PLANT SPECIES DIVERSITY AND ABUNDANCE IN SOIL SEED BANKS OF NATURAL FOREST AND MONOCULTURE PLANTATIONS IN OMO BIOSPHERE RESERVE, NIGERIA

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ABSTRACT

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The concept of forest conservation aims at maintaining the socio-economic values and ecological roles of forests for the benefit of present and future generations. This study evaluated plant species diversity and abundance in soil seed banks of the Strict Nature Reserve (SNR) and five monoculture plantations – Gmelina arborea Plantation (GAP), Theobroma cacao Plantation (TCP), Pinus caribaea Plantation (PCP), Nauclea diderrichii Plantation (NDP) and Tectona grandis Plantation (TGP), in Omo biosphere reserve, at three soil depths (0-5, 5-10 and 10-15 cm), using the seedling emergence method. Results indicated that species richness, seedling abundance, species diversity and similarity in species composition decreased with increasing soil depth in all sites. Species richness was highest in NDP at 0-5 and 5-10 cm depths and in GAP at 10-15 cm depth. Seedling abundance was highest in NDP, TGP and GAP at 0-5 cm, 5-10 cm and 10-15 cm depths, respectively. Species diversity was highest in the SNR (Shannon H =2.28; Simpson 1 − D = 0.87), NDP (Shannon H =2.26; Simpson 1 − D = 0.88), and GAP (Shannon H = 1.77; Simpson 1 − D = 0.81) at 0-5, 5-10, and 10-15 cm soil depths respectively. The older plantations – GAP, NDP and TGP showed closer association with the SNR in their species composition. The conversion of the natural forest to monoculture tree plantations was found to have altered soil seed bank species composition but increased species richness, species diversity and seedling abundance below 0-5 cm soil depth especially in the older plantations.

Keywords: Forest conversion, regeneration, soil seed bank, land use, monoculture

INTRODUCTION

The establishment of monoculture tree plantations has long been recognised as one of the drivers of tropical deforestation. The concept of sustainable forest management (SFM) aims at maintaining and enhancing socio-economic and environmental values of forests for the benefit of present and future generations (UN, 2008). Although, the activities and management practices associated with monoculture tree plantations apparently run contrary to the principle of sustainable forest management, their establishment in various parts of the globe continues unabated including in reserved areas. Omo biosphere reserve presents a very good example of a landscape that has been transformed to a large extent due to the establishment of monoculture tree plantations. Monoculture tree plantations of different species including Nauclea diderrichii, Gmelina arborea, Tectona grandis, Pinus caribaea, and Theobroma cacao, are found in the reserve. However, a recent study by Chima and Adedire (2014) found that the area of the reserve covered by monoculture tree plantations reduced from 26% in 1987 to 11% in 2011, due mainly to unsustainable logging.

The role of soil seed banks in natural forests cannot be over emphasized. They are the main sources of recruitment that may occur during the development of vegetation (Lunt, 1997). In addition, they contribute to the diversity and dynamics of most plant communities (Nathan and Casagrandi, 2004) and restoration of plant communities (Simpson et al., 1989). The composition of the soil seed bank determines the initial colonization of a site after a natural or human disturbance, and provides species for vegetation recovery (Cubiña and Aid, 2001; Kalamees and Zobel, 2002; Abdella et al., 2007). There is paucity of information on the long-term effects of monoculture plantations on the soil seed bank including the extent of impact relating to age of the plantation, logging intensity, and species origin. Omo biosphere reserve with its long history of plantation establishment presents an opportunity to advance knowledge in this area. This study therefore, evaluated the species composition, abundance and diversity of soil seed bank from the natural forest and monoculture plantations of different species and ages, in the reserve.

MATERIALS AND METHODS

Study Area

The study was conducted in Omo Biosphere Reserve which is located between latitudes 6° 35’ and 7° 05’ N and longitudes 4° 19’ and 4° 40’ E in Ogun State, south-western part of Nigeria (Ojo, 2004). The reserve is in a mixed moist semi-evergreen rainforest zone, and presently has various introduced land use types including secondary forests, monoculture tree plantations and arable farmlands. The reserve is made up of several soil types but all
belong to the tertiary sediments (Ola-Adams, 1999). Geologically, the reserve lies on crystalline rocks of the undifferentiated basement complex which in the southern parts is overlain by Eocene deposits of sand, clay and gravel (Isichei, 1995), and has an undulating terrain. The reserve has a mean annual rainfall of 1750 mm, mean relative humidity of 80%, and mean daily temperature of 26.4 °C, while sunshine duration varies between 8 and 10 hours during the rainy season.

**Selection of the study sites**

Six sites were selected from the study area to ascertain the impact of natural forest conversion to monoculture tree plantations on soil seed bank species composition, diversity and abundance. The reference site (6.96598° N and 4.36245° E) was selected from the Strict Nature Reserve (SNR) which has been under protection since its establishment in 1946. The other five sites were selected from Theobroma cacao Plantation (6° 52’ 49.82” N and 4° 24’ 48.91” E) established in the year 2000, Pinus Caribaea Plantation (6° 50’ 03.54” N and 4° 22’ 00.65” E) established in 1997, Tectona grandis Plantation (6° 50’ 08.37” N and 4° 21’ 39.92” E) established in 1989, Gmelina arborea Plantation (6° 54’ 13.94” N and 4° 22’ 30.44” E) established in 1983, and Nauclea diderrichii Plantation (6° 50’ 16.11” N and 4° 22’ 05.56” E) established in 1975 within and around the Plantation Project Management Unit (PMU) residential quarters. Both the Pinus caribaea and Nauclea diderrichii plantations have not been logged since establishment. The Tectona grandis plantation had been logged and was bearing coppices on stumps of felled trees. The Gmelina arborea plantation had been extensively logged, though mature trees and saplings abound with herbaceous undergrowth.

**Seed bank evaluation**

The seedling emergence method was used after Senbeta and Teketay (2001), Lemenih (2004), and Oke et al. (2007) to evaluate soil seed banks from the natural forest and monoculture tree plantations. Five random plots (2 x 2 m in size) were first marked out at each site. Subsequently, three subplots (20 x 20 cm in size) were marked out in a triangular shape, at the centre of each plot. Soil samples were collected from 0-5 cm, 5-10 cm and 10-15 cm soil depths of each subplot. Soil samples of corresponding soil depths were bulked for each site, divided into six equal parts, four of which were randomly selected for germination trials at the Forestry Research Institute of Nigeria (FRIN) Experimental Nursery located in Ibadan, Oyo State. The subplots captured the spatial heterogeneity of soil seed distribution at the various sites. At the nursery, soil samples were spread to a thickness of 3 cm on plastic trays (diameter of 30 cm and depth of 3 cm) perforated at the bottom and watered twice (early in the morning and late in the evening) daily. Emerging seedlings that could be identified immediately were counted, recorded and discarded on monthly basis. Seedlings that could not be identified immediately were counted, labelled, transplanted and grown separately until they could be identified. Soil in germination trays was stirred using a stick to stimulate seed germination after each monthly enumeration. This exercise continued for a period of six months.

**Data analysis**

Measurement of seed bank seedling diversity

Diversity of seedlings from seed banks at the various sites was measured using Simpson Index (Simpson, 1949) and Shannon-Wiener Index (Odum, 1971).

Simpson’s Index is expressed as:

\[
D = \frac{\sum_{i=1}^{q} n_i(n_i-1)}{N(N-1)}
\]

where: \(N\) = total number of seedlings counted; \(n_i\) = number of seedlings of ith species enumerated for \(i=1,\ldots,q\); \(q\) = number of different species enumerated. Simpson’s index was presented as \((1 - D)\) to allow for a direct relationship with diversity since Simpson’s index as obtained with the formula above is inversely related to diversity (i.e. the lower the index, the higher the diversity and vice versa).

Shannon-Wiener Index is expressed as:

\[
H = - \sum_{i=1}^{s} p_i \log p_i
\]

where: \(p_i\) = proportion of seedlings in the ith species; \(s\) = the total number of species. Both Simpson and Shannon-Wiener diversity indices were computed using the PAleontological STatistics (PAST) Software.

**Similarity in species composition of soil seed banks**

Sorensen’s Similarity Index (Pielou, 1969) was used after Ogunleye et al. (2004) and Ojo (2004), to ascertain the level of similarity in species composition of soil seed bank seedlings from the natural forest and the monoculture plantations. Sorensen’s Similarity Index is expressed as:

\[
SI = \frac{c}{a + b + c} \times 100
\]

where: \(a\) = number of species present in both Sites; \(b\) = number of species present in Site 1 but absent in Site 2; \(c\) = number of species present in Site 2 but absent in Site 1.
Classification of sites based on similarity in soil seed bank species composition
Cluster analysis was performed using the PAleontological StAtistics (PAST) software to provide a hierarchical classification of the natural forest and monoculture plantations based on the similarity or otherwise of species composition of their seed banks. The cluster analysis was performed using ecological distances between sites obtained using Sorensen’s index.

RESULTS
Species composition, species richness and seedling abundance at the various sites
The species composition of soil seed banks from the natural forest and the monoculture tree plantations are shown in Tables 1, 2, and 3, for the 0 – 5 cm, 5 – 10 cm, and 10 – 15 cm soil depths respectively. Herbaceous plants dominated in both the natural forest and the monoculture plantations at the three soil depths. Soil seed bank species richness decreased with depth in both the natural forest and monoculture tree plantations, and was highest in the Nauclea diderrichii Plantation (NDP), followed by the Strict Nature Reserve (SNR) and the Gmelina arborea Plantation (GAP) respectively at 0 – 5 cm depth, while the lowest species richness was recorded for the Theobroma cacao Plantation (TCP) (Fig.1). At the 5 – 10 cm depth, the highest and lowest species richness was recorded in NDP and TCP respectively, while GAP and TCP/SNR had the highest and lowest species richness at the 10 – 15 cm depth respectively (Fig.1). Seedling abundance also decreased with increasing depth in all sites and was highest in NDP, followed by GAP and Tectona grandis Plantation (TGP) respectively while the lowest seedling abundance was found in TCP (Fig.2). At the 5 – 10 and 10 – 15 cm depths, TGP and GAP had the highest seedling abundance respectively, while seedling abundance was zero for TCP at both soil depths (Fig. 2).

Table 1: Checklist of species found in 0 – 5 cm soil seed banks from the natural forest and the monoculture plantations

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of seedlings</th>
<th>SNR</th>
<th>GAP</th>
<th>TCP</th>
<th>PCP</th>
<th>NDP</th>
<th>TGP</th>
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SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderrichii Plantation; TGP = Tectona grandis Plantation

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Table 2: Checklist of species found in 5 – 10 cm soil seed banks from the natural forest and the monoculture plantations

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<th>Species</th>
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<th>TCP</th>
<th>PCP</th>
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</tbody>
</table>

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation

Table 3: Checklist of species found in 10 – 15 cm soil seed banks from the natural forest and the monoculture plantations

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of seedlings</th>
<th>SNR</th>
<th>GAP</th>
<th>TCP</th>
<th>PCP</th>
<th>NDP</th>
<th>TGP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borreria scabra</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Calopogonium mucunoides</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chromoanella odorata</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Digitaria ternata</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Euphorbia heterophylla</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Marisus alternifolia</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oplismenus burmanii</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Peperomia pellucida</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sida acuta</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Solenostemum monostachy</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Spigelia anhelmsia</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Trumfetta cordifolia</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Zoysia sp.</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation

Fig. 1: Species richness of soil seed banks from the natural forest and the monoculture plantations at different soil depths

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation
Fig. 2: Total seedling abundance of soil seed banks from the natural forest and the monoculture plantations at different soil depths

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation

Species diversity of seed banks from the natural forest and the plantations

Plant species diversity of soil seed banks at the natural forest and monoculture tree plantations is shown in Table 4 for the three soil depths. Species diversity decreased with increasing soil depth in all the sites, and was highest in the SNR, followed by NDP and GAP respectively, at the 0 – 5 cm depth. At the 5 – 10 cm depth, plant species diversity was highest for NDP, followed by GAP and PCP, respectively while it was zero in TCP. At the 10 -15 cm depth, plant diversity was zero for all the sites except GAP and TGP.

Table 4: Plant species diversity of soil seed banks from the natural forest and the monoculture plantations at different soil depths

<table>
<thead>
<tr>
<th></th>
<th>0 – 5 cm seed banks</th>
<th>5 – 10 cm seed banks</th>
<th>10 – 15 cm seed banks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shannon H</td>
<td>Simpson 1-D</td>
<td>Shannon H</td>
</tr>
<tr>
<td></td>
<td>SNR 2.28</td>
<td>0.87</td>
<td>SNR 0.69</td>
</tr>
<tr>
<td></td>
<td>GAP 2.08</td>
<td>0.85</td>
<td>GAP 1.73</td>
</tr>
<tr>
<td></td>
<td>TCP 1.37</td>
<td>0.69</td>
<td>TCP 0.00</td>
</tr>
<tr>
<td></td>
<td>PCP 1.82</td>
<td>0.81</td>
<td>PCP 1.04</td>
</tr>
<tr>
<td></td>
<td>NDP 2.21</td>
<td>0.85</td>
<td>NDP 0.63</td>
</tr>
<tr>
<td></td>
<td>TGP 1.43</td>
<td>0.65</td>
<td>TGP 0.89</td>
</tr>
</tbody>
</table>

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation

Similarity in species composition of soil seed banks from the natural forest and monoculture tree plantations

The level of similarity in species composition of soil seed bank from the natural forest and the monoculture tree plantations at different depths is shown in Table 5. Similarity in species composition dropped with increasing soil depth, and was lower between the natural forest and the plantations than between the plantations. Soil seed bank species composition between the natural forest and monoculture plantations was most dissimilar between SNR/PCP and SNR/TCP.

Classification of sites based on similarity in their soil seed bank species composition

The association of the different sites with respect to their soil seed bank species composition is shown in Figs. 3, 4 and 5 for 0 – 5 cm, 5 – 10 cm, and 10 – 15 cm depths, respectively. At the 0 – 5 cm depth (Fig. 3) GAP/NDP showed a closer association with the SNR, while PCP and TCP were the farthest from the SNR. At the 5 – 10 cm depth, the closest association between the natural forest and the plantations was found between SNR/TGP with GAP/NDP associating very closely with them; while there was no association whatsoever between TCP and the natural forest/other monoculture plantations. At the 10 -15 cm depth, the closest association was between GAP/TGP while TCP and SNR completely dissociated themselves from the other sites.

DISCUSSION

The soil seed bank of both the SNR and the monoculture plantations were dominated by herbs. Several other studies (e.g. Kebrom and Tesfaye, 2000; Senbata and Teketay, 2002; De Villiers et al., 2003; Jalili et al., 2003;
Wassie and Teketay, 2006; Oke et al., 2007) had also recorded few woody species in comparison to the herbaceous species. Oke et al. (2007) in their study reported that herbaceous species dominated the seed bank and accounted for 98% of the total seed density in each of the four plantations studied, with only three woody species emerging. The paucity of woody species in the seed banks may be attributed to the short-lived nature of their seeds. Wassie and Teketay (2006) observed that seeds of forested species are often short-lived. Dike (1992) equally observed that forest species often complete their germination processes within eighty-four days after dispersal at Omo and Sapoba forest reserves in southwestern Nigeria, leading to few seeds remaining in the seed stores. Other possible factors leading to paucity of seeds of woody species in soil seed bank include quick germination and pathogens/predators (Teketay and Granstrom, 1995, 1997; Teketay, 1997).

Table 5: Sorensen’s similarity indices for soil seed bank species

<table>
<thead>
<tr>
<th></th>
<th>SNR</th>
<th>GAP</th>
<th>TCP</th>
<th>PCP</th>
<th>NDP</th>
<th>TGP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 cm seed bank</td>
<td>SNR</td>
<td>GAP</td>
<td>TCP</td>
<td>PCP</td>
<td>NDP</td>
<td>TGP</td>
</tr>
<tr>
<td>SNR</td>
<td>*</td>
<td>23.81</td>
<td>11.76</td>
<td>10.00</td>
<td>36.36</td>
<td>14.29</td>
</tr>
<tr>
<td>GAP</td>
<td>*</td>
<td>21.43</td>
<td>25.00</td>
<td>40.00</td>
<td>37.50</td>
<td></td>
</tr>
<tr>
<td>TCP</td>
<td>*</td>
<td>18.18</td>
<td>16.67</td>
<td>15.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCP</td>
<td>*</td>
<td>20.00</td>
<td>12.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDP</td>
<td>*</td>
<td>13.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 – 10 cm seed bank</td>
<td>SNR</td>
<td>GAP</td>
<td>TCP</td>
<td>PCP</td>
<td>NDP</td>
<td>TGP</td>
</tr>
<tr>
<td>SNR</td>
<td>*</td>
<td>10.00</td>
<td>0.00</td>
<td>0.00</td>
<td>18.18</td>
<td>16.67</td>
</tr>
<tr>
<td>GAP</td>
<td>*</td>
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<td>9.09</td>
<td>25.00</td>
<td>16.67</td>
<td></td>
</tr>
<tr>
<td>TCP</td>
<td>*</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCP</td>
<td>*</td>
<td>7.69</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDP</td>
<td>*</td>
<td>14.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TGP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 – 15 cm seed bank</td>
<td>SNR</td>
<td>GAP</td>
<td>TCP</td>
<td>PCP</td>
<td>NDP</td>
<td>TGP</td>
</tr>
<tr>
<td>SNR</td>
<td>*</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>GAP</td>
<td>*</td>
<td>0.00</td>
<td>14.92</td>
<td>14.92</td>
<td>22.22</td>
<td></td>
</tr>
<tr>
<td>TCP</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCP</td>
<td>*</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDP</td>
<td>*</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Fig. 3: Cluster dendogram for the natural forest and monoculture plantations based on similarity of the species composition of their 0 – 5 cm seed banks

SNR = Strict Nature Reserve; GAP = Gmelina arborea Plantation; TCP = Theobroma cacao Plantation; PCP = Pinus caribaea Plantation; NDP = Nauclea diderichii Plantation; TGP = Tectona grandis Plantation
Both seedling abundance and species richness decreased with increasing soil depth in both the SNR and monoculture tree plantations. 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, with the highest number of species and densities of seeds in the upper three centimetres of soil, and a gradual decreasing number of species and densities of seeds with increasing soil depth. However, there were marked differences between sites and soil depths in terms of seedling abundance, species richness, species composition, and diversity. With the exception of TCP, the monoculture plantations had higher seedling abundance and species richness than the SNR below the 0 - 5 cm depth. It appears that the soil disturbances associated with different establishment and harvesting operations that go on in the monoculture plantations had helped to incorporate seeds into the lower soil depths. The TCP was the poorest of all the sites in terms of seedling abundance, species richness and diversity. Although, Oke et al. (2007) in their study in Southwestern Nigeria attributed fewer seed bank seedling composition observed in a Cocoa plantation to its very close canopy which reduced the seed rain that may reach the ground, and the exposure of the few seeds that reach the ground to predation because of the thick litter layer which prevents the seed from being buried in the soil easily, the results of this study reveal that the TGP which equally had much litter accumulation, performed better than the TCP with respect to seedling abundance, species richness and diversity. Therefore, conclusion on the factors responsible for low species richness and diversity in soil seed banks under *Theobroma cacao* Plantation requires further investigation that will consider the nature/effect of establishment and management practices, seed dispersal, seed predation, and chemical composition of cocoa leaves.

Despite the fact that the soil seed banks of all land use types were dominated by herbaceous plants, similarity in species composition between the SNR and each of the monoculture plantations was below 37% at the 0 – 5 cm depth, below 19% at the 5 – 10 cm depth, and zero at the 10 - 15 cm depth. The general decrease in similarity of
species between the SNR and the monoculture plantations with increasing soil depth could be attributed to the observed decrease in species richness with increasing soil depth. The closest ecological distance/association between the SNR and NDP in most of the evaluated attributes including species richness and plant diversity underscores the restorative ability of modified/disturbed natural forest ecosystems when protected from further degradation. Although, the Theobroma cacao plantation is protected, management practices favour only cocoa - the preferred species, while in NDP, diversity of species is tolerated since it acts as a buffer to the residential quarters and not managed for commercial purposes.

**CONCLUSION**

The conversion of the natural forest to monoculture tree plantations altered soil seed bank species composition but increased species richness, species diversity and seedling abundance below 0 – 5 cm soil depth especially in the older plantations. Closest association of the SNR with NDP, GAP and TGP (the older plantations) with respect to seed bank species composition at the 0 - 5 cm depth indicates the possibility of long-term recovery in species composition. The very poor state of the Theobroma cacao plantation in terms of soil seed bank species richness, species diversity and seedling abundance, calls for further research. Such research should consider the nature/effect of establishment/management practices on soil seed bank, seed dispersal, seed predation and chemical composition of cocoa leaves.

**REFERENCES**


