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IMPACT OF LAND USE TYPE ON SOIL SEED BANK FLORA IN CHILIMO FOREST, ETHIOPIA: IMPLICATIONS FOR NATURAL RESTORATION OF VEGETATION

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ABSTRACT: A very long history of human interference and pressure from population growth has imparted different land use types in the Chilimo forest: shrub land, closed forest, *Cupressus lusitanica* plantation, *Eucalyptus* plantation, *Juniperus procera* dominated stand, *Olea europaea* subsp. *cuspidata* dominated stand, open forest, *Podocarpus falcatus* dominated stand, abandoned arable land, and grassland. A total of 100 plots (each 20 m x 20 m) were used in ten habitat types (10 plots in each) for the collection of data on the soil seed bank and standing vegetation. Soil samples were collected from within small quadrats (15 cm x 15 cm) from four successive soil layers. A total of 105 plant species were identified from the soil seed bank with total densities ranging between 4991 and 11017 seeds/m^2. Of the total recorded species in the soil seed bank, herbaceous species were represented with the largest number (87.6%) whereas the contribution of woody species was low (11.4%). The highest number of species was recorded from the closed canopy stand while the highest density of seeds was found in the arable land. The overall vertical distribution of seeds showed the highest densities occurring in the upper 3 cm soil depth and gradually decreasing with increasing depth, except in the arable land. There was a significant difference among the habitat types in the density of soil seed bank suggesting different types, level and frequency of disturbance on different habitat types. The very low similarity between the soil seed bank and aboveground flora is reflective of both the current and past standing vegetation.

Key words/phrases: Afromontane, Forest degradation, Restoration, Soil seed bank, Species diversity.

INTRODUCTION

Dry Afromontane forests occur at altitudes between 2300 m-3200 m above sea level in Ethiopia. These areas are characterized by dry periods of up to five months and annual rainfall of about 1000 mm (Tamrat Bekele, 1993; Kidane Mengistu, 2002), with annual temperatures between 14°C and 18°C (Leipzig, 1996). The remnant dry Afromontane forests in Ethiopia are secondary forests and species-rich (EFAP, 1994; Tamrat Bekele, 1993).

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Dry Afromontane forests in Ethiopia have been under a persistent disturbance regime for a very long time: major contributing factors include agricultural expansion, intentional fire, natural mortality of seedlings, overgrazing and fuel wood consumption (Tamrat Bekele, 1993; Mekuria Argaw *et al*., 1999; Tadesse Woldemariam *et al*., 2001; Kidane Mengistu, 2002). The occurrence of remnant forest patches surrounded by agricultural or grazing land is a common form of humanized landscape that is increasing with increasing human population densities. Today, remnant forest vegetations are distributed in restricted areas in the highlands of Ethiopia forming islands on hill sides, mountain tops, and around cultural ritual sites (Tamrat Bekele, 1993; Demel Teketay, 1996; Kidane Mengistu, 2002). These isolated forests maintain some of the endemic species in the country.

The continuous increase of human population has resulted in the clearing and conversion of dry Afromontane forests into arable lands, thereby affecting the size and species composition of the vegetation. Along with this change, the density and composition of the species in the soil seed bank gradually changes too. For example, the woody component of seeds in the soil seed bank of the forest would be much higher than that of the arable land (Demel Teketay, 1997). Soil seed bank investigations carried out in different environments in Ethiopia indicate the dominance of herbaceous species over woody species in the soil seed bank. The implication in the long run is that herbaceous species will have better chances of recovery than woody species after disturbance. The seeds of many woody species are found on the surface of the soil because of their large size, and hence exposed to adverse environmental impacts such as predation and the effect of fire. As a result, underground seed storage of such species and their chance of regeneration after disturbance is kept minimal (Keay, 1960; Demel Teketay and Granstrom, 1995).

Chilimo forest is one of the dry Afromontane forests in Ethiopia with a long history of human disturbance. The main cause for the forest decline is agricultural expansion due to high population growth, selective cutting for commercial timber and various domestic uses (Barrow, 2002; Farm Africa, 2004). The major species in the forest are *Juniperus procera*, *Podocarpus falcatus*, *Prunus africana*, *Olea europaea* subsp. *cuspidata*, *Hagenia abyssinica*, *Apodytes dimidiata*, *Ficus* species, etc. (Birdlife International, 2005). It is also one of the richest highland habitats in Ethiopia in its bird species (Tadesse Woldemariam *et al*., 2001). Plantations of predominantly exotic species, including *Eucalyptus globulus* and *E. camaldulensis* (Barrow, 2002), are exercised by the local community. The forest is home to a number of wild animals such as civet cat, antelope, fox, pigs, monkeys, hyena etc. (Jordan, 2003). At present, Farm Africa (NGO) is trying to introduce Participatory Forest Management (PFM) to rescue the remaining forest patches. The main objective of the present study was to study the soil seed bank composition under different habitat types in the forest, and discuss its contribution to the effort in vegetation restoration in the study area.

MATERIALS AND METHODS

The study area

The study was undertaken at Chilimo forest, located 80 km west of Addis Ababa at 9°05' N and 38°10' E. The altitudinal range of the forest lies between 2300-3000 m a.s.l. The forest lies on the slopes of a chain of hills, and is continuously dissected by ridges and valleys dominating the landscape. The soil is reddish brown, gravelly and shallow at higher altitudes while at lower altitudes it is dark grey and deep (Tamrat Bekele, 1993). Chilimo forest receives a bimodal rainfall, the small rains in March and April, and the big rains between June-September, with a peak in August. The highest average temperatures during the dry and wet seasons are 23°C and 10°C, respectively (Lelisa, 1996).

Reconnaissance survey and vegetation sampling

A reconnaissance survey was conducted across the forest to identify the different habitats based on the prevailing land use. The following ten habitat types were identified: shrub land (SL), closed forest (CF), *Cupressus lusitanica* plantation (CU), *Eucalyptus* plantation (EU), *Juniperus procera* dominated stand (JU), *Olea europaea* subsp. *cuspidata* dominated stand (OL), open forest (OF), *Podocarpus falcatus* dominated stand (PD), abandoned arable land (AL) and grassland (GL).

Data on the standing vegetation was collected from 10 plots (each 20 m x 20 m) in each habitat type following the procedures outlined in Kent and Coker (1992). The plots were established in each habitat type following the procedures outlined in Tamrat Bekele (1993). Woody species were recorded from within an area of 400 m^2 while for herbaceous species subplots of 2 m x 2 m were laid at the centre of the main plot following Mulugeta Lemenih and Demel Teketay (2006). Known plants were recorded using their scientific names and those not readily identifiable specimens were recorded using the local names, and later taken to the National Herbarium, Department of Plant Biology and Biodiversity Management, Addis Ababa

University for identification.

Soil sampling and germination experiment

Soil samples were taken from five subplots (15 cm x 15 cm) situated inside the main plot: one at the centre and four at the four corners. The samples were carefully removed from four successive layers; litter layer; upper layer (0-3 cm); middle layer (3-6 cm); and lower layer (6-9 cm) using a sharp knife and spoon. Samples from similar depths were mixed and divided into five equal parts, from which one was randomly picked and kept in a separate cotton cloth as described by Demel Teketay (1997; 1998); Valbuena (2001); Getachew Tesfaye *et al*. (2004). A total of 400 soil samples were collected, and transported to the green house of Plant Biology and Biodiversity Management Department, Addis Ababa University, for the germination experiment.

All soil samples were sieved using a mesh size of 0.5 mm to recover seeds of some species before soil samples were left for germination experiment. Seeds with white and firm embryo were considered viable (Demel Teketay and Granstrom, 1995; Demel Teketay, 1997). Immediately after sieving, the soil samples were spread on plastic dishes, with perforations at the bottom, and watered every morning to stimulate germination of seeds. After the appearance of the first seedlings after about a week, the substrates were stirred at four weeks interval to facilitate germination of remaining seeds. After germination, the seedlings were identified at the National Herbarium. The germination trial was terminated at the end of six months, when no more new seedlings were emerging.

Data analysis

The density of seeds was calculated by dividing the total number of seeds of each species with the total sampling area of each habitat type (i.e., seeds/m^2). Jaccard's Coefficient of Similarity (JCS) was used to calculate the similarity in species composition (Krebs, 1989) under the two scenarios, i.e.,

i. Between the soil seed bank and aboveground vegetation at each habitat type, and

ii. Among the soil seed banks of different habitat types.

Similarity index was determined between paired samples at a time (H_A and H_B), as follows:

$$JCS = \frac{c}{c + b + a}$$

where, a and b are the number of species found only in samples H_A and H_B respectively, and c is the number of common species found in both samples (H_A and H_B).

The value of Jaccard's similarity coefficient ranges from zero (no number of species in common) to one (identical set of species).

RESULTS

A total of 105 plant species representing 33 families were recorded from all habitat types (Table 1). Out of these, 92 (87.6%) were herbaceous species, 12 (11.4 %) were woody species (trees and shrubs) and one was a climber species. Family Asteraceae is represented by 24 species, followed by Poaceae (16 species), and Caryophyllaceae (7 species).

Table 1. Quantity of viable seeds in soil samples from the ten habitat types in Chilimo forest, West Shoa Zone, Oromia Regional State, Ethiopia (AL-Abandoned arable land, CF-Closed forest, JU-*Juniperus procera* dominated stand, OL-*Olea europaea* subsp. *cuspidata* stand, SL-Shrub land, PD-*Podocarpus falcatus* stand, CU-*Cupressus lusitanica* stand, GL-Grassland, EU-*Eucalyptus* plantation, OF-Open forest).

Species	**Habitat types**									
	AL	**CF**	**JU**	**OL**	**SL**	**PD**	**CU**	**GL**	**EU**	**OF**
Trees and shrubs										
Acacia abyssinica	-	-	-	-	-	-	-	-	3	5
Calpurnia aurea	-	3	-	-	4	-		-	21	6
Clutia abyssinica	-	1	7	-	5	56	12	3	-	-
Cupressus lusitanica	-	-	29	-	-	-	165	-	-	8
Juniperus procera	-	37	301	-	-	64	15	-	21	24
Myrsine africana	-	1	-	4	-	-		-	-	4
Olea europaea subsp. *cuspidata*	-	19	2	231	-	18	-	-	-	35
Podocarpus falcatus	-	9	-	-	-	31	-	-	-	-
Prunus africana	-	13	-	-	-	7	-	-	-	-
Rosa abyssinica	-	14	-	-	7	-	-	-	-	-
Rumex nervosus	-	-	4	-	-	3	17	-	-	-
Urera hypselodendron	-	4	2	-	14	2	-	-	3	7
Climber										
Mikania cordata	-	-	4	-	-	8	9	-	-	-
Herbs										
Achyranthes aspera	-	-	126	-	2	-	39	-	-	14
Acmella caulirhiza	18	2	12	-	13	-	1	-	2	-
Agrocharis melanantha	14	-	-	-	6	28	8	-	-	-

Species	**Habitat types**									
	AL	**CF**	**JU**	**OL**	**SL**	**PD**	**CU**	**GL**	**EU**	**OF**
Alchemilla cryptantha	177	124	239	-	172	45	9	-	-	-
Amaranthus dubius	370	-	2	-	-	-	44	184	181	-
Amaranthus palmeri	2	136	-	7	1	27	11	33	-	28
Anagallis arvensis	8	10	5	-	1	-	7	28	7	-
Bidens pilosa	2	3	2	-	-	12	12	-	16	-
Campanula edulis	29	16	44	2	12	-	41	-	16	-
Cardamine trichocarpa	-	4	3	1	-	17	-	2	-	21
Carduus schimperi	-	307	217	-	12	-	109	5	-	29
Cerastium octandrum	7	11	-	-	20	5	-	-	24	-
Chenopodium murale	14	18	11	42	-	-	-	6	4	-
Cirsium schimperi	7	52	61	1	2	-	9	-	3	21
Commelina africana	-	126	-	-	3	-	-	-	5	3
Commelina subulata	8	-	7	-	4	-	3	-	11	-
Conyza tigrensis	-	1	-	-	-	-	2	31	-	-
Corrigiola capensis	-	-	-	-	-	3	13	-	1	35
Cotula abyssinica	-	1	11	-	6	2	-	87	-	28
Crepis foetida	144	31	5	-	1	18	11	-	-	-
Crepis rueppellii	-	1	2	-	2	-	-	-	34	28
Crepis schultzii	-	8	-	64	9	-	10	-	-	-
Datura stramonium	-	1	-	-	-	-	-	-	-	-
Dicrocephala integrifolia	3	11	13	69	17	16	22	-	12	28
Drymaria cordata	-	1	-	7	-	-	-	-	-	12
Eriosema shirense	-	1	-	-	4	-	138	-	-	-
Erodium moschatum	-	-	-	-	88	-	-	-	1	-
Evolvulus alsinoides	13	162	185	132	299	287	192	119	166	2
Galinsoga parviflora	11	3	3	-	10	-	-	-	6	-
Galinsoga quadriradiata	125	195	124	282	7	-	7	67	-	24
Geranium arabicum	20	33	34	14	2	127	6	12	19	19
Gerbera piloselloides	-	2	-	-	-	-	-	-	-	8
Gnaphalium tweedieae	-	-	-	-	1	-	2	-	-	-
Guizotia scabra	-	2	1	-	18	-	-	17	2	-
Helichrysum schimperi	-	3	-	23	-	-	21	-	-	1
Hypoestes triflora	-	18	3	6	1	-	1	-	6	33
Impatiens rothii	-	13	-	-	29	-	-	2	-	4
Kosteletzkya begoniifolia	9	4	-	-	-	24	-	-	6	-
Laggera crispata	2	3	41	37	6	-	-	1	3	-
Lobelia erlangeriana	215	8	9	-	237	362	4	-	160	28
Lychnis abyssinica	3	185	10	272	149	56	13	139	4	16
Lychnis kiwuensis	201	110	95	480	-	169	46	85	100	55
Medicago polymorpha	17	14	1	-	-	-	51	-	-	-
Mentha aquatica	2	-	-	-	14	-	-	-	2	8
Minuartia filifolia	-	2	-	-	-	-		-	43	-
Ocimum urticifolium	9	-	16	-	9	-	6	21	15	7
Oxalis radicosa	-	21	-	-	14	1	22	-	8	3
Phagnalon abyssinicum	5	-	-	-	-	-	18	-	-	-
Pilea rivularis	-	19	-	-	14	3	-	-	-	6
Pilea tetraphylla	-	-	-	9	2	6	-	-	-	8
Plantago lanceolata	22	16	4	15	7	22	16	51	33	28

Species	**Habitat types**									
	AL	**CF**	**JU**	**OL**	**SL**	**PD**	**CU**	**GL**	**EU**	**OF**
Pseudognaphalium luteo-album	13	15	21	17	6	12	43	19	-	9
Rumex nepalensis	-	6	1	-	-	-	-	-	-	-
Sida ternata	-	-	-	4	-	8	-	-	6	
Sida urens	11	1	172	-	134	-	-	-	134	-
Solanum dasyphyllum	22	4	-	-	-	3	-	5	-	-
Solanum incanum	-	-	16	-	3	-	2	8	-	-
Solanum indicum	2	-	13	-	1	-	17	-	-	1
Sonchus bipontini	-	1	-	35	-	-	-	-	-	9
Sonchus oleraceus	15	13	7	-	3	-	7	1	1	13
Stellaria media	-	-	-	-	1	-	14	-	-	-
Trifolium multinerve	4	14	19	-	3	5	7	-	4	124
Trifolium semipilosum	54	23	40	43	44	27	24	22	51	66
Trifolium tembense	436	6	15	6	30	-	54	176	11	25
Ursinia nana	-	17	2	70	17	2	2	-	-	-
Urtica simensis	-	13	7	-	-	-	1	-	6	-
Valerianella microcarpa	-	32	21	-	14	8	-	-	-	-
Verbascum sinaiticum	9	-	9	-	5	-	-	-	2	-
Verbena officinalis	-	36	-	-	-	-	18	-	-	-
Veronica abyssinica	219	125	130	121	2	204	47	72	137	122
Grasses and sedges										
Andropogon abyssinicus	-	2	-	-	10	-	-	-	8	-
Arthraxon ciliaris subsp. *quartinianus*	43	-	3	3	72	-	10	21	29	-
Cynodon dactylon	-	22	1	-	-	20	-	-	8	15
Cyperus castaneus	9	5	-	-	21	-	-	18	11	-
Cyperus rigidifolius	-	25	7	5	74	21	33	7	21	-
Digitaria nodosa	-	11	-	13	35	-	31	46	44	33
Ehrharta erecta	-	-	-	2	26	-	-	-	-	-
Eleusine africana	-	6	18	-	9	-	-	-	16	-
Eragrostis schweinfurthii	21	-	-	-	1	-	2	-	-	41
Eragrostis tef	22	-	-	-	-	-	-	-	-	-
Fimbristylis longiculmis	45	76	23	37	22	44	48	22	36	15
Koeleria capensis	7	-	-	-	1	-	6	46	-	22
Leersia hexandra	-	2	1	-	25	-	-	23	13	-
Phalaris paradoxa	6	-	-	-	53	-	-	83	-	-
Poa annua	11	3	2	1	18	107	7	15	12	30
Poa leptoclada	32	1	-	-	-	-	-	-	-	-
Polypogon monspeliensis	-	-	-	-	7	-	1	21	-	-
Pycreus flavescens	-	1	16	49	59	-	24	1	-	12
Scirpus costatus	-	-	-	-	17	-	7	18	-	-
Setaria pumila	32	6	1	-	-	-	73	-	-	-
Tragus racemosus	-	2	3	-	9	-	1	-	-	-
Triticum aestivum	9	-	-	-	-	-	-		-	-
Total number of species	**49**	**76**	**60**	**34**	**70**	**40**	**61**	**38**	**52**	**49**

The density of viable seeds from the seed bank ranged between 4991 and 11017 seeds/m^2 (Table 2), with herbaceous species (93.2%) more dominant than woody species (6.7%). Species richness of the soil seed bank varied considerably among habitat types. The soil seed density was the highest in the arable land followed by the closed forest (Table 2). The closed forest had both the highest total number of species and the highest proportion of woody species while the shrub land was the second highest in total number of species. On the other hand, the *Olea europaea* subsp. *cuspidata* dominated stand had the least number of species.

Table 2. Life form composition and number of species (N) and density (D=seeds/m^2) germinated from the different habitats.

Life form		**Habitat types**									
		AL	**CF**	**JU**	**OL**	**SL**	**PD**	**CU**	**GL**	**EU**	**OF**
Herbs	N	38	54	44	25	50	28	45	26	38	35
	D	9830	8989	7637	7819	6551	6541	5053	5382	5573	3468
Grasses & sedges	N	11	13	10	7	16	4	11	11	10	7
	D	1187	631	351	489	1964	853	1049	1347	880	836
Shrubs	N	-	5	3	1	4	3	2	1	2	3
	D	-	102	58	18	133	271	129	13	107	76
Trees	N	-	4	4	1	-	4	2	-	2	4
	D	-	267	1640	1027	-	422	800	-	53	293
Climber	N	-	-	1	-	-	1	1	-	-	-
	D	-	-	18	-	-	36	40	-	-	-
Density		**11017**	**9989**	**9704**	**9353**	**8648**	**8123**	**7071**	**6742**	**6613**	**4991**

The vertical distribution of species in the soil seed bank showed a similar pattern in all habitat types (Fig. 1); a gradual decrease with increasing depth. The highest number of species was recorded in the upper 3 cm layer and the litter layer. Seeds of certain herbaceous species, (e.g. *Veronica abyssinica*, *Lychnis abyssinica*, *Lychnis kiwuensis* and *Evolvulus alsinodes*) were distributed in almost all soil layers, whereas a larger density of seeds was recorded in the deeper soil layers (3-6 cm and 6-9 cm) for other species.

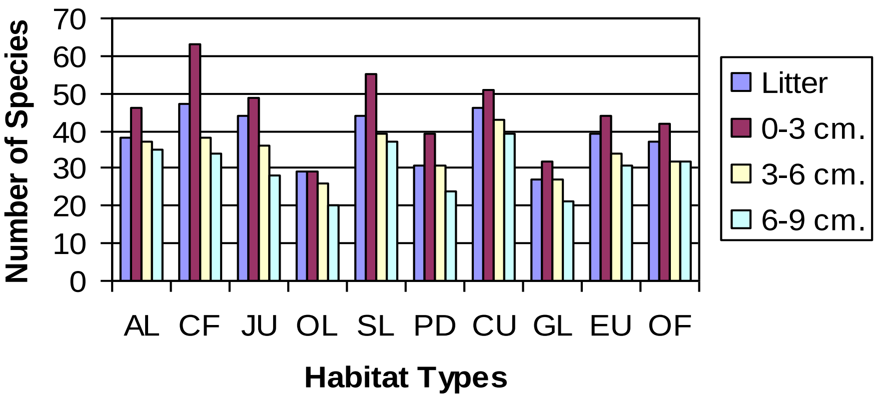

Fig. 1. Number of species in the four layers of the soil seed bank at different habitats.

The vertical distribution of seed density in the arable land, however, followed a slightly different pattern than in the other habitat types. The deepest layer (6-9 cm) contained a higher seed density than the upper layer (3-6 cm) (Fig. 2).

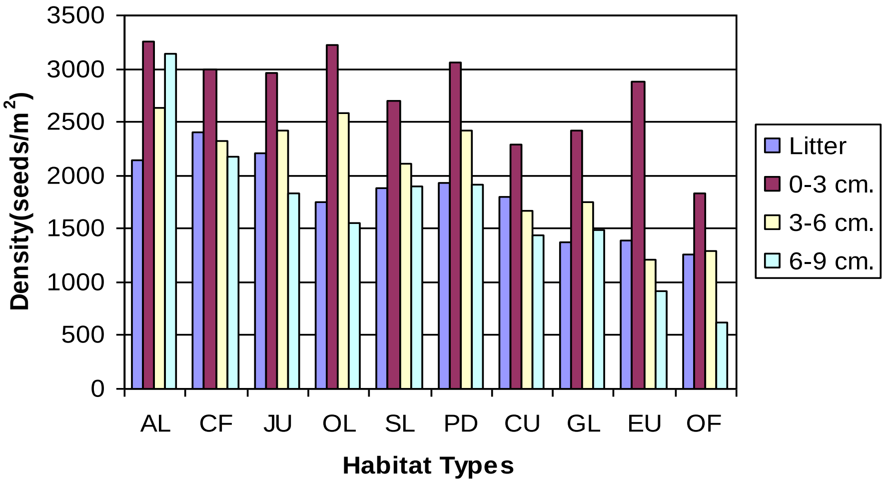

Fig. 2. Density of seeds (seeds/m^2) in different layers at each habitat types.

Some plant forms totally outnumbered others in certain habitat types; for instance, herbaceous species attained 100% representation in arable land. Certain herbaceous species (e.g. *Evolvulus alsinoides*, *Fimbristylis longiculmis*, *Geranium arabicum*, *Lychnis abyssinica*, *Plantago lanceolata*, *Poa annua*, *Trifolium semipilosum*, and *Veronica abyssinica*) were recorded from all habitat types. The seeds of shrub species were recorded from all habitat types except from the abandoned arable land, while the seeds of tree species were recorded in habitats other than shrub land, arable land and grassland. There was a very low similarity in species composition between the soil seed bank flora and the standing vegetation in all habitat types (Table 3).

Table 3. Jaccard's coefficient of similarity between the species composition of the standing vegetation and the soil seed bank.

Habitat type	**Number of spp. only in the standing vegetation**	**Number of spp. only in soil seed bank**	**Common species**	**JCS**
Grassland	25	25	13	0.21
Closed canopy stand	42	55	21	0.18
Arable land	26	37	12	0.16
Eucalyptus plantation	28	42	10	0.13
Podocarpus falcatus stand	31	31	9	0.13
Open forest	59	36	13	0.12
Juniperus procera stand	39	53	9	0.09
Shrub land	38	61	9	0.08
Olea europaea subsp. *cuspidata* stand	37	29	5	0.07
Cupressus lusitanica stand	35	56	5	0.05

The similarity in species composition between habitat types were generally low as well, ranging from 0.26 (between PD and GL) to 0.56 (between CU and JU) (Table 4).

Table 4. Jaccard's coefficient of similarity in the species composition in soil seed banks among the habitat types.

Habitat types	**SL**	**CF**	**CU**	**EU**	**JU**	**OL**	**OF**	**PD**	**AL**	**GL**
SL	-	0.54	0.55	0.49	0.53	0.32	0.43	0.31	0.45	0.42
CF		-	0.44	0.49	0.53	0.38	0.49	0.45	0.39	0.36
CU			-	0.36	0.56	0.34	0.41	0.36	0.47	0.39
EU				-	0.48	0.30	0.38	0.31	0.49	0.32
JU					-	0.33	0.39	0.36	0.46	0.35
OL						-	0.43	0.30	0.29	0.38
OF							-	0.37	0.31	0.30
PD								-	0.31	0.26
AL									-	0.38
GL										-

A total of 1324 seeds were recovered after sieving the soil samples (Table 5): *Juniperus procera* (581), *Olea europaea* subsp. *cuspidata* (449), *Cupressus lusitanica* (235), *Podocarpus falcatus* (45), *Prunus africana* (22), and *Acacia abyssinica* (8). A small proportion of these seeds (22.66%) were non-viable seeds.

Table 5. List of species and quantity of seeds recovered after sieving the soil samples from different habitat types (V=viable; NV=non-viable).

Species		**Habitat types**						
		CF	**JU**	**OL**	**PD**	**CU**	**EU**	**OF**
Acacia abyssinica	V	-	-	-	-	-	3	5
	NV	-	-	-	-	-	-	-
Cupressus lusitanica	V	-	29	-	-	165	-	8
	NV	-	9	-	-	24	-	-
Juniperus procera	V	37	301	-	64	15	21	24
	NV	9	89	2	8	7	1	3
Olea europaea subsp. *cuspidata*	V	19	2	231	18	-	-	35
	NV	23	3	53	24	-	-	41
Podocarpus falcatus	V	9	-	-	31	-	-	-
	NV	-	-	-	6	-	-	-
Prunus africana	V	13	-	-	7	-	-	-
	NV	2	-	-	-	-	-	-
Total number of species		**4**	**3**	**2**	**4**	**2**	**2**	**4**

DISCUSSION

The composition and distribution of the soil seed bank flora reflects the history of the standing vegetation (Garwood, 1989). Human interference is the predominant mode of disturbance in forested land due to selective removal of trees. In grassland and open forest habitats, domestic animals are the major cause of disturbance due to grazing. Tybirk *et al*. (1992) attribute diminished seed density to intensive grazing effect, while Herault and Hiernaux (2004) indicated that grazing affected species composition as well. As described by Mulugeta Lemenih and Demel Teketay (2006), the difference in pressure of disturbance between the land use systems is one of the most likely causes of variations in the soil seed bank density and species composition.

The absence of seeds of woody species in the agricultural area is mainly associated with the successive weeding during the continuous cultivation of the land. The seeds of *Juniperus procera*, *Olea europaea* subsp. *cuspidata* and *Cupressus lusitanica* have relatively large density in the soil seed bank. The soil seed density in the open forest, compared to other habitat types, is found to be the least. This is most likely because of the intensive grazing effect (Tybirk *et al*., 1992). Herault and Hiernaux (2004) have indicated that grazing not only reduces the species composition but also greatly affects the density of seeds.

Some woody species produce fleshy fruits (e.g. *Carissa spinarum*) which are exposed to pre-dispersal predation while on the parent tree itself or after falling to the ground. These result in aborted fruits and impoverished soil seed bank. In addition, according to Demel Teketay (1996), insect attack, decay and shedding of seeds before maturation could reduce the number of viable seeds.

The contribution to the seed bank of woody species producing large-sized seeds is very minimal or none at all. Such seeds lie on the ground and remain exposed to the impacts of predation and harsh climatic conditions that enhance their decomposition (Demel Teketay and Granstrom, 1997). The age of the species in the stand, is among the contributing factors to lack of seeds from the seed bank. For instance, the complete absence of seeds of *Pinus patula* from the seed bank is due to the immaturity of the parent trees in the standing vegetation. Since plants show seasonal variation in flowering and seeding (Looney and Gibson, 1995), time of sampling could also influence the similarity or dissimilarity between standing vegetation and below ground flora.

According to Demel Teketay and Granstrom (1995), the presence of high disturbance favours the incorporation of seeds of herbaceous species into the deeper soil layers. Trampling effect by large animals and increased human activity are discussed as the major causes for the incorporation of seeds into the deeper soil layers by Mekuria Argaw *et al*. (1999). For example, with continuous cultivation of the land, the seeds of weed species (e.g., *Galinsoga* species) are favoured and build up a large density of seeds in the soil within short time (Demel Teketay, 1997). According to Cosyns *et al*. (2005), some of these species (*Evolvulus alsinoides*, *Plantago lanceolata*, *Poa annua* and *Trifolium semipilosum*) are commonly grazed by herbivores, and therefore, animals could be the agents for dispersing the seeds in their faeces in all habitats due to their free movement.

Use of plants in herbal medicine disposes certain species to impacts that lead to under representation in the seed bank. For instance, the flower of *Hagenia abyssinica* is widely used in the treatment of helminth parasite infection in humans. Such use, however, not only reduces the reproductive potential of the species, but also leads to lack of its seeds from the soil. In addition, according to Yamagiwa (2005), the seeds of *Hagenia abyssinica* are highly predated by monkeys thereby contributing to the absence of viable seeds in the soil.

A very low proportion of the seeds were represented by woody species. One probable reason for this could be the relative shorter survival of seeds of some woody species in the soil. For instance, the seeds of *Ekebergia capensis* and *Bersama abyssinica* were adapted to germination more or less immediately after dispersal (Demel Teketay and Granstrom, 1997). This result is in agreement with other previous similar studies conducted earlier in the highlands of Ethiopia (see Demel Teketay, 1996, 1998; Demel Teketay and Granstrom, 1995; Kebrom Tekle and Tesfaye Bekele, 2000; Feyera Senbeta and Demel Teketay, 2001; Mulugeta Lemenih and Demel Teketay, 2006).

Herbaceous species, because of their high seed input, have a better chance of natural recovery than woody species (Welling *et al*., 1988). Whitemore (1991) also pointed out that herbaceous species have greater success in establishing after disturbance due to the production of large number of seeds in a short time and possessing means of longer distance dispersal. For instance, species such as *Alchemilla cryptantha*, *Amaranthus dubius*, *Crepis foetida*, *Galinsoga quadriradiata*, *Lobelia erlangeriana*, *Lychnis kiwuensis*, *Trifolium tembense* and *Veronica abyssinica* dominated (73%) the total seed density in arable land. In addition, the persistent nature of seeds of most herbaceous species enables their seeds to accumulate in the soil without germinating for a long time (Demel Teketay and Granstrom, 1995; Getachew Tesfaye *et al*., 2004).

The recovery of fewer seeds from the litter layer than the top soil layer (0-3 cm) is attributed to the loss of seeds by herbivores such as insects, cattle and wildlife as described by Thompson and Grime (1979). During the field study, it was possible to observe the removal of seeds from the surface by ants and other small insects. As long as the seeds stay on the surface of the soil, exposure to predators and predation becomes inevitable (Mulugeta Lemenih and Demel Teketay, 2006). Seed loss through surface flooding along the steep slopes (Lelisa, 1996; Hopkins and Graham, 1983) is also common again resulting in reduced accumulation in the seed bank. As reported by Mekuria Argaw *et al*. (1999), trampling by domestic and wild animals has some role in altering the viability of seeds of woody species.

The depth distribution of species was highly variable. For instance, seeds of tree species such as *Acacia abyssinica*, *Cupressus lusitanica*, *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Podocarpus falcatus* and *Prunus africana*, have 94.6% of the total viable seeds in the litter and upper 3 cm layer. This is because the seeds of these trees are large in size to be easily incorporated into the deeper soil layers (Demel Teketay, 1996; Demel Teketay and Granstrom, 1997). According to Demel Teketay and Granstrom (1995), the seeds of trees, shrubs and climbers are found mainly in shallow depths than the seeds of herbs, grasses and sedges. The variation of seed density with depth could be explained by differences in seed longevity and seed predation (Demel Teketay, 1998). Agricultural activity is also another major factor that has an effect on the vertical distribution of seeds in the soil seed bank (Soriano *et al*., 1967); the formation of cracks in the agricultural fields, allows the incorporation of seeds into deeper layers.

The reason for the absence of seeds of woody species from some habitat types could be attributed to specific land use histories. For instance, seeds of woody species are absent from abandoned arable field. Viable seeds of tree species were recorded from the closed forest, *Cupressus lusitanica* plantation, *Eucalyptus* plantation, *Juniperus procera* dominated stand, *Olea europaea* subsp. *cuspidata* dominated stand, open forest, and *Podocarpus falcatus* dominated stand. This is attributable to the presence of mature seed producing parent trees in the respective stands (Mekuria Argaw *et al*., 1999). The absence of woody species from grassland and shrub land soils is directly associated with the absence of mature parent trees in the aboveground vegetation in these habitats.

Most shrub species (e.g. *Rosa abyssinica*, *Myrsine africana*, *Calpurnia aurea* and *Clutia abyssinica*) are found under the canopy of their parent trees. However, the presence of few seeds of *Myrsine africana*, *Calpurnia aurea* and *Clutia abyssinica* from habitats that lack their parent trees is indicative of the presence of seed dispersal agents for these species. Dispersal of seeds of *Myrsine africana* by birds, for instance, has been reported by Demel Teketay (1998).

Species composition and abundance of viable seeds in the seed bank are important clues for the possible contribution of the soil seed banks for the restoration processes (Welling *et al*., 1988). The results from the present study clearly indicate that different land management regimes have an impact on the species composition, distribution and density of seeds in the seed bank. For instance, seeds of woody species were absent in arable land. As a result of rapid human population growth, some parts of the forest have been converted into agricultural land. This denies seeds of most woody species the chance of recruitment from the soil seed bank due to the continuous weeding during cultivation. The prevalence of herbaceous species over woody species, both in terms of density and composition, indicate a better chance of natural recovery of the ground flora than the standing woody vegetation. In the present study, more than 80% of woody species that were recorded in the standing vegetation were not recovered from the seed bank.

However, if the pressure on degraded forest areas from degradative forces (i.e., cultivation, grazing, trampling and selective logging) is relaxed, the vegetation can gradually regenerate from the seed bank as well as seed rain that comes from the nearby vegetation. A large number of *Juniperus procera* and *Olea europaea* subsp. *cuspidata* seedlings and saplings were observed during data collection in the standing vegetation, indicating their high regeneration potential in the dry Afromontane forest of Ethiopia. However, in the face of a changing climate, natural regeneration processes could be very much delayed, and the outcome in the long run is not so certain. Therefore, appropriate management interventions that involve regeneration of key species and their subsequent planting could assist the restoration effort.

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REFERENCES

Barrow, E. (2002). Analysis of stakeholder power and responsibilities in community involvement in forest management in eastern and southern Africa. IUCN, Eastern Africa Programme.

BirdLife International (2005). Bird Life IBA Fact Sheet. http://www.birdlife.org.

Cosyns, E., Claerbout, S., Lamoot, I. and Hoffmann, M. (2005). Endozoochorous seed dispersal by cattle and horse in a spatially heterogeneous landscape. *Plant Ecol.* **178**: 149–162.

Demel Teketay (1996). **Seed Ecology and Regeneration in Dry Afromontane Forest of Ethiopia**. Ph.D. Thesis, Swedish University of Agricultural Science, Umea.

Demel Tektay (1997). The impact of clearing and conversion of dry Afromontane forest into arable land on the composition and density of soil seed bank. *Acta Oecol.* **18**: 557–573.

Demel Tektay (1998). Soil seed bank at an abandoned Afromontane arable site. *Feddes Repertorium* **109**: 161–174.

Demel Tektay and Granstrom, A. (1995). Soil seed bank in dry Afromontane forest of Ethiopia. *J. Veg. Sci.* **6**: 777–786.

Demel Tektay and Granstrom, A. (1997). Seed viability of Afromontane tree species in the forest soil. *J. Trop. Ecol.* **13**: 81–95.

EFAP (1994). The Challenges for Development. Ethiopian forestry action program: final report - Volume II. Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.

Farm Africa (2004). Chilimo participatory forest management and reproductive health. Farm Africa, Addis Ababa, Ethiopia.

Feyera Senbeta and Demel Teketay (2001). Regeneration of indigenous woody species under the canopy of tree plantations in central Ethiopia. *J. Trop. Ecol.* **42**(2): 175–185.

Garwood, N.C. (1989). Tropical soil seed banks: A review. In: **Ecology of Soil Seed**

Banks, pp.149–209 (Leck, M.A., Parker, V.T. and Simpson, R.L., eds). Academic Press, London.

Getachew Tesfaye, Demel Teketay, Yoseph Assefa and Masresha Fetene (2004). The impact of fire on the soil seed bank and regeneration of Harenna forest, Southeastern Ethiopia. *Mt. Res. Dev.* **24**: 354–361.

Herault, B. and Hiernaux, P. (2004). Soil seed bank and vegetation dynamics in Sahelian fallows: The impact of past cropping and current grazing treatments. *J. Trop. Ecol.* **20**: 683–691.

Hopkins, M.S. and Graham, A.W. (1983). The species composition of soil seed banks beneath lowland tropical rain forest in North Queensland. *Biotropica.* **15**: 90–99.

Jordan, G. (2003). The development of participatory forest monitoring system for community managed forest. www.interface-nrmco.uk.

Keay, R.W. (1960). Seeds in forest soils. *Niger. For. Inf. Bull.* **4**:1–4.

Kebrom Tekle and Tesfaye Bekele (2000). The role of soil seed banks in the rehabilitation of degraded hillslopes in southern Wello. *Biotropica* **32**: 23–32.

Kent, M. and Coker, P. (1992). **Vegetation Description and Analysis. A Practical Approach**. John Wiley and Sons Ltd., Chichester.

Kidane Mengistu (2002). **Tropical Secondary Forest Management in Africa**. Food and Agricultural Organization, Addis Ababa, Ethiopia.

Krebs, C.J. (1989). **Ecology Methodology**. Harper Collins Publishers, New York.

Leipzig, H. (1996). **Ethiopia: Country Report to the FAO International Technical Conference on Plant Genetics Resource**. Genetic Resource Centre, Addis Ababa, Ethiopia.

Lelisa, M. (1996). General agricultural survey of Chilimo forest area. Research report submitted to Farm Africa. Addis Ababa, Ethiopia.

Looney, P.B. and Gibson, D.J. (1995). The relationship between the soil seed bank and the aboveground vegetation of the coastal barrier island. *J. Veg. Sci*. **6**:825–836.

Mekuria Argaw, Demel Teketay and Olsson, M. (1999). Soil seed flora, germination and regeneration patterns of woody species in an *Acacia* woodland of the rift valley in Ethiopia. *J. Arid. Environ*. **43**: 411–435.

Mulugeta Lemenih and Demel Teketay (2006). Changes in soil seed bank composition and density following deforestation and subsequent cultivation of a tropical dry Afromontane forest in Ethiopia. *J. Trop. Ecol*. **47**: 1–12.

Soriano, A., Zeiger, E., Servy, E. and Suero, A. (1967). The effect of cultivation on the vertical distribution of seeds in the soil. *J. Appl. Ecol*. **5**: 253–257.

Tadesse Woldemariam, Demel Teketay, Edwards, S. and Olsson, M. (2001). A comparative assessment of diversity and density of birds in Chilimo forest, Ethiopia. *Ostrich Supplement* **15**: 216–223.

Tamrat Bekele (1993). Vegetation ecology of remnant Afromontane forests on the central plateau of Shoa, Ethiopia. *Acta. Phytogeogr. Suec*. **79**: 1–59.

Thompson, K. and Grime, J. (1979). Seasonal variation on the seed bank of herbaceous species in ten contrasting habitats. *J. Ecol*. **67**: 893–923.

Tybirk, K., Ashton, B.N. and Auld, C.J. (1992). Notes and records. *Afr. J. Ecol.* **32**: 327–330.

Valbuena, L. (2001). The seed bank in *Pinus* stands vegetation in North-West Spain after wildfire. *Web. Ecol*. **2**: 22–31.

Welling, C.H., Pederson, R.L. and Van valk der, A.G. (1988). Recruitment from the seed bank and the development of emergent zonation during a drawdown in a prairie wetland. *J. Ecol.* **76**: 483–496.

Whitemore, T.C. (1991). Tropical rain forest dynamics and its implication for management. In: **Rain Forest Regeneration and Management**, pp. 67–89 (Gomez-Pompa, A., Whitemore, T.C. and Hadley, M., eds.). UNESCO, Paris.

Yamagiwa, J. (2005). Diet and seasonal changes in sympatric gorillas and chimpanzees at Kahuzi-Biega National Park. *Primates* **47**: 74–79.