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Evaluation of Seed Bank in Three Age-Sequences of Arable Land within a Biosphere Reserve in Southwestern Nigeria

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Abstract

Deforestation through shifting cultivation to feed the burgeoning population in Nigeria is intensifying without adequate knowledge of its impact on the self-repairing mechanisms of the forest ecosystem. This study examined soil seed bank in three age-sequences of arable land – AF_1, AF_2 and AF_3, reflecting short, medium, and long period of cultivation respectively, at three depths – 0 -5, 5 – 10 and 10 – 15 cm. Herbaceous plants accounted for 85% percent of plant species in the seed bank at all age-sequences and soil depths. Species richness dropped sharply with increasing soil depth in all the age-sequences, and was highest in AF_1, AF_2, and AF_3 at the 0 – 5 cm, 5 – 10 cm, and 10 – 15 cm respectively. Seedling abundance decreased sharply with increasing soil depth in all age-sequences with AF_3 having the highest number of seedlings at the 0 – 5 cm depth. Although AF_3 had the highest seedling abundance at the 0 - 5 cm depth, seedling diversity in the age-sequences decreased with increasing length of cultivation with AF_1 and AF_3 having the highest and lowest diversity, respectively. Longer period of cultivation in AF_3 seems to have favoured the populations of some seemingly more tolerant herbaceous species like *Digitaria ternata* and *Spigelia anthelmia*, both of which accounted for 75% of the total seedlings recorded at the 0 – 5 cm depth in AF_3. Similarity in species composition between age-sequences was over 70% at the 0 – 5 cm depth but dropped to below 50% at lower depths, and between soil depths in the same age-sequence except between AF_1 10 – 15 & AF_3 10 – 15 cm and AF_1 5 – 10 & AF_2 5 – 10 cm. The dominance of herbaceous plants in seed banks at AF_1, AF_2 & AF_3, and the cutting of trees associated with shifting cultivation, imply that the native woody species have slim chance of regenerating in the farmlands. Therefore, a more eco-friendly farming system like agroforestry using indigenous species is recommended for the restoration of the native woody flora in the degraded farmlands.

Keywords: Length of cultivation, Soil depth, Seed bank, Species composition, Diversity, Forest regeneration

1. Introduction

The burgeoning population in Nigeria and its associated pressure has led to indiscriminate use of land without much consideration on the ecological consequences. One of the reasons for the establishment of forest reserves in Southwestern Nigeria was to combat the structural and floristic degradation of tropical rainforests (Salami 1998); however, economic and demographic pressures are increasingly causing deforestation and unsustainable use of resources in these reserves.

In Omo biosphere reserve for instance, the original vegetation has changed remarkably due continuous human activities, mainly logging and farming, for almost a century. Ola-Adams (1999) reported that people were permitted to remain living within the 65km^2 of enclaves as at the time the reserve was established in 1925. However, the influx of settler farmers has continued to mount undue pressure on both the natural forest and available farmlands in the reserve. Fallow period has drastically reduced. As human populations continue to grow, land use intensity increases, and the negative effects of deforestation are likely to worsen (Chazdon 2003).

A study into the natural process which influence forest dynamics has shown that soil seed bank is one of the principal sources of recruitment for new individuals in the initial stages of forest succession (Butler and Chazdon 1998). Taketay (1996) observed that the transformation of natural landscapes accelerates biodiversity losses indirectly through the anthropogenic activities that degrade the self-repairing capacity of an ecosystem such as soil seed banks, soil fertility, etc. According to William-Linera (1993), the species richness and abundance in soil seed banks may provide information on the potential of a community for regeneration. In addition, the intensities of disturbance and pathways in natural regeneration as well as the strategies of establishment of individual species (Grime 1979, Degreef *et al* 2002) can be interpreted through soil seed bank analysis.

However, no study had been carried out in Omo Biosphere Reserve to ascertain the impact of length or period of arable cropping on the seed bank. Considering the importance of the seed bank in regeneration, succession and restoration of plant communities, this study examined the impact of length of cultivation on soil seed bank. Specifically, it evaluated species composition, abundance and diversity of seed bank in three age-sequences of arable land – AF_1, AF_2 and AF_3, reflecting short, medium, and long period of cultivation respectively, at different soil depths. It is hoped that the results obtained will be useful in predicting future successions and plant species adaptability to increasing human disturbance.

2. Materials and Methods

2.1 Description of the Study Area

Omo Biosphere Reserve is located between latitudes 6^o 35' to 7^o 05' N and longitudes 4^o 19' to 4^o 40' E in the South-west of Nigeria (Ojo 2004); about 135 km north-east of Lagos, about 120 km east of Abeokuta and about 80 km east of Ijebu Ode (Ola-Adams 1999). The reserve shares a common boundary in its northern part with two other forest reserves – Ago Owu and Shasha in Osun State. It also has a common boundary with Oluwa Forest Reserve in Ondo

State (Karimu 1999); and covers 130,500 hectares of land (Ola-Adams 1999, Ojo 2004).

2.2 Selection and Description of Study Sites

Three chronosequences of arable land - AF_1, AF_2 and AF_3 – reflecting short, medium and long period of cultivation respectively, were selected from around Mile 1 enclave in Area J4, for the study. Chronosequence AF_1 (6^o50'26.77"N and 4^o21'37.03"E; Altitude: 105m) has been subjected to cultivation of crops including *Manihot esculenta*, *Zea mays*, and *Dyscorea* spp. since the past 12 years. Tree species observed on the farm include *Tectona grandis*, *Nauclea diderrichii, Ceiba pentandra, Gmelina arborea, Elaeis guineensis, Terminalia superba, Albizia zygia, Ficus sp.*, and *Alstonia boonei*.

Chronosequence AF_2 (6^o50'29.71"N and 4^o21'37.61"E; Altitude: 104m) has been subjected to cultivation of crops including *Manihot esculenta*, *Zea mays*, and *Dyscorea* spp. since the past 22 years. Tree species present on the farm include *Nauclea diderrichii*, *Albizia zygia, Anarcadium occidentalis, Uapaca guineensis, Gmelina arborea, Ceiba pentandra, Terminalia superba* and *Alstonia boonei*.

Site AF_3 (6^o50'32.80"N and 4^o21'38.85"E; Altitude: 102m) has been subjected to cultivation of crops including *Manihot esculenta*, *Zea mays*, and *Dyscorea* spp. since the past 37 years. Few individuals of *Nauclea diderrichii, Alstonia boonei, Elaeis guineensis, Ficus sp., and Milicia excelsa* were observed on the farm. Figure 1 is the map of Omo Biosphere Reserve showing the study sites.

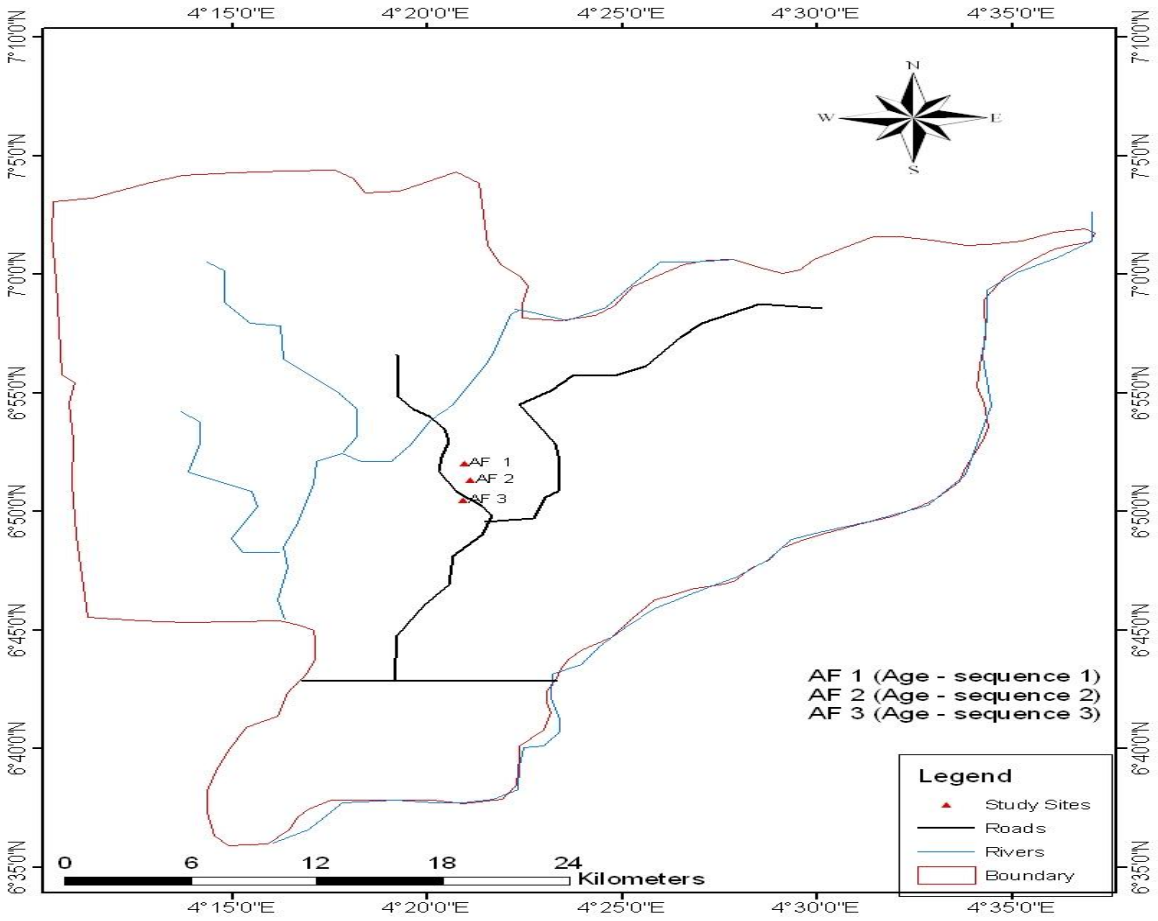

Figure 1. Map of Omo Biosphere Reserve showing the study sites

2.3 Data Collection

Five random plots, 2m x 2m, were marked out at each farmland. Three subplots - 20cm x 20cm, were also marked out in a triangular shape, at the centre of each plot. The rationale for taking subplots was to capture the spatial heterogeneity of soil seed distribution. Soil samples were removed from 0-5cm, 5-10cm and 10-15cm soil layers in each subplot and bulked for corresponding soil layers in each farmland. The bulked sample for each farmland was divided into six equal parts, four of which were randomly selected for germination trials at the Forestry Research Institute of Nigeria (FRIN) Experimental Nursery. Soil samples were spread to a thickness of 3cm on perforated plastic trays (diameter: 30cm and depth: 3cm) that were kept moist continuously.

The seedling emergence method was used to assess the species composition and abundance of seed bank at the three farmlands. This method has been used by other workers (e.g. Senbeta and Taketay, 2001; Lemenih, 2004; Oke et al., 2007) to evaluate soil seed banks in different land use types. Emerging seedlings that are readily identifiable were counted, recorded and discarded on monthly basis. Seedlings that were difficult to identify were counted, labeled, transplanted and grown separately until they could be identified. After identification and counting of seedlings each month, soil samples were stirred to stimulate seed germination. This exercise continued until germination stopped.

2.4 Data Analysis

2.4.1 Seed Bank Species Diversity

Shannon index of general diversity (Odum 1971) was used to measure the diversity of seed bank in each of the age-sequences of arable land.

Shannon index is expressed as:

$$H = -\sum_{i=1}^{s} pi \log pi \quad \text{---------- Eqn. 1}$$

Where

pi = proportion of individuals in the ith species

s = total number of species

2.4.2 Similarity in Seed Bank Species Composition

Sorensen's similarity index (SI) was used to measure similarity in seed bank species composition between age-sequences of arable land. In this study, Sorensen's similarity index was computed following Magurran (2004).

$$SI = \frac{2a}{2a+b+c} \quad \text{---------- Eqn. 2}$$

Where

a = number of species present in both age-sequences.

b = number of species present in age-sequence 1 but absent in age-sequence 2.

c = number of species present in age-sequence 2 but absent in age-sequence 1.

2.4.3 Soil Depth/Species Interaction

Cluster analysis was performed using the PAleontological STatistics (PAST) software to show soil depth/plant species interaction, such that soil depths with more similar species were grouped into the same cluster while those with dissimilar species were grouped into different clusters. In performing the cluster analysis, Sorensen's similarity index was used to measure the ecological distances in species between soil depths.

3. Results

3.1 Plant Species Composition

Checklist of plant species that germinated from seed banks at different soil depths and age-sequences is presented in Table 1. Herbaceous plants represented 85 percent of the species. Only three woody species – *Gmelina arborea, Chromolaena odorata,* and *Trema orientalis*, were observed in the seed banks.

Table 1. Species composition of seed banks at different sites and soil depths

Soil depth (cm)	Species	Family	Population		
			AF_1	AF_2	AF_3
0 – 5	*Argeratum conyzoides*	Asteraceae	2	1	4
	Aspilia africana	Compositae	2	0	2
	Asystasia gigantica	Acanthaceae	4	1	1
	Borreria scabra	Rubiaceae	1	2	4
	Calopogonium mucunoides	Fabaceae	2	1	6
	Centrosema pubescence	Leguminosae – Papilinionaceae	0	2	0
	Chromolaena odorata	Asteraceae	2	1	3
	Digitaria ternata	Cyperaceae	11	21	70
	Discorea sp.	Discoreaceae	1	6	0
	Gmelina arborea	Verbenaceae	7	0	0
	Mariscus alternifolius	Cyperaceae	5	0	0
	Oplismenus burmannii	Poaceae	5	4	3
	Peperomia pellucida	Piperaceae	1	0	3
	Sida acuta	Malvaceae	0	0	1
	Spigelia anthelmia	Loganiaceae	4	6	14
	Solenostemon monostachyus	Labiatae	1	0	0
	Vernonia cinerea	Asteraceae	3	0	1
5 – 10	*Borreria scabra*	Rubiaceae	1	2	0
	Digitaria ternata	Cyperaceae	0	1	6
	Oplismenus burmannii	Poaceae	1	0	0
	Phyllanthus amarus	Euphorbiaceae	0	0	1
	Spigelia anthelmia	Loganiaceae	2	2	0
	Trema orientalis	Cannabaceae	0	1	0
10 – 15	*Calopogonium mucunoides*	Fabaceae	1	0	1
	Chromonaela odorata	Asteraceae	0	1	0
	Digitaria ternata	Cyperaceae	1	0	1
	Euphorbia heterophylla	Euphorbiaceae	0	0	1
	Oplismenus burmannii	Poaceae	1	1	0
	Solenostemon monostachyus	Labiatae	0	0	1

3.2 Species Richness and Seedling Abundance

Species richness dropped sharply with increasing soil depth in all the age-sequences, and was highest in AF_1, AF_2, and AF_3 at the 0 – 5 cm, 5 – 10 cm, and 10 – 15 cm respectively (Figure 2). Seedling abundance also dropped sharply with increasing soil depth in all age-sequences with AF_3 having the highest number of seedlings at the 0 – 5 cm depth (Figure 3).

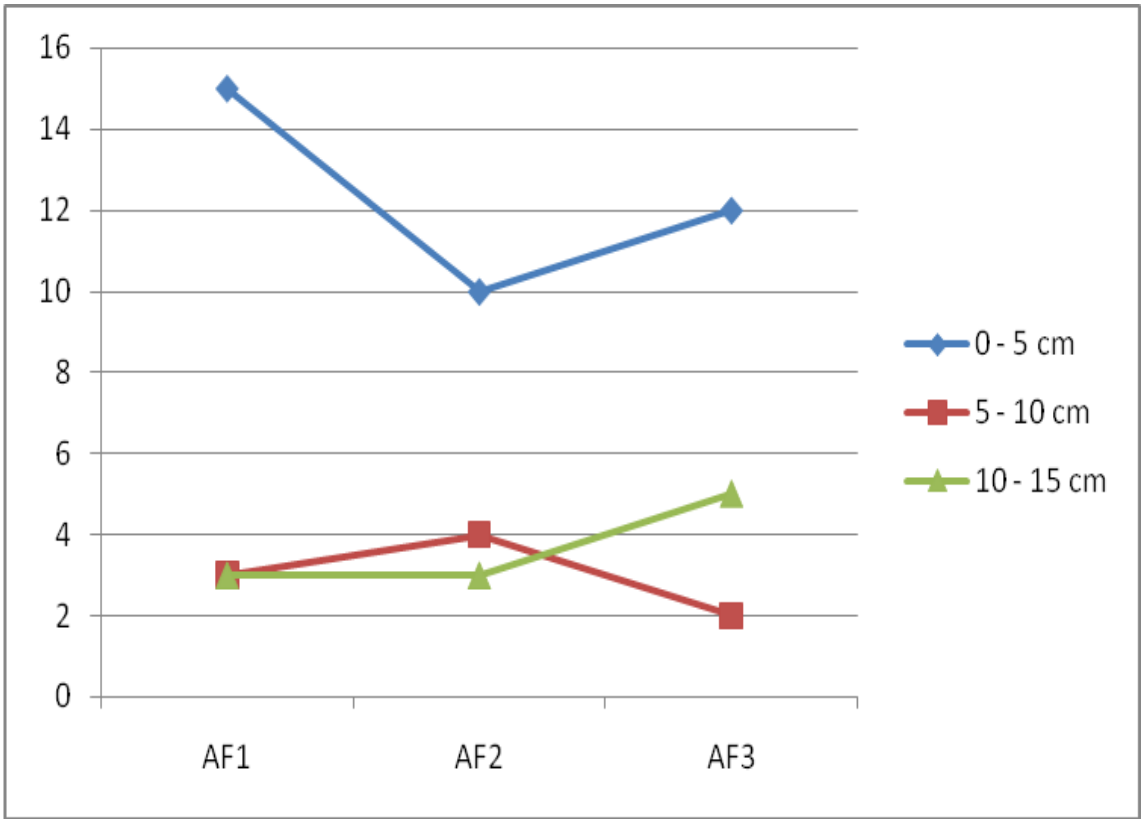

Figure 2. Seed bank species richness at different sites and soil depths

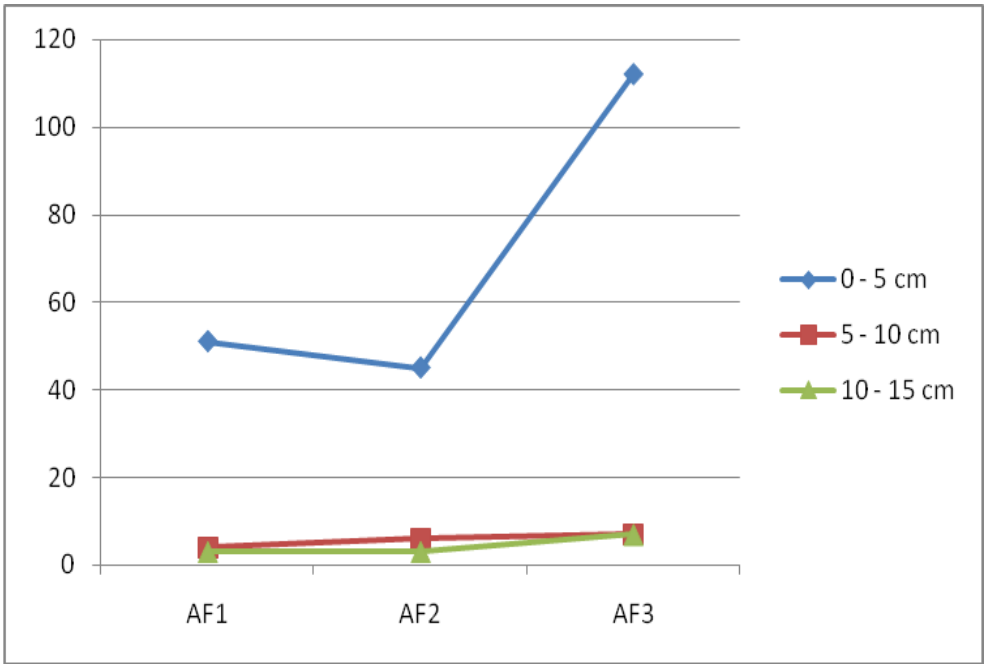

Figure 3. Seed bank seedling abundance at different sites and soil depths

3.3 Species Diversity and Similarity

Species diversity was highest in AF_1, followed by AF_2 and AF_3 respectively at the various soil depths except at the 5 – 10 cm depth where species diversity was highest in AF_2 (Table 2). Similarity in species composition between age-sequences was over 70% at the 0 – 5 cm depth. However, similarity in species composition between age-sequences at lower depths, and between soil depths in the same age-sequence dropped below 50% except between AF_1 10 – 15 & AF_3 10 – 15 cm and AF_1 5 – 10 & AF_2 5 – 10 cm (Table 3). Considering the similarity in species composition, different age-sequences clustered on the basis of soil depth except at 5 – 10 cm depth of AF_3 and 10 – 15 cm depth of AF_2 (Figure 4).

Table 2. Shannon diversity indices for different chronosequences and soil depths

Soil depth (cm)	AF_1	AF_2	AF_3
0 – 5	2.4410	1.7230	1.4380
5 – 10	1.0400	1.3300	0.4101
10 – 15	1.0990	0.6931	0.3860

Table 3. Sorensen similarity indices for different sites and soil depths

	AF_1 0-5	AF_1 5-10	AF_1 10-15	AF_2 0-5	AF_2 5-10	AF_2 10-15	AF_3 0-5	AF_3 5-10	AF_3 10-15
AF_1 0-5	*	0.33	0.33	0.78	0.32	0.24	0.80	0.12	0.32
AF_1 5-10		*	0.33	0.46	0.57	0.40	0.40	0.00	0.00
AF_1 10-15			*	0.46	0.29	0.40	0.40	0.40	0.57
AF_2 0-5				*	0.32	0.12	0.73	0.12	0.21
AF_2 5-10					*	0.00	0.38	0.33	0.25
AF_2 10-15						*	0.29	0.00	0.00
AF_3 0-5							*	0.14	0.25
AF_3 5-10								*	0.33
AF_3 10-15									*

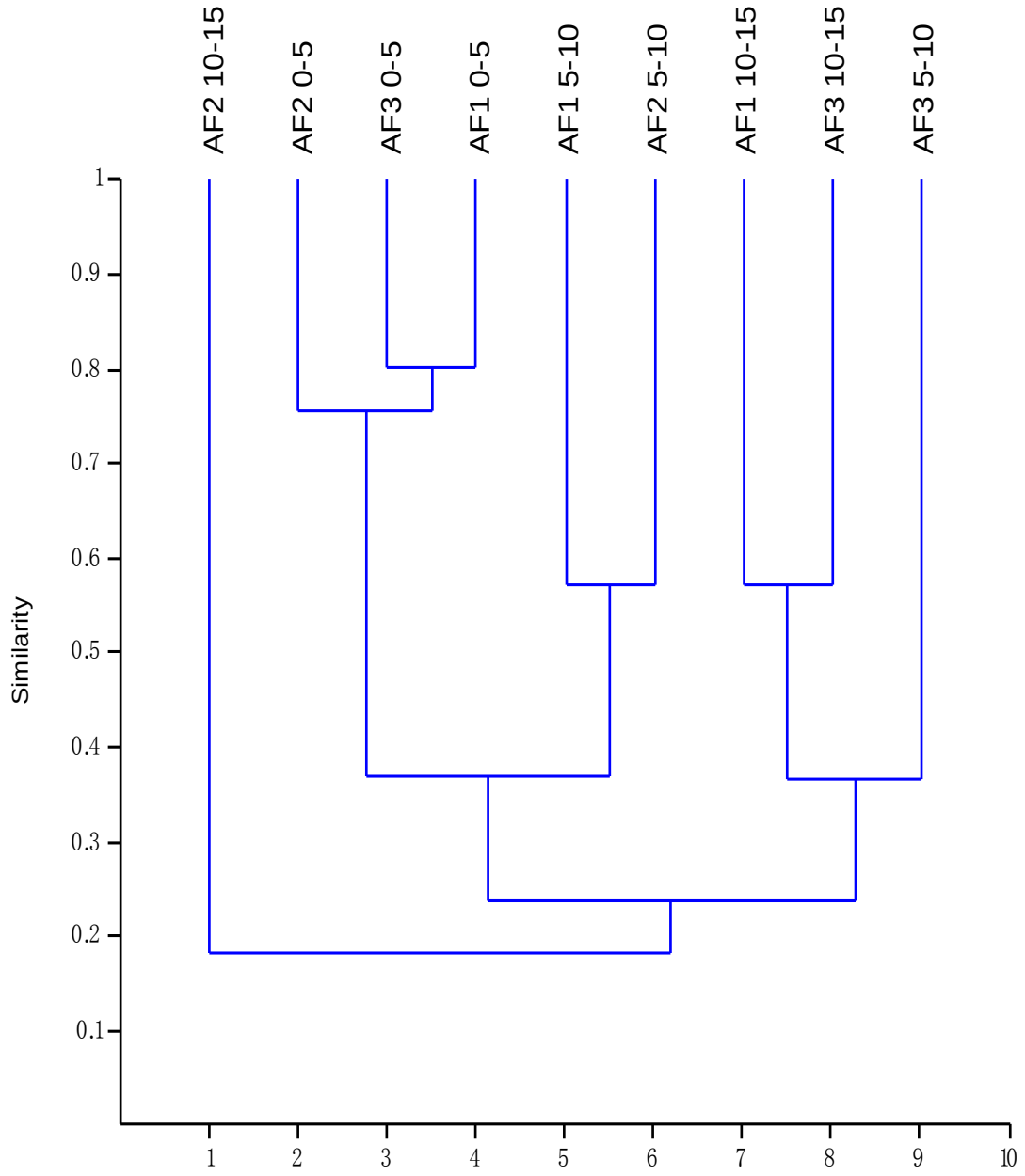

Figure 4. *Cluster dendogram showing within-site and between-site depth-plant species interactions

*Dendogram based on Sorensen's similarity index (Table 3)

4. Discussion

Both seedling abundance and species richness decreased with increasing soil depth in all the age-sequences of arable land, with the 0 -5 cm soil depth accounting for over 80% of the total seedlings that emerged. Senbeta and Teketay (2002) equally observed that the number of seeds in the soil showed similar vertical distribution in almost all plantation stands and the adjacent forests studied, with the highest number of species and densities of seeds in the upper three centimeters of soil, and a gradual decreasing number of species and densities of

seeds with increasing soil depth. However, there were marked differences among the age-sequences and soil depths with respect to seedling abundance and species diversity.

Despite the fact that AF_3 had the highest seedling abundance at the 0 - 5 cm depth, seedling diversity in the age-sequences decreased with increasing length or period of cultivation with AF_1 and AF_3 having the highest and lowest diversity, respectively. It appears that longer period of cultivation in AF_3 has favoured the populations of some seemingly more tolerant herbaceous species like *Digitaria ternata* and *Spigelia anthelmia*, both of which accounted for 75% of the total seedlings recorded at the 0 – 5 cm depth in AF_3. The abundance of both species was also found to have increased with increasing period of cultivation at the 0 -5 cm depth. Although, *Oplismenus burmanii* was found in all age-sequences, its abundance decreased slightly with increasing period of cultivation.

Disturbance of the original forest (through logging, slashing and burning, etc.) usually eliminates the seed bank of rain forest species (Guevara *et al*., 2005). Agricultural use and pasture management (weeding, ploughing, grazing, etc.) decrease the seed density of the pioneer tree species linked to forest gap colonization, and favour the growth of secondary weeds (Dalling and Denslow, 1998; Kellman 1980). We also observed that seed bank in all the age-sequences studied were dominated by herbaceous plants irrespective of the length of cultivation.

Species composition of the various age-sequences, seem not to have been affected by the length of cultivation like species diversity. For instance, AF_1 and AF_3 were slightly more similar in species composition than with AF_2. The clustering pattern of the three age-sequences in relation to their species composition showed closer association for separate soil depths except at the 5 – 10 cm depth of AF_3 and 10 – 15 cm depth of AF_2. The plant species from the 5 – 10 cm seed bank in AF_3 were more similar to those of the 10 – 15 cm in AF_1 and AF_3, while those of the 10 -15 cm in AF_2 were far apart from the others. However, the reasons for these deviations cannot be explained.

The importance of this study with respect to the impact of land cultivation on the regeneration potentials of the native woody flora in the reserve cannot be over-emphasized. The fact that herbaceous plants constitute 85% of the plants that germinated from the seed banks in all the age-sequences and soil depths means that the native woody species have very slim chances of regenerating in the farmlands. To make the matter worse is the fact that indiscriminate logging and shifting agriculture in the reserve are impacting negatively on the populations of tree and animal species that would have provided alternative means of regeneration through seed rain and seed dispersal respectively. Therefore, a more eco-friendly farming system like agroforestry using indigenous species is recommended for the restoration of the native woody flora in the degraded farmlands.

5. Conclusion

Seed bank in all the farmlands were dominated by herbaceous plants irrespective of the length of cultivation. This suggests that the herbaceous plants have better chances of regenerating on deforested lands subjected to arable cropping irrespective of the length or

period of cultivation. However, longer period of cultivation impacted negatively on seed bank diversity. Also, species diversity, species richness, similarity in species composition and seedling abundance of seed banks decreased with increasing soil depths irrespective of the length of cultivation.

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