

Evaluating Undergrowth Species Pattern and Soil Seed Banks Mode for Monitoring Conservation in a Protected Forest of Nigeria

E. Bernard Omomoh^{1*}, Precious Aigbe², E., J. Busayo Alli³, Gbenga Ogunsanwo³, A. Gbenga Akomolafe⁴, D., F. Oluwafemi Adeniji⁵ and K. Isaac Agbede⁶

¹Forestry and Wood Technology Department, Federal University of Technology, Akure, Nigeria

²Department of Botany, Ambrose Alli University, Ekpoma, Edo State, Nigeria

³Department of Botany, University of Lagos, Akoka, Lagos State, Nigeria

⁴Department of Plant Science and Biotechnology, Federal University of Lafia, Lafia, Nasarawa State, Nigeria

⁵Department of Forestry Technology, Federal College of Wildlife Management, New Bussa, Niger State, Nigeria.

⁶Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

*Corresponding author: beomomoh@futa.edu.ng, bernardomomoh@gmail.com, ORCID: <http://orcid.org/0000-0002-0506-4973>

1
25 1
6
7 **Abstract**
8 2
9 3

10 4 As most trees enter senescence, the assessment of undergrowth species and seedling outcomes
11 5 from soil seed banks becomes imminent research and an essential tool to checklist an area
12 6 prioritized for tree conservation. The procedure to ascertain senescent trees are not
13 7 underrepresented is uncommon research, specifically for a buffer zone of a strict nature reserve
14 8 (SNR) in the Akure Forest Reserve. This study evaluates the species richness of the undergrowth
15 9 patterns that are prioritized for conservation and also examines the effective soil depths for
16 10 seedling outcomes. However, four (4) sample plots (50×50m) from lowlands were established at
17 11 the buffer zone of a protected forest to measure the population size of the undergrowth species
18 12 pattern. Similarly, twenty (20) 1 x 1m quadrats of 60 samples were collected at different soil depths
19 13 (0-3cm, 3-6cm, 6-9 cm) and were warm stratified at about 21-39⁰ C in a greenhouse for seedling
20 14 outcome. A total of 97 undergrowth species were encountered aboveground, while a total of 18
21 15 plant species were distributed at 0–3 cm, 16 at 3-6 cm, and 8 at 6–9 cm seedling emergence. The
22 16 results from the statistical analysis showed the observed differences among the soil depths from
23 17 the seedling outcome are significant, and there is a strong dissimilarity between the seedling
24 18 outcome and the undergrowth species. The undergrowth species pattern is more diverse, and the
25 19 species richness is higher, which implies a stable community with little or no disturbance.
26 20 Regrettably, some ageing trees were still underrepresented, despite the undergrowth species
27 21 richness and diversity. More so, the IUCN red list assessment showed that numerous plants, i.e.,
28 22 34 plants out of 97 undergrowth species, fall into the category of Not Evaluated (NE), which
29 23 showed that many plants in this typical forest are still going through IUCN evaluation. The current
30 24 evaluation will assist the IUCN assessment and also help government agents in the conservation
31 25 allotment of underrepresented aging trees in the protected forest. In the meantime, public education
32 26 will be used to manage the unsustainable gathering of wild fruit and forest food in the buffer zone.
33 27 This will be followed by support for home gardens as a means of preventing the overuse of aging
34 28 tree fruit and plants throughout the ecosystem. It was advised that research be done in protected
35 29 areas of the forest on soil depths suitable for seedling recruitment and soil seed bank potential that
36 30 would support conservation action allocation.

37 31
38 32
39 33
40 34
41 35
42 36
43 37
44 38
45 39
46 40
47 41
48 42
49 43
50 44
51 45
52 46
53 47
54 48
55 49
56 50
57 51
58 52
59 53
60 54

Keywords: Buffer zone - Soil seed bank mode - Undergrowth species pattern - IUCN red list – Conservation – Aging tree

50 35
51 36
52 37
53 38
54 39
55 40
56 41
57 42
58 43
59 44
60 45

1 Introduction

61 35 Environmental concerns are rising as human pressure on the current biodiversity increases. As
62 36 with ecosystem disturbance, human activity has altered the planet Earth, making most forests
63 37 incapable of protecting biodiversity (Boonman et al., 2024; Van Lear et al., 2005; Plaza et al.,
64 38 2018). Meanwhile, the biodiversity that would eventually replace the older ones can only be
65 39 protected when human activities cease to interfere with the planet Earth. The way to effectively
66 40 sustain an ecosystem is when humans put passion and dedication into the concepts and processes
67 41 of ecosystem services (Rockwell et al., 2022; DeClerck., 2013; Hector & Bagchi., 2007).
68 42 Considering ecosystem services, in the past and to date, forest food and non-timber forest product
69 43 resources (NTFPs) have brought numerous benefits to both rural and urban dwellers. However,
70 44 there has been an increase in the conflict between the interaction of biodiversity and other managed
71 45 ecosystems, i.e., agriculture. Linking cultivated spaces and natural ecosystems together has been

1
2
3
4 44 a major challenge facing conservation activities, but Siminski et al., (2021) exemplify methods
5 45 that promote forest regeneration in post-agricultural secondary forests in their studies.
6
7 46 Forest regeneration plays a significant role in reclaiming tropical forest lands through natural
8 47 regeneration, and by so doing, all forests can successfully regain the biodiversity that has been lost
9 48 due to disturbance. According to Martnez-Ramos et al., (2016) and Siminski et al., (2021), the
10 49 ongoing disturbance of tropical forests has resulted in significant devastation and a loss of
11 50 biodiversity. Forest disturbance and biological loss were identified as natural processes and part
12 51 of the issues facing biodiversity conservation on a global scale (Omomoh et al., 2020). Usually,
13 52 this disruption leads to the loss of certain species, a decline in the productivity of forest ecosystems,
14 53 and a reduction in biodiversity (Pain et al., 2021; Odeleye et al., 2018; Lôbo et al., 2011).
15 54 Employing natural regeneration approaches and comprehending the associated regeneration
16 55 mechanisms, such as the dispersion agent in forest restoration, is a vital step in the implementation
17 56 of highly effective biodiversity restoration. In the tropical forest, these methods might be
18 57 constrained in various ways. There have been reports of common physical processes in dryland
19 58 seeding that include propagule limitation, abiotic and biotic factors (Shackelford et al., 2021).
20 59 Statistics on the species variety and undergrowth richness of soil seeds are not always available
21 60 for many regions of the world, notably Africa (Mashiane et al., 2023). Consequently, several
22 61 habitats in Africa have disappeared due to disturbances to soil seed banks, which include plant
23 62 species from several environments (Padonou et al., 2022). Other studies (Solar et al., 2015; Piotto
24 63 et al., 2021) revealed that anthropogenic disturbances may restrict indigenous species' peculiarity
25 64 to regenerate secondary forests, which may favor other species' dominance and establishment.
26 65 Nigeria's expanding population is putting strain on its tropical rainforests due to grazing, extensive
27 66 logging, infrastructural development, and other related activities (Odeleye et al., 2018). Nigeria
28 67 has one of the highest annual rates of forest disturbance in the world, at 3.7%. (FAO, 2010). Among
29 68 these disturbances are fire, flood, wind, and human activities like logging and grazing. As a result
30 69 of the widespread attempts to ecologically restore ecosystems disrupted by human activities (Golos
31 70 et al., 2016), there is a greater understanding of how seed banks can affect the colonization and
32 71 organization of plant communities (Doroski et al., 2020). Since seed banks are found in many
33 72 environments and can change the composition and productivity of vegetation, it is crucial to
34 73 understand the mode of seed distribution and the dynamic interaction between above-ground
35 74 vegetation and seed banks (Esaete et al., 2021). Soil seed banks are the components of live
36 75 propagules that are above or below the soil (Price et al., 2010; Thompson & Grime, 1979).
37 76 Research on the mode of soil seed bank distribution is necessary to comprehend how they support
38 77 forest regeneration (Padonou et al., 2022; Butler & Chazdon, 1998). The soil can produce new
39 78 plants from dormant, viable seeds (Fenner, 1985). Soil seed banks serve a critical role in the
40 79 regeneration process after human activities or natural disruptions (Thompson, 1992). Studies on
41 80 tropical forest succession have highlighted the importance of soil seed banks as a source of
42 81 recruitment following disturbances (Huang et al., 2022). Recent research has focused on the
43 82 diversity and composition of soil seed banks in forest ecosystems (Abdella et al., 2007; Butler &
44 83 Chazdon, 1998; Decocq et al., 2004; Kalamees & Zobel, 2002; Madawala et al., 2016; Kalesnik
45 84 et al., 2013). Studies on the composition and diversity of soil seed banks in Nigeria have been
46 85 conducted due to their impact on natural forest regeneration (Akinyemi et al., 2018; Chima &
47 86 Kamalu, 2016; Odeleye et al., 2018; Oke et al., 2007; Olatunji et al., 2015; Omomoh et al., 2019,
48 87 2020). On the other hand, it has been observed that the interaction between environmental
49 88 conditions of undergrowth and forest age affects the prevailing life cycle in the regenerating forest
50 89 of the secondary forest (Piotto et al., 2021).
51
52
53
54
55
56
57
58
59
60

1
2
3
4 90 Adetula, (2008) reports that sixteen forest reserves in Ondo State have records of forest
5 91 disturbance. Of these, the Akure Forest Reserve covers 70.19 sq km, with 21.37% (14.98 sq km)
6 92 of disturbed areas. For this reason, a buffer zone with a strict nature reserve was created to protect
7 93 the forest biodiversity from human disturbance (Omomoh et al., 2019). Although some
8 94 anthropogenic activities were prohibited, the original inhabitants are still able to assess the buffer
9 95 zone for non-timber forest products (NTFPs), with high discrimination against removing senescent
10 96 trees' fruits and seedlings. Similar studies were reported by Keatinge et al., (2010) and Kehlenbeck
11 97 et al., (2013) in sub-Saharan Africa, where most wild fruits are normally gathered from natural
12 98 forests while indigenous fruit trees are usually not cultivated on farms (Weinberger & Lumpkin,
13 99 2005; Simitu et al., 2009), which puts more pressure on the existing forest for forest resources.
14 100 Similarly, in Nigeria, over 1000 wild plants and forest food have been identified as forest resources
15 101 (Idumah et al., 2008). A significant amount of forest food is consistently consumed by rural
16 102 dwellers who collect it for food. However, pressure on the wild plants has impeded progress on
17 103 the undergrowth pattern to replace the aging trees specifically marked for conservation. Studies
18 104 that were carried out over a decade ago (Onyekwelu et al., 2008; Adekunle et al., 2013) and
19 105 compared with the current assessment showed a wide range of undergrowth species patterns and
20 106 a long process of aging trees (Omomoh et al., 2019, 2021). The recent change in undergrowth
21 107 species exposes threats to certain aging trees that are underrepresented for conservation
22 108 assessment, while some plants with a higher rate of species richness and diversity do not capture
23 109 the current IUCN Red List assessment. Therefore, this study aims to contribute data to the IUCN
24 110 species database by evaluating the undergrowth species pattern concerning population size and
25 111 relating it to the aging tree for IUCN conservation statuses. It should be highlighted in this study
26 112 that the majority of the information on mature trees in the aging class that would successfully
27 113 preserve genetic diversity and indigenous knowledge is descriptive. However, the evaluation of
28 114 understory species patterns and soil seed bank modes can yield valuable data on almost all trees
29 115 that are close to senescence. We compare the contrast between forest undergrowth and soil seed
30 116 banks using different soil depth parameters. The results were used to check if the current status of
31 117 this forest has the regenerating potential to replace the senescent trees in no time.

32 118 **2 METHODOLOGY**

33 119 **2.1 STUDY AREA**

34 120 The current study (Figure 1; N07.27228⁰, E005.03560⁰) is being carried out in a tropical rainforest
35 121 at a plant refugium that was established by the Nigerian Forest Department in 1948 (Ola-Adams,
36 122 1978) to safeguard the biodiversity of the Akure forest reserve and preserve the genetic resources
37 123 of indigenous forest tree species in Nigeria. This forest is made up of two distinct seasons. The
38 124 wet season, also known as the first season, normally starts around May and lasts until September
39 125 of the same year, while the dry season, also known as the second season, usually starts around
40 126 October and lasts until April of the following year (Omomoh et al., 2021). The study area was
41 127 situated within the Akure Forest Reserve. Farming is a key activity in the settlements that border
42 128 the forest, and this forest benefits rural residents socioeconomically by providing wild edible
43 129 plants. With the discovery of new research and educational studies, the natural forests offer value
44 130 for traditional and indigenous knowledge for current scientific uses. Recently, the ecosystem's
45 131 habitats have become increasingly unstable as a result of disturbance from surrounding areas,
46 132 which has a particular negative influence on the undergrowth species pattern. The individual plant
47 133 species encountered were based on IUCN Red List assessments (IUCN, 2021), and this was to

1
2
3
4 134 categorize the poorly-recorded species in the Akure forest buffer zone into; Not Evaluated (NE),
5 135 Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered
6 136 (EN), Critically Endangered (CR), Extinct in the Wild (EW), and Extinct (EX) to further enhance
8 137 the research on individual plant conservation status

10 138 **2.2 METHODS**

11
12 139 Four sample plots with similar lowland forest features of 50 m by 50 m each, were established in
13 140 the buffer zone of Akure Forest Reserve (Table 2). At each plot, all plant species were identified
14 141 and counted. Thereafter, their specific habits were classified into herbaceous, lianas, climbers,
15 142 saplings, and shrubs using taxonomic guides (Hutchinson & Dalziel, 1958; 1963, 1968, Akobundu
16 143 & Agyakwa, 1998) and were also rated according to the IUCN, (2021) red list. A plant taxonomist's
17 144 assistance made it simpler to identify plants at the species and family levels, and where certain
18 145 species could not be identified, those plants were transported to the University herbarium (FUTA
19 146 herbarium) for correct authentication. We also engaged the online database-African Plant
20 147 Database, to group the plants into their different habits. Meanwhile, in each sample plot, (five) 1m
21 148 by 1m sub-plots were deterministically derived within the selected plots. The criteria for the
22 149 selection of soil seed bank samples followed Savadogo et al., (2017). Twenty 1 x 1m quadrats, and
23 150 a total of 60 samples (15 samples per depth) were collected using a soil auger at soil depths of 0-
24 151 3, 3-6, or 6-9 cm. The soil depth diameter adopted in this study was multi-layer soil depth for the
25 152 African ecosystem (Padonou et al., 2022). The 15 soil samples taken from multi-layers were used
26 153 to construct 60 composite soil samples because of the plot's similarity. A 5mm mesh size was used
27 154 to separate the soil samples from rocks, boulders, decaying wood and roots, pebbles, and other
28 155 detritus. Many seeds in the tropical rainforest were embedded and deeply buried in a soil seed
29 156 bank, and those with smaller seeds cannot be extracted due to their smaller sizes. Therefore, the
30 157 composite soils were placed into perforated 43cm diameter potted media and warm stratified at
31 158 about 21-39 °C for three months to stimulate germination in a greenhouse where seedling
32 159 emergence was examined. During this period, seedling emergence was studied and monitored
33 160 every week, while identified seedlings were recorded, removed, and thrown away after counting
34 161 the number of individual seedlings in the pots. However, in a situation where the seedling was too
35 162 small to be properly identified, it would be left for an additional one to two weeks to be identified.

43 163 **2.3 STATISTICS ANALYSIS**

44
45 164 There was only one treatment (soil depths) in this experimental unit. The experimental data in this
46 165 study were performed using R software. Using the information from the soil depths, an Excel
47 166 spreadsheet was generated with three categories: treatment (Trt), replication (Rep), and value. The
48 167 file format was modified to CSV (comma delimited) so that the R application could read it. The
49 168 CSV was transformed into a working directory by R Studio (Set as a Working Directory) so that
50 169 it could be examined. Thereafter, a completely randomized design (CRD) was employed for the
51 170 soil depths, and a fixed effect was the type of statistical model used. To ascertain which soil depth
52 171 level had significantly increased or decreased the population of the species, the data from the
53 172 experimental units were transformed, and a follow-up test (LSD) was conducted when the Ho was
54 173 not accepted. Similarly, we used Species richness, Shannon-Wiener, and Simpson diversity in
55 174 Chao et al., (2014) and Chao et al., (2016)'s iNEXT R package to determine the species diversity
56 175 and distribution among the three soil depths. The computation of estimated bootstrap s.e. and
57 176 confidence interval estimators was also obtained through the R/E (extrapolated rarefaction and

1
2
3
4 177 extrapolation) sampling curve. We used a rarefied bootstrapping sampling curve of 100 at the 0.95
5 178 level of the confidence interval in the package to make the data more powerful. The estimated
6 asymptote provided was used to compare species diversity indices. To test for any significant
7 179 difference, the biodiversity indices and principal component analysis (PCA) of species
8 180 undergrowth and seedling outcome were calculated and tabulated using the PAST 4.03 Statistical
9 181 Package. PCA was utilized to quantify the degree of variation in the species distribution across
10 182 various soil depths. Likewise, Origin software (v 2023) was used to project similarity in species
11 183 composition of vegetation and seedling emergence, and two similarity indexes were performed by
12 184 non-metric MDS Bray-Curtis to show similarity within the three soil depths.
13 185

14 186 **3 RESULTS**

15 187 **3.1 Floristic composition of the soil seed banks and undergrowth plants**

16 188 A total of 97 undergrowth species were found across the typical locations (Table 1). The
17 189 occurrence of the life-form categories revealed that 46 saplings (44 species, 35 genera), 26 shrubs
18 190 (26 species, 22 genera), 16 climbers (16 species, 6 genera), and 9 herbs (9 species, 6 genera) were
19 191 distributed across the buffer zone. A total of 38 families were recorded, Apocynaceae (10 species)
20 192 and Rubiaceae (9 species) had the most dominant members. Annonaceae, Caesalpinoideae,
21 193 Euphorbiaceae, Rubiaceae, and Sterculiaceae had 5 members each, while other members within
22 194 the range of 1 to 4 species fell into many families that made up the remaining families. It was
23 195 deduced from the above result that, the herb was remarkably low due to the spread of other
24 196 undergrowth habits, i.e., the sapling, shrub, and climber took the top three spots in the
25 197 undergrowth.
26

27 198 **3.2 Plant species composition in the soil seed bank**

28 199 However, in Table 2, a total of 18 plant species were distributed at soil depths of 0–3 cm, 16 plant
29 200 species at soil depths of 3–6 cm, and 8 plant species at soil depths of 6–9 cm were identified in the
30 201 soil seed bank, even though the fewest species are found in soil between 6–9 cm. *Laportea aestuans*
31 202 and *Asystasia vogeliana* were both thought to have the maximum number and relative density in
32 203 the 0–3 cm soil depths across all three soil depths. The highest number and relative density of
33 204 *Platostoma africanum*, *Laportea aestuans*, and *Panicum maximum* (graminoid) were found in soil
34 205 depths of 3–6 cm, while only *Panicum maximum* (graminoid) was highest in soil depths of 6–9 cm,
35 206 but lowest in all three soil depths observed (Table 1). Among the soil depths (Table 2), herbs, the
36 207 most dominant habitat, were progressively higher given that they are pioneer plants; however,
37 208 saplings were relatively high, indicating that the soil seed bank is significantly rich in tree-seeded
38 209 species, while graminoid and climber were thought to be the lowest.
39

40 210 **3.3. Soil depth and species distribution**

41 211 Within the three soil depths, there was an 84.7 ± 64.5 record of seedling emergence and
42 212 accumulation. The seed density and total seedling emergence were climbers (8 ± 9.64), graminoids
43 213 (8.33 ± 2.31), herbaceous (54.3 ± 44.6), and saplings (14 ± 11). However, in Figure 2 (Soil depth 1)
44 214 and (Soil depth 2), emergence rates for graminoids (grasses) in 3–6 cm and 6–9 cm soil depths were
45 215 higher than 0–3 cm soil depth 1 (Figure 2). Similarly, in 0–3 cm and 3–6 cm soil depths (Figure 2),
46 216 there were a lot more saplings present and higher than the 6–9 cm soil depths. As a result, the total
47 217
48 218
49 219
50 220
51 221
52 222
53 223
54 224
55 225
56 226
57 227
58 228
59 229
60 230

seedling outcome for the 0-3cm soil depths was 93.3%; the herbaceous species dominated the 0–3 cm soil depth, making up 73.1% of the species discovered. 10.1% of the plant species were saplings, 5.4% were climbers, and 4.7% were grasses in the soil seed bank (Figure 2). Some perennial species were discovered, including *Asystasia vogeliana*, *Chromolaena odorata*, *Commelina diffusa*, *Laportea aestuans*, *Palisota hirsuta*, *Platostoma africanum*, *Physalis angulata*, *Pouzolzia guineensis*, *Sida acuta*, *Spermacoce ocynoides*, and *Synedrella nodiflora*. The two saplings identified were *Discoglypsemna caloneura* and *Celtis zenkeri*. *Dioscorea preussii* and *Sida urens* were the only climbers found, while *Panicum maximum* was the sole grass present. More specifically, at 3-6 cm depth, the total seedling outcome was 97.1%. However, herbaceous species dominated the soil since they made up 69.7% of all the species that were found in the soil seed bank from the location; saplings made up 13.7%, grass made up 12.6%, and climbers made up the final 1.1%. *Celtis zenkeri* was the only sapling found in the soil. The plant species *Asystasia vogeliana*, *Chromolaena odorata*, *Commelina diffusa*, *Laportea aestuans*, *Platostoma africanum*, *Physalis angulata*, *Pauridiantha hirtella*, *Spermacoce ocynoides*, *Sida acuta*, and *Synedrella nodiflora* are the herbaceous species found here. Only *Panicum maximum* was discovered there. A total of 126.4 % was found in the soil depth 6-9cm. Similarly, grass and herbs made up the majority of the seed bank at a soil depth of 6-9 cm, accounting for 36.8% and 42.2%, respectively. 42.1% of the saplings discovered were trees, with climber species making up the lowest percentage (5.3%) of the total seedling outcome. The two species identified there were *Dioscorea preussii*, a climber, and *Panicum maximum*, a grass. The soil seed bank contained *Platostoma africanum*, *Laportea aestuans*, *Physalis angulata*, *Sida acuta*, and *Synedrella nodiflora* among other perennial herbaceous species.

3.4 Principal component analysis (PCA) of soil depths

The relationships between species behaviors in the three soil depths are shown in Figure 5. It demonstrates that the four selected habits had the largest relative species densities in saplings. However, unlike the climber, graminoid, and herb, which are noticeably varied among the habits, the saplings do not differ much from the three other habits. The degree of variation in the distribution of the species across the three soil depths (Table 6; Figure 3) was explained in principal component analysis (PCA). The first principal component (PC1), which accounted for 66.32% of the variance, showed the highest degree of variation. Following this were the second principal component (PC2), which had the largest degree of variation (25.73%), and the third principal component (PC3), which had the lowest degree of variance (7.94%). All three soil depths strongly correlated with PC1 and the species that contributed mostly to the variations were *Laportea aestuans*, *Platostoma africanum*, *Pauridiantha hirtella*, *Asystasia vogeliana*, *Synedrella nodiflora*, *Panicum maximum* etc.

3.4 Analysis and significant effect of soil depths

The ANOVA showed that there is a significant difference in species diversity among the soil depths because $p < 0.05$ at the significance code in Table 3 shows the level of significance. The LSD test (Table 4) showed a slight difference among the three depths. The most highly influenced soil depth benefited from the soil nutrient, notably with a higher seedling outcome. However, seedling patterns among the three depths were nearly similar in species richness and slightly different in species diversity. Seedling outcomes were positively influenced at the first depth (Soil Depth 1) than at the two other depths studied, which implies that the nearer the soil depth to the

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

topsoil, the better the seedling outcome. The variation in Table 5 shows the percentage of variance that was found in seedling outcomes at different soil depths. Axis 1, with an equivalent of 1.989, was more influenced than the two other axes, 0.772 for axis 2 and 0.238 for axis 3. The results indicate that the soil depth of 0-3 cm yielded the highest results across all measured parameters (Table 2). Nevertheless, the overlap in the confidence interval of the rarefied and extrapolated curves demonstrated that the observed species richness of the three soil depths did not significantly differ from each other (Figure 4a). The rarefied and extrapolated curve of observed Shannon diversity and species evenness of 0-3 cm soil depth proved the depth as the only depth significantly different from the other two soil depths observed in the species accumulation curves in Figure 4(b and c)

3.5 Undergrowth species IUCN rating

In all the research, thirty-four plant species were Not Evaluated (NE), five species were of Least Concern (LC), one species of plant was found to be Endangered (EN), five as Vulnerable (VU), and thirty-seven as of least concern (LC) according to the Red List ranking of plant conservation status (Table 1). The field survey that was carried out around the communities surrounding the protected forest showed that some rural dwellers are planting some of the fruit-producing trees in their homes to reduce the stress and competition of going to the forest for forest fruit harvesting. Idumah et al., (2008) studies two decades ago also corroborated some of the trees found in the descriptive study in Table 7 of this study.

4 DISCUSSIONS

The relationship between the aging trees and the undergrowth species pattern begins from the soil seed banks mode of the typical forest. Since each species has a unique germination mechanism, the interface between the undergrowth species pattern and the soil seed bank mode of different forest communities will continually differ in species diversity. However, the forest sampling of this study revealed that there is no strong affinity between the undergrowth and the soil seed banks. Meanwhile, given the current results, the sampling in the forest buffer zone cannot be interpreted as a degraded forest that was disturbed. The transition of soil seed banks into forest undergrowth from soil depths in this study, were evaluated for species conservation. Although, soil depths within the range of 0-5 and 10-15 cm are still increasingly used in forest ecosystems (Douh et al., 2018), in this study, the soil seed assessment with respect to soil depth sampling; 0-3cm and 6-9cm, has led to a great influence on the seedling outcome. The seeds that constitute soil seed banks are mostly produced by parents that are nearby, and the remaining seeds are produce by plant communities that are geographically far away from the parent plants (Piotto et al., 2021; Chaideftou et al., 2011, Solomon, 2011). Studies on the list of threatened species (IUCN, 2021), showed some species of plants that are tagged as Near Threatened (NT), Critically Endangered (CR), Extinct in the Wild (EW), and Extinct (EX) species were not found in the forest undergrowth assessment. However, those predominating species of plants that were found in this current study could still be given proper assessment, while those that are Endangered (EN) are to be given utmost priority in the entire forest ecosystem. The common dominant species are native species found on the IUCN (2021) red lists of Least Concern (LC) and Not Evaluated (NE). Previous studies revealed the majority of them as saplings of trees and shrubs with a high Importance Value Index (IVI) that had the highest number of occurrences in this forest (Omomoh et al., 2019; Onyekwelu et al., 2021). This implies that vegetation transition are driven by the Least Concern (LC) and Not

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

303 Evaluated (NE) species of the IUCN list assessment (Marsh et al., 2023; IUCN 2021). At first, we
304 expected a shift in species priority but rather found a loss of species specifically red-listed for
305 conservation. Onyekwelu et al., (2008) studies revealed a higher number of endangered species in
306 other regions of Southern Nigeria, and some of them were absent in this part of the forest, e.g.,
307 *Holoptelea grandis*, *Diospyros mespiliformis.*, *Lovoa trichilioides* etc. Seed distribution in the soil
308 seed bank and seedling recruitment in the aboveground vegetation rely on native factors for species
309 richness and abundance (Pragasan, 2023). However, in this current study, saplings have a higher
310 number of species despite the environmental complexity of the soil seed bank and aboveground
311 vegetation. The disparity between the regenerating undergrowth species and the soil seed banks
312 provides a solid assessment of the type of seed present in the current studies and provides
313 information about the management of the buffer zone that is present in the specific areas (Lopez-
314 Marino et al., 2000).

315 Table 1 of this study showed a general trend at which vegetation transitions are occurring and the
316 conservation measure implemented to combat anthropogenic activity. The species richness
317 revealed a hotspot of species diversity, while the soil depths, being one of the prevailing factors
318 affecting seedling outcome with the passage of time, were more favorable to the herbaceous cluster
319 in the buffer zone (Figure 4). Soil nutrient penetration by seeded species and its proximity to the
320 upper layer are the primary limitations facing seed propagule in most of the forest (Shackelford et
321 al., 2021). In this study, *Triplochiton scleroxylon* dominated the sapling layer, with a higher species
322 richness than most other sapling species examined. An indication of a stable and transitions forest
323 with little or no disturbance is when the species richness of the herbaceous understory becomes
324 relatively low. This observation concurred with Oroboade et al., (2023) and Zida et al., (2020)
325 studies that disturbance, canopy gaps, and open regions bring about herbaceous forest ecosystems.
326 Piotto et al., (2021) reported that a forest with average or more forest disturbance could impede
327 the recolonization potential of endemic species in regenerating forests. Generally, a regenerating
328 forest with a good yield of seedlings and saplings is an efficient producer of long-lived seeds
329 (Wodkiewicz & Kwiatkowska-Falinska, 2010). The vegetation transitions of the undergrowth
330 studies and seedling outcome in this study was considered higher compared to other studies in
331 Southwest Nigeria (Akinyemi et al., 2018; Onyekwelu et al., 2021). A nature-based approach to
332 forest disturbance is when seedling recruitment is given a holistic solution to scale up the
333 ecological balance or ecosystem stability. The choice of natural regeneration was prescribed by
334 Siminski et al., (2021). *Celtis zenkeri*, which was present in saplings and seedlings in this
335 investigation, was found to be well-represented at the adult stage (Rawat et al., 2018).
336 Additionally, *Discoglyprena caloneura*, Least Concern (LC), was also represented in this study's
337 saplings as well as at the adult stage (Omomoh et al., 2019). According to Butler et al., (1998),
338 factors including floristic composition, the phenology of the surrounding vegetation, and
339 disturbance at the forest boundary have an impact on the composition and quantity of soil seed
340 bank species as well as the dispersion of living things. However, when the mature trees failed to
341 regenerate at all in the sapling and seedling stages, as a result of being poorly represented at the
342 adult stage, they became seriously vulnerable to anthropogenic disturbance (Wani et al., 2022). In
343 this forest, where saplings of different tree species are removed for other purposes, we believe that
344 external forces of an anthropogenic nature is still dominating the undergrowth cover. Such patterns
345 were found in grazing-induced areas that significantly decrease and largely increase some
346 undergrowth cover of some herbs as reported in a certain study area (Coop et al., 2014). Shift in
347 habitat patterns in the sapling layer outweighed other life forms with canopy closeness, even
348 though key species encountering danger of extinction were not found (Dar & Parthasarathy, 2022).

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

349 On the contrary, Piotto et al., (2021) reported no connection in a forest where the canopy openness
350 of mature forest persists. Escudero et al., (2005) investigated the connection between above- and
351 below-ground species composition. His research found little overlap between soil seed banks and
352 vegetation types. However, Cuni-Sanchez et al., (2021) noted that seed rain from nearby places as
353 well as current and former above-ground vegetation affect a seed bank's composition, while Liu et
354 al., (2021) found a reflection of seed rain was evident in the above-ground plant community at
355 76% to 95%. The pioneering seeds of an herbaceous cluster that make up the soil seed bank at the
356 early stage of plant succession may be responsible for the failure of key species (Gayley & Sridith,
357 2020). When single species come in a clump of herbs, they frequently alter how tree-seeded species
358 respond to germination (Günter et al., 2007). Results showed that the profusion of herbs and their
359 seed mechanisms over tree-seeded species was due to successful seed dispersal (Bist & Shrestha,
360 2022) and their longer and finer roots over woody plants (Valverde-Barrantes et al., 2020).
361 Likewise, the herbaceous sampling of this study concurred with the agricultural weeds of Sri
362 Lankan semi-deciduous forests (Perera, 2005), and other factors were as a result of different land-
363 use types (Omomoh et al., 2020; Piana et al., 2019). For instance, in the three different forests
364 studied and evaluated by Baidya et al., (2021), only one forest, Bichikiri, had higher species
365 richness and recruitment, and this was due to the low human habitat living near the forest. On the
366 other hand, diverse drivers influence the vegetation transitions and regenerating potential of
367 undergrowth saplings and soil seed banks. Soil seed banks are mostly susceptible to the direct
368 attack of these drivers, which reduces their ability to enter the germination stage. Sommerville et
369 al., (2018), Meehan et al., (2002), and Alderotti & Verdiani, (2023) reported pests and diseases as
370 some of the reasons seed germination and regeneration were hindered in the regenerating forest.
371 The species's adaptation belowground determines how naturally seedling root branch systems are
372 selected to mycorrhizal partners for nitrogen uptake (Valverde-Barrantes et al., 2021). Moyano et
373 al., (2020) and Kothandaraman et al., (2022) reported the rooting system of some new species may
374 suppress key species and the seedling outcome. As a result, allelopathy inherent in certain plants
375 provide suitable habitat to deleteriously compete in the natural conditions (Akomolafe et al., 2024;
376 Omomoh et al., 2021). Annual weather changes affect soil seed, seed storage, and germination
377 rates with the passage of time (Julia Raquel et al., 2019). From the descriptive study (Table 7),
378 according to a study from Gangoo et al., (2017), the collection of non-timber forest products
379 (NTFPs) has increased by 60% in some parts of the world. This indicates that unsustainable
380 collection of wild species can constitute a serious threat to some tropical ecosystems if forest
381 resources are not managed effectively. A further contributing element is the low educational
382 attainment of forest residents that manifests as a lack of environmental awareness and a focus
383 solely on revenue generating (Thoker et al., 2024). However, some findings projected scientific
384 ways to mitigate the trends. Studies such as Crouzeilles et al., (2020) and Siminski et al., (2021)
385 presented natural regeneration as the most practiced and effective method in the ecosystem
386 restoration, meanwhile in a severe disturbance, natural succession take time in the recovery of tree
387 biodiversity (Shackelford et al., 2021; Van den Berg & Kellner, 2005). The introduction of assisted
388 regeneration (Siminski et al., 2021) in the re-establishment of big-seeded trees in a natural forest
389 where dispersal agents like animals are scarce should be considered when selecting seed-bearing
390 plants for biological conservation (Alderotti & Verdiani, 2023). Similarly, observation from the
391 descriptive studies showed that introduction and integration of local forest food in small spaces in
392 urban region to secure food among the urban dwellers can also be encourage among the rural
393 dwellers to discourage overexploitation of forest resources in the protected areas (Rockwell et al,
394 2022). However, plantation/enrichment planting can be regarded as an alternate technique to speed

1
2
3
4 395 recovery in cases where natural regeneration is unable to restore restoration (Omomoh et al., 2021;
5 396 Onyekwelu & Olabiwonnu, 2016, Reid et al., 2021, Wani et al., 2022). Specifically, Reid et al.,
6 397 (2021) reported that biological control has been improved by this action. However, this technique
7 398 has no direct replacement for natural forest ecosystem, because the non-timber forest products
8 399 (NTFPs), which are direct forest food resources and income generation for rural dwellers, will
9 400 gradually be lost (Ogunjobi et al., 2008).
10
11 401

12 402 **5. CONCLUSION**

13
14 403 Other managed ecosystems are increasingly becoming susceptible to climate change as a result of
15 404 the degradation of natural resources. Despite growing awareness of this decline, a large population,
16 405 according to Sharma et al., (2020), still depends on natural resources for living and income
17 406 generation. However, it is important to preserve current natural regenerating forests because the
18 407 loss of an ecosystem affects the lives of the creatures that directly depend on it. While there is a
19 408 growing need for forest resources for rural dwellers, there are concerns about the risk of losing the
20 409 regeneration potential of the next generation of trees. The present research specifically studies the
21 410 species distribution of undergrowth patterns and soil seed bank modes in this forest. It can be
22 411 deduced from the report that herbaceous plants generally dominate the soil seed banks in the three
23 412 soil depths. This study recognizes the influence of wild fruit collection as one of the factors
24 413 influencing the low seedling outcome in the soil seed bank and their poor representation of the
25 414 undergrowth pattern. Forest resources are widely used across the globe, and they are recognized
26 415 to have a significant impact on rural inhabitants' daily income and food security. The same forest
27 416 potentials on a regular basis also contributed to the regeneration potential of every forest
28 417 ecosystem. However, when it is consistently and indiscriminately removed, it can alter the species
29 418 composition of the forest. The species makeup of a community can be altered by human activities,
30 419 and this can change the functions provided by the community. The data from this research would
31 420 make it easier for conservation planning to evaluate the most underrepresented plants on the IUCN
32 421 list in this forest. Nevertheless, forest food domestication via home garden was recommended as
33 422 the solution for rural dwellers so as to reduce the stress and competition on most sources after
34 423 forest trees for income generation. The home garden therefore provides a bridge between the social
35 424 and the biological, linking cultivated spaces and natural ecosystems, combining and conserving
36 425 species diversity and cultural diversity. When most of the non-timber forest products (NTFP's) are
37 426 domesticated in the form of home gardens this will definitely reduce the pressure on natural
38 427 resources. It is critical to understand that natural forest restoration is a dependable strategy for
39 428 safeguarding the regenerating forest under its natural environment. Growth from seed plants to
40 429 herbaceous plants indicates vegetation changes that face natural regeneration. However, further
41 430 research is necessary to determine the potential importance of soil seed bank availability in
42 431 predicting future forest regeneration constraints.
43
44
45
46
47
48
49
50
51
52

53 432 **6. ACKNOWLEDGMENTS**

54
55
56 433 Our appreciation goes to IDEAWILD's awards of small grants (ID: OMOMNIGE0722). Their
57 434 support and donation assisted this project in data gathering.
58
59

60 435 **CONFLICT OF INTEREST**

1
2
3
4 436 The authors have no conflicts of interest to declare. All co-authors have seen and agree with the
5 437 contents of the manuscript. We certify that the submission is original work and is not under review
6
7 438 at any other publication.
8

9 439 DATA AVAILABILITY STATEMENT

10
11 440 The data that supports the findings of this study is available in the supplementary material of this
12 441 article
13

14 15 442 REFERENCES

- 16
17 443 Abdella, M., Tamrat, B., & Sileshi, N. (2007). Soil seed bank analysis and site description of the
18 444 Afro-alpine vegetation of Bale Mountains, Ethiopia. *Acad. Sci. Publ.* 19: 279-387.
19 445 African Plant Database (version 4.0.0). Conservatoire et Jardin botaniques de la Ville de Genève
20 446 and South African National Biodiversity Institute, Pretoria, "Retrieved [set month and
21 447 year]", <http://africanplantdatabase.ch>
22 448 Akinyemi, D. S., & Oke, S. O. (2013). Soil Seed bank Dynamics and Regeneration in three
23 449 different physiognomies in Shasha Forest reserve in Southwestern, Nigeria. *Ife J. Sci.*,
24 450 15:2-11. DOI: https://scholar.oauife.edu.ng/ijs/files/akinyemi_and_oke_16.pdf
25 451 Akinyemi, D. S., Oseni, S. R., & Oke, S. O. (2018) Effect of heat on soil seedbank of three
26 452 contrasting physiognomies in Shasha forest reserve, Southwestern Nigeria. *Acta*
27 453 *Oecologica*. <https://doi.org/10.1016/j.actao.2018.03.00>
28 454 Akobundu, I. O., & Agyakwa, C. W. (1998). A handbook of West African weeds (p. 565).
29 455 International Institute of Tropical Agriculture
30 456 Akomolafe G. F., Rosazlina R., & Omomoh. B. (2024). Soil seed bank dynamics of two invasive
31 457 alien plants in Nigeria: implications for ecosystem restoration. *AoB PLANTS*, 16, 1–9
32 458 <https://doi.org/10.1093/aobpla/plae003>
33 459 Alderotti, F. & Verdiani, E. (2023). God Save the Queen! How and why the dominant evergreen
34 460 species of the Mediterranean Basin is declining? *AoB PLANTS*, 15, 1-14.
35 461 <https://doi.org/10.1093/aobpla/plad051>
36 462 Baidya, S., Thakur, B., & Devi, A. (2021). The influence of tree population structure on
37 463 regeneration potential in the sacred forests of Assam, India. *Tropical Ecology*
38 464 <https://doi.org/10.1007/s42965-021-00208-8>
39 465 Bist, M. R., & Shrestha, B. B (2022). Weed community structure in upland farming system of
40 466 the middle mountain region in far-western Nepal, *Acta Oecologica Sinica xxx (xxxx) xxx*
41 467 <https://doi.org/10.1016/j.chnaes.2022.05.002>
42 468 Boonman, C. C. F., Serra-Diaz, J. M., Hoeks, S., Guo. W., Enquist, B. J., Maitner, B., Malhi, Y.,
43 469 Merow, C., Buitenwerf, R., & Svenning, J. (2024). More Than 17,000 Tree Species are at
44 470 Risk from Rapid Global Change. *Nature Communications* (2024) 15:166.
45 471 <https://doi.org/10.1038/s41467-023-44321-9>
46 472 Butler, B. J., & Chazdon, R. L. (1998). Species richness, spatial variation and abundance of the
47 473 soil seed bank of a secondary tropical rainforest. *Biotropica*, 30: 214-222.
48 474 <http://www.jstor.org/stable/2389164>.
49 475 Chaideftou, E., Thanos, C. A., Bergmeier, E., Kallimanis, A. S., & Dimopoulo, P. (2011). The
50 476 herb layer restoration potential of the soil seed bank in an overgrazed oak forest. *Journal*
51 477 *of Biological Research-Thessaloniki* 15: 47 – 57.
52 478 Chao, A., Gotelli, N. J., Hsieh, T. C., Sander, E. L., Ma, K. H., Colwell. R. K., & Ellison, A. M.

- 1
2
3
4 479 (2014). Rarefaction and extrapolation with Hill numbers: a framework for sampling and
5 480 estimation in species diversity studies. *Ecological Monographs*, 84, 45-67.
- 6
7 481 Chao, A., Ma, K. H., & Hsieh, T. C. (2016). iNEXT (iNterpolation and EXTrapolation) Online:
8 482 Software for Interpolation and Extrapolation of Species Diversity. Program and User's
9 483 Guide published at [http://chao.stat.nthu.edu.tw/wordpress/software_download/inext-](http://chao.stat.nthu.edu.tw/wordpress/software_download/inext-online/)
10 484 [online/](http://chao.stat.nthu.edu.tw/wordpress/software_download/inext-online/).
- 11
12 485 Chazdon, R. L., Lindenmayer, D., Guariguata, M. R., Crouzeilles, R., Rey Benayas, J. M., &
13 486 Lazos Chavero, E. (2020). Fostering natural forest regeneration on former agricultural
14 487 land through economic and policy interventions. *Environ. Res. Lett.* 15:ab79e6. doi:
15 488 10.1088/1748-9326/ab79e6
- 16
17 489 Chima, U. D., & Kamalu, O. J. (2016). Plant species diversity and abundance in soil seed banks
18 490 of natural forest and monoculture plantations in Omo Biosphere Reserve, *Nigeria*.
19 491 *Nigerian Journal of Agriculture, Food and Environment*. 12(4):73-81
- 20
21 492 Crouzeilles, R., Beyer, H. L., Monteiro, L. M., Feltran-Barbieri, R., Pessôa, A. C. M., Barros, F.
22 493 S. M., et al. (2020). Achieving cost-effective landscape-scale forest restoration through
23 494 targeted natural regeneration. *Conserv. Lett.* 13:e12709. [https://doi: 10.1111/conl.12709](https://doi.org/10.1111/conl.12709)
- 24
25 495 Coop J. O., Barker, K. J., Knight., A. D., & Pecharich, J. S (2014). Aspen (*Populus tremuloides*)
26 496 stand dynamics and understory plant community changes over 46 years near Crested Butte,
27 497 Colorado, USA *Forest Ecology and Management* 318: 1-12
28 498 <http://dx.doi.org/10.1016/j.foreco.2014.01.0>
- 29
30 499 Cuni-Sanchez, A., et al. (2021). High aboveground carbon stock of African tropical montane f
31 500 orests. *Nature*. Vol 596, pp 536-557. <https://doi.org/10.1038/s41586-021-03728-4>
- 32
33 501 Dar, A. A., & Parthasarathy, N. (2022). Understory diversity and floristic differentiation of
34 502 Kashmir Himalayan coniferous forests: implications for conservation. *Tropical Ecology*
35 503 <https://doi.org/10.1007/s42965-022-00252-y>
- 36
37 504 DeClerck, F. (2013). Harnessing Biodiversity from diets to landscape: Diversifying food and
38 505 diets: using agricultural biodiversity to improve nutrient and health (ed. Jessica Fanzo,
39 506 Danny Hunter, Teresa Borelli, and Federica Mattei) First edition, Pp. 22-23
- 40
41 507 Decocq, G., Bertille, V., Toussaint, B., Hendoux, F., Saguez, R., & Bardat, J. (2004). Soil seed
42 508 bank composition and diversity in a managed temperate deciduous forest. *Biodiversity*
43 509 *and Conservation* 13: 2485-2509.
- 44
45 510 Doroski, D. A., Duguid, M. C., & Ashton, M. S. (2020). Forest patch size predicts seed bank
46 511 composition in urban areas. *Appl Veg Sci*. 00: 1–13. doi: 10.1111/avsc.12534
- 47
48 512 Douh, C., Daïnou K., Joël Loumeto J., Moutsambote J. M., Fayolle A., Tosso F., Forni E.,
49 513 Gourlet Fleury S., & Doucet J. L (2018). Soil seed bank characteristics in two central
50 514 African forest types and implications for forest restoration. *Forest Ecology and*
51 515 *Management* 409: 766-776. - doi: 10.1016/j.foreco.2017.12.012
- 52
53 516 Esaete, J., Bongo, A., Lado, T., Bojoi, T., & Busulwa, H. (2021). Natural vegetation regeneration
54 517 from soil seed banks in the cultivated edges of Sudd wetlands in Juba, Southern Sudan.
55 518 *East African Journal of Science, Technology and Innovation*, Vol. 2 (2)
- 56
57 519 Escudero, A., Olano, J. M., & Loidi, J. (2005) Regenerative role of seed banks following
58 520 an intense soil disturbance. *Acta Oecologica* 27: 57–66
- 59
60 521 FAO. (2010). The second report on the state of the world's plant genetic resources for food and
61 522 agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy.
62 523 DOI: <https://doi.org/10.1017/S0014479711000275>
- 63
64 524 Fenner, M. (1985). Seed Ecology. Chapman and Hall, London, England.
- 65

- 1
2
3
4 525 Garwood, N. C. 1989. Tropical soil seed banks: a review. In: Leck, M., Parker, V. &
5 526 Simpson, R. (eds.) *Ecology of Soil Seed Banks*, pp. 149-209. Academic Press, San Diego,
6 CA.
7 527
- 8 528 Gangoo, S. A., Islam, M. A., & Tahir, M. (2017). Wealth of non-timber forest products and their
9 529 trade in Jammu and Kashmir. *The Indian Forester*, 143(9), 737–744.
10 530
- 11 531 Gayley, K., & Sridith, K. (2020). The vegetation status of regrowth forests in abandoned
12 532 farmlands in the subtropical forest of Eastern Bhutan Himalaya. *Taiwania* 65(3): 336–
13 533 347, 2020 DOI: 10.6165/tai.2020.65.336
14 533
- 15 534 Golos, J. P, Dixon, W. K., & Erickson, E.T. (2016). Plant recruitment from the soil seed bank
16 535 depends on topsoil stockpile age, height, and storage history in an arid environment.
17 *Restoration Ecology*, 24(2): 53–61 DOI: <https://doi.org/10.1111/rec.12389>.
18 536
- 19 537 Günter, S., Weber, M., Erreis, R., & Aguirre, N. (2007). Influence of distance to forest edges on
20 538 natural regeneration of abandoned pastures: a case study in the tropical mountain rain
21 539 forest of Southern Ecuador, *Eur J Forest Res*, 126: 67–75. DOI 10.1007/s10342-006-
22 0156-0
- 23 540 Huang, L., Zhang, Z., Wang, Q., Yang, G., Que, Q., & Liu, X. (2022). Impact of landscape
24 541 patterns on herb-layer diversity and seed size of *Schima superba* in urban remnant
25 542 vegetation: A case study in Guangzhou, Southern China. *Tropical Ecology*
26 543 <https://doi.org/10.1007/s42965-022-00255-9>
27 544
- 28 544 Hector, A. & Bagchi, R. (2007) Biodiversity and ecosystem multifunctionality, *Nation*, vol. 448,
29 545 no. 7157, pp. 791-793
- 30 546 Hutchinson, J., & Dalziel, J. (1958). Flora of West Tropical Africa (Vol. 1, 2nd ed., p. 828).
31 547 Crown Agents for Overseas Government and Administrations.
32 548
- 33 549 Hutchinson, J., & Dalziel, J. (1963). Flora of West Tropical Africa (Vol. II, 2nd ed., p. 544).
34 549 Crown Agents for Overseas Government and Administrations.
- 35 550 Hutchinson, J. & Dalziel, J. (1968). Flora of West Tropical Africa. Vol III. Part 1. Crown Agents
36 551 for Overseas Government and Administrations
- 37 552 Julia Raquel, S. A., Manguera Karen, R., Holl Ricardo., & Rodrigues. (2019). Enrichment
38 553 planting to restore degraded tropical forest fragments in Brazil, *Ecosystems and People*,
39 554 15:1, 3-10. <https://doi.org/10.1080/21513732.2018.1529707>
40 554
- 41 555 IUCN (2021). The IUCN Red List of Threatened Species. Version 2021-1.
42 556 URL:<https://www.iucnredlist.org>. Downloaded on [july 10 2021
43 557
- 44 557 Kalamees, R., & Zobel, M. (2002). The role of seed bank in gap regeneration in a calcareous
45 558 grassland community. *Ecology*, 83 (4): 1017–1025.
- 46 559 Kalesnik, F., Sirolli, H., & Collantes., M. (2013). Seed bank composition in a secondary forest in
47 560 the Lower Delta of the Paraná River (Argentina). *Acta Botanica Brasilica* 27(1): 40-49.
- 48 561 Keatinge, J. D. H., Waliyar, F., Jannadass, R. H., Moustafa, A., Andrade, M., Drechsel, P.,
49 562 Hughes, J. A., Kadirvel. P., & Luther. K. (2010). Relearning old lessons for the future of
50 563 food – by bread alone no longer: Diversifying diets with fruit and vegetables, *Crop*
51 564 *Science*, vol 50.pp S51-S62
- 52 564
- 53 565 Kehlenback., K., Asaah, E, & Jannadass, R. (2013). Diversity of Indigenous fruit trees and their
54 566 contribution to nutrition and livelihoods in sub-Saharan Africa, examples from Kenya and
55 567 Cameron: Diversifying food and diets: using agricultural biodiversity to improve nutrient
56 567 and health/ edited by Jessica Fanzo, Danny Hunter, Teresa Borelli, and Federica Mattei-
57 568 First edition Page 257-268
58 569
- 59 570 Kothandaraman, S., Dar, J. A., Bhat, N. A., Sundarapandian, S., & Khan, M. L. (2022). Tree
60
61
62
63
64
65

- 1
2
3
4 571 Plantation: A Silver Bullet to Achieve Carbon Neutrality? Page 205-228. Land
5 572 Degradation Neutrality: Achieving SDG 15 by Forest Management.
6 <https://doi.org/10.1007/978-981-19-5478-8>
7 573
- 8 574 Liu, B., Liu, Q., Zhu, C., Liu, Z., Huang, Z., Tigabu, M., He, Z., Liu, Y., & Wang, Z. (2021).
9 575 Seed rain and soil seed bank in Chinese fir plantations and an adjacent natural forest in
10 576 southern China: Implications for the regeneration of native species. *Ecology and*
11 577 *Evolution*. 2022;12:e8539. <https://doi.org/10.1002/ece3.8539>
12 578
- 13 578 Lôbo, D., Leão T., Melo., F. P. L, et al. (2011). Forest fragmentation drives Atlantic forest of
14 579 Northeastern Brazil to biotic homogenization. *Divers Distrib* 17:287–296
15 580
- 16 580 Lopez-Marino, A., Luis-Calabuig. E., Fillat, F., & Bermudez, F. (2000). Floristic composition of
17 581 vegetation and the soil seed bank in pasture communities under different traditional
18 582 management regimes. *Agr. Ecosyst. Environ.*, 78: 273-282.
19 583
- 20 583 Madawala, H. M. S. P., Ekanayake., S. K., & Perera., G. A. D. (2016). Diversity, composition
21 584 and richness of soil seed banks in different forest communities at Dotalugala Sri Lanka.
22 585 *Ceylon Journal of Science* 45(1) 2016: 43-55
23 586 DOI: <http://dx.doi.org/10.4038/cjs.v45i1.7363>
24 587
- 25 587 Marsh, C. J., Syfert, M. M., Aletrari, E., Gavish, Y., Kunin, W. E., & Brummitt, N. (2023). The
26 588 effect of sampling effort and methodology on range size estimates of poorly-recorded
27 589 species for IUCN Red List assessments. *Biodiversity and Conservation*.
28 590 <https://doi.org/10.1007/s10531-023-02543-9>
29 591
- 30 591 Martínez-Ramos, M., Ortiz-Rodríguez, I., Piñero, D., Dirzo, R., & Sarukhán, J. (2016).
31 592 Anthropogenic disturbances jeopardize biodiversity conservation within tropical
32 593 rainforest reserves. *Curr. Issues*, 113 (19): 5323-5328.
33 594 DOI: www.pnas.org/cgi/doi/10.1073/pnas.1602893113
34 595
- 35 595 Mashiane, K. K., Ramoelo, A., Adelabu, S., & Daemane, E. (2023). Estimating mountainous
36 596 plant species richness and diversity for monitoring global change in a protected
37 597 grassland park. *African Journal of Ecology*.00:1–9.
38 598
- 39 598 Means, D. B. (2006). Vertebrate faunal diversity of longleaf pine ecosystems. Pp. 157-213 in S.
40 600 Jose, E.J. Jokela, and D.L. Miller, eds., *The Longleaf Pine Ecosystem: Ecology, Silviculture and Restoration*. Springer, New York
41 601
- 42 601 Meehan, H. J., McConkey, K. R., & Drake, D. R. (2002). Potential disruptions to seed dispersal
43 602 mutualism in Tonga, Western Polynesia. *Journal of Biogeography*. 29: 695–712.
44 603 doi:10.1046/j.13652699.2002.00718.x
45 604
- 46 604 Moyano, J. M., Rodriguez-Cabal, A., & Nunez, M. A. (2020). Highly invasive tree species
47 605 are more dependent on mutualisms. *Ecology* 00(00): e02997. 10.1002/ecy.2997
48 606
- 49 606 Odeleye, A. A., Akinyemi, D. S., Olatunji, O. A., Komolafe, E. T., & Oke, S. O. (2018). Seed
50 607 bank dynamics and restoration of Ibodi monkey forest reserve, Southwestern
51 608 Nigeria. *Int. J. Biol. Chem. Sci.* 12(6): 2830-2845, December 2018 ISSN 1997-342X
52 609 (Online), ISSN 1991-8631 (Print).
53 610 <http://ajol.info/index.php/ijbcs> <http://indexmedicus.afro.who.int>
54 611
- 55 611 Ogunjobi, K. M., Adetogun, A. C., & Omole, A. O. (2008). Biodiversity indicators: Tool for
56 612 Sustainable forest Management. In: *Research for Development In Forestry, Forest*
57 613 *Products and Natural Resources Management* (ed. Onyekwelu, J. C., Adekunle, V. A .J.,
58 615 & Oke. D. O.) *Proceeding of the first National Conference of the Forests and Forest*
59 616 *Products Society, Federal University of Technology, Akure, Nigeria. 16th -18th April,*
60
61
62
63
64
65

- 1
2
3
4 617 Oke, S. O., Ayanwale, T. O., & Isola., O. A. (2007). Soil seedbank in four contrasting
5 618 plantations in Ile-Ife area of Southwestern Nigeria. *Res. J. Bot.*, 2: 13-22.
- 6 619 Ola-Adams, B. A. (1978). Conservation of genetic resources of indigenous forest tree species in
7 620 Nigeria: possibilities and limitations Forest Genetic Resources Information, no. 7. FAO,
8 621 Rome
- 9 622 Olatunji, O. A., Oke, S. O., Isola, E. F., Akinyemi, D. S., & Omodara, A. A. (2015).
10 623 Relationship between the Standing Vegetation, Soil Properties and Soil Seed bank of an
11 624 industrially degraded Vegetation of Iron Smelting Factory. *Int. J. Biol. Chem. Sci.*, 9(2):
12 625 614-632. DOI: <http://dx.doi.org/10.4314/ijbcs.v9i2.4>
- 13 626 Omomoh, B. E., Akomolafe, F. G., & Brown, S. L. (2021). A 17-year successional enrichment
14 627 plantation of tree recruitment and restoration in a tropical rainforest forest. *Vegetos*.
15 628 <https://doi.org/10.1007/s42535-021-00255-5>
- 16 629 Omomoh, B.E., Brown, L., Meijer, K., Adekunle, V.A.J., & Oboh, G. (2021). Ecological studies
17 630 on introduction of alien species (*Clerodendrum paniculatum* Linn) in forest plantation
18 631 and nature reserve forest of tropical Africa, Nigeria. *Vegetos*.
19 632 <https://doi.org/10.1007/s42535-021-00313-y>
- 20 633 Omomoh, B. E., Adekunle., V. A. J., Aigbe, P. D., Ademoh, F. O., & Omomoh, B.
21 634 M. (2020). Evaluation of soil seed bank-vegetation and regeneration potential of *Tectona*
22 635 *grandis* L. f. plantation (Taungya farm) in Akure forest reserve, Ondo State, Nigeria.
23 636 *Tropical Plant Research* 7(1): 37–45. DOI: 10.22271/tpr.2020.v7.i1.006
- 24 637 Omomoh, B. E., Adekunle, V., Lawal, A., & Akinbi, O. (2019) Tree species diversity and
25 638 regeneration potential of soil seed bank in Akure forest reserve, Ondo state, Nigeria.
26 639 *Taiwania* 64(4): 409-416, doi: 10.6165/tai.2019.64.409
- 27 640 Onyekwelu, J.C., Mosandl, R., & Stimm, R. (2008) Tree Species Diversity and Soil
28 641 Status of Primary and Degraded Tropical Rainforest Ecosystems in South-Western
29 642 Nigeria. *Journal of Tropical Forest Science* 20(3): 193–204.
- 30 643 Onyekwelu J. C and Olabiwonnu A. A (2016). Can forest plantations harbour biodiversity similar
31 644 to natural forest ecosystems over time? *International Journal Of Biodiversity Science,*
32 645 *Ecosystem Services & Management*, 2016 Vol. 12, Nos. 1–2, 108–115
33 646 <http://dx.doi.org/10.1080/21513732.2016.1162199>
- 34 647 Onyekwelu, J. C., Lawal, A., Mosandl, R., Stimm, B., & Agbelade, A. D. (2021)
35 648 Understory species diversity, regeneration and recruitment potential of sacred
36 649 groves in south west Nigeria. *Tropical Ecology* [https://doi.org/10.1007/s42965-021-](https://doi.org/10.1007/s42965-021-00157-2)
37 650 00157-2
- 38 651 Oroboade, J., Awotoye, O., Jegede, M., & Olusola, J. (2023). Land use effects on plant
39 652 nvasion, plant communities and soil properties in Southwestern Nigeria. *Acta Ecologica*
40 653 *Sinica*, <https://doi.org/10.1016/j.chnaes.2022.12.005>
- 41 654 Padonou. E. A, Akakpo, B. A, Tchigossou., B, & Djossa B (2022). Methods of soil seed
42 655 bank estimation: a literature review proposing further work in Africa. *iForest* 15: 121-
43 656 127. doi: 10.3832/ifor3850-015
- 44 657 Pain A, Marquardt K, Lindh A and Hasselquist N. J (2021) What Is Secondary about
45 658 Secondary Tropical Forest? Rethinking Forest Landscapes. *Human Ecology* 49:239–
46 659 247 <https://doi.org/10.1007/s10745-020-00203-y>
- 47 660 Piotto D., Luiz, Magnago, L. F. S., Montagnini, F, Ashton, M. S., Oliver, C., & Thomas,
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

- 1
2
3
4 661 W. W. (2021). Nearby mature forest distance and regenerating forest age influence tree
5 662 species composition in the Atlantic forest of Southern Bahia, Brazi. *Biodiversity and*
6 663 *Conservation*. <https://doi.org/10.1007/s10531-021-02192-w>
- 8 664 Pragasas, L. A. (2023) Seed dispersal modes of tree species and their relation with altitudinal
9 665 gradient from tropical forests of Eastern Ghats, India. *Acta Ecologica Sinica* 43 (2023)
10 666 106–111. <https://doi.org/10.1016/j.chnaes.2021.10.006>
- 12 667 Price, J. N., Wright, B. R., Gross, C. L & Whalley, R. D. B. (2010). Comparison of seedling
13 668 emergence and seed extraction techniques for estimating the composition of soil seed
14 669 banks. *Methods in Ecology and Evolution* 1:151-157.
- 15 670 Perera, G. A. D. (2005) Diversity and dynamics of the soil seed bank in tropical semi-deciduous
16 671 forests of Sri Lanka. *Tropical Ecology* 46(1): 65-78.
- 18 672 Piana, M. R., Aronson, M. F. J., Pickett, S. T. A., & Handel, S. N. (2019). Plants in the city:
19 673 understanding recruitment dynamics in urban landscapes. *Front Ecol Environ*.
20 674 doi:10.1002/fee.2098
- 21 675 Rawat, D. S., Dash, S. S., Sinha, B. K., Kumar, V., Banerjee, A., & Singh, P. (2018) Community
22 676 structure and regeneration status of tree species in Eastern Himalaya: A case study from
23 677 Neora Valley National Park, West Bengal, India. *Taiwania* 63(1): 16-24,
24 678 DOI: 10.6165/tai.2018.63.16
- 26 679 Reid, J. L, Zahawi, R. A., Zarrate-Chary, D. A., Rosales, J. A., Holl, K. D., & Kormann,
27 680 U. (2021). Multi-scale habitat selection of key frugivores predicts large-seeded tree
28 681 recruitment in tropical forest restoration Multi-scale habitat selection of key frugivores
29 682 predicts large-seeded tree recruitment in tropical forest restoration, *Ecosphere* 12(12):
30 683 e03868. [10.1002/ecs2.3868](https://doi.org/10.1002/ecs2.3868)
- 32 684 Rockwell, C. A., Crow, A., Guimarães, E. A., Recinos, E., & La Belle, D. (2022). Species
33 685 Richness, Stem Density, and Canopy in Food Forests: Contributions to Ecosystem
34 686 Services in an Urban Environment. *Urban Planning*. Volume 7, Issue 2, Pages 139–154
35 687 <https://doi.org/10.17645/up.v7i2.5135>
- 37 688 Safar N. V. H, Magnago L. F. S, and Schaefer C. E. G. R (2020) Resilience of lowland Atlantic
38 689 forests in a highly fragmented landscape: insights on the temporal scale of landscape
39 690 restoration. *For Ecol Manage* 470–471:118183
- 41 691 Savadogo P., Sanou L, Dayamba., S. D., Bognounou F., & Thiombiano, A. (2017). Relationships
42 692 between soil seed banks and above-ground vegetation along a disturbance gradient in the
43 693 W National Park trans-boundary biosphere reserve, *West Africa*. *Journal of Plant*
44 694 *Ecology* 10 (2): 349-363. - doi: 10.1093/jpe/rtw025
- 46 695 Shackelford, N., Paterno, G. B., Winkler, D. E., et al., (2021). Drivers of seedling establishment
47 696 success in dryland restoration efforts. *Nature Ecology & Evolution*
48 697 <https://doi.org/10.1038/s41559-021-01510-3>
- 49 698 Sharma, P., Thapa, R. B., & Matin, M, A, (2020). Examining forest cover change
50 699 and deforestation drivers in Taunggyi District, Shan State, Myanmar. *Environment,*
51 700 *Development and Sustainability* (2020) 22:5521–5538 [https://doi.org/10.1007/s10668-](https://doi.org/10.1007/s10668-019-00436-y)
52 701 [019-00436-y](https://doi.org/10.1007/s10668-019-00436-y)
- 54 702 Siminski, A., Zambiasi, D. C., dos Santos, K. L., & Fantini, A. C. (2021) Dynamics of Natural
55 703 Regeneration: Implications for Landscape Restoration in the Atlantic Forest, Brazil.
56 704 *Front. For. Glob. Change* 4:576908. doi: 10.3389/ffgc.2021.576908
- 58 705 Sommerville, K. D., Clarke, B. B., Keppel, G., McGill, C., Newby, Z., Wyse, S.V., James, S.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

A., & Offord, C. A. (2018). Saving rainforests in the South Pacific: challenges in ex situ conservation. *Australian Journal of Botany Review*. <https://doi.org/10.1071/BT17096>

708 Thoker, I. A., Bhat, M. S., Shah, S. A., Lone, F. A., Mir, S., Parrey, H. A., & Akbar, M. (2024).
709 Towards sustainable forest management: an examination of environmental knowledge
710 among forest dwellers in the Kashmir Himalayas. *Environment, Development and*
711 *Sustainability*. <https://doi.org/10.1007/s10668-024-04823-y>

712 Thompson, K. (1992). The functional ecology of seed banks. *In* M. Fenner (Ed.). *Seeds: the*
713 *ecology of regeneration in plant communities*. C. A. B. International, United Kingdom.

714 Thompson, K., & Grime, J. P. (1979) Seasonal variation in the seed banks of herbaceous
715 species in ten contrasting habitats. *The Journal of Ecology*. Vol. 67(3): 893-921.

716 Valverde-Barrantes O. J., Authier L., Schimann H., & Baraloto C. (2021). Root anatomy helps
717 to reconcile observed root trait syndromes in tropical tree species. *American Journal of*
718 *Botany* 108(5): 1–12. doi:10.1002/ajb2.1659

719 Valverde-Barrantes, O. J., H. Maherali, C. Baraloto, and C. B. Blackwood. 2020. Independent
720 evolutionary changes in fine-root traits among main clades during the diversification of
721 seed plants. *New Phytologist* 228: 541–553.

722 Van Lear, D. H., Carroll, W., Kapeluck, P., & Johnson. R. (2005). History and restoration of the
723 longleaf pine-grassland ecosystem: Implications for species at risk. *Forest Ecology and*
724 *Management*. 211:150-165

725 Wani, Z. A., Akash., & Pant, S. (2022). Tree diversity and regeneration dynamics in Gulmarg
726 Wildlife Sanctuary, Kashmir Himalaya, *Acta Ecologica Sinica*,
727 <https://doi.org/10.1016/j.chnaes.2022.05.003>

728 Weinberger, K., & Lumpkin, T. A. (2005). Horticulture for poverty alleviation – the unfunded
729 revolution. Working paper No. 5. AVRDC (The World Vegetation Center). Shanhua
730 Taiwan

731 Wodkiewicz, M., & Kwiatkowska-Falinska, A. J. (2010). Similarity between seed bank and herb
732 layer in a natural deciduous temperate lowland forest. *Acta Societatis Botanicorum*
733 *Poloniae*. Vol 9, no 2: 157-166

734 Zida, D., Sanou, L., Diawaraa, S., Savadogoc, P., & Thiombianob, A. (2020). Herbaceous
735 seeds dominate the soil seed bank after long-term prescribed fire, grazing and selective
736 tree cutting in savanna-woodlands of West Africa. *Acta Oecologica* 108 (2020) 103607
737 <https://doi.org/10.1016/j.actao.2020.103607>

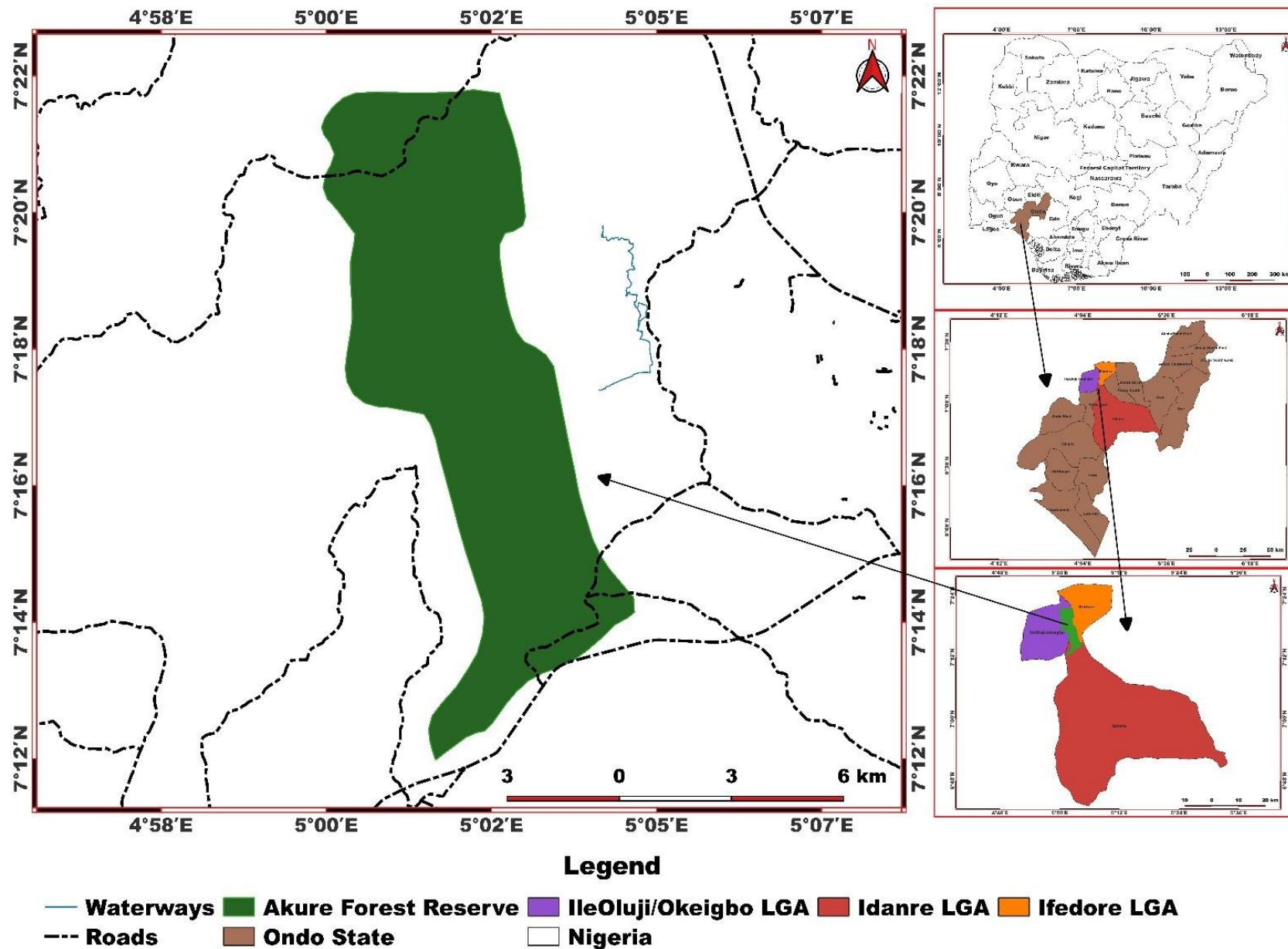


Figure 1 showing the map of the study area

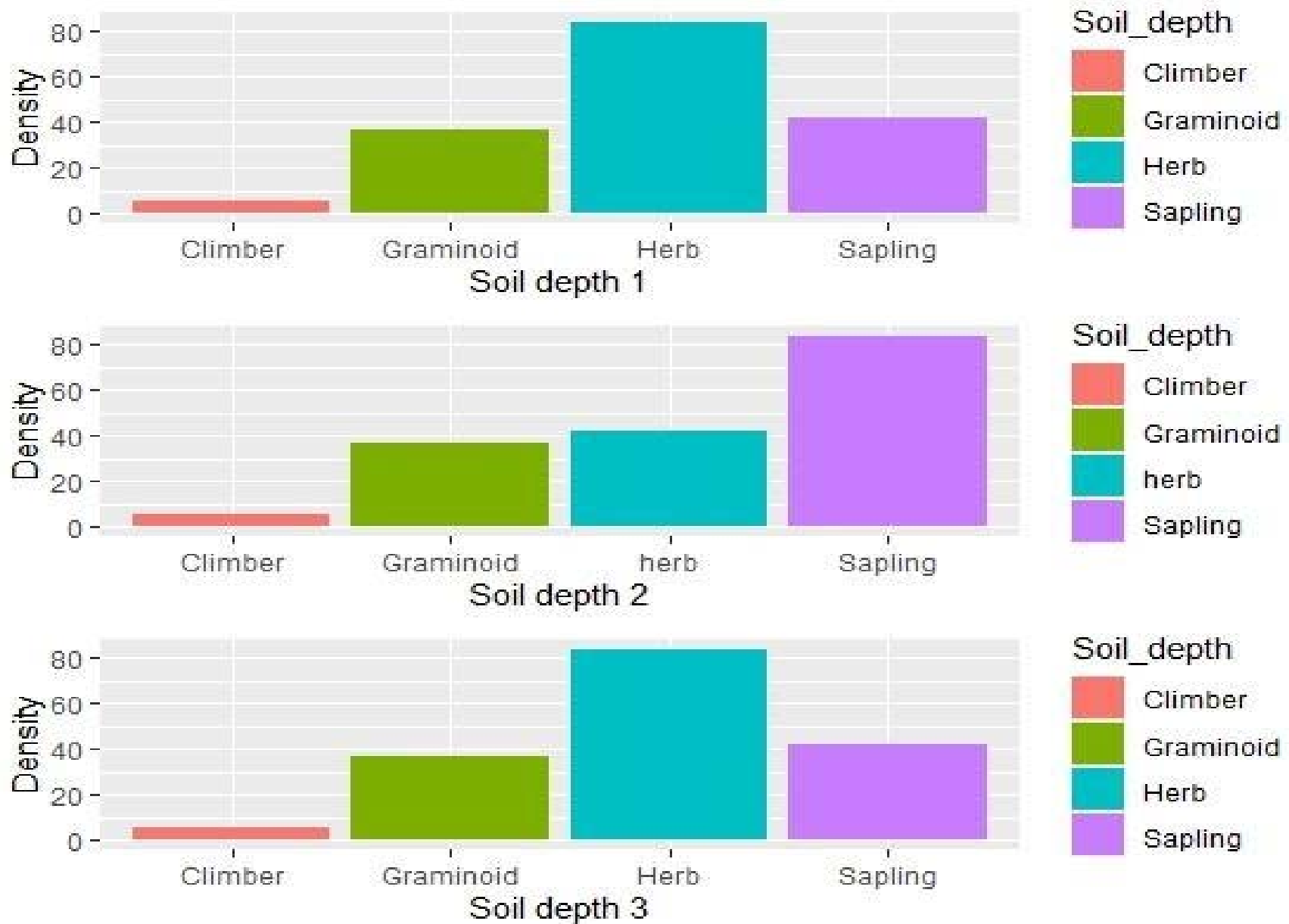


Figure 2: Comparative studies of species composition of the three soil depths

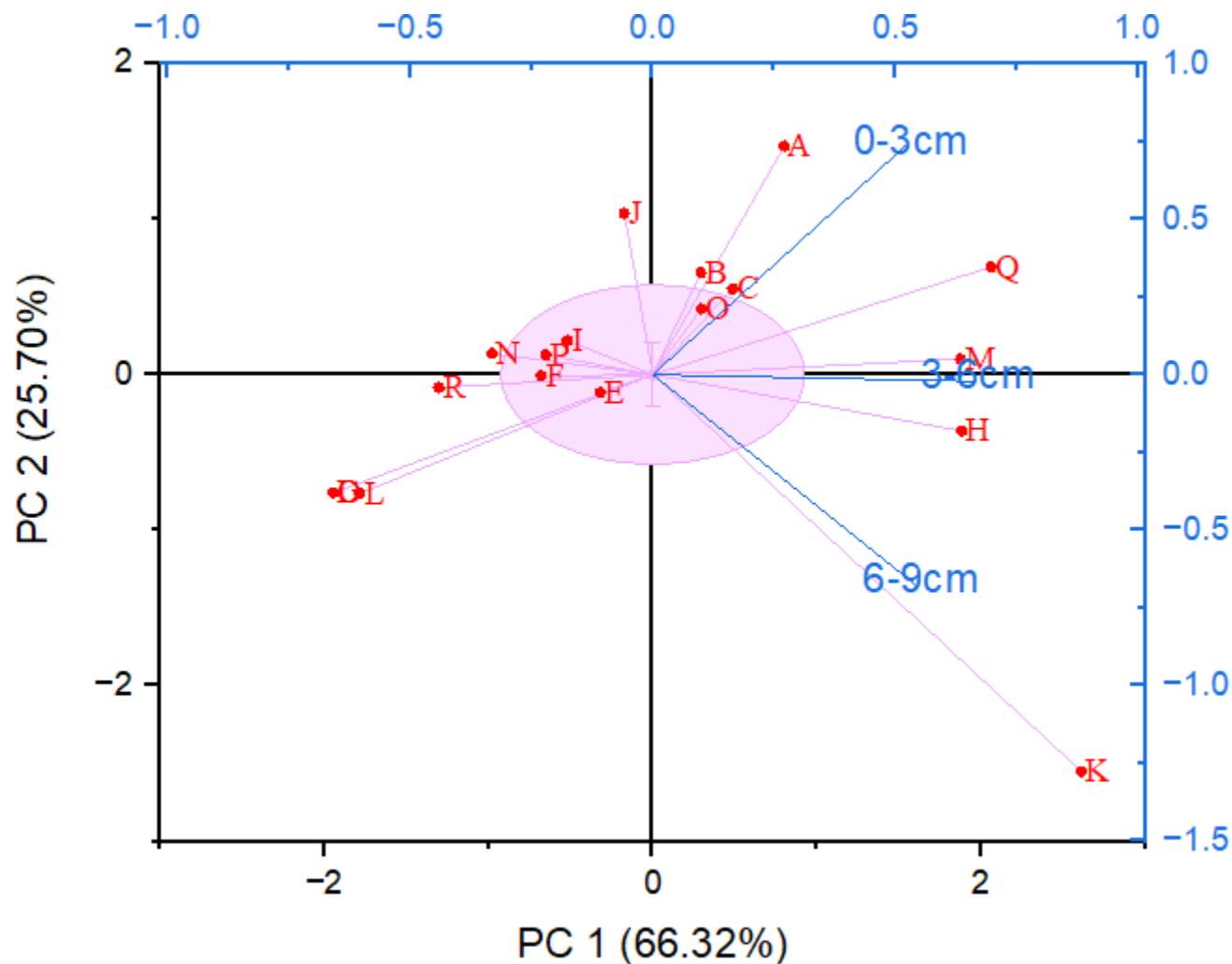
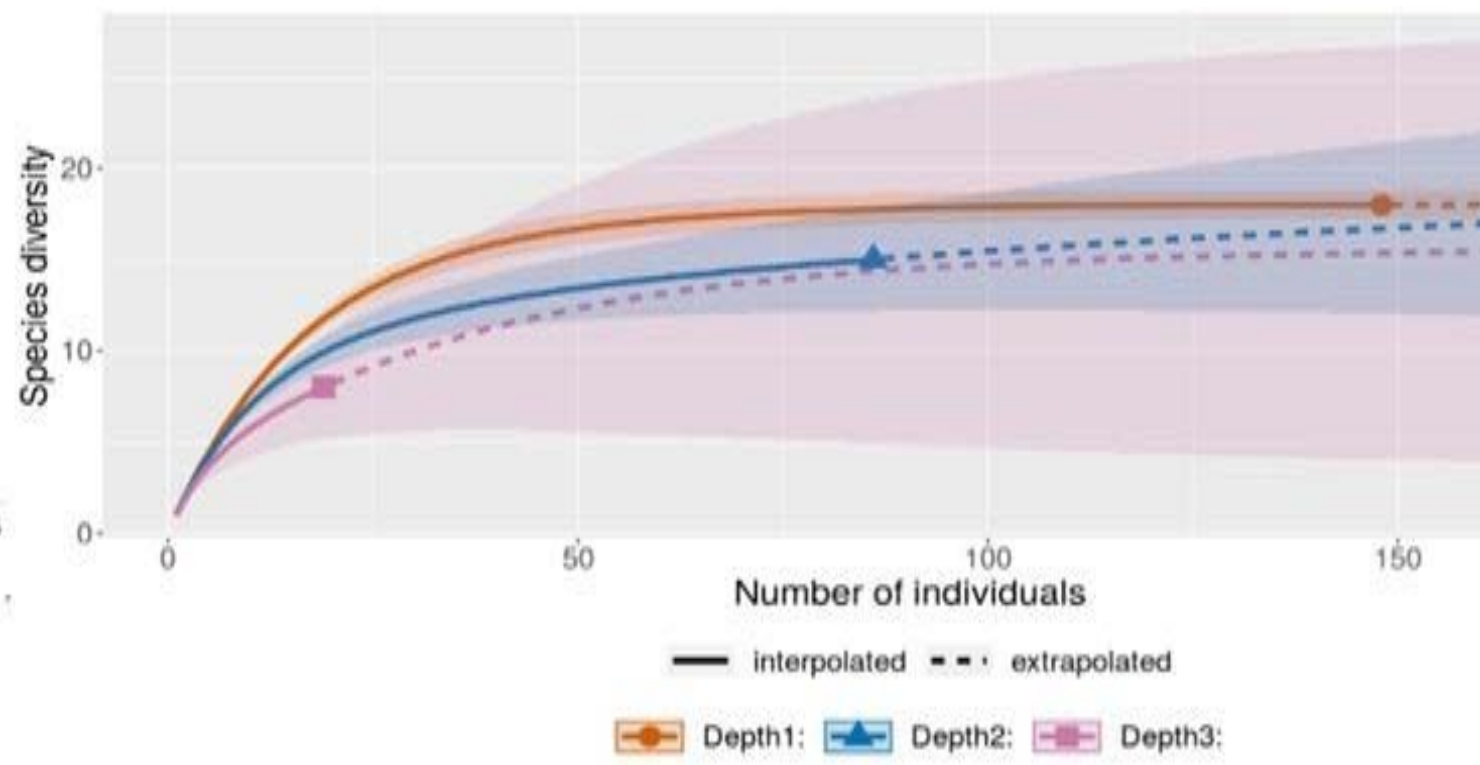
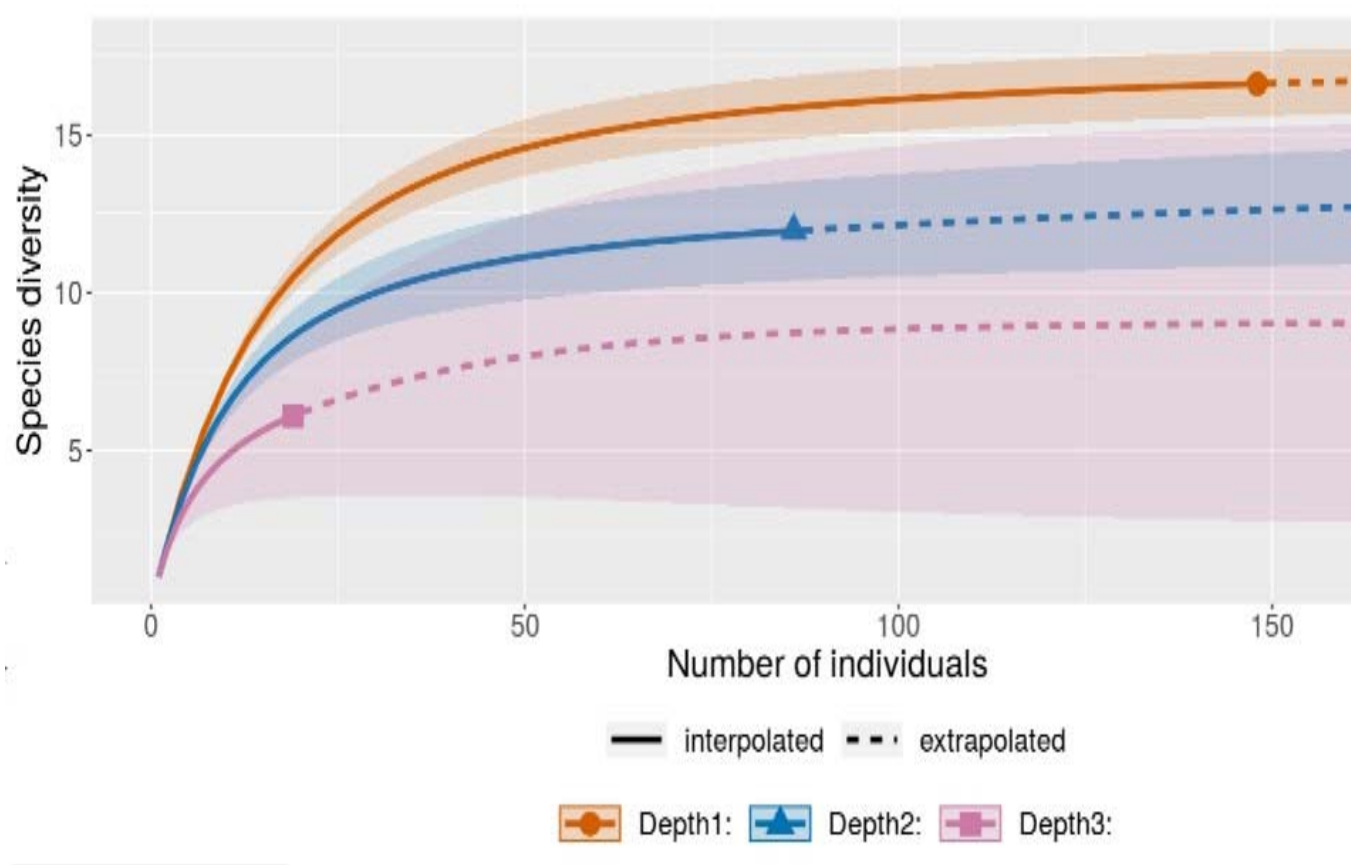


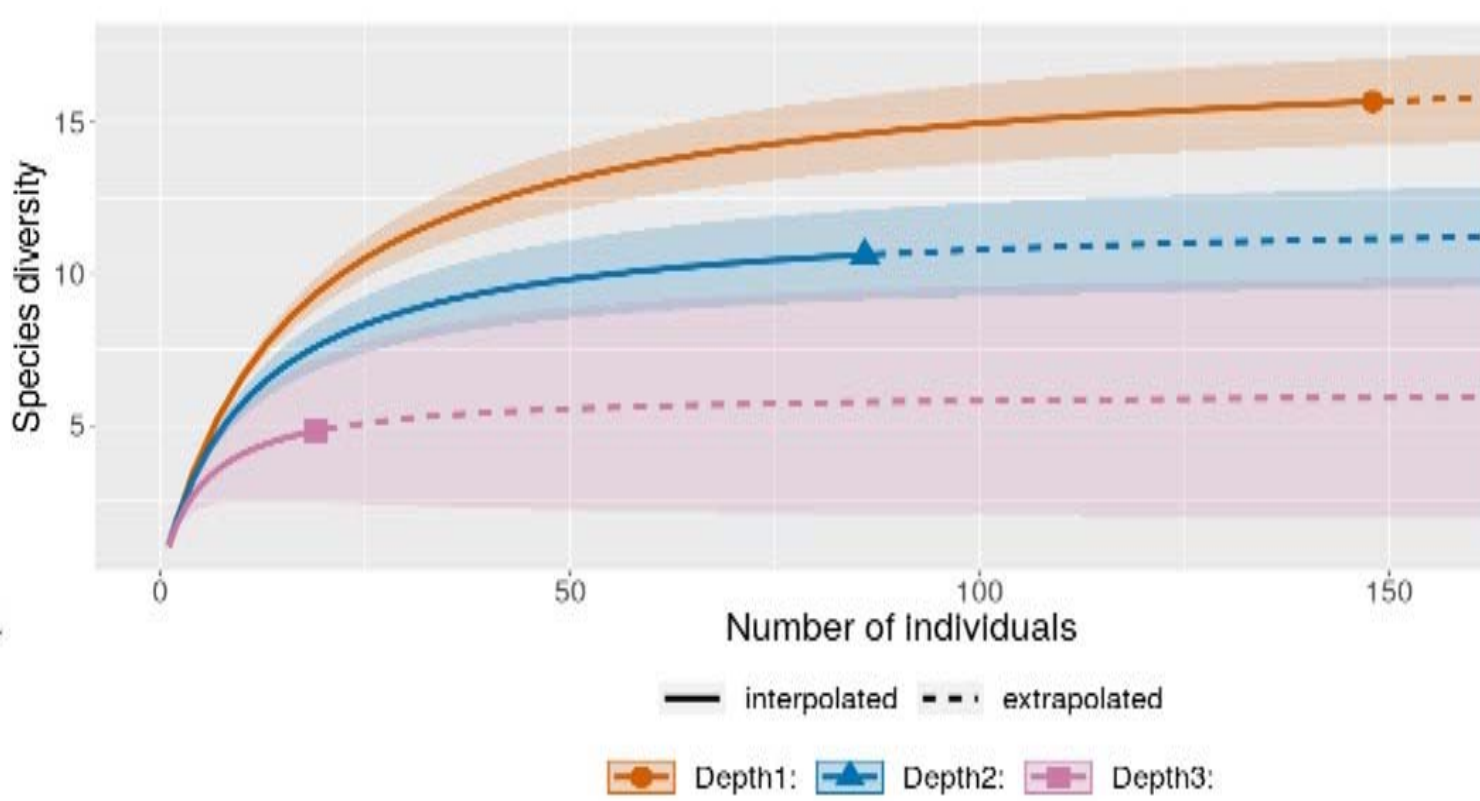
Figure 3. PCA scatter plot of the three soil depths variable in the study area. **Key:** **A**= *Asystasia vogeliana*, **B**= *Synedrella nodiflora*, **C**= *Chromolaena odorata*, **D**= *Palisota hirsute*, **E**= *Commelina diffusa*, **F**= *Dioscorea preussii*, **G**= *Discoglyprena caloneura*, **H**= *Platostoma africanum*, **I**= *Sida acuta*, **J**= *Sida urens*, **K**= *Panicum maximum*, **L**= *Chassalia kolly*, **M**= *Pauridiantha hirtella*, **N**= *Spermacoce ocynoides*, **O**= *Physalis angulate*, **P**= *Celtis zenkeri*, **Q**= *Laportea aestuans*, **R**= *Pouzolzia guineensi*



(4a)



(4b)



(4c)

Figure 4a, b and c showing the Individual-based rarefied–extrapolated Species richness, Shannon diversity and Simpson diversity curves for the three-soil depths.

Table 1: Undergrowth species distribution across the four plots

Family	Name	Habit	IUCN Status	Plot 1	Plot 2	Plot 3	Plot 4
Acanthaceae	<i>Acanthus montanus</i> (Nees) T. Anders. in J. Linn.	Herb	LC	x	x	x	x
Annonaceae	<i>Anonidium mannii</i> (Oliv.) Engl. & Diels Monogr	Sapling	LC				x
	<i>Cleistopholis patens</i> (Benth.) Engl. & Diels	Sapling	LC	x	x	x	x
Apocynaceae	<i>Monodora myristica</i> (Gaertn.) Dunal	Sapling	LC		x		
	<i>Annickia chlorantha</i>	Shrub	LC		x		
	<i>Hexalobus crispiflorus</i> A. Rich. in Sagra	Shrub	LC		x	x	
	<i>Oncinotis gracilis</i> Stapf in Kew Bull.	Climber	NE				x
	<i>Alafia barteri</i> Oliv.	Liana	NE	x	x	x	
	<i>Baisseia subsessilis</i> (Benth.) Stapf ex Hutch. & Dalz.	Liana	NE	x	x	x	x
	<i>Motandra guineensis</i> (Thonning) A. DC.	Liana	NE	x	x	x	x
	<i>Alstonia boonei</i> De Wild.	Sapling	LC	x	x	x	x
	<i>Funtumia elastica</i> (Preuss) Stapf	Sapling	LC	x	x	x	
	<i>Picralima nitida</i> (Stapf) Th. & H. Dur	Shrub	NE	x	x	x	x
Araceae	<i>Rauvolfia vomitoria</i> Afzel.	Shrub	LC	x	x	x	x
	<i>Tabernaemontana pachysiphon</i> var. <i>cumminsii</i> (Stapf) H. Huber	Shrub	LC				x
	<i>Voacanga africana</i> Stapf in J. Linn. Soc.	Shrub	LC				x
	<i>Culcasia scandens</i> P. Beauv.	Climber	LC	x	x	x	x
	<i>Rhaphidophora africana</i> N. E. Br.	Climber	NE	x	x	x	
Asclepiadaceae	<i>Amorphophallus abyssinicus</i> (A. Rich.) N. E	Herb	NE		x		x
	<i>Anchomanes difformis</i> var. <i>difformis</i> Hepper	Herb	LC	x	x	x	x
	<i>Mondia whitei</i> (Hook. f.) Skeels	Liana	NE	x	x	x	x
Bignonoceae	<i>Secamone afzelii</i> (Schultes) K. Schum.	Liana	NE	x	x		
	<i>Kigelia africana</i> (Lam.) Benth.	Sapling	LC	x	x		
	<i>Newbouldia laevis</i> (P. Beauv.) Seemann. ex Bureau	Sapling	LC	x	x	x	
Burseraceae	<i>Ceiba pentandra</i> (Linn.) Gaertn.	Sapling	LC			x	
	<i>Canarium schweinfurthii</i> Engl.	Sapling	LC	x	x	x	x

14									
15									
16									
17									
18									
19									
20	Caesalpinoideae	<i>Mezoneuron benthamianum</i> Baill. F. T. A. 2: 261;	Liana	NE	x				
21		Chev.Bot.219 APDacc							
22		<i>Anthonotha obanensis</i> (Bak. f.) J. Léonard in Bull. Jard.	Sapling	NE	x	x	x	x	
23		Bot. Brux.							
24		<i>Brachystegia eurycoma</i> Harms	Sapling	LC	x	x	x	x	
25		<i>Brachystegia nigerica</i> Hoyle & A. P. D. Jones	Sapling	VU	x	x	x	x	
26		<i>Pterocarpus osun</i> Craib	Sapling	LC			x		
27	Capparidaceae	<i>Ritchiea longipedicellata</i> Gilg	Liana	NE	x	x			
28		<i>Buchholzia coriacea</i> Engl.	Sapling	LC	x	x	x	x	
29	Combretaceae	<i>Combretum racemosum</i> P. Beauv	Liana	NE	x				
30		<i>Terminalia ivorensis</i> A. Chev.	Sapling	VU			x	x	
31	Commelianaceae	<i>Palisota ambigua</i> (P. Beauv.) C. B. Cl. in DC.	Herb	NE		x			
32		<i>Palisota hirsuta</i> (Thunb.) K. Schum. in Engl., Bot. Jahr	Herb	NE		x			
33	Connaraceae	<i>Cnestis ferruginea</i>	Shrub	NE	x	x	x		
34	Convolvulaceae	<i>Ipomoea hederifolia</i> Linn.	Climber	NE		x			0
35	Ebenaceae	<i>Diospyros dendo</i> Welw. ex Hiern	Shrub	LC	x	x	x	x	
36		<i>Diospyros monbuttensis</i> Gürke	Shrub	LC	x	x	x		
37		<i>Diospyros suaveolens</i> Gürke in Engl	Shrub	LC	x	x	x	x	
38	Euphorbiaceae	<i>Macaranga barteri</i> Müll. Arg.	Sapling	LC	x	x			x
39		<i>Macaranga hurifolia</i> Beille	Sapling	LC	x	x	x	x	
40		<i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Pax	Sapling	LC	x	x	x	x	
41		<i>Antidesma laciniatum</i> Müll. Arg. var. laciniatum	Shrub	LC		x			
42		<i>Drypetes gilgiana</i> (Pax) Pax & K. Hoffm.	Shrub	LC	x	x	x		
43	Icacinaceae	<i>Ipomoea hederifolia</i> Linn.	Shrub	NE	x	x	x	x	
44		<i>Pyrenacantha staudtii</i> (Engl.) Engl.	Shrub	NE	x	x	x	x	
45	Irvingiaceae	<i>Irvingia wombolu</i> Vermeesen	Sapling	LC	x	x			
46	Maranthaceae	<i>Marantochloa congensis</i> (K. Schum.) Léonard & Mullend.	Herb	NE	x	x	x		
47		<i>Marantochloa leucantha</i> (K. Schum.) Milne-Redh.	Herb	NE	x	x	x	x	
48	Meliaceae	<i>Entandrophragma utile</i> (Dawe & Sprague) Sprague	Sapling	VU	x	x	x	x	
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									

14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

	<i>Khaya grandifoliola</i> C. DC.	Sapling	VU	x	x		
	<i>Trichilia heudelotii</i> Planch. ex Oliv.	Shrub	NE	x		x	x
Menispermaceae	<i>Rhigiocarya racemifera</i> Miers—Diels	Liana	NE		x		
	<i>Triclisia gillettii</i> (De Wild.) Staner	Liana	NE	x	x		x
	<i>Sphenocentrum jollyanum</i> Pierre	Shrub	NE	x	x	x	x
Moraceae	<i>Musanga cecropioides</i> R.Br.	Sapling	LC			x	x
	<i>Myrianthus arboreus</i> P. Beauv.	Sapling	LC	x	x	x	x
Myristicaceae	<i>Pycnanthus angolensis</i> (Welw.) Warb.	Sapling	LC	x	x	x	x
	<i>Staudtia stipitata</i> Warb.	Sapling	NE				x
Nyctaginaceae	<i>Napoleona imperialis</i> P. Beauv.	Sapling	LC	x	x	x	x
	<i>Napoleonaea vogelii</i> Hook. & Planch.	Sapling	LC	x		x	
Olacaceae	<i>Strombosia pustulata</i> Oliv.	Sapling	LC	x	x	x	x
Pandaceae	<i>Microdesmis puberula</i> Hook. f. ex Planch.	Shrub	LC			x	
Papilionoideae	<i>Leptoderris micrantha</i> Dunn	Liana	NE	x	x	x	
	<i>Amphimas pterocarpoides</i> Harms	Sapling	LC	x			
Passifloraceae	<i>Barteria fistulosa</i> Mast.	Sapling	LC	4		x	x
Polygalaceae	<i>Carpolobia lutea</i> G. Don	Sapling	LC	x	x	x	x
Rubiaceae	<i>Geophila obvallata</i> (Schumach.) F. Didr.	Herb	NE	x	x	x	x
	<i>Cuviera truncata</i> Hutch. & Dalz.	Liana	NE	x			
	<i>Massularia acuminata</i> (G. Don) Bullock ex Hoyle	Sapling	NE	x			
	<i>Rothmannia hispida</i> (K. Schum.) Fagerlind	Sapling	LC			x	
	<i>Rothmannia longiflora</i> Salisb.	Sapling	LC	x	x		
	<i>Rothmannia whitfieldii</i> (Lindl.) Dandy in F. W. Andr.	Sapling	LC	x		x	x
	<i>Chassalia kolly</i> (Schumach.) Hepper	Shrub	NE	x	x		x
	<i>Oxyanthus speciosus</i> DC	Shrub	LC		x		
	<i>Rytigynia umbellulata</i> (Hiern) Robyns	Shrub	NE	x			
Rutaceae	<i>Zanthoxylum parvifoliolum</i> (A. Chev. ex Keay) W.D. Hawth.	Shrub	LC	x		x	x
	<i>Zanthoxylum rubescens</i> Planch. ex Hook. f.	Shrub	LC	x	x	x	x
Sapindaceae	<i>Blighia sapida</i> Konig in Konig & Sims, Ann.	Sapling	LC				x

14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Sapotaceae	<i>Chrysophyllum perpulchrum</i> Mildbr. ex Hutch. & Dalz.	Sapling	LC	x				
	<i>Pachystela brevipes</i> (Bak.) Baill. ex Engl. Monogr	Shrub	LC				x	
Sterculiaceae	<i>Cola gigantea</i> var. <i>glabrescens</i> Brenan & Keay	Sapling	LC	x	x		x	x
	<i>Cola hispida</i> Brenan & Keay	Sapling	LC	x			x	x
	<i>Cola nigerica</i>	Sapling	VU				x	
	<i>Mansonia altissima</i> (A. Chev.) A. Chev. var. <i>altissima</i>	Sapling	EN	x	x		x	x
	<i>Triplochiton scleroxylon</i> K. Schum.	Sapling	LC	x	x		x	x
Tiliaceae	<i>Desplatsia dewevrei</i> (De Wild. & Th. Dur.) Burret in Mildbr.	Sapling	LC	x	x		x	
	<i>Glyphaea brevis</i> (Spreng.) Monachino	Shrub	LC			x		
Ulmaceae	<i>Celtis mildbraedii</i> Engl.	Sapling	LC					x
	<i>Celtis philippensis</i> Blanco	Sapling	LC	x			x	
	<i>Celtis zenkeri</i> Engl.	Sapling	LC	x	x		x	x
Violaceae	<i>Rinorea brachypetala</i> (Turcz.) O. Ktze.	Shrub	NE				x	x
	<i>Rinorea dentata</i> (P. Beauv.) O. Ktze.	Shrub	NE	x	x		x	x
Zingiberaceae	<i>Aframomum sceptrum</i> (Oliv. & D. Hanb.) K. Schum	Herb	LC	x	x		x	
No of Species				70	66		65	56

Keys: X = Present, definition of NE= Not Evaluated (NE), DO=Data Deficient (DD), LC= Least Concern (LC), NT= Near Threatened (NT), VU= Vulnerable (VU), EN= Endangered (EN)

Table 2

	Soil_Depth_1	Soil_depth_2	Soil_depth_3
Taxa_S	18	16	8
Individuals	148	87	19
Dominance_D	0.06373	0.09209	0.2078
Simpson_1-D	0.9363	0.9079	0.7922
Shannon_H	2.81	2.515	1.808
Evenness_e^H/S	0.9225	0.7728	0.762
Margalef	3.402	3.359	2.377
Equitability_J	0.9721	0.907	0.8693

Table 3 ANOVA table for soil seed bank samples obtained across the locations

Source of Variance	Df	Sum Sq	Mean Sq	F. Value	Pr (>F)
Soil depth (Trt)	2	199.0	99.49	8.963	0.000627***
Residual	39	432.8	11.10		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4 Seedling emergence obtained from soil depths across the locations

Treatment	Value
Soil depth 1(0-3cm)	8.22±3.24 ^a
Soil depth 2 (3-6cm)	5.44±3.86 ^b
Soil depth (6-9cm)	2.38±2.07 ^c

The values with different letters are significantly different while there is no values with same letters

Values are mean±SD

Table 5: Eigen values and percentage correlation Matrix of the three soil depths

	Eigenvalue	Percentage of Variance
1	1.98968	66.32%
2	0.772	25.73%
3	0.23832	7.94%

Table 6: Variables intraset correlation of species composition of soil depths.

Species composition	PC 1	PC 2
<i>Asystasia vogeliana</i> Benth.	0.80115	1.46972
<i>Synedrella nodiflora</i> Gaertn.	0.28973	0.63716
<i>Chromolaena odorata</i> (L.) R. M. King	0.49046	0.56037
<i>Palisota hirsuta</i> (Thunb.) K. Schum.	-1.94663	-0.76075
<i>Commelina diffusa</i> J. K. Morton	-0.31017	-0.09588
<i>Dioscorea preussii</i> Pax	-0.68188	-0.01389
<i>Discoglyprena caloneura</i> (Pax) Prain	-1.94663	-0.76075
<i>Platostoma africanum</i> P. Beauv.	1.89019	-0.35205

4	<i>Sida acuta</i> Burm. f.	-0.51636	0.21928
5	<i>Sida urens</i> Linn	-0.18533	1.02329
6	<i>Panicum maximum</i> Jacq.	2.59846	-2.56095
7	<i>Chassalia kolly</i> (Schumach.) Hepper	-1.78989	-0.76551
8	<i>Pauridiantha hirtella</i> (Benth.)	1.86985	0.09095
9	<i>Spermacoce ocynoides</i> Burm. F.	-0.98048	0.12867
10	<i>Physalis angulata</i> Linn.	0.3046	0.43253
11	<i>Celtis zenkeri</i> Engl.	-0.65276	0.11871
12	<i>Laportea aestuans</i> (L.) Chew	2.05901	0.6951
13	<i>Pouzolzia guineensis</i> Benth.	-1.29334	-0.06599

Table 7: Forest food trees and their uses to the rural dwellers around the forest communities

	Forest food tree species	Uses	Status
1	<i>Azelia africana</i> Sm.	Condiments	VU
2	<i>Brachystegia eurycoma</i> Harms	Condiments	LC
3	<i>Brachystegia nigerica</i> Hoyle & A. P. D. Jones	Condiment	VU
4	<i>Buchholzia coriacea</i> Engl.	Edible fruits	LC
5	<i>Canarium schweinfurthii</i> Engl.	Edible fruits	LC
6	<i>Ceiba pentandra</i> (Linn.) Gaertn.	Vegetables	LC
7	<i>Cola gigantea</i> A. Chev.	Condiment	LC
8	<i>Cola pachycarpa</i> K. Schum.	Edible fruits	LC
9	<i>Dennettia tripetala</i> Bak. f	Edible fruits	LC
10	<i>Ficus sur</i> Forssk.	Vegetables	LC
11	<i>Garcinia kola</i> Heckel	Nuts and Fruits	VU
12	<i>Irvingia gabonensis</i> (Aubry-Lecomte ex O'Rorke) Baill.	Jam Jelly	NT
13	<i>Monodora myristica</i> (Gaertn.) Dunal	Spice	LC
14	<i>Myrianthus arboreus</i> P. Beauv.	Vegetables	LC
15	<i>Pterocarpus mildbraedii</i> Harms	Vegetables	VU
16	<i>Pterocarpus osun</i> Craib	Vegetables	LC
17	<i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Pax	Oil	LC
18	<i>Trilepisium madagascariense</i> DC.	Nuts and Fruits	LC
19	<i>Xylopiya aethiopica</i> (Dunal) A. Rich.	Spice	LC
20	<i>Lecaniodiscus cupanioides</i> Planch. ex Benth.	Edible fruits	LC
21	<i>Dialium guineense</i> Willd.	Edible fruits	LC

Source: Field Survey

60
61
62
63
64
65