is located in the southern zone of Tigray at about 630 km north of Addis Ababa and some 160 km south of Mekelle, the capital of Tigray Regional State. It is located between 12° 36' and 12° 42' N latitude, and 39° 31' and 39° 34' E longitude at an altitudinal range of 2110 to 2688 meter above sea level (masl) (Fig1).

Based on the information obtained from a reconnaissance survey and floristic composition study of the forest (Luel Kidane et al., 2010; Ermias Aynekulu, 2011), the area was classified into four forest sites. The use of local name of each forest site was adopted following Reubens et al. (2007); and Zaghoul (2008). These forest community sites were found at

different topography and altitudes, had different types and levels of disturbance intensity; and the dominant and character species for each of the four forest community sites were different (Table 1 and Appendix I).

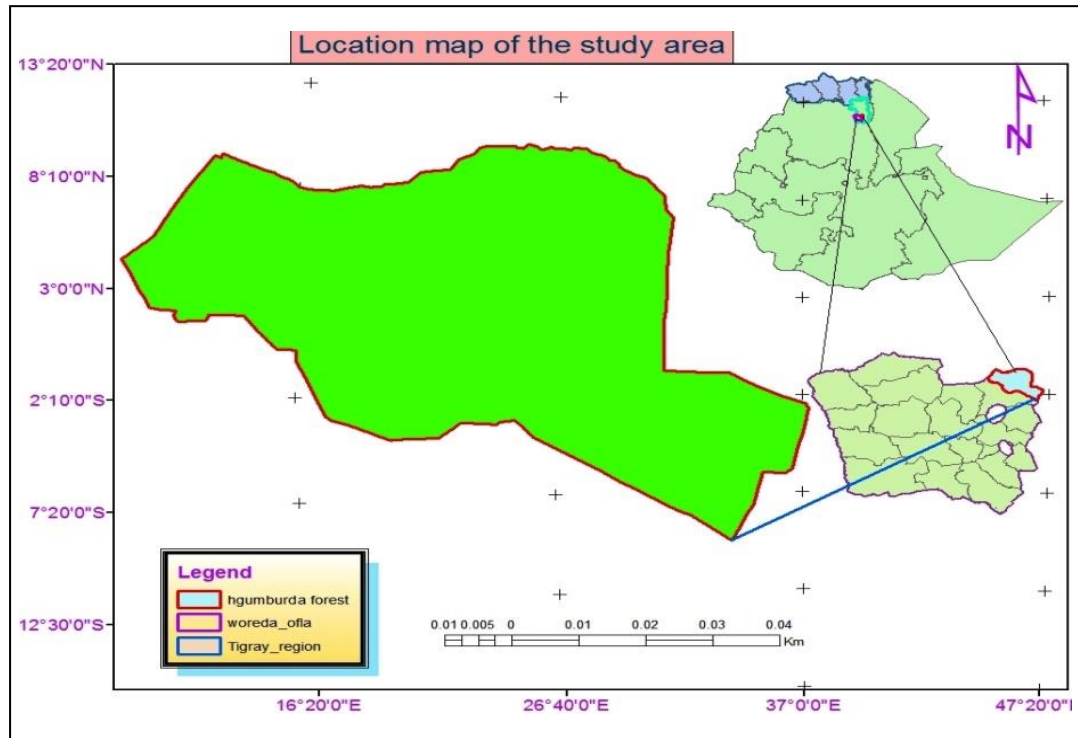


Figure 1. Hgumbirda NFA located in south Tigray Regional State (NE part of Oflla district).

Table 1. Comparative description of the studied forest sites of Hgumbirda NFA.

Forest Site	Description
Gerebshihaita	<ul style="list-style-type: none"> • Located adjacent to local residents and the most disturbed area except the church forests located in the far north. • Occur at altitudinal range between 2488 and 2601 m above sea level (masl). • Dominated by an indigenous shrub (<i>Becium grandiflorum</i>), which is used as honey bee forage.
Ksadaider	<ul style="list-style-type: none"> • Characterized by deep forest of <i>Juniperus procera</i>, which is the shelter for many wild animals. <i>Olea europaea</i> is found as character species. • Found at altitude of 2442 – 2487masl. • Relatively, it is well protected. On the rare occasion, local people use it for grazing purpose by their cattle.
Sebhiendodo	<ul style="list-style-type: none"> • The only site where <i>Afrocarpus falcatus</i> is extremely dominant with <i>Cupressus lusitanica</i> and <i>Juniperus procera</i> as character species. • Habitat for various wild animals. • Lies between altitudes of 2297 – 2321 masl. • Well protected deep forest (less intensity of disturbance) compared to others.
Bandra	<ul style="list-style-type: none"> • Occur at low altitude, 2170 – 2218 masl. • <i>Opuntia ficus-indica</i> is most abundant and used as food and feed by the locals. • <i>Cordia purpurea</i> and <i>Acacia tortilis</i> are character species in the shrub and tree layers, respectively. • High intensity of disturbance by local people, using it for their livelihood and their livestock.

2.2. Vegetation Data Collection

The composition of standing vegetation data of Hgumbirda forest was collected to study the similarity between above ground and soil seedbank flora. A total of 36 quadrants, nine quadrants in each of four forest sites were laid at 100 m interval along 1000 m long line transects having quadrant size of 20 m x 20 m (400 m²) following Esmailzadeh et al. (2011). The altitude of each quadrat was recorded by using global positioning system devices (GPS60 and GPS315). Plant species found within each sampling plot were photographed and identified by their vernacular and scientific names using the published volumes of flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards et al., 2000; Edwards et al., 1995; Azene Bekele, 2007) and NDA (Natural Database for Africa) software.

2.3. Soil Sampling

Soil seedbank density, diversity, vertical distribution and composition were assessed by collecting 144 soil samples (4 vertically successive layers x 36 plots) from 36 quadrants (9 in each four selected forest community sites along 100 m interval of 1000 m long line transects). Soil samples were collected carefully from the 3 separate soil layers, each layer was 3 cm thick (0-3 cm, 3-6 cm and 6-9 cm), totally 9cm deep as done by Feyera Senbeta and Demel Teketay (2001, 2002) by using digger and labelled metal rods (Appendix II). The litter layer was included with the soil samples as 4th layer because it contained a high number of seeds (Esmailzadeh et al., 2011). Then persistent seeds in each sample were counted following the methodology used by Getachew Tesfaye et al. (2004). The samples were taken from five points covering 10 cm x10 cm (one at the centre and the other four at the corners) of each 36 sample quadrants. Similar layers from these five points within a quadrant were mixed to form a soil composite in order to reduce variability within the quadrants. The composite sample for each soil layer was again divided into five equal parts among which one was randomly selected for further study.

Sampling was completed within two weeks to avoid differences between habitats, and thus any temporal bias in seed availability and composition following the method used by Toledo and Ramos (2011). The samples from each soil layer were used to determine variations of seed distribution at each depth of the soil layers (Mulugeta Lemenih and Demel Teketay, 2006). Soil samples from each layer were picked in to plastic bags and transported to the garden of Biology program, Bahir Dar University.

Soil samples were first sieved (Dainoua et al., 2011) with a mesh size of 2 mm and then using a mesh size of 0.5 mm to recover seeds of various plant species. The recovered seeds were

collected into paper bags and taken back to the study area for identification by discussing (asking) with local people and then checked with seeds of the above ground flora. Internet web pages were also used to know more about the recovered seeds. Once seeds were found and identified, their viability was determined using cutting test method following Eyob Tenkir (2006); and Feyera Senbeta and Demel Teketay (2002).

Since there is no universally accepted maximum duration for a germination test, cutting test is useful for many deeply dormant woody species to check maturity and quality of viable seeds and it was quick and uses low cost equipments than germination test. Since germination is highly influenced by environmental conditions (temperature, moisture, etc), dormancy breakage of many seeds may not be known, which add difficulty for determination of viability.

Soil samples remained after sieve were spread immediately in 20×20×6 cm rectangular plastic trays in Bahir Dar University nursery site, for germination of the seeds that were not recovered by sieving (Appendix II). Each plastic tray was perforated at the bottom and plugged by cotton to facilitate proper drainage of water without losing soil. To control and detect contamination of external seed rain, thin transparent plastic was stretched over the sample trays following Eyob Tenkir (2006). The seedling trays were kept continuously moist by daily watering following the method used by Toledo and Ramos (2011); and to avoid differences in light exposure, the position of the trays was changed every 2 weeks following the method used by Esmailzadeh et al. (2011). Daily temperature for the nursery site ranged from 20-30°C. The emerging seedlings were identified, counted, recorded and discarded. Photo of seedlings were taken to the study area to identify by the local people and confirmed by comparing with the standing vegetation. Seedling recruitment was terminated after 5 months (December 22, 2012 to May 22, 2013).

2.4. Data Analysis Techniques

In order to analyze the diversity of above ground vegetation, Shannon-Weiner index (H') (Shannon, 1948) was used following the method used by Fordjour et al. (2009); and Wolde Mekuria and Mastewal Yami (2013) and also for soil seedbank flora (Getachew Tesfaye et al., 2004; Tinsae Assefa, 2011). The species richness (S) and evenness (E) of soil seed bank composition in each soil profile was analyzed following methodology used by Getachew Tesfaye et al. (2004); and Perera (2005). Jaccard's coefficient of similarity (JCS) (Jaccard, 1901) was used to analyze the similarity between soil seedbank compositions among four forest community sites. Variance analysis of species abundance in each soil layer and forest

sites was done by ANOVA using SPSS software (Version 20). The composition and density of seeds in the soil was determined by combining the data obtained from sieving and germination. The density of seeds was derived from the total number of seeds recovered from the soil samples. On the other hand, to analyze the depth distribution of seeds in each, the number of seeds recovered in similar layers were combined and converted to provide the density of seeds/m² at that particular soil depth following methodology used by Getachew Tesfaye et al. (2004); and Eyob Tenkir (2006).

3. RESULTS AND DISCUSSION

A total of 54 standing woody species, representing 39 plant families were recorded from the four selected forest sites of Hgumbirda NFPA. There were 6 species in Gerebshihaita, 26 species in Bandra, 31 species in Sebiendodo and 34 species in Ksadaider. Almost all above ground woody species were dominated by shrubs followed by trees except the rare climbers in Ksadaider and Sebiendodo.

Out of the 54 standing woody plant species, 35 were exclusively represented by above ground flora and the rest 19 species (representing 13 families) were found in soil seedbank flora (17 from seed count and 2 from seedling emergence). This finding of only two woody species from the seedling emergence method is consistent with the findings of other authors such as Tinsae Assefa (2011) who worked on the seed bank composition of Bezawit forest at Abay Millennium Park, Ethiopia. Tinsae found 28 species out of a total of 48 species in the standing vegetation to be represented by the seedbank flora of Abay Millennium Park. Only five of the species were recovered by seedling emergence method. The reason for a lesser number of species recorded by the seedling emergence method may be due to recovery of most seeds by the seed count method similar to the result found by Eyob Tenkir (2006), and lack of suitable weather conditions comparable to study area for germination (Demel Teketay, 2005).

From the 19 woody species recovered in the soil seedbank 5, 10, 11, and 7 were recorded from Gerebshihaita, Ksadaider, Sebiendodo and Bandra forest sites, respectively. Similar to other Ethiopian afro-montane forests reported by different authors (Feyera Senbeta and Demel Teketay, 2002; Getachew Tesfaye et al., 2004; Mulugeta Lemenih and Demel Teketay, 2006; Reubens et al., 2007) most of these rare woody species recorded from seedbank flora belonged to shrubs and trees but no climbers except in Ksadaider (Fig.2). This finding, less number of woody species in seedbank, could be due to relatively short residence time of most

woody species (Demel Teketay, 2005) except *Juniperus procera*, which was the dominant species, accounting to 50.5% of the seed bank flora. This high number of seeds of *Juniperus procera* in Hgumbirda NFPA is similar to the result of other works (Feyera Senbeta and Demel Teketay, 2002; EyobTenkir, 2006). They reported high accumulation of *Juniperus procera* and had high potential to regenerate from seeds buried in the soil of Ethiopian afro-montane forests.

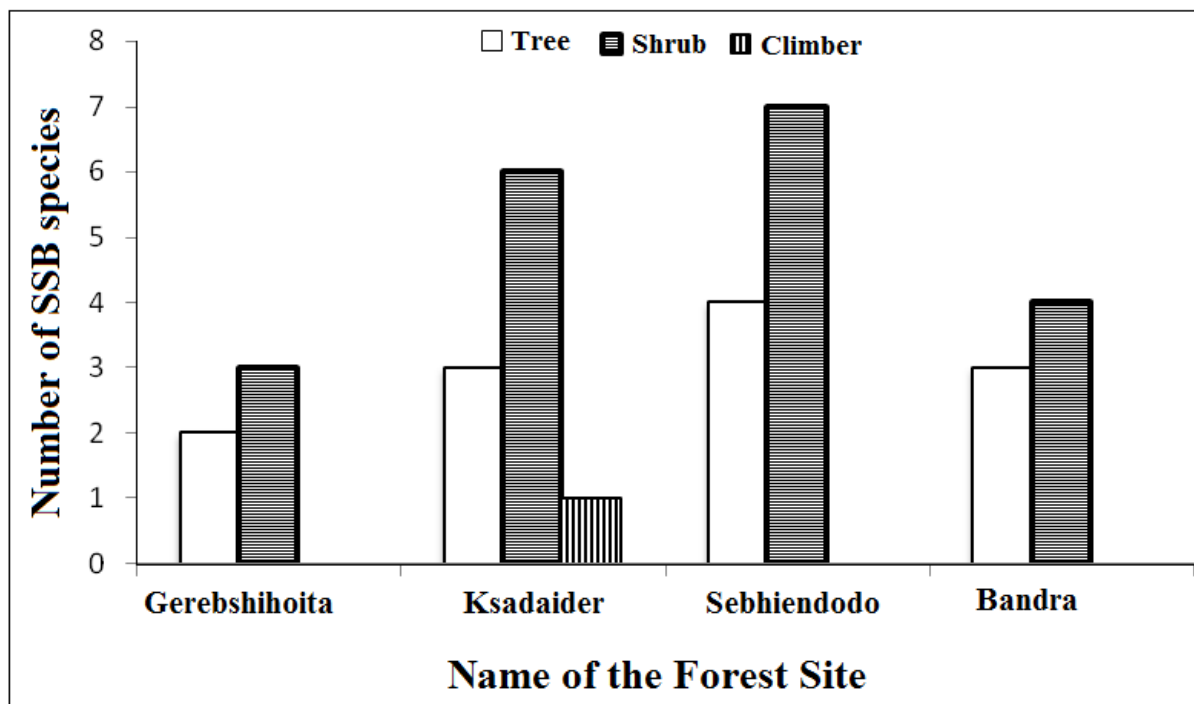


Figure 2. Number of soil seedbank of woody flora with their corresponding habit recorded from four forest sites of Hgumbirda NFPA.

Additional probable reason for the minority of seeds of woody species other than *Juniperus* in the seedbank might be the size and fleshy nature that attract animals which may affect germination of seeds by aborting the fruit before maturation as well as killing the seed in digestive tracts (Rawda, 2007); and seeds which lack apparent adaptation for dispersal may be eroded by disturbances. According Eyob Tenkir (2006) seeds of woody species which lack dispersal adaptation are carried in mud, on the feet of animals; and those seeds which have adaptation for attachment to skin are dispersed to another site. Mulugeta Lemenih and Demel Teketay (2006) also noted that as long as seeds of woody species remain on the surface they are either attacked by predators or immediately germinate. As previous studies (Feyera Senbeta and Demel Teketay, 2001; Feyera Senbeta et al., 2002; Mulugeta Lemenih et al., 2004; Mulugeta Lemenih and Demel Teketay, 2006) have indicated, most woody species in

the dry Afromontane forests of Ethiopia depend on seed rain and formation of seedling banks under the shades of mature forest canopy as strategies for regeneration.

3.1. Similarity between Soil Seed Bank Flora of Four Forest Sites

The similarity in species composition of the soil seedbank between the four forest sites was generally low and ranged from JCS values of 0.07 to 0.4 (Table 2). Highest and lowest JCS values are 0 and 1, respectively. This finding is fairly similar with other researchers, namely EyobTenkir (2006) who reported low similarity among ten sites of Dodola forest in Ethiopia; and Mulugeta Lemenih and Demel Teketay (2006) who reported low JCS value among different aged farm fields and natural forests of tropical dry afromontane forests in Ethiopia. In Hgumbirda, *Afrocarpus falcatus*, *Dodonaoea angustifolia* and *Cadia purpurea* were found in seedbank of all forest habitats except in Gerebshihaita. Additionally, the similarity value (JCS=0.07-0.4) of soil seedbank among the four forest sites was relatively low compared to the similarity value (JCS=0.21-0.43) between soil seedbank and above ground flora of all forest sites. This result is similar to the findings by different authors in Ethiopia (Emiru Brhane et al., 2006; Mulugeta Lemenih and Demel Teketay, 2006).

Table 2. Jaccard's coefficient of Similarity in species composition of soil seedbanks between the four forest sites of Hgumbirda NFPA.

	<i>Gerebshihaita</i>	<i>Ksadaider</i>	<i>Sebhiendodo</i>	<i>Bandra</i>
Gerebshihaita	-----	0.07	0.25	0.09
Ksadaider	-----	-----	0.4	0.21
Sebhiendodo	-----	-----	-----	0.29
Bandra	-----	-----	-----	-----

3.2. Similarity of Soil Seed Bank and Above Ground Flora

As has been shown in other Afromontane forests of Ethiopia by different authors (Feyera Senbeta and Demel Teketay, 2001; EyobTenkir, 2006; Mulugeta Lemenih and Demel Teketay, 2006) and outside Ethiopia such as in Northern flora in Hgumbirda was very low (ranging from JCS values of 0.21 for Bandara to 0.43 for n Iran (Esmailzadeh et al., 2011), the similarity between the soil seed bank and above grou Gerebshihaita). Seedling emergence method gave less similarity compared to direct seed count method (Table.3). The reason for such a weak similarity between soil seed bank and above ground flora by the germination method compared to the direct count method may be the transient nature of seeds, which germinate immediately after dispersal rather than stay for long period of time (Chaideftou et al., 2009). Therefore, it could be indicated that this persistent soil seed bank is not capable of

restoring the existing vegetation of the studied sites. *Juniperus procera*, which is the most abundant species in seed bank, was commonly found in both soil seed bank and above ground of all the forest sites except in Bandra. The exotic species, *Eucalyptus globules*, was restricted to above ground forest habitat of Ksadaider. This result differs with the work of Mulugeta Lemenih and Demel Teketay (2006) who reported presence of *Eucalyptus globulus* in soil seedbank of Ethiopian afro-montane forests. *Cupressus lusitanica* is the only exotic species recorded from seedbank flora of Hgumbirda NFPA. The presence of exotic woody species in seedbank flora may relatively become source of invasion and risk for future regeneration of both degraded and undegraded native flora by competing and changing the ecosystem (Matthew et al., 2004; Ferreira et al., 2006; Lehouck et al., 2009). However, scanty distribution of the standing canopy of those two exotic species (*Cupressus lusitanica* and *Eucalyptus globulus*) may not affect regeneration ability of most native flora. *Hagenia abyssinica*, which was rare in the above ground flora, was not found in all forest sites soil seedbank flora. This shows that the species is one of the plants in the red list of extinction from the area.

Table 3. Jaccard's coefficient of Similarity between species composition of soil seedbank and the above ground vegetation in Hgumbirda.

Names of Forest sites	Method	Species exclusive to soil seed bank flora	Species exclusive to Standing flora	Species in common	Jaccard's Similarity index	
					For each	Total
Gerebshihaita	Seed count	2	2	3	0.43	0.43
	Seedling	0	0	0	0	
Ksadaider	Seed count	1	27	7	0.2	0.26
	Seedling emergence	0	32	2	0.06	
Sebhiendodo	Seed count	2	21	8	0.26	0.29
	Seedling emergence	0	28	1	0.03	
Bandra	Seed count	1	21	6	0.21	0.21
	Seedling emergence	0	0	0	0	

3.3. Species Density of Soil Seedbank (SSB) Flora in the Study Sites

The total seed density in the upper nine centimetres with litter fall both from seedling emergence and seed counting method was 12,611.1 seeds/m² (12,344.4 seeds/m² viable and 266.7seeds/m² non-viable). This result showed considerably higher density than Harena

forest of Ethiopia (Getachew Tesfaye et al., 2004). The highest total densities of viable seeds among forest habitats were recorded in Ksadaider (4,544.44 seeds/m², of which 79.95% was *Juniperus procera*) followed by Gerebshihaita (2,833.33 seeds/m²) (Fig 3).

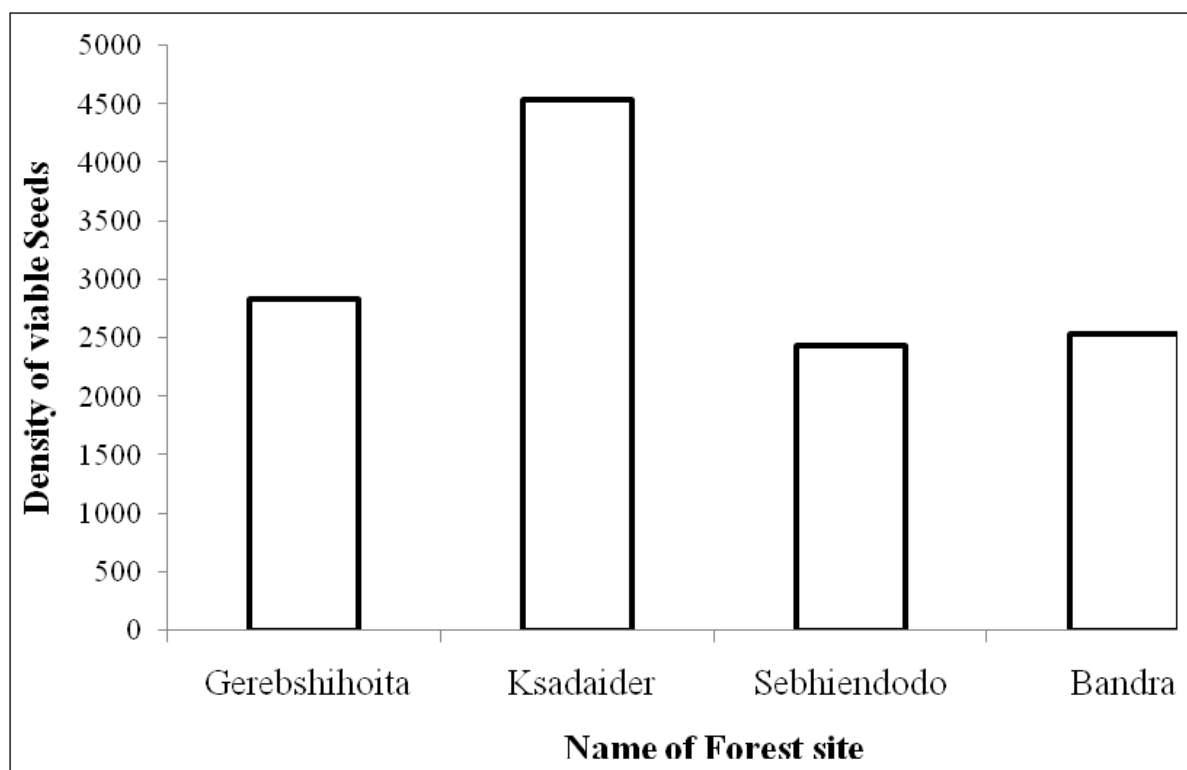


Figure 3. Total density of viable seeds in each forest site.

The seeds of *Afrocarpus falcatus* were highly dense in Sebhiendodo and all were nonviable. More than half of the total soil seed bank density (50.5%) was *Juniperus procera*. This high number of *Juniperus procera* is consistent with the report of EyobTenkir (2006), who studied Dodola forest, Ethiopia. *Juniperus procera* was the species that had a higher viable seed density and distributed in all forest habitat types with exception of Bandra, which could possibly be attributed to have capability to ensure its continuation and regeneration. Mean seed density of soil seedbank in the upper nine centimetres with litter was ranged from the highest 566.7 seeds/m² (Gerebshihaita), through 458.89 seeds/m² (Ksadaider), 363.5 seeds/m² (Bandra), to the lowest 240 seeds/m² (Sebhiendodo). This result is much less than that of Menagesha-Suba and Munessa-Shashemene forest sites in central and southern Ethiopia (ranged from 27,200 seeds/ m² to 82,600 seeds/ m²) and higher than outside Ethiopia in Sinai desert (264.7 seeds/ m² to 29.66 seeds/ m²) reported by Feyera Senbeta and Demel Teketay (2002); and Zaghoul (2008), respectively.

3.4. Distribution of Viable Seeds in Soil Layers

The maximum viable seed density was recorded in the first sampling layer (litter) for all four selected Forest sites (Fig 4). The total seed bank density of Sebhiendodo forest decrease as the soil layer depth increase. This observation is consistent with some earlier studies in Ethiopia (Feyera Senbeta and Demel Teketay, 2001; Tinsae Assefa, 2011). In Gerebshihaita and Bandra sites, higher number of seedbank was recorded from last soil layer (6-9 cm) than next layer (3-6 cm) (Fig 4). This might be due to burial activity of rodents and other organisms' disturbance (Shrestha, 2004).

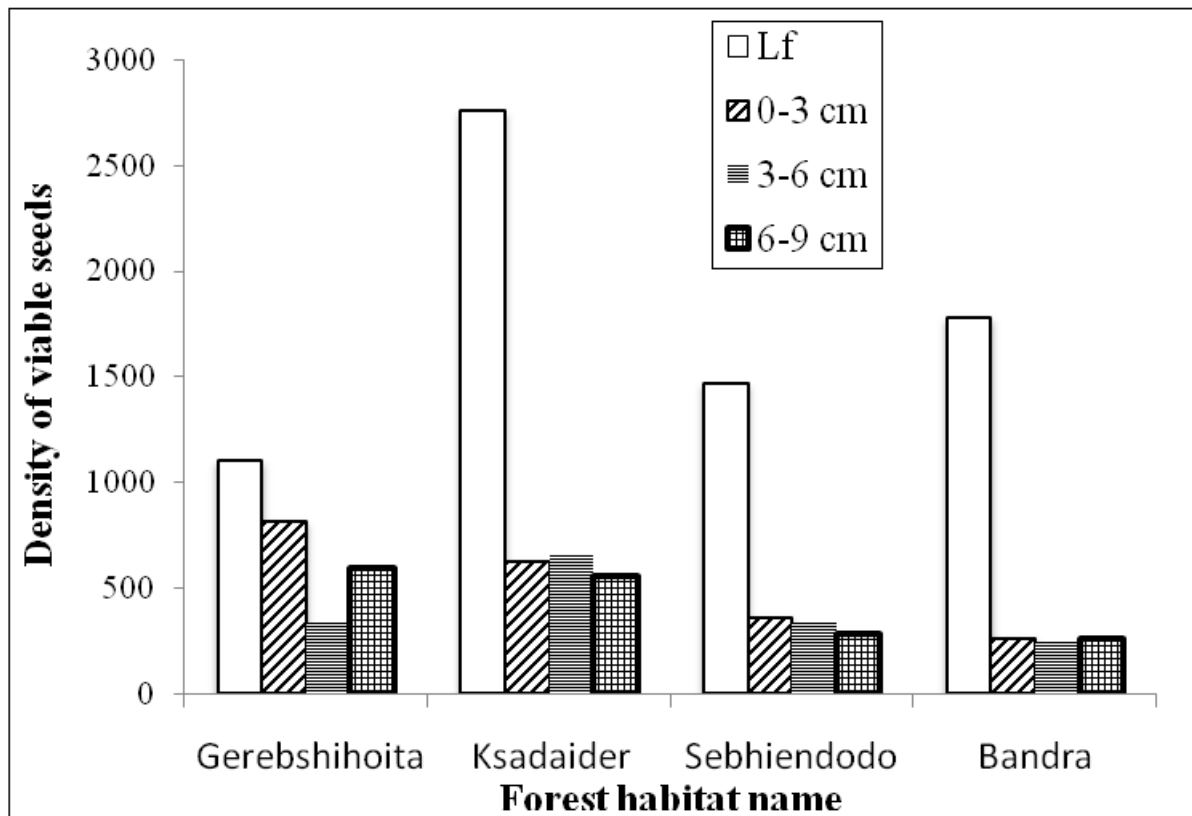


Figure 4. Distribution of viable in each soil layer of four forest sites of Hgumbirda NFPA.

Densities of seeds in the soil layer collected from the four forest sites showed significant differences [two-way ANOVA: $P < 0.05$]. A smaller amount of seeds found within the 0 to 3 cm depth as compared to 3 to 6 cm depth could be an indication for the presence of secondary seed dispersion taking place in the soil by below ground organisms and/or by spatial variability of percolating soil water (Jennifer et al., 2011). This could also be as a result of impaired seed germination due to increased depth; hence seeds accumulated in lower soil depths instead of germinating. Increased soil depths may impair seed germination by altering

moisture, air, light and temperature, hence making seeds to remain in a state of dormancy for long time (Singh and Khurana, 2001; Gutterman et al., 2007).

3.5. Species Richness, Diversity and Evenness of Soil Seedbank (SSB) Flora

The Shannon diversity index demonstrated low value for the diversity of SSB in Hgumbirda NFPA ($H'=1.763154$) (Table.4). The result was lower than Harena (Getachew Tesfaye et al., 2004), but higher than Bezawit forest (Tinsae Assefa, 2011). Comparatively higher diversity value was observed in Gerebshihaita (1.38222) followed by Ksadaider (1.11079) and Sebhiendodo (1.09783); but little value in Bandra (0.9428). The relatively higher diversity of all studied forest sites was found on the litter layer followed by 0-3 cm, and 6-9 cm, respectively. Generally species richness decreased down the soil layers (Table 4).

Table 4. Soil seed bank species richness, diversity and evenness of Hgumbirda forest.

<i>Forest site name</i>	<i>Soil layers</i>	<i>S</i>	<i>H'</i>	<i>E</i>
Gerebshihaita	Litter layer	5	0.9149	0.182979
	0-3 cm	3	0.8655	0.2885
	3-6 cm	3	0.45109	0.150364
	6-9 cm	3	0.79704	0.265681
	Total	5	1.38222	0.276445
Ksadaider	Litter layer	8	0.89239	0.111549
	0-3 cm	7	0.07188	0.010269
	3-6 cm	6	0.68546	0.114243
	6-9 cm	3	0.48872	0.162907
	Total	10	1.11079	0.111079
Sebhiendodo	Litter layer	8	1.39059	0.173824
	0-3 cm	5	1.20709	0.241418
	3-6 cm	6	1.35158	0.225263
	6-9 cm	4	1.00795	0.251988
	Total	11	1.09783	0.099803
Bandra	Litter layer	7	1.14585	0.163693
	0-3 cm	3	0.82234	0.274115
	3-6 cm	2	0.30464	0.152318
	6-9 cm	4	1.10513	0.276282
	Total	7	0.9428	0.134686
All forest habitats (Hgumbirda NFPA)	Litter layer	17	1.719107	0.101124
	0-3 cm	12	1.671954	0.13933
	3-6 cm	10	1.495762	0.149576
	6-9 cm	10	1.575576	0.157558
	Total	19	1.763154	0.092798

On the other hand, the Shannon evenness index (E) had no consistence value among the soil layers of each forest site; but totally viewed as litter>0-3 cm>6-9 cm>3-6 cm. The overall

SSB evenness was 0.092798 which is less than the combined evenness of all four forest sites (Table 4). This may be due to variation in seed rain and seed deterioration of different standing vegetation among the four forest sites (Perera, 2005). This result is very low compared with Harena forest in Ethiopia (Getachew Tesfaye et al., 2004). Relatively, evenness index among four sites was ranged from maximum in Gerebshihaita to minimum in Sebhindodo. Of the four sites of the forest, the highest Shannon diversity and evenness index was recorded from Gerebshihaita (Table 4), which show the better status of this forest site compared to the other sites. Likewise, difference in magnitude and intensity of disturbances could add up to the variation in diversity and evenness of SSB (Kellerman, 2004; Taye Jara, 2006; Eliana et al., 2012).

3.6. Viability Test for Native and Exotic Species of SSB Flora

Results from viability test (cutting test) and seedling emergence method revealed that almost all seeds of SSB flora (18 species= 97.88%) were viable except seeds of *Afrocarpus falcatus* (2.11%). Since the large above ground vegetation canopy of Sebhindodo was dominated by *Afrocarpus falcatus* and some *Cupressus lusitanica*, there is shortage of light in the forest floor which may be a reason for seed death. The allelopathic effect of exotic species (*Cupressus lusitanica*) in SSB (Toledo and Ramos, 2011; Gioria et al., 2012) could also contribute to the non-viability of the *Afrocarpus falcatus* seeds. Furthermore, seed borne fungal diseases in SSB of *Afrocarpus falcatus* could have a big contribution (Abdella Gure, 2004).

Out of the total 1,135 seeds checked for viability, only 42 seeds (3.7 %) were the non-native/exotic viable seeds of *Cupressus lusitanica*. The rest 1093 seeds (97%) were viable seeds of native species. Out of the 42 seeds of *Cupressus lusitanica* 95.24% were found in Gerebshihaita, which is located very adjacent to the villages. This could be due to the cultivation of the species by the Maichew Particle Board Factory. The 573 viable seeds (50.5 %) of native species belonged to *Juniperus procera*, which was very dominant in the SSB and above ground vegetation. This could increase the opportunity of regeneration. *Dodonaea angustifolia* (155 seeds=13.66%) was the second most abundant viable native species followed by *Calpurnia aurea* (93 seeds=8.17%) and *Opuntia ficus-indica* (92 seeds=8.11), respectively. *Opuntia ficus-indica* was dominant in both SSB and above ground flora of Bandra (the lowest altitude=2170–2218m) and also few seeds were recorded from a very far site in Gerebshihaita (the highest altitude=2488–2601m). This long path dispersal may be the consequence of the local peoples gathering and importing of edible fruits and

leaves of *Opuntia ficus-indica* for themselves and their cattle (Zemu Gebre-Egziabher, 2011) from Bandra to Gerebshihaita and other nearby forests. *Grewia mollis*, *Solanum incanum*, *Asparagus racemosus*, *Carissa edulis/spinarum* were species with least amount of viable seeds. Seeds of these species might be easily decomposable and also predated and dispersed to very far distance (Singh and Khurana, 2001; Demel Teketay, 2005; Eyob Tenkir, 2006; Levey et al., 2008) or germinate immediately (Kellerman, 2004; Pullo, 2005; Mulugeta Lemineh and Demel Teketay, 2006; Johansmier, 2009).

3.7. Implication and Potential of SSB Flora for Regeneration Status

With the exception of *Afrocarpus falcatus*, all species possessed viable seeds. The species which have plenty viable seeds range from *Juniperus procera* down to low seeded species (*Solanum incanum*, *Asparagus racemosus*, *Grewia mollis*, and *Carissa edulis*). Potential regeneration may depend on the number of viable seeds because species having more viable seeds, the more will have opportunity to regenerate. Generally viability test implies all viable species of SSB may have the potential to regenerate (recruit) themselves if and only if the species obtain suitable and naturally favoured conditions (Singh and Khurana, 2001; Demel Teketay 2005; Abella and Springer, 2011). But species exclusive to above ground flora, especially *Becium grandiflorum* and *Hagenia abyssinica*, which were absent from SSB are at risk of potential regeneration unless vegetatively propagated. This may be due to the food and medicinal use of the species by the local people who do not wait until seeds are produced.

4. CONCLUSION

The result of assessment of soil seedbank of woody species in Hgumbirda NFPA revealed that the species recorded from soil seed bank compared to standing flora were very low. Therefore, it is possible to conclude that the persistent soil seed bank is not capable of restoring all species of the existing vegetation. Conversely, *Juniperus procera* not only build up more viable seeds in the soil seedbank but also had higher number of standing plant populations in the above ground flora of Hgumbirda NFPA. As a result, the restoration of this woody species may be easy and fast. No alien species, except *Cupressus lusitanica*, was recorded at all in SSB flora of Hgumbirda NFPA.

The similarity between SSB and above ground flora was very low showing that regeneration of species exclusive to the above ground flora is very difficult unless seedling plantation and plant management strategies are carried on. Thus, establishment of nursery facilities and

enriching the vegetation with endogenous species is suggested. Further, protections and managed use of the protected area is a necessity.

5. ACKNOWLEDGEMENTS

Financial support from the Ministry of Education and Bahir Dar University is duly acknowledged. We are also grateful to Ato Zemariam (District administrator for natural resources) and Ato kiros Haile (manager of Hugumbirda national forest priority area) for the provision of access and information and also for material support. We would like to extend our gratitude to local elders and Korem high school students for their help in data collection and provision of local plant names.

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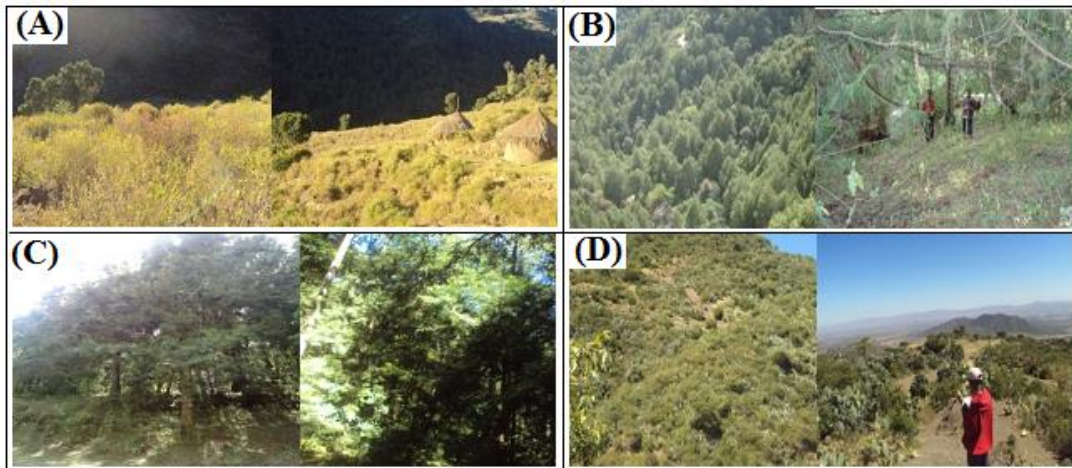
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Appendix 1. Representative vegetation of the study forest sites of Hgumbirda NAFFP.



- Key:** (A) Partial view of Gerebshihaita dominated by *Becium grandiflorum* and highly disturbed. (B) Partial view of Ksadaider dominated by *Juniperus procera* and rarely grazed by animals. (C) Partial view of Sebhiendodo forest dominated by *Afrocarpus falcatus*. (D) Partial view of Bandra forest dominated by *Opuntia ficus-indica*.

Appendix II. Methods used in determining soil seedbank from different soil layers.



- Key:** A) Collection of soil samples from four layers; B) Recovering of seeds by sieving; C) Spreading soil samples on trays after sieving; D) Putting the recovered seeds into labelled paper bags; E) Watering the soil samples; F) Checking identity of the recovered seeds with the local people; G) Comparing and contrasting the recovered seeds with seeds of standing vegetation; and H) Checking the viability of seeds using cutting test in the laboratory.