



# A 17 year successional enrichment plantation of tree recruitment and restoration in a tropical rainforest forest

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## Abstract

The Enrichment Plantation of Akure Forest Reserve is one of the forests currently experiencing a 17-year-long post-disturbance following deforestation and fragmentation in the country. To better understand the contribution of enrichment planting on forest regeneration and restoration, the Enrichment Plantation after 17 years of post-disturbance was examined. We studied the recruitment drive of aboveground and underbrush stands of an Enrichment plantation in a tropical forest. We assess the trees diversity, species compositions, species richness, and growth forms of the vegetations. A total of 3 (50 m × 50 m) plots were sampled with a total of 47 aboveground tree species and 45 underbrush stands from Enrichment plantation were identified. The result shows an increase in the diversity and an even distribution of the species of the aboveground forest trees, compared to the underbrush stands. Conversely, the aboveground forest trees have lower species richness as compared to the level of underbrush stands. The sapling density was significantly higher than the aboveground tree of the forest (one-way ANOVA:  $P < 0.05$  and  $P = 0.000$ ). The mean  $\pm$  standard deviation of  $2.41 \pm 1.55$  aboveground tree species was extremely low to what was obtained of tree sapling ( $17.55 \pm 8.06$ ) in the forest structure. It was also observed that the aboveground forest trees and underbrush stands are somewhat similar in species compositions, which implies that sapling recruitment is a key determinant of the tree species composition of the forest. It is then concluded that the method adopted for restoration encouraged species diversity in this successional forest among the aboveground trees species and underbrush.

**Keywords** Aboveground tree · Underbrush · Undergrowth · Sapling · Successional forest · Disturbed forest · Enrichment plantation · Strict nature reserve · Forest regeneration · Sapling recruitment · Forest fragmentation · Remnant · Post-disturbance · Conservation ecology · Biodiversity in Nigeria · Parks management · Akure forest reserve

## Introduction

Forest disturbance in the tropical rainforest has become a natural phenomenon that occurs with time. It is important to know how range of forest disturbances determines and changes the forest growth and forest diversity. However, with various degrees of unmanaged challenges facing wood management of tropical rainforest and animals that lives in it, these challenges has brought about inability to adequately

provide growing global demand of ecosystem services like food, wood production, fuel, fresh water, charcoal, and firewood (Hoffmann and Baumung 2013) needed by man. Such challenges are however a global struggle against forest disturbance or degradation which may be alleviated via forest recruitment and restoration. Forest disturbance is tentatively associated with the removal of vegetation cover of an ecosystem leading to a change in ecological imbalance. Technically, many countries have developed management that is acceptable in managing forest restoration of degraded or disturbed forest. This management comes via various methods which can either be endemic to a particular geographical location (temperate or tropical), or suitable to the general locality. Among this forest management, Julia Raquel (2013) mentioned a good number of research studies that have tested methods (Gardner et al. 2009; Brancalion et al 2013; Melo et al 2013; Bertacchi et al. 2015; Montagnini et al. 1997), of forest management via enrichment plantation.

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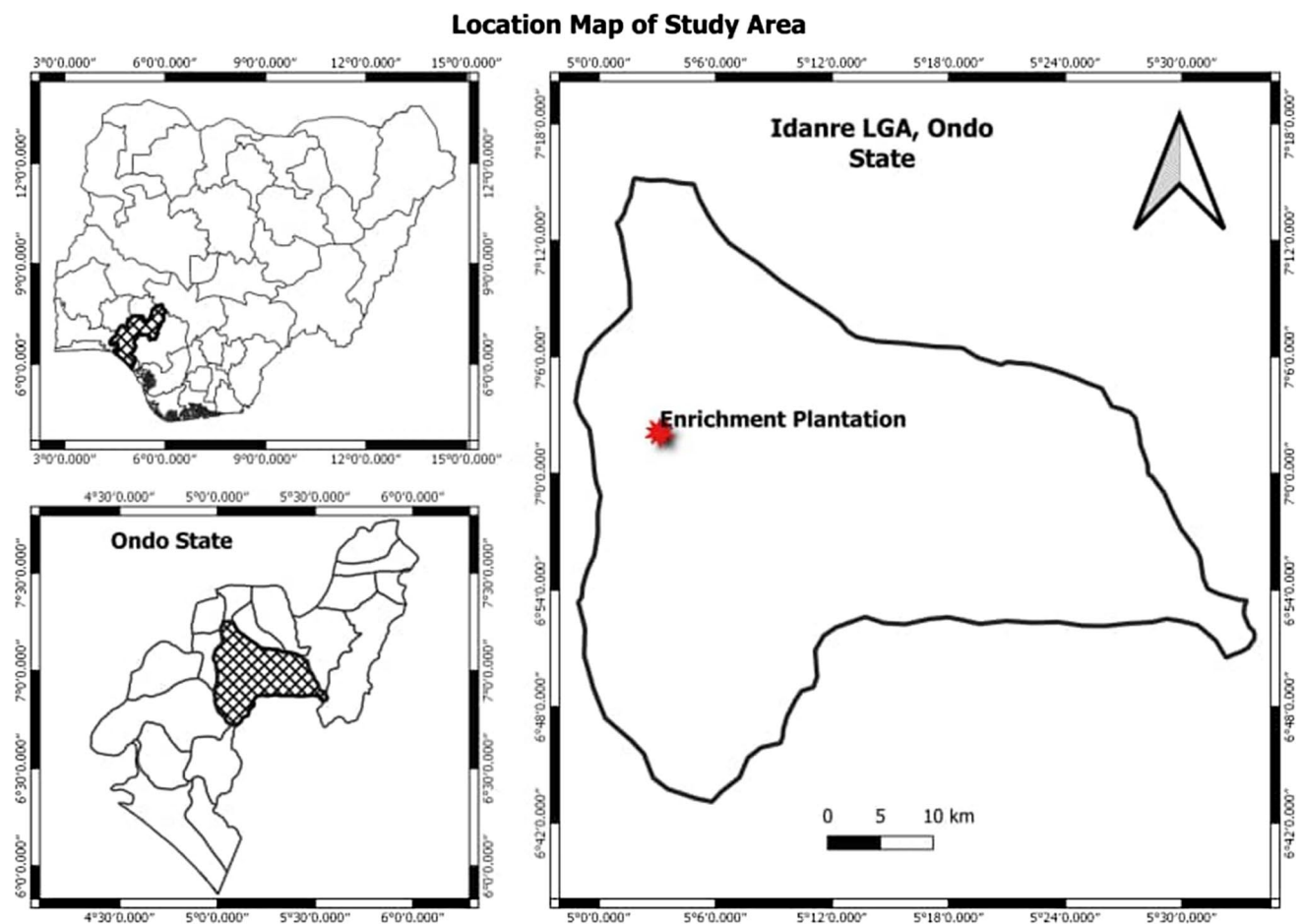
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Other research carried out tested endangered seed enrichment plantations in the tropical forest of Tan Phu, Vietnam (Millet, et al. 2013). The natural regeneration of trees was widely used in Zinder and Maradi, Niger. Reji et al. (2009) reported varied remarkable data benefiting and transforming the region.

Akure forest reserve is a well known forest reserve in Nigeria and was previously known to be highly rich in diverse of plants and animals until recent time when studies began to shows for various reasons and for a long period of time that the reserve had faced human disturbance resulting in exploitation of its flora and fauna with no adequate regeneration strategies for restoration. As part of strategies to conserve the animal and plant biodiversity of this forest, in 1948 (see details in Ola-Adam 1978), a Strict nature reserve (SNR), as a natural high forest, was first demarcated from the forest reserve with the aims of protecting and conserving the indigenous species from human exploitation. In furtherance to conserving the biodiversity of this ecosystem, this forest reserve was further subjected to three monitory reserves. The first reserve,

Strict nature reserve, earlier mentioned, covered the 32 hectares of natural high forest called Strict Nature Reserve (Queen’s plot), the buffer zone with 15 hectares. More recently, in 2004, a regeneration method called Enrichment plantation (Fig. 1) was adopted to cover an additional 5 hectares of the forest reserve where removal of selected aboveground trees had occurred. Regenerating trees were manually planted to replace what was removed from the ecosystem. A recent accompanying paper by Omomoh et al. (2019) was used in comparing the current status of this study of a related undisturbed tropical forest as the only existing adjacent natural forest where an unperturbed species composition still exists.

Therefore, the objective of this study was to quantify the recruitment and restoration pattern of trees and undergrowth of a 17-year long post-disturbance tropical forest. We assessed the species composition and growth form of both aboveground tree species and undergrowth. Finally, we evaluated whether species richness follows succession.



**Fig. 1** Map of the study area

## Materials and methods

### Study area

The Enrichment plantation is a remnant area of the Akure Forest Reserve which was assigned for indigenous trees species regeneration and restoration. The regeneration method adopted for the Enrichment plantation was carried out in 2004 (Fig. 1) under the auspices of the Federal Government of Nigeria as a forest assisted-project with the objective of recuperating the forest with regenerating trees. Since then the forest had been under intensive care and protection of the Forestry Research Institute of Nigeria. The seedling ages at the time of planting were not known, but due to its 17 years of post-disturbance of Enrichment plantation, this forest can be categorized as an older successional forest type (Perera 2005) or late-successional forest. In this context, we observed that this typical tropical older or late-successional forest is devoid of mid- and early-successional driven trees such as *Trema orientalis* (L.) Blume, *Manihot glaziovii* Müll. Arg. and *Alchornea laxiflora* (Benth.) Pax and K. Hoffm etc. The transitional dynamics of early- and mid-successional forest to late-successional forest most times brings about the natural removal of trees of mid-successional species in the late-successional forest. To be more specific in this context, regenerating trees or young trees are referred to as sapling, herbaceous as forbs, climber as a vine, and plants of early-disturbance as pioneer plants, e. g. agricultural weeds.

The study area (Fig. 2) is located in Akure Forest Reserve, Nigeria at  $N07^{\circ}.2645^1$ , and  $E005^{\circ}.03675^1$ . Akure Forest Reserve is one of the tropical forests in world with a history of deforestation and fragmentation (Adekunle et al. 2013). Before the Enrichment plantation project, a remnant portion of the Akure Forest Reserve that was known to have undergone a series of anthropogenic activities such as timber logging and exploitation in the hands of illegal fellers was in



Fig. 2 The Enrichment plantation showing the study area

2004 projected out for enrichment planting. However, this remnant and fragmented part was located at the adjacent area of the Strict Nature Reserve. The purpose of the enrichment planting was for forest restoration and regeneration. Recent studies described the forest climatic condition of this study (Omomoh 2018; Omomoh et al. 2019, 2020).

### Sampling and identification techniques

The laying of the plots was carried out using the systematic line transects method as shown in Fig. 3. A 50 m transect was centrally located in the forest where three sampling plots of 50 m × 50 m were laid in alternate sides with the aids of the prismatic compass and ranging poles for positioning.

To establish the species composition of the aboveground vegetation, trees, and shrubs, the floristic composition of each study plot was enumerated. The saplings girth > 0.8 m of woody species at the height ranging from 1 to 2 m were measured with diameter tape. Other non-woody species such as forbs and vines encountered were also counted. A grey text book of flora of tropical West Africa (Hutchinson et al 1963) and Tree of Nigeria (Keay 1989) were adopted in the plant species identification of the study area but the classification of the legume family and members found followed the order of new families of the legume phylogeny working group (LPWG) of Azani et al. (2017). The current change of

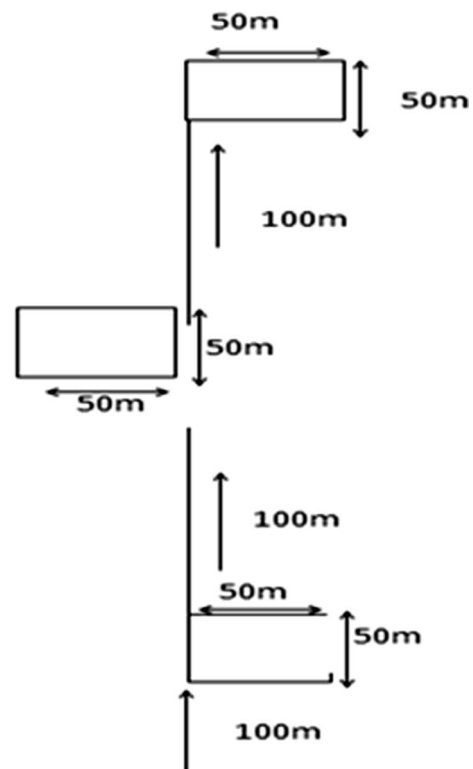


Fig. 3 Systematic line transects sampling technique for the study area

names of plant species from old name in the grey textbook (Hutchinson et al 1963) to new names were narrated using a guide to the forest trees, shrubs and lianes from Senegal to Ghana textbook (Hawthorne and Jongkind 2006). Plant specimen of plant species that cannot be identified immediately on field were collected, pressed, and taken to FUTA herbarium of Federal University of Technology, Akure (FUTA) for proper identification.

### Forest structure

The forest structure was evaluated using the forest parameters and indices. The basal area, relative density, relative dominance, importance value (IVI), and family importance value (FIV) were determined using the following formula:

1. Basal area (BA):

$$BA = \frac{\pi D^2}{4}$$

where BA is the basal area ( $m^2$ ), D is the diameter at breast height (cm), and n is the pie (3.142). The total BA for each plot was obtained by adding all trees BA in the plot.

2. Relative density (%) (Brashears et al. 2004):

$$RD = \frac{n_i}{N} \times 100$$

where RD is the relative density of the species,  $n_i$  is the number of individuals of species  $i$ , and N is the total number of all individual trees.

3. Species relative dominance (%) (Curtis and McIntosh 1950):

$$RD_O = \frac{\sum Ba_i \times 100}{\sum Ba_n}$$

where,  $Ba_i$  is the basal area of individual tree belonging to species  $i$ , and  $Ba_n$  is the stand basal area.

4. Family importance value (FIV):

$$FVI = \frac{(\text{Relative density} + \text{Relative dominance})}{2}$$

5. Importance Value Index (IVI) (Brashears et al. 2004):

$$IVI = \frac{(\text{Relative density} \times \text{Relative dominance})}{2}$$

### Plant species diversity

Diversity indices such as Shannon–Wiener diversity index (Shannon 1948) and the species evenness (Pielou 1969) was used.

1. Shannon–Wiener diversity index:

$$H' = - \sum_{i=1}^S p_i \ln(p_i)$$

where  $H'$  is the Shannon diversity index, S is the the total number of species in the community,  $p_i$  is the proportion S (species in the family) made up of the  $i$ th species, and  $\ln$  is the natural logarithm.

2. The Species evenness (E), using Pielou (1969):

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^S P_i \ln(P_i)}{\ln(S)}$$

These equations still follow the calculation of the Shannon and Wiener function above.

### Data analyses

The analysis of variance (One-way ANOVA) was applied to determine the significant differences between the variances, using IBM SPSS Version 23. The diversity indices were quantified using 1000 bootstrap replicates in the PAST software 3.0 to observe the forest structure of this study. The principal component analysis (PCA) ordination and multi-variate clustering graph were also employed to explain the variations of the two physiognomies of the forest.

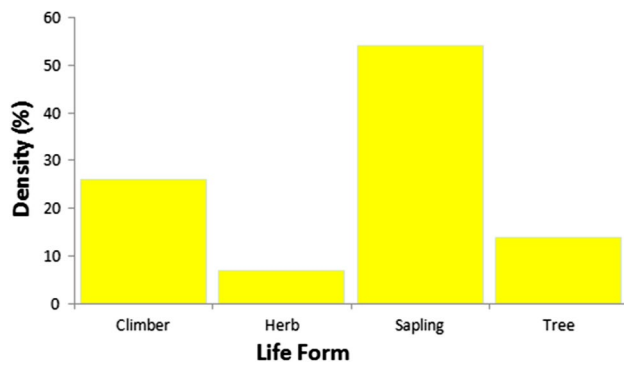
## Results

### Species composition structure

The study site consisted of sixty-five (65) plant species distributed across forty-nine (49) genera, and twenty-eight (28) families within the entire vegetation of the study area (Appendix 1 in ESM).

### Trees diversity of the aboveground vegetation

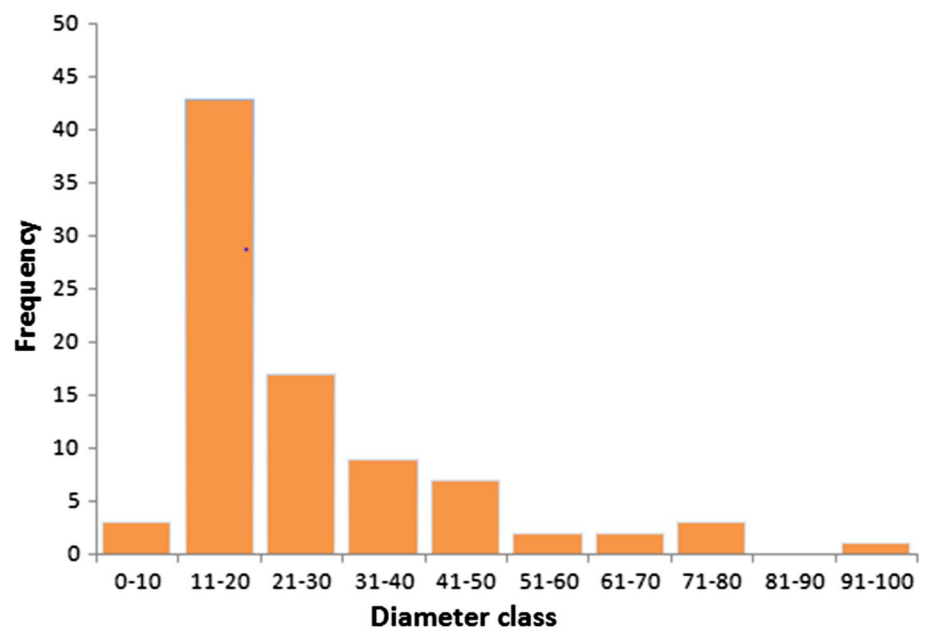
There were forty seven mature trees in all the three plots of the forest trees in the study area (Appendix 2 in ESM). In the study area (Fig. 4), Sterculiaceae, Moraceae, Leguminosae (Caesalpinioideae and Detarioideae), Anacardiaceae, Euphorbiaceae and Ebenaceae, with dominances of 15%, 11%, 10%, 9% and 6% (Anacardiaceae and Euphorbiaceae) respectively, are the known dominant families in the forest,



**Fig. 4** The different life form of Enrichment Plantation

with species members falling between the ranges of 6 to 5 different species. The Sterculiaceae family recorded the highest number of members (6) with the following species: *Cola gigantea* var. *glabrescens* Brenan & Keay., *Mansonia altissima* (A. Chev.) A. Chev. var. *altissima*, *Pterygota macrocarpa* K. Schum., *Sterculia rhinopetala* K. Schum., *Sterculia tragacantha* Lindl, and *Triplochiton scleroxylon* K. Schum. The family with five members of species were narrated as follows; *Antiaris toxicaria* var. *africana* Scott-Elliot ex A. Chev., *Ficus exasperata* Vahl, *Milicia excelsa* (Welw.) C.C. Berg., *Myrianthu sarboreus* P. Beauv, and *Trilepisium madagascariense* DC. Syn *Bosqueia angolensis* Ficalho, and 5 species members from Legumimosae contributing viz. *Albizia adianthifolia* (Schum.) W. F. Wight (Caesalpinioideae), *Albizia zygia* (DC.) J. F. Macbr (Caesalpinioideae), *Anthonotha macrophylla* P. Beauv (Detarioideae), *Anthonotha obanensis* (Bak. f.) J. Léonard (Detarioideae)

**Fig. 5** Diameter class showing diameter distribution among the aboveground trees species in the study area



and *Piptadeniastrum africanum* (Hook. f.) Brenan (Caesalpinioideae). The families with four members were; Annonaceae and Euphorbiaceae. The only family with intermediate dominant members is Ebenaceae. Other families were found in low dominant members ranging between one to two species (Appendix 2 in ESM).

The total basal area of the aboveground species per hectare is 109.51. In the Ebenaceae family, the genus *Diospyros* contributed the highest number of three species viz. *Diospyros barteri* Hiern, *Diospyros dendo* Welw. ex Hiern., and *Diospyros monbuttensis* Gürke, with a total basal area of 1.25m<sup>2</sup>ha<sup>-1</sup> and relative density of 4 individualsha<sup>-1</sup>. The most dominant tree species, *Picalima nitida* (Stapf) Th. & H. Dur, contributed a total basal area of 6.525m<sup>2</sup>ha<sup>-1</sup> all together with a relative density of 7.95 of individualsha<sup>-1</sup>. The least dominant tree species encountered were 28 with a relative density of one (1) individualsha<sup>-1</sup> (Appendix 3 in ESM).

The other dominant trees quantitative information was illustrated among the much more mature trees measured. The species with higher relative densities were *Pterygota macrocarpa* K. Schum., *Buchholzia coriacea* Engl, *Celtis zenkeri* Engl, *Sterculia rhinopetala* K. Schum, and *Trilepisium madagascariense* DC (Appendix 2 in ESM). The diameter class was extremely high, with only in 11–20 DBH among all the diameter class distributions recorded (Fig. 5). The two most prominent tree species in this diameter class distribution were *Buchholzia coriacea* and *Picalima nitida*. However, the diameter class from 91–100 cm to 51–60 cm decreases but was extremely low at 0–10 cm. The analysis of variance for sapling density was varied and significantly higher than the aboveground

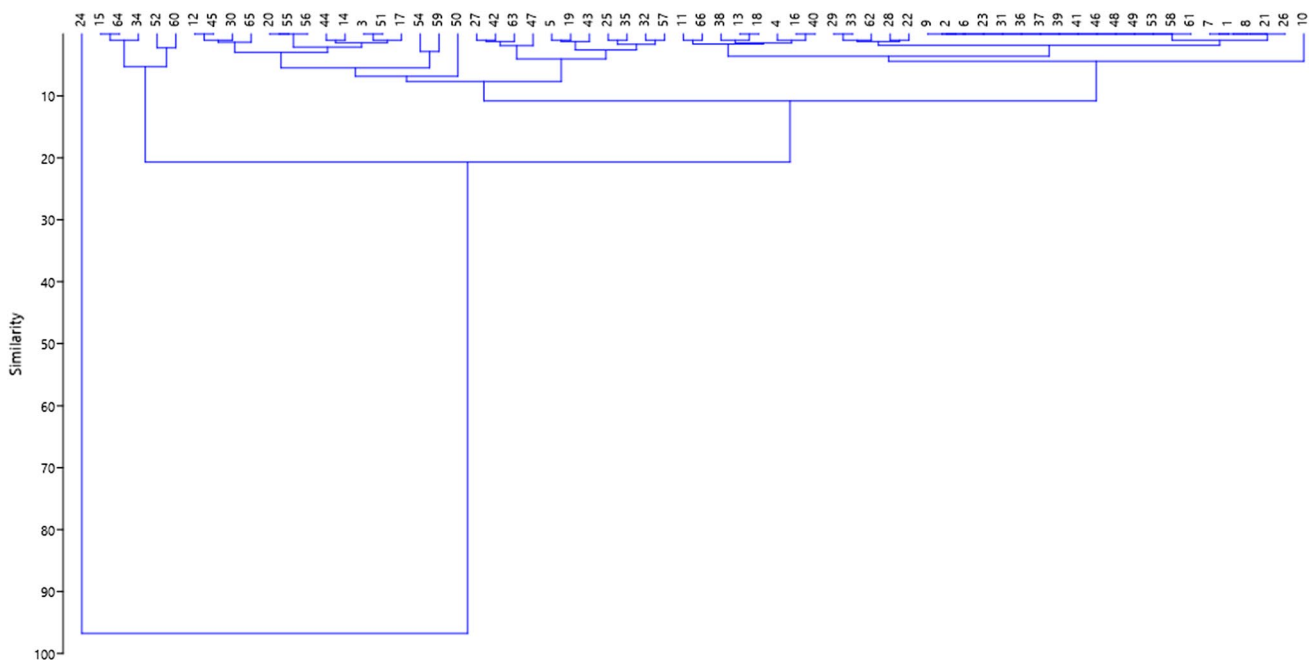
tree of the forest (one way ANOVA:  $P < .005$  and  $P = 0.000$ ). The mean  $\pm$  standard deviation of  $2.41 \pm 1.55$  tree species was extremely low to what was obtained ( $17.55 \pm 8.06$ ) of tree sapling in the forest structure. From Table 4, the Shannon–Wiener index ( $H'$ ), Simpson’s index (CD), and Evenness index ( $e$ ) for the tree species were obtained as 3.59, 0.05, and 0.80, respectively.

**The forest underbrush status and recruitment**

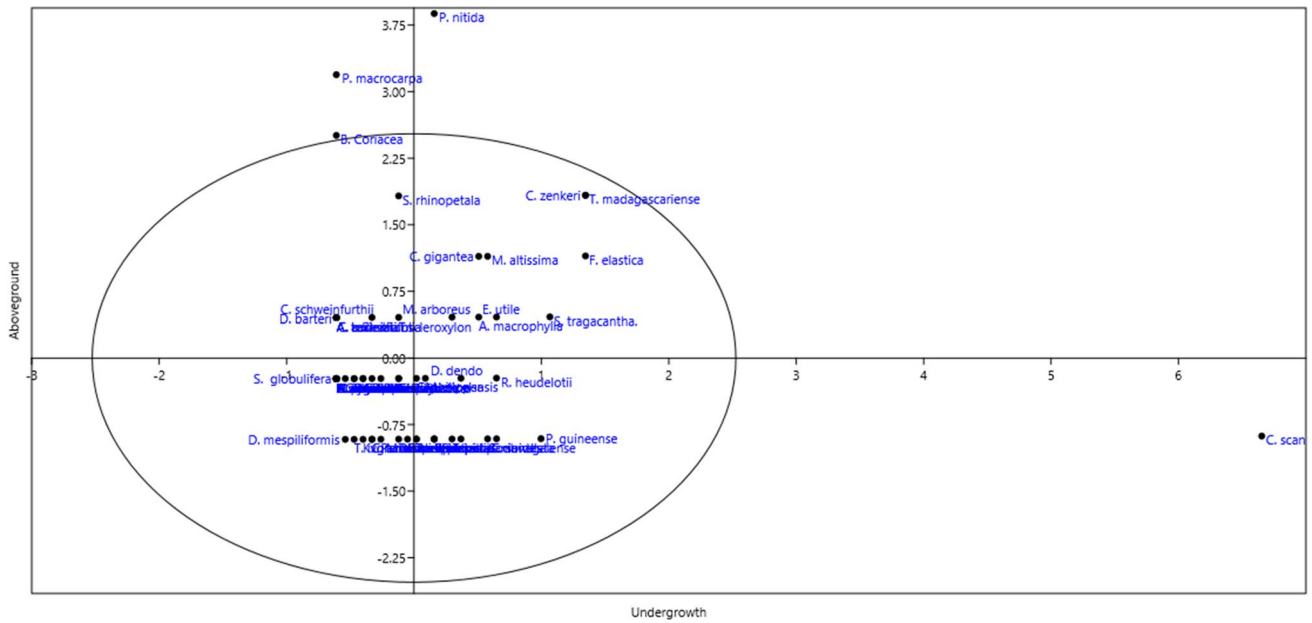
36 tree saplings, 6 vines, and 3 forbs made up of forty-five (45) forest underbrush species that were identified in the forest floor of this study (Appendix 1 in ESM). One of the most notable differences in this forest underbrush is the rate of occurrence at which the life forms recruit and regenerate in the forest floor (Fig. 6). Our results show that the sudden increase in recruitment level of tree saplings can be linked to natural disappearance or removal of early- and mid-successional species to later stages in succession. Our records show a remarkable impact on the regeneration of life forms owing to a wide increase in sapling occurrence (Fig. 6). Of the different life forms observed in the forest underbrush, tree saplings show the highest percentage of regeneration (54%), followed by vines, 26%, mature trees 14%, and forbs 7%. The result from Appendix 3 in ESM shows the species diversity of forbs and vines in this forest to be extremely low and invariably consists of what flora of West tropical Africa described as forest forbs and vines, namely; *Anchomanes difformis*, *Cyrtosperma senegalense*, *Geophila*, and *Culcasia scandens*. According to the tree sapling record,

the underbrush stand of the total families’ dominance was estimated to 97 families (Fig. 4). Sterculiaceae, a popularly known family in the tropical rainforest in Africa is ultimately the most dominant family in this current study whilst 18% family’s dominance contributing *Cola acuminata*, *Cola gigantea*, *Cola hispida*, *Mansonia altissima*, *Pterygota macrocarpa*, *Sterculia rhinopetala*, *Sterculia tragacantha*, and *Triplochiton scleroxylon*, a total of 22.9% of individual members (8) to the recruitment status of the underbrush. Other families with intermediate family dominance were Ebenaceae and Moraceae, with 11.4% of total individual members (4). On the contrary, families under-represented in this study are with relatively low percentage dominant such as 3(5.7%); Annonaceae and Ulmaceae, 2(5.7); Apocynaceae and Sapotaceae, 1(2.9%); Bombacaceae, Boraginaceae, Burseraceae, Combretaceae, Detariodeae, Euphorbiaceae, Meliaceae, Rutaceae, and Sapindaceae were found in the lesser families. The population structure of underbrush reveals the density of individuals  $ha^{-1}$  (Appendix 3 in ESM) of 11 dominant tree saplings found among the underbrush was different from what was accounted for in the forest tree viz. *Funtumia elastica* (28), *Anthonotha macrophylla* (16), *Diospyros dendo* (14), *Ricinodendron heudelotii* (18), *Entandrophragma utile* (18), *Trilepisium madagascariense* (28), *Lecaniodiscus cupanioides* (14), *Cola gigantea* (16), *Mansonia altissima* (17), *Sterculia tragacantha* (24), *Celtis zenkeri* (28).

The one-way cluster analysis shows plants relationships among the different plant types as it is seen in Fig. 7. This clustering is relatively smaller in some



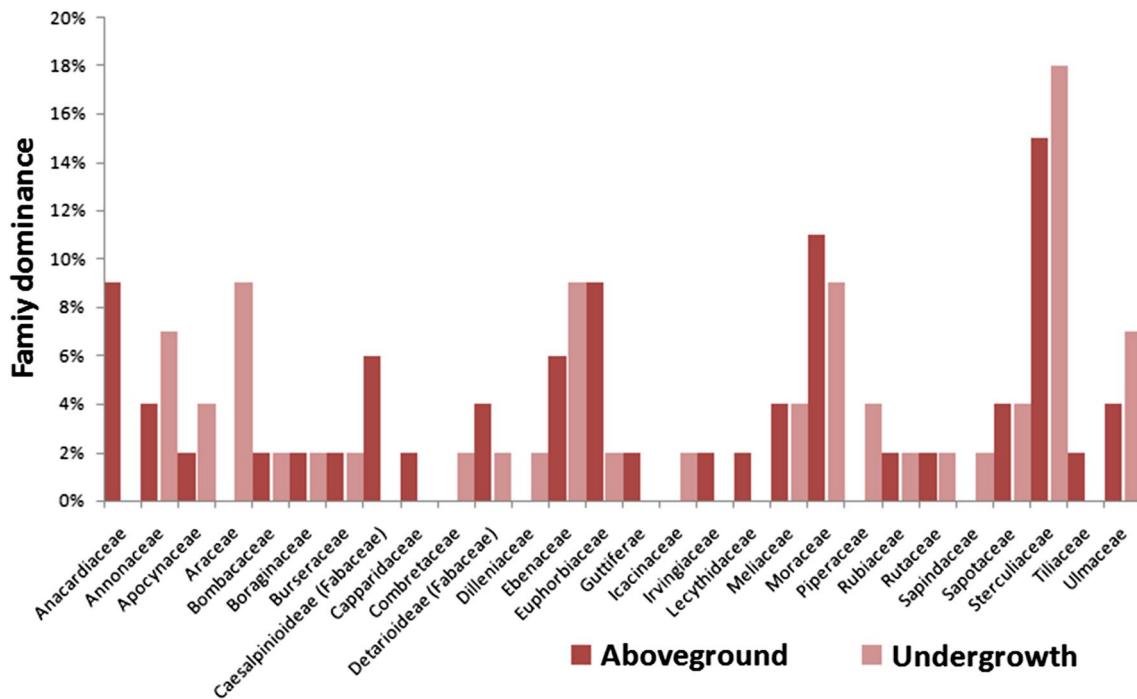
**Fig. 6** Clustering of plant species population in the study area. Each number represents the species name which is shown in Table 1



**Fig. 7** Principal component analysis showing variations in the distribution of plant species with regards to the above ground and undergrowth

species associations, like in the cases of the *Celtis zenkeri* and *Trilepisium madagascariense*, *Ceiba pentandra* and *Monodora myristica*, *Anchomanes difformis* and *Piper guineense*, *Celtis mildbraedii* and *Cola acuminata*, *Chrysophyllum albidum* and *Lanea welwitschii*, *Diospyros monbuttensis* and *Ficus exasperata*, *Cola hispida*,

*Rhaphidophora africana* and *Ricinodendron heudelotii*. The large clustering were observed among the following plant types: *Bridelia micrantha*, *Albizia zygia*, *Anthonia obanensis*, *Croton penduliflorus*, *Entandrophragma angolense*, *Glyphaea brevis*, *Lecaniodiscus cupanioides*, *Myrianthus arboreus*, *Pachystela brevipes*, *Picalima*



**Fig. 8** The family composition in the study area consisting of total number of tree families

*nitida*, *Pterygota macrocarpa*, *Sterculia rhinopetala*, and *Terminalia ivorensis*. Several other smaller clusters were found in secondary clusters and sub-clusters consisting of some other closely associated plant species. Results of the PCA show there was a large variation of plant species at the aboveground level as compared with the undergrowth (Fig. 8). *Pterygota macrocarpa*, *Picralima nitida*, and *Culcasia scandens* were the outliers of the 95% ellipse.

## Discussion

The growing number of plants and tree species of above-ground trees and undergrowth stands in a 17 year long enrichment plantation establishment of a tropical forest has revealed a significant difference in species recruitment and aboveground trees of the successional forest. Our findings show that the tropical forest is the most diverse forest known to have the family Sterculiaceae members as major dominant in tree diversity (Omomoh et al. 2019; Adekunle et al. 2013; Onyekwelu et al. 2008) which substantiate what Cronquist (1981) said about Sterculiaceae mainly found in tropical and subtropical regions. Sterculiaceae had higher members of tree species diversity. However, our study confirmed the comparable results of Sharkar and Devi (2014) in a semi-tropical forest where Moraceae, Meliaceae, Apocynaceae, Euphorbiaceae, Ebenaceae, and Fabaceae were found to be the major family species drivers in the restoration status of a tropical semi-evergreen forest of Assam, Northeast India.

This study further demonstrated the seedling diversity of non-woody species of undergrowth identified at the soil surface level in which Araceae, a forest non-woody family, were identified as the second highest dominant species, e.g.: *Anchomanes difformis*, *Culcasia scandens*, *Cyrtosperma senegalense*, and *Rhaphidophora africana*. The impact of the dominant species, with the exception of *Anchomanes difformis*, on the annual undergrowth is the natural regenerative ability to establish as a long-lived understorey in a tropical humid rainforest. In general, when pioneer species of early-successional forest (Omomoh et al. 2020) decrease, i.e. the agricultural weeds give ways to forest tree seedlings/saplings, hence an indication of the forest transitioning to a stable forest. Obviously, our studies shows that the dense natural regeneration of saplings increases in association with abundant light availability, an important factor precluding regeneration (Covey et al. 2015; De Lombaerde et al. 2020) before the removal of overstorey trees. The *Geophila obvallata* (Appendix 3 in ESM), a forest non-woody creeping prostrate herb usually found in the stable forest floor and often around the base of tropical forest trees, confirms the forest becoming species-rich in plant diversity. This can be categorized as

a late-successional forest based on the associated forest attribute described in Perera (2005). The enrichment plantation shows us that the agricultural weeds associated with and peculiar to young successional forest and forest plantation (Omomoh et al. 2020) are nearly absent in this forest type. This study is in support of Perera (2005) finding that the common herbaceous density decreases after 15 years in the older successive forest and natural high forest with very low seed densities. The total basal area of the above-ground tree species in this study area is 109.51, which was significantly lower than what was obtained in strict nature reserve, Akure (Omomoh et al. 2019). The differences can be seen in the disparity between the tree's diameter class categories. The small diameter tree species pre-dominate the successional forest. The individual basal area per hectare falls between the range of the 11–30 cm diameter class which, nevertheless, was quite similar to what was reported in the older natural high forest (Omomoh et al. 2019 and Adekunle et al. 2013). Interestingly, this is in agreement with Sokpon and Biaoou (2012) description where diameter classes with continuous recruitment and expanding population are categorized as stable or expanding species. Similarly, Pugu Forest Reserves (Rocky and Mligo 2012) reported a diameter size class, 11–15 cm (Fig. 4) in Tanzania. Moreso, in Assam, northeast India, (Sarkar and Devi 2014), the diameter class in the tropical forest of Hollongapar Gibbon Wildlife Sanctuary falls within the smaller diameter class.

Mamo et al. (2012) report also shows us the highest diameter percentage distribution among the smaller DBH class of 2–10 cm in Wondo Genet Afromontane forest. Likewise, in Ethiopia, the older successional forest was reported to have more individual trees ranging in average from 5 to 20 diameter classes. However, looking at the result of this study (Fig. 5), the floristic composition and forest structure of this forest were consistent except for where there were fewer or no older trees to compete with. The trees with the highest Importance Value Index (IVI) value, *Trilepisium madagascariense* (29.84), have 4 individual plants ha<sup>-1</sup>, followed by *Pterygota macrocarpa* (19.41), with six individual plants ha<sup>-1</sup>. These two tree species are highly economic due to the high-density properties in Africa, and for that, they are mostly found in the multi-species rich ecosystem. Despite forest disturbance of the trees composition in the study area, the result obtained from the Importance Value Index of selected trees species such as *Mansonia altissima*, *Celtis zenkeri*, and *Triplochiton scleroxylon*, are still of little variance to what was obtained from other studies (Omomoh et al. 2019; Onyekwelu et al. 2008). The exceptions to this were *Rothmannia whitfieldii*, *Cola gigantea* and *Pterygota macrocarpa*, with higher Importance Value Index in this study area (Appendix 2 in ESM).



Apparently, others with a relatively higher number of individual plants  $\text{ha}^{-1}$  across the different dominant species were observed to have low IVI values. This can be attributed to the extremely low cumulative DBH. The ability of a tree to increase in population size and increase in girth within a space of time depends on the objective of forest management. Poor or lack of management was recognized as a factor in an older Forest Plantation in Nigeria where the issue of thinning since establishment was causing retarded growth to the many species of ground flora (Onyekwelu et al. 2010). Other factors are environmental stress and anthropogenic disturbance at the young stages of any species (Sarkar and Devi 2014).

The pre-disturbance history of Enrichment plantation (Brudvig et al. 2017) which were usually commercially value added trees are a reflection of the true value of a natural tropical forest i.e. the dominant trees of larger size found in Strict nature reserve, an adjacent forest of the study area (Omomoh et al. 2019). Our studies revealed that the timber trees were under-represented and somewhat well represented among the saplings (Nuñez et al. 2019). This may have supported the efforts of enrichment plantation in this forest to restore tree diversity (Bertacchi et al. 2015). The low number of aboveground trees per hectare has created a light opening. Its incursion may have contributed more to the increase in seedling regeneration and sapling recruitment (Webb and Sah 2003) than any other life form. The tree recruitment of an ecosystem depends greatly on the population structure and level of disturbance (Sarkar and Devi 2014). An ecosystem with a mild disturbance would regenerate easily at a shorter period of time than seriously disturbed vegetation (Ganlin et al. 2006). The result shows that aboveground forest trees are somewhat diverse and more even than undergrowth species except in the species richness, where forest undergrowth was higher than the aboveground forest trees. This diversity index ( $H^1$ ) shows little dissimilarity between the aboveground forest trees and undergrowth. Diversity indices of a typical tropical forest are generally range from 1.5 to 3.5 and it is also exceptionally rare to exceed normal range but rarely exceed 4.5 (Kent and Coker 1992). In this study, the undergrowth Shannon–Wiener diversity index value (3.37) falls within the normal range. On the other hand, aboveground trees diversity ( $H^1$ ) is higher and exceeds the normal range reported by Kent and Coker (1992). This result is not in any way at variance with what was published on Queen's, Oluwa and Elephant forest by Onyekwelu et al. (2008). It is even in more consonance with other studies in Indian forests (Sarkar and Devi 2014; Parthasarathy et al. 1992; Visalakshi 1995) where the diversity index ranged from 0.83 to 4.1. There are species consistence in species evenness index values of aboveground forest (0.8) and

undergrowth (0.6). This was reported in Ganlin et al. (2006), and Palmer et al. (2000), where species richness was higher in a low disturbance. However, there is no significant difference in the relative density between the forest trees and saplings ( $P=0.341$ ). This confirmed that the aboveground trees and saplings are dissimilar in species abundance, which apparently means that sapling density is surviving the tree species composition of the forest.

## Recommendation

Biodiversity loss following disturbance of tropical forest and animal living in it in Africa is calling for world organisation intervention to extenuate this current menace. Steps to mitigate the forest disturbance by individual were not really enough compare to the extent of damages done by uncensored activities done in the forest by poachers and illegal fellers. A collaborative effort on ecosystem restoration and sustainable forest management can intensify the biodiversity integrity of disturbed forests for the next decade to come (Bernier et al. 2017; Chazdon et al. 2009). We recommend that a successional forest would need a collaborative forest management campaign to reduce and stop anthropogenic disturbance such as nomad colony, herdsmen, and cattle rearers from infringing and settling into susceptible forests. These are the current and prevailing factors affecting African forests.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s42535-021-00255-5>.

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**Data availability** None.

## Declarations

**Conflict of interest** We have no conflict of interests.

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