Ethiop. J. Biol. Sci. 21(2): 91–111, 2022

ISSN: 1819-8678

RESEARCH ARTICLE

COMPARISON OF SOIL SEED BANK AND ABOVE GROUND FLORAL COMPOSITION BETWEEN THREE LAND-USE TYPES OF ARSI-BALE MASSIFS IN SOUTHEAST ETHIOPIA

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ABSTRACT: The aim of this study was to determine the floristic composition, diversity, density of soil seed bank, and relationship of soil seed bank and above ground vegetation in forest patch, riverine and grazing lands of Arsi-Bale Massifs of Southeast Ethiopia. Soil samples were collected from 56 plots of 10 cm x 10 cm quadrats size from four layers (litter layer, 0–3 cm, 3–6 cm and 6–9 cm). Regarding above ground vegetation, 30 m x 30 m for trees, 5 m x 5 m for shrubs and 1 m x 1 m quadrat sizes for herbaceous were used for sampling from the same 56 plots. Shannon-Weiner diversity index was used for soil seed bank and above ground vegetation. Similarities among the land use types, soil seed bank and above ground vegetation were analyzed using Jaccard coefficient of similarity (JCS). Variance analysis of species abundance in each soil layer and land use types was done by ANOVA using SAS software (Version 9.0). A total of 292 vascular plant species from standing vegetation and 107 species from soil seed bank were identified. A total of 10,828.57 seedlings per m^2 with mean density of 34.27 ± 7.79 individuals/m^2 was recorded. The mean density of soil seed bank among the soil seed bank layers did not show significant difference (one-way ANOVA, $(F3, 316) = 0.13$, $P<0.94$). The Jaccard's similarity index value between the soil seed bank and above ground flora show the highest dissimilarity (JC = 0.22). The species composition, diversity and seed density in grazing land use type was lower than other land use types. Generally, only small number of above ground plant species were represented in the soil seed bank.

Key words/phrases: Above ground vegetation, Density, Dry Afromontane Vegetation, Land use types, Species diversity.

INTRODUCTION

Fragmentation and loss of native habitats due to intensive agricultural practices have resulted in the loss of biodiversity of plants (Barrera *et al*., 2021). The human interference has strongly affected the configuration of

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natural and semi-natural habitats and increased the degree of habitat fragmentation in the global scale (Hassan *et al*., 2005). Particularly, the highest density of human population in the study area (CSA, 2007) poses extra agricultural land expansion which always minimizes the size of the remnant patches and increase isolation between patches of the study area in particular. This mainly affects the dynamics of both above ground and soil seed bank vegetation of the area. Therefore, understanding the dynamics of soil seed banks is useful to evaluate the potential of a plant community after disturbances (Leck *et al*., 1989). Conservation of biodiversity in a wide variety of ecosystems has become a major environmental and natural resources management issue of national and international importance to mitigate natural and human impacts (Salwasser, 1991; Angermeier and Karr, 1994; Lovett *et al*., 2000).

Soil seed banks play an important role in the composition and conservation of plant communities (Leck *et al*., 1989). The composition of the seed bank depends on the composition and production of current and previous plant communities, as well as the longevity of seeds under local conditions. Seeds that have been brought in from surrounding areas also contribute to the seed bank. In addition to this, species dispersal ability and seed bank persistence are regarded as key traits in the survival of plants in fragmented and changing agricultural landscapes (Geertsema *et al*., 2002). Therefore, studying the population dynamics of viable seeds buried in the soil may play an important role in vegetation dynamics (Pickett and McDonnell, 1989) and in the restoration of plant communities (van der Valk and Pederson, 1989).

Different studies related to seed bank and regeneration ecology have been undertaken in various Afromontane vegetation of Ethiopia (Demel Teketay and Granström, 1995; Getachew Tesfaye *et al*., 2004; Mulugeta Lemenih and Demel Teketay, 2006; Alemayehu Wassie, 2007; Mamo Kebede *et al*., 2012; Degafi Sileshi and Berhanu Abraha, 2014; Zewdu Kelkay *et al*., 2017). Soil seed bank study is very crucial to determine the natural regeneration potential of the studied vegetation. It also shows the overall distribution trends of herbaceous and woody plant species in different ecosystems. Understanding the density, species richness and diversity of the soil seed bank is important for developing conservation and management plan in remnant vegetation. Buried seed populations are considered very essential components of the plant community since they help in reclaiming plant communities after disturbance (Song *et al*., 2017).

The study area is mainly dominated by agriculture and patches of forests and grazing areas are scattered across this farmscape. The roles of soil seed bank in this landscape matrix for habitat restorations are little known. Therefore, the objectives of this study were to investigate the following hypothesis: 1) the species richness, diversity, soil seed bank density and life forms in three land use types; 2) the similarity of plant species between below and above ground vegetation; and 3) the vertical and horizontal distribution of soil seed bank species of the studied vegetation.

MATERIALS AND METHODS

Description of the study area

The present study was carried out in the fragmented agricultural landscape system of Arsi-Bale Massifs, which is located between 06º 52′ 27″ to 07º 58′ 19″ N latitude and 39º 06′ 26″ to 39º 44′ 24″ E longitude of Oromia regional state in the southeast of Ethiopia (Fig. 1). The study area included six districts (Tiyo, Digaluna Ticho, Bekoji, Kofele, Dodola and Adaba) with a total human population of 2,635,515 in Arsi and 1,815,274 in newly established West Arsi zone. Out of this population, about 89% are rural dwellers. Moreover, the topographic features of the study area include the plain lands of the pastures and agricultural fields, which are found on the border valleys, following the streams. The agricultural fields are distributed in the small patches of the forest, which are located on the top hills of the mountain peaks and at lower altitudes following streams or rivers (NRGO, 2011). Generally, the study area is situated in the Dry Afromontane Vegetation types with grass land complex, and Ericaceous belt of Chilalo and Galama Mountains. Three land use types (grazing, riverine and forest patch) were selected to carry out this research, and their descriptions are given below.

Grazing land use type: The unploughed/open lands which are found among the farm systems, near the forest patches and 30 m away from the margins of the riversides. There are sparsely distributed trees and shrubs within the opened grazing land.

Forest patch: the area of land with an area greater than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than ten percent or trees able to reach these thresholds *in situ*.

Riverine: The land use type found along the riverside which is covered with shrubs and trees.

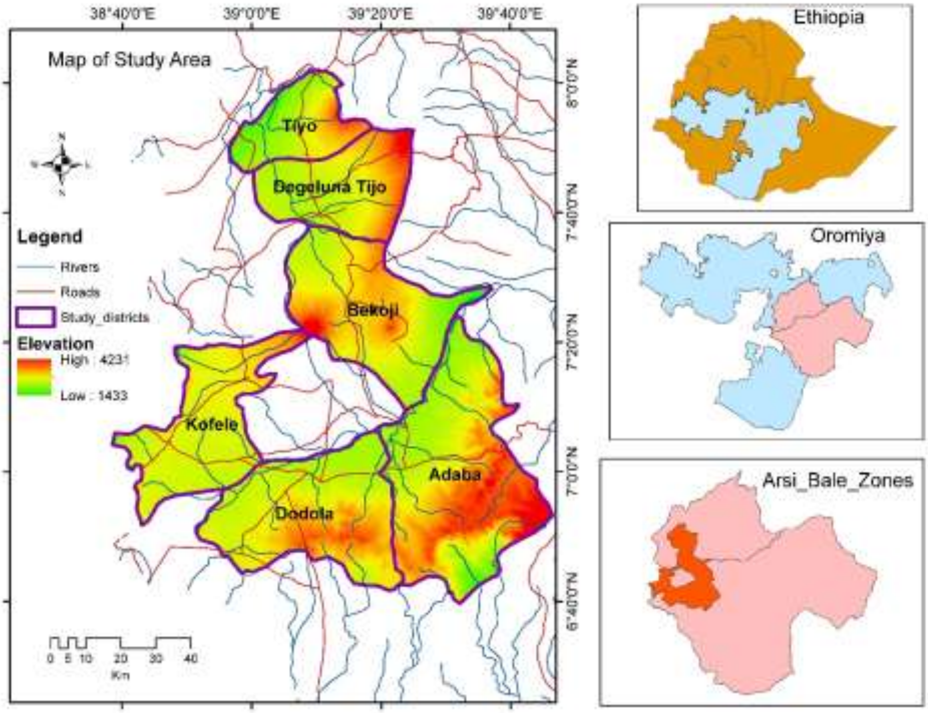

Fig. 1. Map of the study area.

Climate

The weather condition of the study area is given in Fig. 2. The annual mean temperature of the study area ranges between 14.1ºC and 17.1ºC (Fig. 2a-f). The annual mean precipitation ranges from 731 mm in Sagure to 888 mm in Asella (Fig. 2a-f). Whereas, the highest precipitation of the wettest months is commonly observed in July and August, the driest months are December and January. The main rainy season is from May to September with the highest rain fall in August. The driest months are from November to February. An exception is Kofele, which is slightly different.

Above ground vegetation sampling

Reconnaissance survey was conducted in August 2015 to collect the baseline information, observe vascular plant species distribution, and identify the possible sampling sites to be laid along grazing land, riverine forest and the remnant patches of the forest across Arsi-Bale Massifs. Accordingly, a total of 56 plots were systematically selected along altitudinal gradient. For sampling trees, 30 m x 30 m, shrubs 5 m x 5m and herbs 1 m x 1 m quadrats were used. A selection of these sampling plots was based on the presence of remnant forest patches using Google Earth Satellite map.

As result, six districts, namely Kofele, Adaba, Dodola from West Arsi and Tiyo, Digalu and Bekoji districts from East Arsi were selected. The plant samples were dried under dryer for two weeks and placed inside refrigerator for 72 hours or three days for vascular plants to take the samples into the herbarium for identification. All plant samples were identified by using Flora volumes of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards *et al*., 1995; 2000; Phillips, 1995; Mesfin Tadesse, 2004; Hedberg *et al*., 2003; 2006; 2009), compared with existing annotated specimens at the National Herbarium of Ethiopia, Addis Ababa University. All identified plant specimens were confirmed by Sileshi Nemomissa.

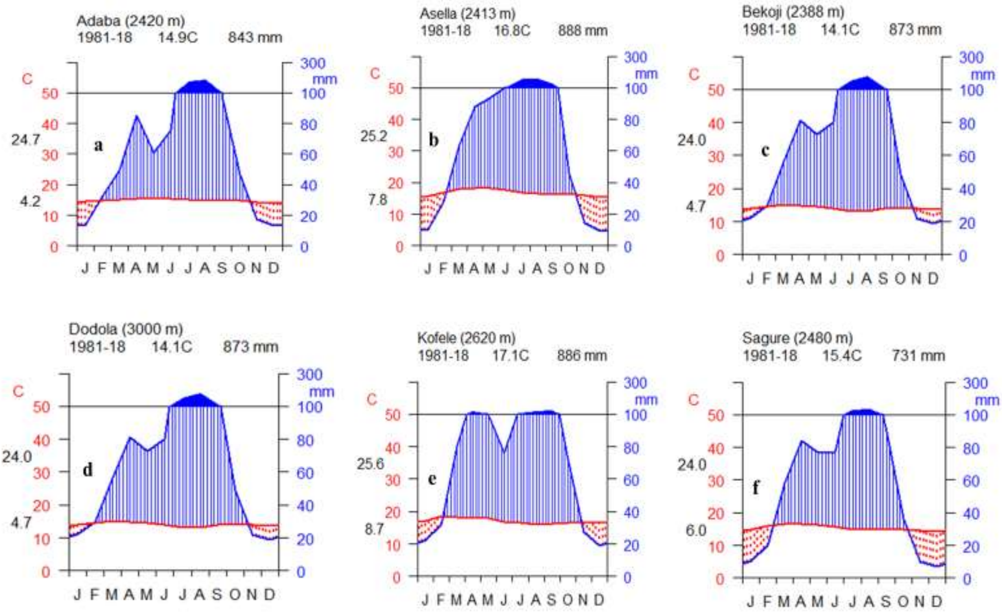

Fig. 2. Climate diagram of meteorology stations of the study area.

Soil seed bank data collection

Soil seed bank samples were collected between 10 October and 30 November 2017 from the same 56 plots used for sampling above ground vegetation. Soil samples were collected from 4 layers, that is, the litter layer, upper (0–3 cm), middle (3–6 cm) and lower (6–9 cm) layers using labeled metal rods following the method of Feyera Senbeta and Demel Teketay (2001; 2002). The samples were taken from five points each covering 10 cm x 10 cm (one at the centre and the other four at the corners) of each sample quadrats. Soil cores for each depth were mixed to obtain a composite sample (Amaha Kassahun *et al.,* 2009) before estimating the composition of soil seed banks to reduce variability within the quadrats. Sampling was completed within eight weeks to avoid differences between habitats (Toledo and Ramos, 2011). The samples were kept in separate cement bags, shaded and air dried to prevent damage from heat and mold, and transported to the greenhouse. Soil samples were spread immediately in 20 x 20 x 6 cm rectangular plastic trays in green house for germination and perforated at the bottom to facilitate proper drainage of water (Degafi Sileshi and Berhanu Abraha, 2014). The seedlings in the trays were kept moist continuously by watering them daily (Toledo and Ramos, 2011). The seedling trays were kept under a daily temperature range of 20–30°C. The emerging seedlings in each plastic trays were identified, counted, recorded, removed and their photos (for example see Fig. 3) were taken to support identification in the Herbarium.

Fig. 3. Green house germination photos for emerging seedlings (photo by Negalign Awoke, 2019).

Data analysis techniques

Floristic diversity was calculated to investigate above ground species diversity using Shannon-Weiner index (H′) based on a natural logarithm that gives equal weight to rare and abundant species (Shannon, 1948). It was assumed that the higher the value of H′, the greater the floristic diversity. The species richness (S) and evenness (E) of soil seed bank in each soil profile were analyzed (Getachew Tesfaye *et al.*, 2004; Perera, 2005). The formulae to calculate the species diversity, evenness and Jaccard's coefficient of similarity are given below:

Species diversity:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where, H′ = Shannon-Weiner diversity index, S = total number of species, Pi = the proportion of individuals or abundance of the ith species as a proportion of total cover and ln = log base.

Evenness (J) = H′/ H′max, where H′max = lns.

Jaccard's coefficient of similarity (Cj) (Jaccard, 1901) was applied to investigate the similarity between below and above ground vegetation.

$$Cj = \frac{a}{a+b+c}$$, where a is the number of species common to both sites, b is the number of species found in site b only and c is the number of species found in site c only.

Variance analysis of species abundance was done by ANOVA using SAS (Version 9). The density of seeds was derived from the total number of seeds recovered from the soil samples. The number of seeds recovered in similar layers were combined and converted to provide the density of seeds/m^2 at that particular soil depth (Almaz Tadesse, 2009).

RESULTS

Species composition

A total of 107 species belonging to 43 families and 85 genera were documented in the soil seed bank of the study area. Asteraceae was the most dominant family with 20(18.7%) species, followed by Poaceae and Fabaceae with 13(12.1%), and 7(6.5%) species, respectively. The family Urticaceae, Solanaceae, Polygonaceae and Lamiaceae were represented by 4 (4.7%) species each. Out of the remaining 36 families twenty-three were represented by 1(0.9%) species each (Table 1 and appendix). The species, *Cheilanthes coriaceae*, *Cheilanthes farinosa*, *Pteris vittata* and *Selaginella kraussiana* were Pteridophyte taxa found from the soil seed bank (Table 1). The life form distribution was dominated by the herbs comprising 74(69.20%) species followed by 16(14.95%) species of grasses and sedges. Furthermore, shrubs were represented by 10(9.3%) and climbers and trees by 3(2.80%) species each.

Table 1. Density of soil seed bank flora along for soil layers (LL = litter layer, 1 = upper layer, 2 = middle layer, 3 = lower layer and total plots (N = 56).

	Soil layers				Density (N = 56)
Species	**LL**	**1**	**2**	**3**	
Veronica glandulosa	61	109	226	264	1,178.6
Pilea tetraphylla	202	127	115	57	894.6
Oxalis corniculata	80	145	102	156	862.5
Oplismenus hirtellus	134	82	62	77	633.9
Wahlenbergia flexuosa	33	98	113	82	582.1
Anagallis arvensis	46	93	80	65	507.1
Cyperus sesquiflorus	46	103	61	64	489.3
Cheilanthes farinosa	21	60	89	37	369.6
Centella asiatica	28	89	34	24	312.5
Cheilanthes coriacea	7	25	50	75	280.4
Thalictrum rhynchocarpum	17	39	55	34	258.9
Poa annua	66	19	15	36	242.9
Alchemilla abyssinica	22	39	36	26	219.6
Dicrocephala integrifolia	36	28	35	23	217.9
Galinsoga parviflora	25	35	36	26	217.9
Erica arborea	5	74	26	13	210.7
Juncus bufonius	0	14	40	59	201.8
Other SSB species	358	453	418	425	3,148.6
Total	1,258	1,647	1,608	1,151	10,828.9

Soil seed bank density

A total of 10,828.6 seeds/m^2 was recorded from the soil seed bank samples (Table 1 and appendix). The mean density throughout the soil layers did not show significance differences ($P<0.05$). Whereas the highest mean density (67.58 ± 8.22 seeds/m^2) was recorded in the third soil layer, the lowest mean density (31.3 ± 7.55 seeds/m^2) was characterized by the litter layer (Table 2). Moreover, the depth distribution of soil seed bank showed variations but were not significant across the sampled soil layers. The highest density of seed count was recorded in the surface layer (2937.5 seeds/m^2) followed by layer 2 and 3 with 2889.3 seeds/m^2 and 2751.8 seeds/m^2, respectively (Fig. 4). Riverine land use type has the highest seed density, 4,589.3 seeds/m^2 and is followed by forest patches (4,101.8 seeds/m^2) (Fig. 5 and Table 4). There is a gradual decrease in the density of seeds in lower layer (Table 5).

Table 3. Soil seed bank floristic composition, mean density (± SE (Mean error) and diversity throughout the soil layers (LL = Litter layer, 1 = 0–3 cm, 2 = 3–6 cm, and 3 = 6–9 cm).

Soil layer	Richness	Number of seeds	Mean density (± SE) per m^2	Diversity index (H′)	Evenness (J)
LL	70	1,227	31.3 ± 7.55	3.4	0.8
1	89	1,645	33.01 ± 7.44	3.57	0.799
2	77	1,618	63.3 ± 7.96	3.49	0.806
3	79	1,541	67.58 ± 8.22	3.39	0.778

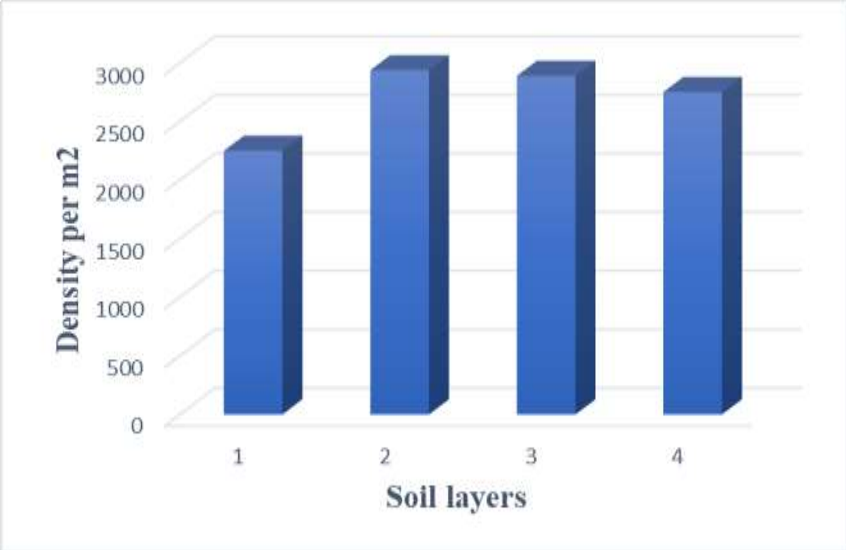

Fig. 4. Number of seeds in each soil layer sample of the study area. Legend: Soil layers (1 = litter layer, 2 = 0–3 cm, 3 = 3–6 cm, and 4 = 6–9 cm).

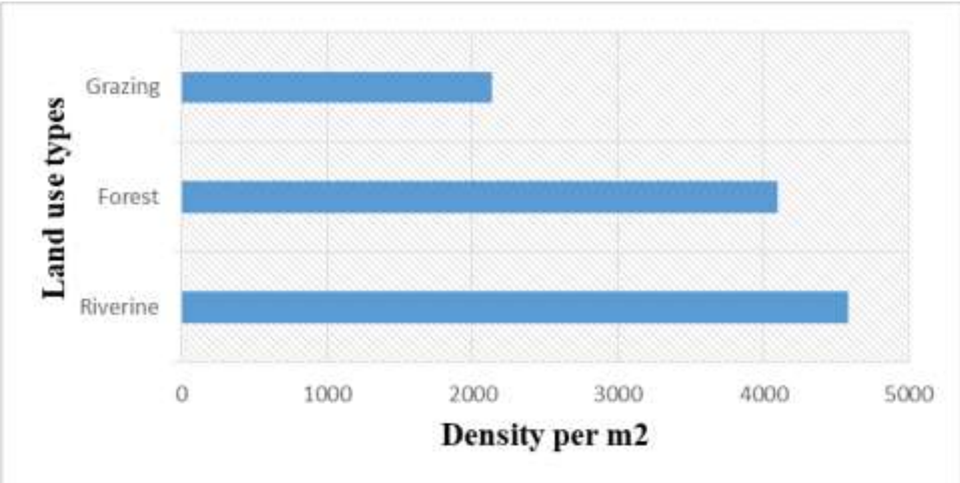

Fig. 5. Soil seed density along the land use types of the study area.

Table 4. Soil seed bank floristic composition and diversity along the land use types.

Land use type	**Richness**	**Number of seeds**	**Density (seeds/ m^2)**	**Diversity index (H)**	**Evenness (J)**
Riverine	84	2,570	4,589.3	3.51	0.792
Grazing	59	1,197	2,137.5	3.15	0.772
Forest patch	85	2,297	4,101.79	3.59	0.808

Table 5. Density of seeds along the three land use types (density of seeds per m^2) in the study area.

Land use types		**Soil layers**			**Total**
	Litter layer	**0–3 cm**	**3–6 cm**	**6–9 cm**	
Riverine	1,089.3	1,214.3	1,208.9	1,076.8	4,589.3
Forest patch	837.5	1,005.4	1,155.4	1,103.6	4,101.8
Grazing	323.2	717.9	525	571.4	2,137.5
Total	2250	2,937.5	2,889.3	2751.9	10,828.6

The soil seed bank was dominated by *Veronica glandulosa* (1,178.6 seeds/m^2), *Pilea tetraphylla* (894.6 seeds/m^2), *Oxalis corniculata* (862.5 seeds/m^2), *Oplismenus hirtallus* (633.9 seeds/m^2), *Wahlenbergia flexuosa* (582.1 seeds/m^2), *Anagallis arvensis* (507.1 seeds/m^2) and *Cyperus sesquiflorus* (489.3 seeds/m^2) (Table 1). These species contributed 47.5% of total density of soil seed bank flora. The species, *Delphinium wellbyi*, *Lactuca inermis*, *Leucas glabrata*, *Plantago lanceolata*, *Ranunculus oligocarpus* and *Veronica abyssinica* have the least soil seed bank density.

Similarity of below and above ground flora

A total of 292 standing vascular plant species, representing 82 families and 193 genera were in the above ground vegetation. Out of these, riverine land use type comprised of 221, forest patches 166 and grazing land 156 species.

Both above ground and soil seed bank vegetation was dominated by herbaceous species in all land use types. Out of the 292 above ground species, 71(24.1%) were common to both soil seed bank and above ground vegetation with less similarity ratio (Cj = 0.22) (Table 6).

Table 6. Jaccard's similarity index between soil seed bank (SSB) and above ground vegetation (AGV) of the study area.

Land use types	**Number of species in SSB only**	**Number of species in AGV only**	**Number of species common in SSB and AGV**	**Jaccard's index (Cj)**
Riverine	36	185	48	0.18
Grazing	38	118	23	0.13
Forest	43	123	40	0.19

DISCUSSION

Species composition and soil seed bank density

The total species of soil seed bank in present study was higher than those reported from other similar studies (e.g., Figueroa *et al*., 2004; Mulugeta Lemenih and Demel Teketay, 2006; Degafi Sileshi and Berhanu Abraha, 2014; Mamo Kebede *et al*., 2012; Zewdu Kelkay *et al*., 2017). On the other hand, its species richness is lower than that of Harenna forest (Getachew Tesfaye *et al*., 2004). Generally, small seeded species form the largest contribution to the seed bank, compared to the large seeded species, which supports the negative correlation between seed size and seed longevity (Bekker *et al*., 1998). The current study has revealed the highest soil seed bank number for small-seeded plant species such as herbs, grasses and sedges (Table 1 in appendix). The dominance for seeds of herbaceous species in soil seed bank was reported elsewhere (Mulugeta Lemenih and Demel Teketay, 2006; Degafi Sileshi and Berhanu Abraha, 2014; Savadogo *et al*., 2016). Our result indicates that indicate that, herbaceous species have better chances of establishing from the soil seed banks following disturbance than shrub and tree species.

Spatial distribution of soil seed bank density

The soil seed bank density was dominated by only a few species: *Veronica glandulosa*, *Pilea tetraphylla*, *Oxalis corniculata*, *Oplismenus hirtallus*, *Wahlenbergia flexuosa*, *Anagallis arvensis* and *Cyperus sesquiflorus*. The lowest number of seedlings in grazing land use types and litter layer were observed. This might be due to disturbances like frequent grazing and selective cutting of woody plant species before releasing their seeds. Furthermore, the abundance of seeds in the soil seed bank vary according to proximity to the parent plants, seed persistence or state of dormancy, and physiological state and dispersal units (Walck *et al*., 2005).

The three land use types have different number of soil seed bank density but not significant variations. *Oplismenus hirtellus*, *Oxalis corniculata* and *Veronica glandulosa* were recorded for the highest seeds in the grazing land use type and forest patches. The highest number of seeds of *Wahlenbergia flexuosa* was also found in grazing land. On the other hand, the riverine was dominated by *Pilea tetraphylla*, *Anagallis arvensis* and *Cyperus sesquiflorus* (Fig. 5), which is attributed to their habitat preference. Noteworthy is that the number of seed soil seed bank is determined by the ecological requirements and inherent habitat adaptations of the species. This is also manifested by the occurrence of distinct species in grazing land and forest patches on one hand and riverine on the other. The similarities in the density of seeds between grazing land and forest patches may be grazing land use type could be the result of the conversion of former forested areas. Woody species such as, *Ficus vasta*, *Osyris quadripartita*, *Maesa lanceolata* and *Solanum marginatum* had low soil seed bank density (Table 1 in appendix). The low number of woody species might be due to their less persistent nature of their seeds. This is because the observation has frequently been made that there is a connection between possession of a persistent seed bank and seed size and shape (Leck *et al*., 1989). Furthermore, short-lived seeds are usually large and either flattened or elongate.

The vertical distribution of the seed bank does not show significant difference at the four layers for the study plots (one-way Anova, $F(3,316) = 0.13$, $P<0.94$) with the highest densities in the upper layer (0–3 cm) of soil and gradually decreasing densities with increasing depth. Relatively high densities were also recorded in layer 2 (Fig. 4). Similar distribution patterns were also reported in other Dry Afromontane Vegetation Types (Demel Teketay and Granström, 1995; Feyera Senbeta and Demel Teketay, 2001; Degafi Sileshi and Berhanu Abraha, 2014).

Species diversity in below ground vegetation

The highest species richness (89 species) was documented for soil layer 1, followed by soil layer 3 and 2 with 79 and 77 species, respectively. The lowest was observed in the litter layer. Soil layer 1 has the highest diversity index value ($H' = 3.57$) followed by soil layer 2 ($H' = 3.49$). On the other hand, species evenness values for all soil layers does not show significant variation.

Disturbance, forest fragmentation and selective cutting of woody species before releasing their seeds reduces the number of species in the upper layers. Although some species tolerate disturbance and other may locally extinct due to this factor (Sagar *et al*., 2003), disturbance is a limiting factor of the density of seeds of woody species in the study area. The least number of species richness and diversity was recorded for grazing land use type (Table 6). During data collection one of the authors has observed overgrazing, which probably has affected the germination, recruitment and survivor and reproductive potential of the species. This may in turn influence the competitive relationships among the different species (Smith, 1979; Bilotta *et al*., 2007). Therefore, heavily grazed areas lose more species than lightly grazed areas.

Similarity of below and aboveground flora

In the present study, only small proportion (24.1%) of above ground vegetation were represented in below ground flora with a high dissimilarity ratio (Js = 0.22). Lower number of species in the soil seed bank compared to above ground vegetation has been reported variously (Degafi Sileshi and Berhanu Abraha, 2014). In terms of habit, herbs contributed the highest proportion to both the soil seed bank and above ground vegetation and, followed by shrubs and trees. This may be a recalcitrant nature of seeds of some species of the study area. Lower Jaccard's similarity index value between the soil seed bank and above ground vegetation was reported (e.g. Degafi Sileshi and Berhanu Abraha, 2014) similar to the current study. Low similarity index value between soil seed bank and above ground vegetation in grazing land use type may be attributed to disturbances. For example, grazing by livestock and direct removal of flowers and seeds result in this difference (Sternberg *et al*., 2003). The highest similarity of the soil seed bank and above ground floral composition of the forest land use type may show less disturbances of the remnant forest patches compared to riverine and grazing land use types. Thirteen plant species such as *Achyranthes aspera*, *Cheilanthes farinosa*, *Cyperus sesquiflorus*, *Dicrocephala integrifolia*, *Erica arborea*, *Helichrysum schimperi*, *Hypoestes triflora*, *Laggera crispata*, *Oplismenus hirtallus*, *Solanum anguivi* and *Solanum marginatum* were common in both soil seed bank and above ground vegetation in all land use types. On the other hand, thirty-six species were found only in the soil seed bank and 221 species in the above ground vegetation. In general, only a few woody and perennial grass species of the above ground vegetation were represented in the soil seed bank due to low seed production (Touzard *et al*., 2002) because they alternate between sexual reproduction and vegetative forms and their seeds persist in the soil for short periods of time.

Similarity of soil seed bank flora between three land use types

The similarity of species composition between the three land use types in the soil seed bank was relatively higher compared with the similarity of species composition among the soil seed bank and above ground vegetation (Table 5 and 6). The low Jaccard's similarity coefficient in species composition between the soil seed bank and above ground vegetation was also observed in various studies (Figueroa *et al*., 2004; Mulugeta Lemenih and Demel Teketay, 2006; Esmailzadeh *et al*., 2011; Mamo Kebede *et al*., 2012; Degafi Sileshi and Berhanu Abraha, 2014). They were reported that the contribution of the woody plants to the total number of seeds in the soil was low. The poor correspondence between the above ground vegetation and soil seed bank is attributed to lack of dormancy mechanisms and to ability of non-dormant seeds of many species to germinate (Archibold, 1979; Sem and Enright, 1996; Baskin and Baskin, 1998; Esmailzadeh *et al.*, 2011). Accordingly, our study revealed from a total of 118 woody species of the above ground vegetation, only *Ficus vasta*, *Leucas glabra*, *Lobelia rhynchopetalum*, *Maesa lanceolata*, *Osyris quadripartita*, *Pterolobium stellatum*, *Solanum marginatum*, *Sparmannia macrocarpum*, *Sparmannia ricinocarpa* and *Vernonia amygdalina* were represented in the soil seed bank. Many woody species of the above ground vegetation were not represented in the soil seed bank. This may be due to lack of a persistent seed (Esmailzadeh *et al*., 2011) or most of the tree species produce seeds that germinate within a few days or weeks after dispersal and do not form large soil seed banks (Demel Teketay, 2005). Other factors that probably contributed to our findings may be the difference in composition of seed banks are that the seeds of large woody species are heavily predated and decompose rapidly (Demel Teketay, 2005). Furthermore, large seeds usually remain on the surface and may be damaged by disturbances and were not deposited in the soil and some tree species produce fruits and seeds infrequently (Savadogo *et al*., 2016).

The observed similarity index of this study (62% similarity) among land use types is much greater than reported for other Afromontane vegetation types of Ethiopia (e.g. Degafi Sileshi and Berhanu Abraha, 2014; Mulugeta Lemenih and Demel Teketay, 2006). Species similarity among the land use types between soil seed bank and above ground vegetation.

CONCLUSION

Soil seed bank may be used as refugia for many plant species. The soil seed bank flora in this study is higher than plant species reported in many other Afromontane vegetation of Ethiopia. However, the seed density in present study were considerably lower than those reported in other Afromontane vegetation types of Ethiopia. From a total of 107 identified soil seed bank species, *Delphinium wellbyi*, *Lactuca inermis*, *Leucas glabrata*, *Plantago lanceolata*, *Ranunculus oligocarpus*, *Veronica abyssinica*, *Ficus vasta*, *Osyris quadripartita*, *Maesa lanceolata* and *Solanum marginatum* have a low density. Although some of these species are common, others are locally rare (e.g. *D. wellbyi*) and have scattered individuals (e.g. *F. vasta*).

The current study recovered both vascular and non-vascular plants from soil seed bank. Soil is very important repository for seeds and spores that may aid restoration of ecosystems. The much higher density of soil seeds/m^2 than individuals of the species in the above ground vegetation may show that soil shields plant biodiversity from disturbances creating opportunities for species recovery. Furthermore, soil seed bank may play key roles for conserving soil seed bank species diversity in the face of the current climate change. But the impacts of soil warming triggered by project climate change on the long-term persistence of soil seed bank flora and their value for ecosystem restoration may be a subject for future research.

ACKNOWLEDGEMENTS

The authors would like to thank Addis Ababa and Wachemo Universities for supporting the research. We are grateful to Oromia regional, zonal and Woreda Agricultural Bureau for the permission to carry out the study in Arsi-Bale Massifs Agricultural Landscapes of East and West Arsi zone.

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Appendix 1. Total number of seedlings, and corresponding soil seed bank densities per m^2, of species that germinated in the 4 soil layers (LL = Litter Layer, 1 = 0–3 cm, 2 = 3–6 cm, and 3 = 6–9 cm; total plots (N=56)).

				Soil layers			**Density (N=56)**
Species	**Family**	**Habit**	**LL**	**1**	**2**	**3**	
Achyranthes aspera	Amaranthaceae	H	10	1	1	2	25
Acmella caulirhiza	Asteraceae	H	4	9	8	4	44.6
Agrocharis incognita	Apiaceae	H	1	1	1	1	7.1
Alchemilla abyssinica	Rosaceae	H	22	39	36	26	219.6
Alchemilla pedata	Rosaceae	H	9	12	13	5	69.6
Anagallis arvensis	Primulaceae	H	46	93	80	65	507.1
Andropogon amethystinus	Poaceae	G	8	5	12	8	58.9
Brachiaria brizantha	Poaceae	G	0	0	4	2	10.7
Bromus pectinatus	Poaceae	G	13	1	15	14	76.8
Calpurnia aurea	Fabaceae	S	4	0	0	0	7.1
Cardamine hirsuta	Brassicaceae	H	0	0	0	1	1.8
Centella asiatica	Apiaceae	H	28	89	34	24	312.5
Cheilanthes coriacea	Sinopteridaceae	H	7	25	50	75	280.4
Cheilanthes farinosa	Sinopteridaceae	H	21	60	89	37	369.6
Chenopodium murale	Chenopodiaceae	H	0	0	3	4	12.5
Cineraria deltoidea	Asteraceae	C	0	1	1	1	5.4
Cirsium vulgare	Asteraceae	H	0	0	0	6	10.7
Colpodium hedbergii	Poaceae	G	0	10	0	0	17.9
Commelina africana	Commelinaceae	H	0	1	0	4	8.9
Cotula anthemoides	Asteraceae	H	5	4	3	2	25
Crotalaria incana	Fabaceae	S	0	1	0	6	12.5
Cynoglossum lanceolatum	Boraginaceae	H	0	1	4	0	8.9
Cyperus sesquiflorus	Cyperaceae	Sy	46	103	61	64	489.3
Datura stramonium	Solanaceae	H	0	1	0	1	3.6
Delphinium wellbyi	Ranunculaceae	H	0	1	0	0	1.8
Desmodium repandum	Fabaceae	H	2	3	2	2	16.1
Dicrocephala chrysanthemifolia	Asteraceae	H	0	3	1	0	7.1
Dicrocephala integrifolia	Asteraceae	H	36	28	35	23	217.9
Digitaria velutina	Poaceae	G	71	15	15	8	194.6
Droguetia iners	Poaceae	H	5	5	5	5	35.7
Eragrostis ciliansis	Poaceae	G	0	1	2	0	5.4
Eragrostis schweinfurthii	Poaceae	G	0	0	3	2	8.9
Erica arborea	Ericaceae	S	5	74	26	13	210.7
Eruca sativa	Brassicaceae	H	2	2	1	3	14.3
Euphorbia schimperiana	Euphorbiaceae	H	4	1	0	1	10.7
Festuca abyssinica	Poaceae	G	0	11	4	35	89.3
Ficus vasta	Moraceae	T	0	2	0	0	3.6
Galinsoga parviflora	Asteraceae	H	25	35	36	26	217.9
Galinsoga quadriradiata	Asteraceae	H	0	17	0	5	39.3
Galium simense	Rubiaceae	H	1	3	0	1	8.9
Geranium arabicum	Geraniaceae	H	5	5	9	4	41.1
Geranium ocellatum	Geraniaceae	H	3	1	2	1	12.5
Guizotia scabra	Asteraceae	H	2	0	1	1	7.1
Haplocarpha schimperi	Asteraceae	H	1	1	0	0	3.6

Species	Family	Habit	LL	Soil layers 1	2	3	Density (N=56)
Helichrysum formosissimum	Asteraceae	H	2	6	14	7	51.8
Helichrysum forsskahlii	Asteraceae	H	1	4	13	10	50
Helichrysum schimperi	Asteraceae	H	2	4	8	1	26.8
Hydrocotyle sibthorpioides	Apiaceae	H	11	1	5	52	123.2
Hypericum peplidifolium	Hypericaceae	H	3	7	8	8	46.4
Hypoestes triflora	Acanthaceae	H	28	12	9	14	112.5
Impatiens rothii	Balsaminaceae	H	25	4	0	0	51.8
Juncus bufonius	Juncaceae	Sy	0	14	40	59	201.8
Juncus effusus	Juncaceae	Sy	10	40	16	25	162.5
Kalanchoe petitiana	Crassulaceae	H	16	12	12	19	105.4
Lactuca inermis	Asteraceae	H	1	0	0	0	1.8
Lactuca seriola	Asteraceae	H	0	1	0	1	3.6
Laggera crispata	Asteraceae	H	4	2	9	0	26.8
Leucas glabrata	Lamiaceae	S	0	0	1	0	1.8
Leucas martinicensis	Lamiaceae	H	3	4	0	0	12.5
Linum trigynum	Linaceae	H	0	0	1	1	3.6
Lobelia rhynchopetalum	Lobeliaceae	T	0	10	4	6	35.7
Lobelia scebelii	Lobeliaceae	H	1	2	10	1	25
Lythrum rotundifolium	Lythraceae	H	0	3	2	1	10.7
Maesa lanceolata	Myrsinaceae	S	3	1	1	5	17.9
Melilotus elegans	Fabaceae	H	0	5	4	0	16.1
Microglossa pyrifolia	Asteraceae	L	0	9	0	0	16.1
Oplismenus hirtellus	Poaceae	G	134	82	62	77	633.9
Osyris quadripartita	Santalaceae	S	0	0	1	1	3.6
Oxalis corniculata	Oxalidaceae	H	80	145	102	156	862.5
Oxalis latifolia	Oxalidaceae	H	1	2	2	3	14.3
Parieteria debilis	Urticaceae	H	3	5	0	3	19.6
Persicaria nepalensis	Polygonaceae	H	22	21	15	6	114.3
Pilea tetraphylla	Urticaceae	H	202	127	115	57	894.6
Plantago lanceolata	Plantaginaceae	H	0	1	0	0	1.8
Plantago major	Plantaginaceae	H	0	1	1	0	3.6
Plectranthus lanuginosus	Lamiaceae	H	5	4	0	1	17.9
Poa annua	Poaceae	H	66	19	15	36	242.9
Polygonum aviculare	Polygonaceae	H	0	8	0	3	19.6
Polypogon fugax	Poaceae	H	0	1	3	0	7.1
Pteris vittata	Pteridaceae	H	1	8	1	4	25
Pterolobium stellatum	Fabaceae	S	0	3	2	0	8.9
Ranunculus oligocarpus	Ranunculaceae	H	0	0	0	1	1.8
Rumex abyssinicus	Polygonaceae	H	3	0	0	0	5.4
Rumex nepalensis	Polygonaceae	H	1	1	0	0	3.6
Satureja paradoxa	Lamiaceae	H	1	2	0	0	5.4
Selaginella kraussiana	Selaginellaceae	H	28	4	1	6	69.6
Senecio hadiensis	Asteraceae	C	3	0	0	0	5.4
Snowdenia polystachya	Poaceae	G	28	34	11	9	146.4
Solanum anguivi	Solanaceae	H	9	25	9	5	85.7
Solanum marginatum	Solanaceae	S	0	2	0	1	5.4
Solanum nigrum	Solanaceae	H	6	20	28	22	135.7
Sparmannia macrocarpa	Tiliaceae	S	2	0	1	0	5.4

Species	**Family**	**Habit**	**LL**	**Soil layers** 1	2	3	**Density (N=56)**
Sparmannia ricinocarpa	Tiliaceae	S	4	12	10	7	58.9
Sporobolus pyramidalis	Poaceae	G	16	12	6	3	66.1
Stellaria sennii	Caryophyllaceae	H	5	26	50	9	160.7
Stephania abyssinica	Menispermaceae	C	2	2	0	0	7.1
Swertia kilimandscharica	Gentianaceae	H	6	8	17	18	87.5
Tagetes minuta	Asteraceae	H	1	1	0	1	5.4
Thalictrum rhynchocarpum	Ranunculaceae	H	17	39	55	34	258.9
Trifolium burchellianum	Fabaceae	H	0	7	17	14	67.9
Trifolium semipilosum	Fabaceae	H	0	0	13	25	67.9
Uebelinia abyssinica	Caryophyllaceae	H	18	5	15	7	80.4
Urtica dioica	Urticaceae	H	4	5	1	0	17.9
Vernonia amygdalina	Asteraceae	T	0	2	2	3	12.5
Veronica abyssinica	Scrophulariaceae	H	0	0	0	1	1.8
Veronica glandulosa	Scrophulariaceae	H	61	109	226	264	1178.6
Wahlenbergia flexuosa	Campanulaceae	H	33	98	113	82	582.1
Total			1,258	1,647	1,608	1,151	1,0828.9