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SOIL SEED BANKS DYNAMICS AND RESTORATION POTENTIAL OF SOME SELECTED FOREST RESERVES IN SOUTHWEST, NIGERIA.

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ABSTRACT: *This research investigated the regeneration potential of soil seed-bank along three soil depths in three secondary forest communities within Southwest Nigeria, for a better understanding of the potentials of the soil seed banks in facilitating succession towards a more natural forest of native tree species in International Institute of Tropical Agriculture (IITA) Forest Ibadan, Elephant Forest reserve Omo and Emerald Forest in Ikoyi Nigeria. Eight temporary plots of 20m by 40m using systematic line transect were laid in each forest. Soil samples were taken at three depths of 0–5 cm, 5–10 cm and 10–15cm and the seed bank composition was determined under a greenhouse condition. The results show that IITA forest has an abundance of 93 species with the highest in soil depth of 5-10 (35) and least exists at 10-15cm (24). The species evenness ranged from 0.92 to 0.96, with an average value of 0.94. Emerald forest had a total of 74 tree species with 0-5 cm depth having the highest species abundance (34), while depth of 5-10 cm (21) exhibit the least species abundance. At the forest, results of Species diversity indices show that at 0-5 cm depth 2.47 index value was recorded, a value much higher than what was recorded at 5-10 cm (2.40) and 10-15cm (2.36) respectively. The result of Elephant Forest reserve shows that a total of 87 tree species were recorded with 0-5 cm depth having the highest species abundance (40) followed by 5-10 cm (27), 10-15 (26) respectively. The Shannon Wiener index for Elephant Forest shows that 2.28 were recorded at 0-5 cm depth, 1.40 at 5-10 cm depth, and 1.70 at 10-15cm depth respectively. The soil seed bank could help in determining the status of regeneration potential of the three forests investigated. However, high dominance of tree species in the soil seed banks* implies that the forest is disturbed and there is likelihood of tree species succeeding and dominating the forest ecosystem.

KEYWORDS: Seed bank, soil, Diversity, Abundance and Forest communities.

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INTRODUCTION

Soil seed banks can be referred to as an aggregation of viable seeds in the soil and in the upper litter of the soil that is capable of replacing adult plants in a degraded ecosystem (González-Alday et al., 2009). They play crucial roles in restoring invaded ecosystems and help in the global management of endangered plant species (Richardson & Kluge, 2008). Baker (1989) explained that this group of seeds have not yet germinated, but have the potential to replace or succeed annual adult plants that have died naturally or due to human activities. It also includes seeds from perennial plants that are susceptible to diseases, animal predation, and various disturbances, including those caused by humans. The challenges associated with other ecosystem restoration methods have made soil seed banks a preferred option, as they are less labor-intensive and require minimal technical knowledge (Fowler et al., 2015). The soil seed bank functions as a reservoir of 'hidden diversity,' including species that are absent from the aboveground vegetation but have the ability to establish themselves in certain locations, effectively representing the missing part of a site-specific species pool (Moeslund et al., 2017; Brown et al., 2019; Carmona & Pärtel, 2020).

The soil seed bank provides a survival mechanism for plants in adverse conditions (Fenner & & Thompson, 2006; James *et al*., 2007), helping to stabilize unpredictable fluctuations in species abundance within the existing vegetation. They represent a pool of species that could germinate and establish plant communities thereby forming a key factor for ecosystem reclamation (Wang *et al*., 2020). These seed banks are a major component of ecosystem resilience, playing an important role in the maintenance of species diversity worldwide (Vandvik *et al*., 2016; Poschlod & Rosbakh, 2018), thereby forming an important seed resource for natural vegetation restoration (Ma *et al*., 2018).

This implied that species overcome periods of unfavorable weather conditions by building up large seed stock in the soil, which is known as “soil seed banks”. This strategy protects plant species diversity against local extinction of the species during the disturbance and provides information on the past population dynamics and structure as well as the future regeneration potential of degraded land (Aponte *et al*., 2010).

Compared with aboveground vegetation, seed banks are more tolerant of disturbances, diseases and herbivores. Under harsh environments, maintenance of species diversity and population recruitment depends greatly on seed banks. It should be noted that not all plant species form large and persistent soil seed banks. However, these seed banks help conserve genetic diversity and minimize environmental changes caused by seed immigration, allowing the local species to remain stable (Leishman et al., 2000). Seed banks are especially useful for supporting vegetation recovery in conservation and restoration efforts on sites lacking remnant vegetation or covered with bare soil (Brown, 1998; Ma *et al*., 2018). Certain species remain as buried seeds in the soil, surviving past disturbances until new gaps emerge.

Species employ various strategies for seed persistence in the soil, with some seeds remaining viable for short periods (up to 2 years), while others persist for medium (1–5 years), long (5–25 years), or even semi-permanent durations (over 25 years) (Tyler *et al*., 2021). The distribution of these strategies among species is shaped by factors such as habitat type, site conditions, and the history of land management and disturbances (Hutchings & Booth, 1996; Bekker *et al*., 1997). These environmental and historical influences determine the composition

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of the soil seed bank in different areas. To fully understand forest biodiversity, the richness of species hidden within the soil seed bank must be considered.

The general objective of this study, therefore is to investigate and examine the soil seed bank and regeneration potential by comparing the composition, abundance and diversity of the germinable seeds in the soil of the three selected forest reserves in South-western Nigeria (IITA Forest, Emerald Forest and Elephant sanctuary) with a view to ascertain the recovery process of the forest after disturbance.

METHODOLOGY

Study Sites

IITA Forest

The International Institute of Tropical Agriculture (IITA) forest lies on latitude 7°3 0' 8" and 7° 28' 55.52" North and longitudes 3° 54' 47.50" and 3° 52' 44.49" East in Ibadan. (Moormann *et al*., 1975; Komolafe & Ige, 2020). The forest has about 300-hectares that preserves some of the region's indigenous flora and fauna and is located inside 1000-ha of IITA headquarters Ibadan campus land. The forest is a secondary rainforest that lies in the transition zone between savannah and rainforest, and it was originally part of much larger forests in South-western Nigeria but now surrounded by the city of Ibadan, in Oyo State.

The forest reserve has a low lying and gentle undulating topography with an elevation ranging between 243m to 292m (Tenkouano & Baiyeri, 2007). The rainfall pattern is bimodal with an annual total which ranges from 1300-1500 mm, most of which falls between May and September. The average daily temperature ranges between 21°C and 23°C while the maximum is between 28°C and 34°C. Radiation is about 5285 MJ/m /year. Mean relative humidity is in the range of 64% to 83% (Tenkouano & Baiyeri, 2007). The soils are predominantly Ferric Luvisols (Moormann *et al*., 1975). IITA Forest falls within the humid tropical lowland region with two unique seasons: the longer wet season and shorter dry season. The wet season lasts for eight months and it extends from March to October while the dry season lasts for four months, from November to February.

Emerald Forest, Ikoyi

The Emerald Forest is a privately owned secondary rainforest located at the Abayomi Farm Estate in Ikoyi, Isokan Local Government Area of Osun State in South-western Nigeria. It lies between latitudes 7º35ˈto 7°29ˈN and longitudes 4º14ˈto 4º12ˈE, with an average temperature of 24ºC (Alade *et al*., 2023). The forest lies on the East of the equator with a total land area of about 120/ha (Awoyemi *et al*., 2020). The topography of the forest is bisected by two seasonal streams, the Aworin and Akinrin that join at the Emerald confluence to form the Aduni River, all of which are reduced to puddles in the dry season. The Osun River is an important perennial river, which is dammed by the government to provide water to communities in the surrounding areas (Olajire & Imeokparia, 2000). The river is bordered by gallery forests that serve as an important habitat corridor. Adjacent to the forest are patches of rocky outcrops and farmland. Most of the basement rocks in Emerald Forest are very ancient in age and they showed great variations in grain size and in mineral composition. The soils belong to the highly ferruginous

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tropical red soils associated with basement complex rocks. The forest has a tropical continental climate of humid tropical rainforest and experiences a humidity of about 88% with annual precipitation of about 1400 mm. The forest has two distinct types of seasons: dry and rainy seasons. The dry season between October and March is usually a period of minimal rainfall, while the rainy season covering about eight months starts around April to November. The vegetation of the forest reserve is rich and composed of diverse species of conserved woody trees many of which are indigenous and are scarce in the general market (Alade *et al*., 2023).

Elephant Forest, Omo Forest Reserve

The study area is situated on latitude 6^0 35' and 7^0 05' North and longitude 4^0 19' and 4^0 40' East in Ogun State, in the South-western part of Nigeria (Amusa *et al.*, 2012). It is located about 135km North-East of Lagos and 80 km east of Ijebu Ode and covers an area of 130,500 hectares (322,000 acres) (Adeyemi, 2012). Its terrain is undulating with an elevation that is about 300m on some rocky hills. The climate is humid subtropical since it is within the tropical rainforest ecological zone with relative humidity during the rainy season ranging from 85 to 100% and less than 60% during the dry season (Fashinmirin & Oguntuase, 2008). The reserve has a mean annual rainfall between (1600 – 2000 mm) and an average temperature of 270 C. The average elevation in Omo is 123 m and the soils are predominantly ferruginous tropical, which is typical of the variety found in intensively weathered areas of basement complex formations in the rainforest zone of south-western Nigeria. The soils are well-drained, mature, red, stony and gravely in the upper parts of the sequence; the texture of the topsoil is mainly sandy loam (Onyekwelu *et al*., 2008). The terrain is largely flat and well-drained, with some low rolling hills, and forms part of the Omo River watershed. Over two hundred species of tree have been recorded in the reserve, the most common trees being *Diospyrous spp*, *Drypetes spp, strombosia pustulata*, *Rinorea dentata* and *Voacanga africana* and the most common family include
Araceae, Asteraceae, Ebenaceae, Faboideae, Liliaceae, Poaceae, Rubiaceae and Violacea (Adeyemi, 2012).

Data Collection

The soil samples were collected in February during the rainy season in the year 2022 and were under study till August 2022.

Sampling Technique and Selection of Sample Plots

The laying of the plots was carried out using the line transects. A 500m transect was centrally located in the forest types where eight sample plots of 20 m × 40 m were laid in the alternate side. In each sample plot at the center of each plot a 1 m × 1 m radius was tagged and identified to ascertain tree species diversity. Soil sample was taken using a soil auger with depths from 0-5, 5-10, 10-15cm diagonally at the beginning, center and end of the plot.

The sample was sieved with a 2 mm mesh size before the beginning of the investigation based on Daïnou *et al*. (2011) in order to remove rough plant parts including leaves, pieces of wood and stones. The seeds with a diameter higher than 2 mm were recovered and re-deposited in the sieved soil samples. The sample was taken to the greenhouse at the Department of Forestry and Wood Technology's nursery, FUTA, in accordance with the recommendation of Lopez-Toledo and Martínez-Ramos (2011); the soil was spread out in a circular plastic tray, watered

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every morning, and incubated for seed germination in the greenhouse. Every two weeks, the soil samples were stirred to stimulate seed germination and to encourage seed sprouting during the period of the project. The seedlings readily recognizable were identified, counted and discarded after recording following the methodology used by Tessema *et al*. (2016) to reduce shade effect Biodiversity indices were adopted to determine species abundance and evenness and to compare community diversity. Descriptive statistics were used to determine the density of trees, shrubs, saplings, seedlings and abundance of soil seed bank distribution.

RESULTS AND DISCUSSION

The result in table 1 presents an abundance of plant species in the seed bank of IITA Forest at different soil depths (0-5 cm, 5-10 cm, and 10-15 cm) respectively. The table lists the scientific name, family, and form (tree, herb, or climber) of each species. The result from the soil samples collected at the three depths in the seed bank of IITA revealed that a mean total of 93 seeds/m^2 belonging to 20 families germinated (Table 1). The site comprised 35 species from which 26 were trees, 8 were herbs and 1 was a climber. The soil samples collected at 0-5 cm depth revealed that a mean total of 34 seeds/m^2 emerged comprising 22 species out of which 18 were trees, 4 herbs and 17 families. At the soil depth of 5-10 cm a mean total of 35 seeds/m^2 were recorded which comprised 25 species (18 trees, 6 herbs, and 1 climber) belonging to 15 families. Finally, at the soil depth of 10-15 cm, 14 plant species were identified belonging to 10 families, out of which 11 were trees and 1 was a herb. Some species were present at all soil depths, such as *Albizia zygia*, Antiaris *contiguous*, *Antiaris toxicaria*, *Clausena anisata*, *Cola nitida*, *etc.* Some species were present at two depths, such as *Alchornea cordifolia*, *Boerhavia diffusa, Ocimum basilicum, Lecanodisous cupaniodes* etc., which were found at the depth of 0-5 cm and 5-10 cm respectively. Some species were encountered in a specific soil depth such as *Cola gigantea*, *Entandrophragma spp, Diospyros celebica* all found at 0-5cm depth. which was only found at the 10-15 cm depth.

Table 1: Plant Species Abundance in the Soil Seed Bank of IITA Forest at 0–5 cm, 5–10 cm and 10–15 cm

	Scientific Name	Family	Form	0-5 cm	5-10 cm	10-15cm
1	*Ageratina adenophora*	Asteraceae	Herb	*	-	-
2	*Albizia ferruginea*	Fabaceae	Tree	-	*	-
3	*Albizia zygia*	Fabaceae	Tree	*	*	*
4	*Alchornea cordifolia*	Euphorbiaceae	Tree	*	*	-
5	*Antiaris corylifolia*	Moraceae	Tree	*	*	*
6	*Antiaris toxicaria*	Moraceae	Tree	*	*	*

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7	*Basil weed*	Lamiaceae	Herb	-	*	-
8	*Blighia Sapida*	Fabaceae	Tree	*	-	-
9	*Boerhavia diffusa*	Nyctaginaceae	Herb	*	*	-
10	*Brachystegia eurycoma*	Caesalpinioideae	Tree	*	-	-
11	*clausena anisata*	Rutaceae	Tree	*	*	*
12	*Cola nitida*	Malvaceae	Tree	*	*	*
13	*Cola gigantea*	Malvaceae	Tree	*	-	-
14	*Chromolaena odorata*	Asteraceae	Herb	-	*	*
15	*Danielia ogea*	Fabaceae	Tree	*	*	*
16	*Dialium pellucida*	Fabaceae	Tree	-	*	-
17	*Diospyros celebica*	Ebenaceae	Tree	*	-	-
18	*Dialium guineense*	Fabaceae	Tree	-	*	-
19	*Entandrophragma spp.*	Meliaceae	Tree	*	-	-
20	*Funtumia elastica*	Apocynaceae	Tree	*	-	-
21	*Lecaniodiscus cupanioides*	Sapindaceae	Tree	*	*	*
22	*Mabea occidentalis*	Fabaceae	Tree	-	*	-
23	*Monodora myristica*	Annonaceae	Tree	*	*	-
24	*Newbouldia laevis*	Bignoniaceae	Tree	*	*	*
25	*Ocimum basilicum*	Lamiaceae	Herb	*	*	-
26	*Orthosiphon aristatus*	Lamiaceae	Herb	-	*	*
27	*Palisota hirstella*	Commelinaceae	Herb	-	*	*
28	*Peperomia pellucida*	Piperaceae	Tree	*	*	-
29	*Piper guinness*	Piperaceae	Climber	-	*	-
30	*Pterocarpus osun*	Fabaceae	Tree	-	*	*

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31	*Rollinia weed*	Annonaceae	Herb	*	-	-
32	*Sterculia foetida*	Sterculiaceae	Tree	*	-	-
33	*Strobilanthes crispa*	Acanthaceae	Tree	-	*	-
34	*Trichilia monadelpha*	Meliaceae	Tree	-	-	*
35	*Trichilia subcordata*	Meliaceae	Tree	-	*	*

Key: - = Absent

*** = Present**

Species Diversity of IITA forest

The result in table 2 showed the mean density (Seeds/m^2) and percentage (%) contribution of different plant species in the soil seed bank at three different soil depths (0-5 cm, 5-10 cm, and 10-15cm) examined during the experiment in the IITA Forest. The table represented the scientific names of each plant species and their corresponding densities and percentages of contribution. The result revealed that *Albizia zygia* had a mean density of 6 seeds/ m^2 at 0-5 cm depth, which represented 17.65% of the total seed bank at this depth. At 5-10 cm depth, its density was 5 seeds/m2 and represented 14.29% of the total seed bank while at 10-15cm depth, its density was 4 seeds/m2, thereby representing 16.67% of the total seed bank in this depth. Some plant species had no seeds recorded at some depths, such as *Dialium pellucida and Albizia ferruginea* which had no seeds recorded at 0-5 cm depth but had a mean density of 1 seed/m^2 at 5-10cm depth, which represented 2.86% of the total seed bank at this depth. The table also includes some herbs, such as *Ocimum basilicum* and *Boerhavia diffusa* with low densities and contributions to the seed bank.

Table 2: Relative Density (Seeds m-2) and Relative Percentage Contribution of each Species in the Seed Bank at 0– 5 cm, 5–10 cm and 10–15 cm in IITA Forest

S/N	Scientific Name	0- 5 cm Freq.	RF (%)	5-10 cm Freq.	RF (%)	10-15cm Freq.	RF (%)
1	*Ageratina adenophora*	1	2.94%	-	0.00%	-	0.00%
2	*Albizia ferruginea*	-	0.00%	1	2.86%	-	0.00%
3	*Albizia zygia*	6	17.65%	5	14.29%	4	16.67%
4	*Alchornea cordifolia*	1	2.94%	1	2.86%	-	0.00%
5	*Antiaris contiguous*	1	2.94%	2	5.71%	1	4.17%
6	*Antiaris toxicaria*	2	5.88%	1	2.86%	2	8.33%
7	*Basil (weed)*	-	0.00%	1	2.86%	-	0.00%
8	*Blighia Sapida*	1	2.94%	-	0.00%	-	0.00%
9	*Boerhavia diffusa (weed)*	1	2.94%	1	2.86%	-	0.00%
10	*Brachystegia eurycoma*	1	2.94%	-	0.00%	-	0.00%

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11	*Clausena anisata*	5	14.71%	1	2.86%	1	4.17%
12	*Cola nitida*	2	5.88%	1	2.86%	1	4.17%
13	*Cola gigantea*	1	2.94%	-	0.00%	-	0.00%
14	*Chromolaena odorata*	-	0.00%	1	2.86%	2	8.33%
15	*Daniellia ogea*	1	2.94%	1	2.86%	4	16.67%
16	*Dialium pellucida*	-	0.00%	1	2.86%	-	0.00%
17	*Diospyros celebica*	1	2.94%	-	0.00%	-	0.00%
18	*Dialium guineense*	-	0.00%	1	2.86%	-	0.00%
19	*Entandrophragma spp.*	1	2.94%	-	0.00%	-	0.00%
20	*Funtumia elastica*	1	2.94%	-	0.00%	-	0.00%
21	*Lecaniodiscus cupanioides*	1	2.94%	2	5.71%	1	4.17%
22	*Mobae occidentalis*	-	0.00%	2	5.71%	-	0.00%
23	*Monodora myristica*	1	2.94%	2	5.71%	-	0.00%
24	*Newbouldia laevis*	2	5.88%	2	5.71%	2	8.33%
25	*Ocimum basilicum*	1	2.94%	1	2.86%	-	0.00%
26	*Orthosiphon aristatus*	-	0.00%	1	2.86%	1	4.17%
27	*Palisota hirstella*	-	0.00%	1	2.86%	1	2.86%
28	*Peperomia pellucida*	1	2.94%	1	2.86%	-	0.00%
29	*Piper guinness (Climber)*	-	0.00%	1	2.86%	-	0.00%
30	*Pterocarpus osun*	-	0.00%	1	2.86%	1	4.17%
31	*Rollinia weed*	1	2.94%	-	0.00%	-	0.00%
32	*Sterculia foetida*	1	2.94%	-	0.00%	-	0.00%
33	*Strobilanthes crispa*	-	0.00%	2	5.71%	-	0.00%
34	*Trichilia monadelpha*	-	0.00%	-	0.00%	2	8.33%
35	*Trichilia subcordata*	-	0.00%	1	2.86%	1	4.17%
		34	100.00%	35	100.00%	24	100.00%

Diversity Indices of IITA Forest

The result in table 3 represents measurements of vegetation parameters at three different soil depths (0-5 cm, 5-10 cm, and 10-15cm) in the IITA forest. Specifically, the Shannon wiener index, Species richness, Species evenness, and abundance per hectare were measured. The Shannon wiener Index is a measure of diversity that takes into account both the number of species present and their relative abundance. In this study, the Shannon wiener index ranged from 2.60 to 3.17, with an average value of 2.90. This indicates a moderate to high level of diversity in the vegetation at the studied depths. Species Richness refers to the number of

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different species present in the sample area. In this study, the Species richness ranged from 14 to 25, with an average value of 20. This indicates a relatively high number of different species present in the studied depths. Species evenness is a measure of how evenly distributed the individuals of each species are in the sample area. A value of 1 indicates perfect evenness, while a value of 0 indicates complete unevenness. In this study, the Species evenness ranged from 0.92 to 0.96, with an average value of 0.94. This indicates a relatively even distribution of individuals among the different species in the studied depths. The result of the abundance per hectare refers to the number of individuals of all species combined per hectare of the sample area. In this study, the result of abundance per hectare ranged from 24 to 35, with an average value of 30.

Table 3: Diversity Indices Measured in IITA Forest

Parameters	0-5 cm	5-10 cm	10-15cm
Shannon Wiener Index	2.93	3.17	2.60
Species Richness	22	25	14
Species Evenness	0.92	0.96	0.94
Abundance per hectare	34	35	24

Abundant of Species at Emerald Forest, Ikoyi

The result in table 4 shows the abundance of various plant species in the soil seed bank of Emerald Forest at three different soil depths: 0-5 cm, 5-10 cm, and 10-15 cm respectively. An asterisk (*) denotes the presence of the species at that particular depth. Some notable species with high abundance in all three depths include *Albizia zygia, Baphia nitida, Blighia sapida*, and *Lecaniodiscus cupanioides*. Other species, such as *Celtis phipliphesis, Corchorus capsularis, Euphorbia hirta*, were also present in the soil depth.

Table 4. Plant Species Abundance in the Seed Bank of Emerald Forest at different Soil Depth

S/N	Scientific Name	Family	Form	Soil Depths		
				0-5 cm	5-10 cm	10-15cm
1	*Albizia zygia*	Fabaceae	Tree	*	*	*
2	*Baphia nitida*	Fabaceae	Tree	*	*	*
3	*Blighia sapida*	Fabaceae	Tree	*	*	*
4	*Celtis phipliphesis*	Cannabaceae	Tree	-	-	*
5	*Celtis zenkeri*	Cannabaceae	Tree	*	*	*
6	*Cassia scadens*	Caesalpiniaceae	Tree	*	*	-
7	*Cola gigantea*	Malvaceae	Tree	*	-	-
8	*Corchorus capsularis*	Malvaceae	Herb	*	-	-
9	*Daniellia ogea*	Fabaceae	Tree	*	-	-
10	*Euphorbia hirta*	Euphorbiaceae	Herb	-	-	*
11	*Ficus exasperata*	Moraceae	Tree	*	-	-

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12	*Funtumia elastica*	Apocynaceae	Tree	-	-	*
13	*Lecaniodiscus cupanioides*	Sapindaceae	Tree	*	*	*
14	*Maracuja spp*	Passifloraceae	Tree	-	*	*
15	*Monodora tenuifolia*	Annonaceae	Tree	*	*	*
16	*Montandra guineensis*	Apocynaceae	Tree	*	*	-
17	*Newbouldia laevis*	Bignoniaceae	Tree	-	-	*
18	*Pterygota macrocarpa*	Malvaceae	Tree	-	-	*
19	*Sterculia tragacantha*	Sterculiaceae	Tree	*	-	-
20	*Strobilanthes crispa*	Acanthaceae	Tree	-	-	*
21	*Strombosia pustulata*	Olacaceae	Tree	*	*	*
22	*Tectona grandis*	Lamiaceae	Tree	-	*	-
23	*Trichilia subcordata*	Meliaceae	creeper	*	-	-
24	*Triplochiton scleroxylon*	Malvaceae	Tree	-	-	*

Key: - = Absent

*** = Present**

Species Diversity of Emerald Forest

The result in table 5 shows the mean density (seeds per square meter) and percentage contribution of different plant species in the seed bank at three different soil depths (0-5 cm, 5-10 cm, and 10-15cm) in Emerald Forest. The table showed a mean total of 74 seeds/m^2 emerged in the seed bank at the Emerald Forest. At the 0-5 cm depth of the soil sample, a mean total of 32 seeds/m^2 emerged, *Baphia nitida* was the most abundant species and was represented by a mean density of 5 seeds per square meter, which represents 15.63% of the total seed bank at this depth. Also, at the 0-5 cm soil depth, *Albizia zygia, Blighia sapida, Celtis zenkeri, Lecaniodiscus cupaniodes* were encountered with a mean density of 3 seeds per square meter each representing 9.38% of the total soil seed bank at the depth. At the 5-10 cm depth, *Blighia sapida* is the most abundant species, with a mean density of 4 seeds per square meter, representing 20.00% of the total seed bank at the depth. At the 10-15cm depth, the most abundant species are *Baphia nitida* and *Blighia sapida*, with a mean density of 4 seeds and 3 seeds per square meter respectively, representing 18.18% and 13.64% of the total seed bank at the depth. There are also some species that only have one or two seeds per square meter at each depth, such as *Cupaniopsis spp., Strombosia pustulata, and Funtumia elastica respectively*. The only herb that emerged at the site was *Euphorbia hirta* while the only creeper was *Trichilia subcordata*.

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Table 5: Relative Density (Seeds m-2) and Relative Frequency (%) at Different Soil Depth 0– 5 cm, 5–10 cm and 10–15 cm in Emerald Forest

S/N	Scientific Name	0-5 cm	RF%	5-10 cm	RF%	10-15cm	RF%
1	*Albizia zygia*	3	9.38%	1	5.00%	1	4.55%
2	*Baphia nitida*	5	15.63%	3	15.00%	4	18.18%
3	*Blighia sapida*	3	9.38%	4	20.00%	3	13.64%
4	*Celtis phipliphesis*	-	-	-	-	1	4.55%
5	*Celtis zenkeri*	3	9.38%	2	10.00%	2	9.09%
6	*Cassia scadens*	2	6.25%	1	5.00%	-	0.00%
7	*Cola gigantea*	1	3.13%	-	-	-	0.00%
8	*Corchorus capsularis*	1	3.13%	-	-	-	0.00%
9	*Daniellia ogea*	1	3.13%	-	-	-	0.00%
10	*Euphorbia hirta*	-	-	-	-	1	4.55%
11	*Ficus exasperata*	1	3.13%	-	-	-	0.00%
12	*Funtumia elastica*	1	3.13%	-	-	-	0.00%
13	*Lecaniodiscus cupanioides*	3	9.38%	1	5.00%	1	4.55%
14	*Maracuja spp*	-	-	1	5.00%	1	4.55%
15	*Monodora tenuifolia*	2	6.25%	2	10.00%	2	9.09%
16	*Montandra guianensis*	3	9.38%	2	10.00%	-	0.00%
17	*Newbouldia laevis*	-	-	-	-	2	9.09%
18	*Pterygota macrocarpa*	-	-	-	-	1	4.55%
19	*Sterculia tragacantha*	1	3.13%	-	-	-	0.00%
20	*Strobilanthes crispa*	-	-	-	-	1	4.55%
21	*Strombosia pustulata*	1	3.13%	1	5.00%	1	4.55%
22	*Tectona grandis*	-	-	2	10.00%	-	0.00%
23	*Trichilia subcordata*	1	3.13%	-	-	-	0.00%
24	*Triplochiton scleroxylon*	-	-	-	-	1	4.55%
		32	100.00%	20	100.00%	22	100.00%

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Diversity Indices of Emerald Forest

The result in table 6 shows the different vegetation parameters that were measured in the Emerald Forest. The three parameters measured at three soil depths (0-5 cm, 5-10 cm, and 10-15cm) include Shannon-wiener diversity Index, Species richness and Species evenness. The result of the diversity indices shows that at 0-5 cm depth, the index value was 2.47, a value higher than 2.40 and 2.36 which were derived from depths of 5-10 cm and 10-15 cm respectively, indicating that the biodiversity was higher at the shallower depth. The results of the species richness at 0-5 cm depth revealed that 16 species were present, which was higher than the number of species encountered at 5-10 cm (11) and 10-15cm (14) depths. While the results of the species evenness showed that 0.97 value was obtained at 5-10 cm depth, a value higher than 0.87 and 0.89 that were derived from 0.5cm and 10-15 cm respectively, indicating that the species were more evenly distributed at this depth compared to the other depths. Additionally, the table shows the result for abundance per hectare which revealed that at 0-5 cm depth, the highest abundance was obtained (32), which was higher than the abundance at 5-10 cm (20) and 10-15cm (22) depths respectively.

Table 6: Diversity Indices Measured in Emerald Forest

Parameters	0-5 cm	5-10 cm	10-15cm
Shannon Wiener Index	2.47	2.40	2.36
Species richness	16	11	14
Species evenness	0.87	0.97	0.89
Abundance Per hectare	32	20	22

Species Abundance of Elephant Sanctuary

Table 7 shows the abundance of different plant species in the seed bank of Elephant Sanctuary at three different soil depths: 0-5 cm, 5-10 cm, and 10-15 cm. The table lists the scientific names of the plant species and indicates their presence (*) or absence in each of the three soil depths. Some of the plant species identified in the seed bank include *Blighia sapida, Celtis zenkeri, Cola nigerica, Funtumia elastica, and Sterculia rhinopetala* while the herbs were *Amaranthus viridis and Chromolaena odorata*. The table provides valuable information about the composition of the seed bank and the potential for future plant growth in the area.

Table 7: Plant Species Abundance in the Seed Bank at Elephant Sanctuary at different Soil Depths

S/N	Scientific Name	Family	Form	0-5 cm	5-10 cm	10-15cm
1	***Amaranthus viridis***	Amaranthaceae	Herb	-	-	*
2	***Baliama grass***	Poaceae	Grass	-	-	*
3	***Blighia sapida***	Fabaceae	Tree	*	*	*
4	***Celtis philippensis***	Cannabaceae	Tree	*	-	-
5	***Celtis zenkeri***	Cannabaceae	Tree	*	*	*

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6	***Chromolaena odorata***	Asteraceae	Herb	-	-	*
7	***Cola nigerica***	Malvaceae	Tree	*	*	*
8	***Cola nitida***	Malvaceae	Tree	*	-	-
9	***Dioscorea preussii***	Dioscoreaceae	Climber	-	*	-
10	***Dracena marginata***	Asparagaceae	Climber	*	*	-
11	***Ficus exasperata***	Moraceae	Tree	*	-	-
12	***Funtumia elastica***	Apocynaceae	Tree	*	-	-
13	***Lecaniodiscus cupanioides***	Sapindaceae	Tree	*	-	-
14	***Motandra guineensis***	Annonaceae	Climber	*	*	*
15	***Sterculia rhinopetala***	Sterculiaceae	Tree	*	*	*
16	***Stombodia postulata***	Olacaceae	Tree	*	*	-
17	***Triplochiton scleroxylon***	Malvaceae	Tree	*	-	-

Key: **- = Absent**

*** = Present**

Species Diversity of Elephant Sanctuary

The result in Table 8 shows the mean density (seeds/m^2) and percentage contribution of different plant species in the seed bank of Elephant Sanctuary at three different soil depths (0-5 cm, 5-10 cm, and 10-15cm). A mean total of 40 seeds/m^2 emerged at the 0-5 cm depth of the soil seed bank while 27 seeds/m^2 germinated at the 5-10cm of the seed bank depth, lastly at the 10-15cm depth 26 seeds/m^2 were recorded. According to the table, Baliama grass had no seed in the 0-5 cm depth but contributed 12% of the seeds in the 10-15cm depth. Conversely, *Celtis philippensis* had only 2 seeds in the 0-5 cm range and contributed no seeds in the 5-10 cm and 10-15 cm respectively. The result further revealed that *Celtis zenkeri* contributed the highest percentage in the three soil depths as it presented 25% of the seeds in the 0-5 cm depth, 59% of the seeds in 5-10 cm, and 46% of the seeds in the 10-15cm depth. *Amaranthus viridis* and *Chromolaena odorata* are the only herbs present on the site made up of 12% of the seeds in the 10-15cm depth.

Table 8: Relative Density (Seeds/m^2) and Relative Percentage of each Species in the Seed Bank at different Soil Depth in Elephant Sanctuary

S/N	Scientific Name	0-5cm	RF%	5-10cm	RF%	10-15cm	RF%
1	***Amaranthus viridis***	-	0.00%	-	0.00%	1	4%
2	***Baliama grass***	-	0.00%	-	0.00%	3	12%
3	***Blighia sapida***	5	13%	1	4%	2	8%
4	***Celtis philippensis***	2	5%	-	0.00%	-	0.00%
5	***Celtis zenkeri***	10	25%	16	59 %	12	46%
6	***Chromolaena odorata***	-	0.00%	-	0.00%	2	8%
7	***Cola nigerica***	4	10%	1	4%	1	4%
8	***Cola spp***	2	5%	-	0.00%	-	0.00%
9	***Dioscorea preussii Pax***	-	0.00%	1	4%	-	0.00%

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10	***Dracena marginata***	1	3%	1	4%	-	0.00%
11	***Ficus exasperata***	6	15%	-	0.00%	-	0.00%
12	***Funtumia elastica***	1	3%	-	0.00%	-	0.00%
13	***Lecaniodiscus cupanioides***	2	5%	-	0.00%	-	0.00%
14	***Motandra guineensis***	2	5%	2	7%	2	8%
15	***Sterculia rhinopetala***	3	8%	4	15%	3	12%
16	***Stombodia postulate***	1	3%	1	4%	-	0.00%
17	***Triplochiton scleroxylon***	1	3%	-	0.00%	-	0.00%
		40	100%	27	100%	26	100%

Diversity Indices of Elephant Sanctuary

The result in table 9 shows several vegetation parameters measured in Elephant Forest. The result of Shannon Weiner diversity index at Elephant Sanctuary shows that 2.28, 1.40 and 1.70 values were obtained at the depths of 0-10cm, 10-20 cm, and 10-15cm depth respectively. The result of species evenness revealed that 0.89 values were obtained at the 0-5 cm depth, 0.67 values at the 5-10 cm depth, and 0.82 values at the 10-15cm depth. These values suggest that the distribution of individuals within species is relatively even at the shallow depth, but becomes less even at deeper depths. Moreso, the results of abundance per hectare were also presented in table below and about 40 individuals per hectare were represented at the 0-5 cm depth, 27 individuals per hectare at the 5-10 cm depth, and 26 individuals per hectare at the 10-15cm depth respectively.

Table 9: Result of Diversity Indices Measured in Elephant Sanctuary

Parameters	0-5 cm	5-10 cm	10-15cm
Shannon Wiener Index	2.28	1.40	1.70
Species Richness	13	8	8
Species Evenness	0.89	0.67	0.82
Abundance per hectare	40	27	26

DISCUSSION

The qualities of a seed bank of a specific habitat help in managing the current vegetation's composition and structure, as well as in restoring indigenous vegetation in several forms (Hui & Keqin, 2006). Species composition of soil seed banks across the different soil depths showed that tree species dominated the three layers of the soil depths investigated, indicating that the soil is loaded with a collection of viable tree seeds that are capable of replacing the forests thus playing a major role in succession dynamics of the forest ecosystem. Soil seed bank therefore acts as a repository of viable seeds, and information derived from it, can also play an important role in determining plant resilience in disturbed forests. In the three sites investigated, namely: the IITA Forest, the Emerald Forest Ikoyi, and the Elephant Sanctuary, there are significant differences in their levels of species diversity and richness. The IITA Forest had the highest values for all parameters measured, with a Shannon Wiener Index ranging from 2.60 to 3.17,

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Species Richness ranging from 16 to 27, Species Evenness ranging from 0.92 to 0.96, and Abundance per hectare ranging from 24 to 35. These values indicate a relatively high level of diversity and richness in the IITA Forest, particularly in the 5-10 cm layer. High species richness and diversity encountered in IITA forest could be a result of rich soils and abundant moisture present in the site as corroborated by Oladoye (2015). Seed germination and emergence are influenced by their position in the seed bank profile (Traba *et al*., 2004). A higher number of seeds were recorded in the first soil bank depth of the three forest reserves, making them the greatest seed reservoir.

Researchers revealed that there is an inverse relationship between the soil depth and seed bank density as documented in this finding (Vandvik *et al*., 2016; Omomoh *et al*., 2020). The results of this study are consistent with previous studies conducted in other forest reserves in Nigeria, which also reported high levels of diversity and richness in the first bank depth (Oguntoyinbo and Akintoye, 2012). In contrast, Emerald Forest had lower values for all parameters measured, with a Shannon Wiener Index ranging from 2.36 to 2.47, Species Richness ranging from 12 to 17, Species Evenness ranging from 0.87 to 0.97, and Abundance per hectare ranging from 21 to 34 as compared with IITA. These values suggest a lower level of diversity and richness in the Emerald Forest, particularly in the 5-10 cm layer. According to Zhu *et al*. (2023), environmental factors and anthropogenic factors among others have a great impact on seed diversity and composition of soil seed banks which could be the reason for the low diversity experienced in Emerald Forest.

However, the values are still relatively high compared to other ecosystems in Nigeria and other regions. For example, a study conducted in the Lopé National Park in Gabon reported a Shannon Wiener Index of 2.36 and Species Richness of 9.8 per hectare (Couteron & Pelissier, 2005). The Elephant Sanctuary had the lowest values for all parameters measured, with a Shannon Wiener Index ranging from 1.40 to 2.28, Species Richness ranging from 8 to 13, Species Evenness ranging from 0.67 to 0.89, and Abundance per hectare ranging from 26 to 40. These values suggest the lowest level of diversity and richness in the Elephant Sanctuary compared to the other reserves, particularly in the 5-10 cm and 10-15 cm layers of the soil depth. This could be that the site is relatively disturbed. According to Zhao *et al*. (2022), a disturbed site will have a lower composition and low richness of species in the soil seed bank. The measurement of vegetation parameters is critical for conservation efforts and management strategies in forest reserves and other ecosystems. The results of these measurements provide valuable information for understanding the state of vegetation diversity and richness in the reserves, identifying areas of high conservation value, and developing management strategies to protect and enhance the biodiversity and ecological health of the reserves. For example, the results of this study suggest that the Elephant Sanctuary may require more conservation attention and management intervention to improve the levels of diversity and richness in the reserve.

CONCLUSION

In conclusion, three forest reserves—IITA Forest, Emerald Forest Ikoyi, and Elephant Sanctuary, Omo Forest -- were studied to assess their soil seed bank. Overall, it was discovered that the soil seed banks in these reserves were diversified and plentiful, suggesting that these forests are capable of self-regeneration even after disturbances such as deforestation, logging,

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and other activities that impact the vegetation. The soil seed bank composition of IITA Forest has a relatively high level of diversity with a moderate to high number of individuals and species present in the studied depths. For the flora to regenerate and grow in the forest reserves, it is crucial to preserve the soil's natural qualities. As a result, the study offers crucial information about the soil seed in the three Nigerian forest reserves.

It is obvious that additional study is required to fully comprehend the intricacies of these forest reserves and to create plans for their sustainable management. Despite this, this research offers crucial insights into how forest ecosystems work and the significance of maintaining their soil and vegetation components.

RECOMMENDATIONS

These are the following recommendations deduced from the result of this study:

- It was discovered that even after disruptions, the forest reserves have the potential to regenerate. Hence, encouraging reforestation initiatives in these reserves by state governments where these forests are situated can aid in restoring damaged regions and enhancing the biodiversity of the reserves.

- Human activities, such as deforestation and logging, can have a significant impact on the soil and vegetation in the forest reserves. Therefore, monitoring and managing these activities can help to ensure the sustainable management of these reserves. The state government within which these reserves are situated should therefore set a taskforce to monitor and manage the activities of man within the forest.

Overall, implementing these recommendations can help to ensure the sustainable management of the forest reserves and promote their long-term conservation.

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