# 17 Years Successional Enrichment Plantation of Tree Recruitment and Restoration in Tropical Forestland

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**Research**

**Keywords:** Overstorey, undergrowth, sapling, successional forest, disturbed forest, enrichment plantation

**Posted Date:** January 5th, 2021

**DOI:** https://doi.org/10.21203/rs.3.rs-138855/v1



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# Abstract

Background

We examine the recruitment drive of overstorey and undergrowth of tropical forested reserve by assessing the tree diversity, species composition, species richness, and growth form of the undergrowth on 17 years of post-disturbance.

Result

The result show an increase in the diversity and even distribution of the species of the overstorey, compared to the undergrowth. Conversely, the overstorey has a lower in species richness as compared to the level of undergrowth. One way ANOVA results shows that there is no significant difference (P = 0.341). However, undergrowth density (individual/ha) is found to be significantly (P = 0.000) higher than the overstorey trees.

Conclusions

It is evident that the forest trees and saplings are dissimilar in species abundance, 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.


# Background

Forest diversity is a significant role player in the heart of every ecosystem with various degrees of unmanaged challenges facing ecosystem integrity (flora and fauna) which are growing global demand of ecosystem services viz. food, timber, fuel, water, charcoal, firewood (Hoffimann and Baumung 2013). The 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 and this management comes in various methods which can either be endemic (temperate or tropical) to a particular geographical location or suitable to the general locality. Among this forest management, Julia Raquel (2013) mentioned a good number of research studies to have tested method (Gardner et al. 2009; Brancalion et al 2013, Melo et al 2013, Bertacchi et al 2015, Montagnini et al 1997), of forest management viz enrichment plantation. Other research carried out speaks on 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.

Therefore, this present study investigated the level of recruitment and restoration of trees and undergrowth in a tropical forestland 17 years post-disturbance, by assessing the changes in species composition and growth form of the undergrowth. Finally, we evaluate whether species richness increase following succession. The forest reserve is a popular forest surrounded by two distinct communities formerly known to have provided various flora and fauna biodiversity but for some reason and for a very long time had faced human disturbance following exploitation of 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, covered the 32 hectares of natural high forest called strict nature reserve (Queen plot), the buffer zone with 15 hectares and in recent time, 2004, a regeneration method called enrichment plantation (figure 1) was adopted to cover an additional 5 hectares of the forest reserve where selected overstorey removal had occurred. Regenerating trees were manually planted to replace what was removed from the ecosystem. A recent accompany paper (Omomoh et al 2019) was used in comparing the current status of this study to a related undisturbed tropical forest as the only existing adjacent natural forest where an unperturbed species composition still exist

# Materials And Methods

## Study area

The regeneration method of enrichment plantation was established in 2004 (Fig 2) under the auspices of the Federal Government of Nigeria as forestry 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 for over a decade till date. The seedling ages at the time of planting were not known but since 17 years of post-disturbance of enrichment plantation, this forest can be categorized to what is called 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 absolutely devoid of mid- and early-successional driven trees e.g. *Trema orientalis, Manihot glazovia, Alchornea laxiflora* (Benth.) Pax & K. Hoffm *e*tc. The transitional dynamics of early- and mid-successional forest to late-successional forest usually brings about the natural tree removal of mid-successional species in 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 vine, grasses as graminoid, and plants of a early forest disturbance as pioneer plants e. g. agricultural weeds.

The forest is located in Nigeria at N07$^{0}$.2645$^{1}$, and E005$^{0}$.03675$^{1}$. Before enrichment plantation was embarked upon, a vast portion of the forest reserve was consistently known to have undergone heavy and series of anthropogenic activities such as timber logging and exploitation in the hands of illegal fellers. However, by 2004 (Figure 2), an adjacent area of the strict nature reserve was designated for the purpose of forest regeneration. The recent studies described the forest climatic condition of this study (Detail; Omomoh 2018, Omomoh et al 2019, and Omomoh et al 2020) in full.

### Data Collection

To establish the species composition of the overstorey vegetation, trees, and shrubs enumeration of the floristic composition of each study plot were enumerated. Identification of the species and their nomenclature followed the flora of tropical West Africa (Hutchinson et al 1963) and Tree of Nigeria (Keay 1989) while the leguminous members (Fabaceae) followed the order of new families of legume phylogeny working group (LPWG) of Azani et al (2017). Samples of plant species whose identification is in doubt were collected, pressed for identification, and taken to FUTA herbarium for proper identification.

### Sampling technique and selection of sample plots

The laying of the plots was carried out using the systematic line transects as shown in figure 3. A 50 m transect was centrally located in the forest where three sampling plots of 50 x 50 m were laid in alternate sides with the aids of the prismatic compass and ranging poles for positioning. The forest biodiversity indices were used to investigate the diversity of trees, shrubs, and other life forms of the study site. Relative density for quantitative and Shannon-Wiener diversity index was used (Kent & Coker. 1992; Guo et al. 2004), the species evenness (Pielou. 1969; Kent & Coker. 1992).

## Results

### Forest trees and species composition structure

Four-eight forest trees were identified from all the three plots of this study area (Table 1). In forest trees, Sterculiaceae, Moraceae, and Fabaceae family (Caesalpinioideae and Detarioideae) are the known dominant families in this forest with 6 to 5 different species members. The Sterculiaceae have the highest members (6) with these 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. Moraceae having 5 members with these following member species, *Antiaris toxicaria* var. *africana* Scott-Elliot ex A. Chev., *Ficus exasperata* Vahl., *Milicia excelsa* (Welw.) C.C. Berg., *Myrianthus arboreus* P. Beauv., and *Trilepisium madagascariense* DC. syn*Bosqueia angolensis* Ficalho., followed by Fabaceae contributing 5 species members viz. *Albizia adianthifolia* (Schum.) W. F. Wight., *Albizia zygia* (DC.) J. F. Macbr. *Anthonotha macrophylla* P. Beauv., *Anthonotha obanensis* (Bak. f.) J. Léonard.., and *Piptadeniastrum africanum* (Hook. f.) Brenan., while the families, Annonaceae and Euphorbiaceae with 4 species members. The only family with intermediate dominant members is Ebenaceae. Other families were found in low dominant members ranging between one to two species (Table 1). Under 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. The total basal area of the tree species was 1.25m$^2$.ha$^{-1}$ with relative density (4) individuals.ha$^{-1}$. The most dominant tree species was *Picralima nitida* (Stapf) Th. & H. Dur (Apocynaceae) which contributed 5.77 important values (IVI) having relative density of 7.95 individuals.ha$^{-1}$ with basal area of 6.525 m$^2$.ha$^{-1}$. Quantitative details of other dominant trees were recorded among the mature tree measured, the species with more high relative density were

*Pterygota macrocarpa* K. Schum., *Buchholzia coriacea*Engl.,*Celtis zenkeri* Engl., *Sterculia rhinopetala* K. Schum., and *Trilepisium madagascariense* DC (Table 1).The diameter class was extremely high only in 11-20 girth among all the diameter class distribution recorded (Fig. 5). The two most dominant tree species in this diameter class distribution were *Buchholzia coriacea*Engl., and *Picralima nitida* (Stapf) Th. & H. Dur. The diameter class decreased from 51-60 cm to 91-100 cm but extremely low at 0-10 cm. The analysis of variance for density of sapling varied and significantly higher than the tree of the forest (one way ANOVA: P <. 0.05 and P= 0.000). However, there is no significant difference in the relative density between the forest tree and sapling (P= 0.341). This confirmed that the forest trees and saplings are dissimilar in species abundance, which however means that sapling density is surviving the tree species composition of the forest. Figure 6 shows the graph of mean ± standard deviation of 2.41±1.55 tree species and 17.55±8.06 of tree sapling obtained in the forest structure (Fig 6). The Shannon-Wiener index (H'), Simpson's index (CD) and Evenness index (e) for the tree species were calculated as 3.59, 0.05 and 0.80, respectively.

## Recruitment status of forest undergrowth

Four-five (45) forest undergrowth species were identified in the forest floor of this study consisting of 6 vines, 3 forbs, and 36 tree saplings (Table 2). One of the most notable differences in this forest undergrowth is the occurrence at which the life forms recruit and regenerate in the forest floor (Fig 4). Our results show that the sudden increase in recruitment level of tree sapling can be linked to natural disappearance or natural removal of early- and mid-successional species to later stages in succession. Our records show a remarkable impact on the regeneration life form owing to a wide increase in sapling occurrence (Fig 4). The different life forms observed in the forest undergrowth, tree sapling show the highest percentage (54%), followed by vines, 26%, mature trees 14%, and forbs 7%. The result from table 2 shows 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 obvallata* and *Culcasia scandens*. According to tree sapling context, Sterculiaceae is the most dominant family contributing the total of 22.9% of its individual members (8) to the recruitment status viz. *Cola acuminata*, *Cola gigantea*, *Cola hispida*, *Mansonia altissima*, *Pterygota macrocarpa*, *Sterculia rhinopetala*, *Sterculia tragacantha* and *Triplochiton scleroxylon*. Other families with intermediate family dominance were Ebenaceae and Moraceae with 11.4 % of total individual members (4). On the contrary, relatively low percentage family dominant were recorded in the remaining families i.e. 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. The population structure of undergrowth reveals the density of individual $ha^{-1}$ (Table 2) of 11 dominant tree sapling found among the undergrowth were 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).

# Discussion

With the growing number of plant and tree species of overstorey and understorey in tropical forest, 17 years of enrichment plantation establishment, has revealed a lot of difference in species recruitment and composition of the successional forest. The findings showed that the tropical forest is known to have the family Sterculiaceae member as major dominant in tree diversity (See detail: 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, aside this, our study confirmed the comparative finding of Sharkar and Devi (2014) in a semi-tropical forest where; Moraceae, Meliaceae, Apocynaceae, Euphorbiaceae, Ebenaceae, and Fabaceae were found to be family major species driver in the restoration status of a tropical semi-evergreen forest of Assam, Northeast India.

Our study further exemplified, 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 except *Anchomanes difformis* the annual undergrowth is their natural regeneration to establish as long-lived understorey in a tropical humid rainforest. In general, when pioneer species of early forest succession (Omomoh et al 2020) decreases i.e. when agricultural weeds of early-successional forest is giving ways to forest tree seedling/sapling, hence an indication of forest transiting to stable forest. It is obvious from our studies that the dense natural regeneration of sapling's increase in this forest type is 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* (Table 2) a forest non-woody creeping prostrate herb usually found in stable forest floor, often around the base of tropical forest tree confirms the forest becoming species-rich in plant diversity. This can be categorized as 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 small diameter tree species pre-dominate the successional forest with individual basal area per hectare falling between the range of 11-30 cm diameter class which nevertheless much more similar to what was also reported in the older natural high forest (Omomoh et al. 2019 and Adekunle et al. 2013). Interestingly, this agreed with what Sokpon & Biaou (2012) described as diameter class category to have continuous recruitment and expanding population that can be called stable or expanding species. Comparative studies (Rocky & Mligo. 2012) from Pugu forest reserves reported diameter size class, 11 to 15 cm (Figure 4), Tanzania. Moreso, in Assam, northeast India, (Sarkar & Devi. 2014) the diameter class in the tropical forest of Hollongapar Gibbon Wildlife Sanctuary, fall within the smaller diameter class and Mamo et al (2012)'s report also show the highest diameter percentage distribution among the smaller DBH class 2-10 cm in Wondo Genet Afromontane forest, Ethiopia which further substantiates the fact that older successional forest may have more individual trees averagely ranging at 5-20 diameter class. However, looking at the result of this study (Figure 5), the floristic composition and forest structure of this forest were consistent except the fewer or no older trees to compete with. Apparently, trees with larger canopy cover may have been selectively removed looking at the species similarity gap between the mature trees and sapling of this study as also reported in the comparative study.

Several dominant tree species which were highly valued timber trees in natural tropical forest (Omomoh et al. 2019) are apparently the natural history (Brudvig et al. 2017) of enrichment plantation during pre-disturbance. 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 effort of enrichment plantation in this forest to restore trees diversity (Bertacchi et al. 2015). This absence of overstorey trees has created light opening and its incursion may have contributed greatly to the increase in seedling regeneration and sapling recruitment (Webb & Sah 2003) than any other life form. The regeneration of an ecosystem depends greatly on the level of vegetation disturbance. An ecosystem with a mild disturbance would regenerate easily at a shorter period of time than heavily disturbed vegetation (Ganlin et al. 2006). The diversity index results obtained from Shannon-Wiener, species richness and species evenness showed (Table 3) that the forest trees are somewhat diverse and more even than the undergrowth species except in species richness where forest undergrowth was higher than the forest trees. This diversity index showed vast dissimilarity between the forest trees and undergrowths and this was likewise reported (Ganlin et al. 2006 & Palmer et al. 2000) where species richness was higher in a low disturbance.

### Recommendation

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 nomads from infringing into susceptible forests to uproot the wildling/seedling (sapling) for commercial garden or forest plantation production at local and international level.

## Declarations

### Acknowledgements

I would like to thank two anonymous resource persons for providing pictures of the forest and for other logistics needed to carry out the fieldwork.

### Ethical approval and consent to participate

Not applicable

### Authors' contribution

BE and VAJ conceived the study area and planned the work. BE prepared the dataset, data analysis and manuscript writing with active participation from VAJ as the head of lab. We read and approved the final manuscript.


### Funding

Nil


### Availability of data and materials

All data are fully provided in this manuscript

### Consent for publication

The authors declare that they have no competing interests

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# Tables

**Table 1: Tree species diversity, relative frequency, volume and diversity index of the Enrichment forest plantation**

| Family | Scientific Name | $Ha^{-1}$ | $Baha^{-1}$ | RD | $RD_0$ | IVI | FVI |
|---|---|---|---|---|---|---|---|
| Guttiferae | *Symphonia globulifera* Linn. f. | 1 | 2.87 | 1.14 | 2.62 | 1.49 | 1.88 |
| Irvingiaceae | *Irvingia wombolu* Vermoesen | 1 | 0.58 | 1.14 | 0.53 | 0.30 | 0.83 |
| Anacardiaceae | *Lannea welwitschii* (Hiern) Engl. | 1 | 2.61 | 1.14 | 2.39 | 1.36 | 1.76 |
| | Annickia chlorantha (Oliv.) Setten & Maa syn *Enantia chlorantha* Oliv | 1 | 0.17 | 1.14 | 0.15 | 0.09 | 0.65 |
| | *Hexalobus crispiflorus* A. Rich. | 1 | 0.31 | 1.14 | 0.28 | 0.16 | 0.71 |
| Annonaceae | *Monodora myristica* (Gaertn.) Dunal | 1 | 1.44 | 1.14 | 1.32 | 0.75 | 1.23 |
| | *Monodora tenuifolia* Benth. | 1 | 0.13 | 1.14 | 0.12 | 0.07 | 0.63 |
| Apocynaceae | *Funtumia elastica* (Preuss) Stapf | 3 | 2.04 | 3.41 | 1.86 | 3.17 | 2.63 |
| | *Picralima nitida* (Stapf) Th. & H. Dur. | 7 | 1.59 | 7.95 | 1.45 | 5.77 | 4.70 |
| Bombacaceae | *Ceiba pentandra* (Linn.) Gaertn. | 1 | 0.27 | 1.14 | 0.25 | 0.14 | 0.69 |
| Boraginaceae | *Cordia millenii* Bak. | 1 | 6.77 | 1.14 | 6.18 | 3.51 | 3.66 |
| Burseraceae | *Canarium schweinfurthii* Engl. | 2 | 0.85 | 2.27 | 0.78 | 0.89 | 1.53 |
| Caesalpinioideae | *Albizia adianthifolia* (Schum.) W. F. Wight | 2 | 1.98 | 2.27 | 1.80 | 2.05 | 2.04 |
| | *Albizia zygia* (DC.) J. F. Macbr. | 1 | 0.84 | 1.14 | 0.77 | 0.44 | 0.95 |
| | *Piptadeniastrum africanum* (Hook. f.) Brenan | 1 | 0.24 | 1.14 | 0.22 | 0.13 | 0.68 |
| Capparidaceae | *Buchholzia coriacea* Engl. | 5 | 0.66 | 5.68 | 0.61 | 1.72 | 3.14 |
| Detarioideae | *Anthonotha macrophylla* P. Beauv. | 2 | 0.72 | 2.27 | 0.65 | 0.74 | 1.46 |
| | *Anthonotha obanensis* (Bak. f.) J. Léonard | 1 | 0.18 | 1.14 | 0.16 | 0.09 | 0.65 |
| Ebenaceae | *Diospyros barteri* Hiern | 2 | 0.28 | 2.27 | 0.26 | 0.29 | 1.27 |
| | *Diospyros dendo* Welw. ex Hiern | 1 | 0.71 | 1.14 | 0.65 | 0.37 | 0.89 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Diospyros monbuttensis* Gürke | 1 | 0.26 | 1.14 | 0.24 | 0.14 | 0.69 |
| Euphorbiaceae | *Antidesma laciniatum* Müll. Arg. var. laciniatum | 2 | 0.82 | 2.27 | 0.75 | 0.85 | 1.51 |
| | *Bridelia micrantha* (Hochst.) Baill. | 1 | 0.65 | 1.14 | 0.60 | 0.34 | 0.87 |
| | *Croton penduliflorus* Hutch. | 1 | 2.58 | 1.14 | 2.36 | 1.34 | 1.75 |
| | *Ricinodendron heudelotii* (Baill.) Pierre ex Pax | 1 | 12.0 | 1.14 | 10.96 | 6.23 | 6.05 |
| Lecythidaceae | *Napoleona imperialis* P. Beauv. | 1 | 0.14 | 1.14 | 0.12 | 0.07 | 0.63 |
| Meliaceae | *Entandrophragma angolense* (Welw.) C. DC. | 1 | 6.73 | 1.14 | 6.15 | 3.49 | 3.64 |
| | *Entandrophragma utile* (Dawe & Sprague) Sprague | 2 | 1.34 | 2.27 | 1.23 | 1.39 | 1.75 |
| Moraceae | *Antiaris toxicaria* var. *africana* Scott-Elliot ex A. Chev. | 2 | 1.78 | 2.27 | 1.62 | 1.84 | 1.95 |
| | *Ficus exasperata* Vahl | 1 | 1.90 | 1.14 | 1.74 | 0.99 | 1.44 |
| | *Milicia excelsa* (Welw.) C.C. Berg | 1 | 0.36 | 1.14 | 0.33 | 0.19 | 0.73 |
| | *Myrianthus arboreus* P. Beauv. | 2 | 0.45 | 2.27 | 0.41 | 0.46 | 1.34 |
| | *Trilepisium madagascariense* DC. syn *Bosqueia angolensis* Ficalho | 4 | 14.4 | 4.55 | 13.13 | 29.84 | 8.84 |
| Rubiaceae | *Rothmannia whitfieldii* (Lindl.) Dandy | 1 | 0.14 | 1.14 | 0.13 | 0.07 | 0.63 |
| Rutaceae | *Zanthoxylum rubescens* Planch. ex Hook. f. | 1 | 1.94 | 1.14 | 1.77 | 1.01 | 1.45 |
| Sapotaceae | *Chrysophyllum albidum* G. Don | 1 | 2.74 | 1.14 | 2.50 | 1.42 | 1.82 |
| | *Pachystela brevipes*. P. syn *Synsepalum brevipes* (Baker) T. D. Pennington | 1 | 0.80 | 1.14 | 0.73 | 0.41 | 0.93 |
| Sterculiaceae | *Cola gigantea* A. Chev. var. *Gigantea* | 3 | 8.81 | 3.41 | 8.04 | 13.71 | 5.73 |
| | *Cola millenii* K. Schum. | 2 | 0.60 | 2.27 | 0.55 | 0.63 | 1.41 |
| | *Mansonia altissima* (A. Chev.) A. Chev. var. *altissima* | 3 | 2.57 | 3.41 | 2.35 | 4.00 | 2.88 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Pterygota macrocarpa* K. Schum. | 6 | 6.23 | 6.82 | 5.69 | 19.41 | 6.26 |
| | *Sterculia rhinopetala* K. Schum. | 4 | 4.41 | 4.55 | 4.03 | 9.15 | 4.29 |
| | *Sterculia tragacantha* Lindl. | 2 | 4.21 | 2.27 | 3.85 | 4.37 | 3.06 |
| | *Triplochiton scleroxylon* K. Schum. | 2 | 4.82 | 2.27 | 4.40 | 5.00 | 3.34 |
| Tiliaceae | *Glyphaea brevis* (Spreng.) Monachino | 1 | 0.25 | 1.14 | 0.22 | 0.13 | 0.68 |
| Ulmaceae | *Celtis philippensis* Blanco syn *Celtis brownii* Rendle | 1 | 0.40 | 1.14 | 0.36 | 0.21 | 0.75 |
| | *Celtis zenkeri* Engl. | 4 | 2.94 | 4.55 | 2.68 | 6.09 | 3.61 |

**Table 2: Summary of floristic Composition of undergrowths Enrichment Plantation**

| Family | Name | Life form | $Ha^{-1}$ | RD |
|---|---|---|---|---|
| Annonaceae | *Annickia chlorantha* (Oliv.) Setten & Maa Syn *Enantia chlorantha* Oliv | Sapling | 3 | 0.540 |
| | *Hexalobus crispiflorus* A. Rich. | Sapling | 5 | 0.899 |
| | *Monodora myristica* (Gaertn.) Dunal | Sapling | 7 | 1.259 |
| Apocynaceae | *Funtumia elastica* (Preuss) Stapf | Sapling | 28 | 5.036 |
| | *Picralima nitida* (Stapf) Th. & H. Dur. | Sapling | 11 | 1.978 |
| Araceae | *Anchomanes difformis* var. *difformis* Hepper | Herb | 9 | 1.619 |
| | *Culcasia scandens* P. Beauv. | Climber | 104 | 18.71 |
| | Cyrtosperma senegalense (Schott) Engl. | Herb | 18 | 3.237 |
| | *Rhaphidophora africana* N. E. Br | Climber | 11 | 1.978 |
| Bombacaceae | *Ceiba pentandra* (Linn.) Gaertn. | Sapling | 7 | 1.259 |
| Boraginaceae | *Cordia millenii* Bak. | Sapling | 1 | 0.18 |
| Burseraceae | *Canarium schweinfurthii* Engl. | Sapling | 4 | 0.719 |
| Combretaceae | *Terminalia ivorensis* A. Chev. | Sapling | 2 | 0.36 |
| Deteriodeae | *Anthonotha macrophylla* P. Beauv. | Sapling | 16 | 2.878 |
| Dilleniaceae | *Tetracera potatoria* Afzel. ex G. Don | Climber | 13 | 2.338 |
| Ebenaceae | *Diospyros dendo* Welw. ex Hiern | Sapling | 14 | 2.518 |
| | Diospyros mespiliformis Hochst. ex A. DC. | Sapling | 1 | 0.18 |
| | *Diospyros monbuttensis* Gürke | Sapling | 2 | 0.36 |
| | *Diospyros suaveolens* Gürke | Sapling | 7 | 1.259 |
| Euphorbiaceae | *Ricinodendron heudelotii* (Baill.) Pierre ex Pax | Sapling | 18 | 3.237 |
| Icacinaceae | *Pyrenacantha staudtii* (Engl.) Engl. | Climber | 11 | 1.978 |
| Meliaceae | *Entandrophragma utile* (Dawe & Sprague) Sprague | Sapling | 18 | 3.237 |
| | *Khaya grandifoliola* C. DC. | Sapling | 3 | 0.54 |
| Moraceae | *Ficus exasperata* Vahl | Sapling | 2 | 0.36 |
| | *Milicia excelsa* (Welw.) C.C. Berg | Sapling | 10 | 1.799 |
| | *Myrianthus arboreus* P. Beauv. | Sapling | 13 | 2.338 |
| | *Trilepisium madagascariense* DC. | Sapling | 28 | 5.036 |

| | | | | |
|---|---|---|---|---|
| Piperaceae | *Piper capense* Linn. F | Climber | 9 | 1.619 |
| | *Piper guineense* Schum. & Thonn. | Climber | 23 | 4.137 |
| Rubiaceae | Geophila obvallata (Schumach.) F. Didr. | Herb | 17 | 3.058 |
| Rutaceae | *Zanthoxylum rubescens* Planch. ex Hook. f. | Sapling | 4 | 0.719 |
| Sapindaceae | *Lecaniodiscus cupanioides* Planch. ex Benth. | Sapling | 14 | 2.518 |
| Sapotaceae | *Chrysophyllum albidum* G. Don | Sapling | 3 | 0.54 |
| | *Chrysophyllum perpulchrum* Mildbr. ex Hutch. & Dalz. | Sapling | 8 | 1.439 |
| Sterculiaceae | *Cola acuminata* (P. Beauv.) Schott & Endl. | Sapling | 4 | 0.719 |
| | *Cola gigantea* var. *glabrescens* Brenan & Keay | Sapling | 16 | 2.878 |
| | *Cola hispida* Brenan & Keay | Sapling | 11 | 1.978 |
| | *Mansonia altissima* (A. Chev.) A. Chev. var. altissima | Sapling | 17 | 3.058 |
| | *Pterygota macrocarpa* K. Schum. | Sapling | 5 | 0.899 |
| | *Sterculia rhinopetala* K. Schum. | Sapling | 7 | 1.259 |
| | *Sterculia tragacantha* Lindl. | Sapling | 24 | 4.317 |
| | *Triplochiton scleroxylon* K. Schum. | Sapling | 7 | 1.259 |
| Ulmaceae | *Celtis mildbraedii* Engl. | Sapling | 4 | 0.719 |
| | *Celtis philippensis* Blanco | Sapling | 9 | 1.619 |
| | *Celtis zenkeri* Engl. | Sapling | 28 | 5.036 |
| | | | 576 | |

**Table 3 Summary of the results of various diversity indices conducted**

| Population Structure | Shannon-Wiener ($H^{-1}$) | Species richness (M) | Species evenness (E) |
|---|---|---|---|
| Forest trees | 3.59 | 19.6 | 0.80 |
| Forest undergrowths | 3.45 | 90.5 | 0.55 |

# Figures

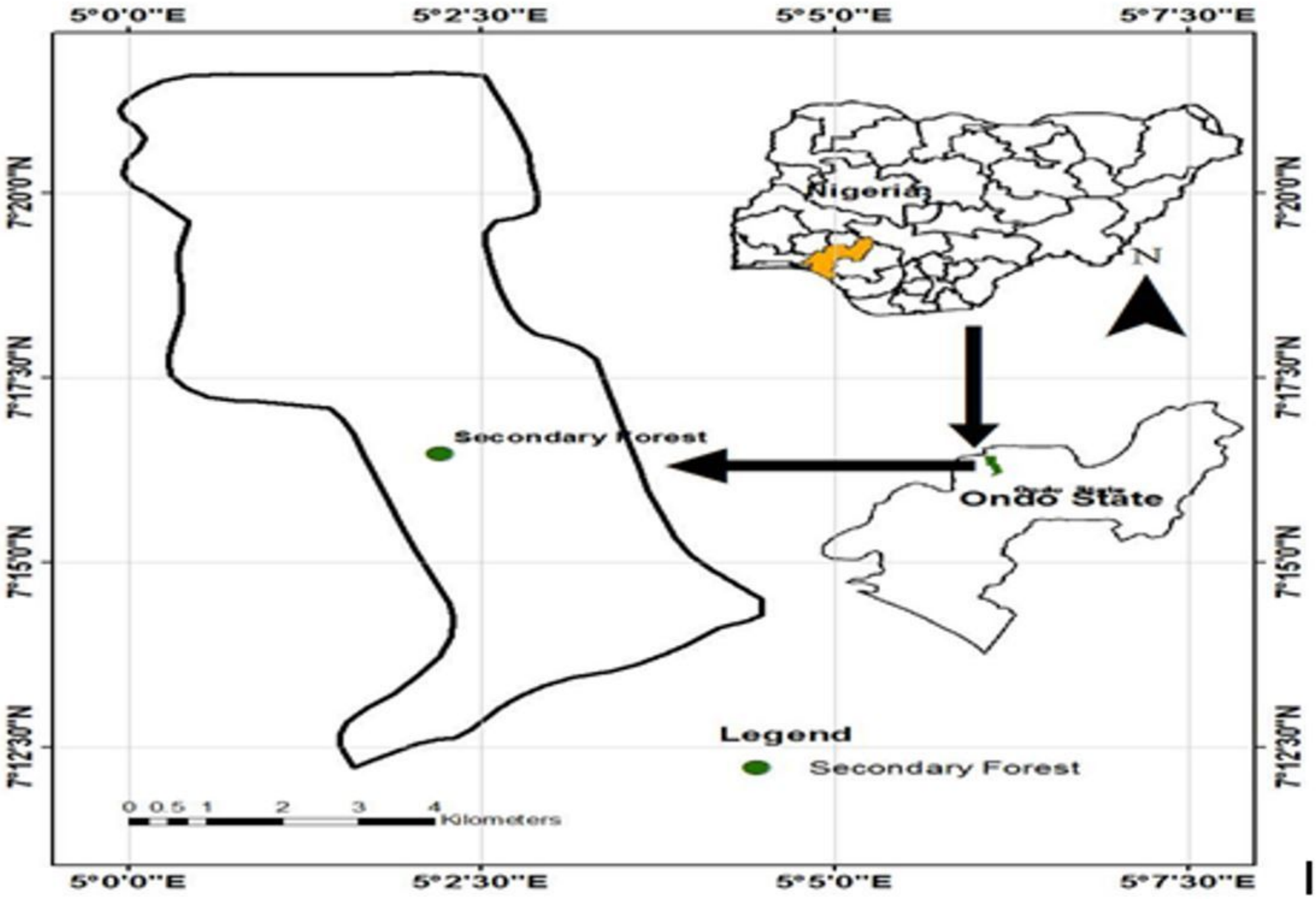



Figure 1

Map showing the location of Akure forest reserve enrichment plantation. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.


**Figure 2**

Enrichment plantation

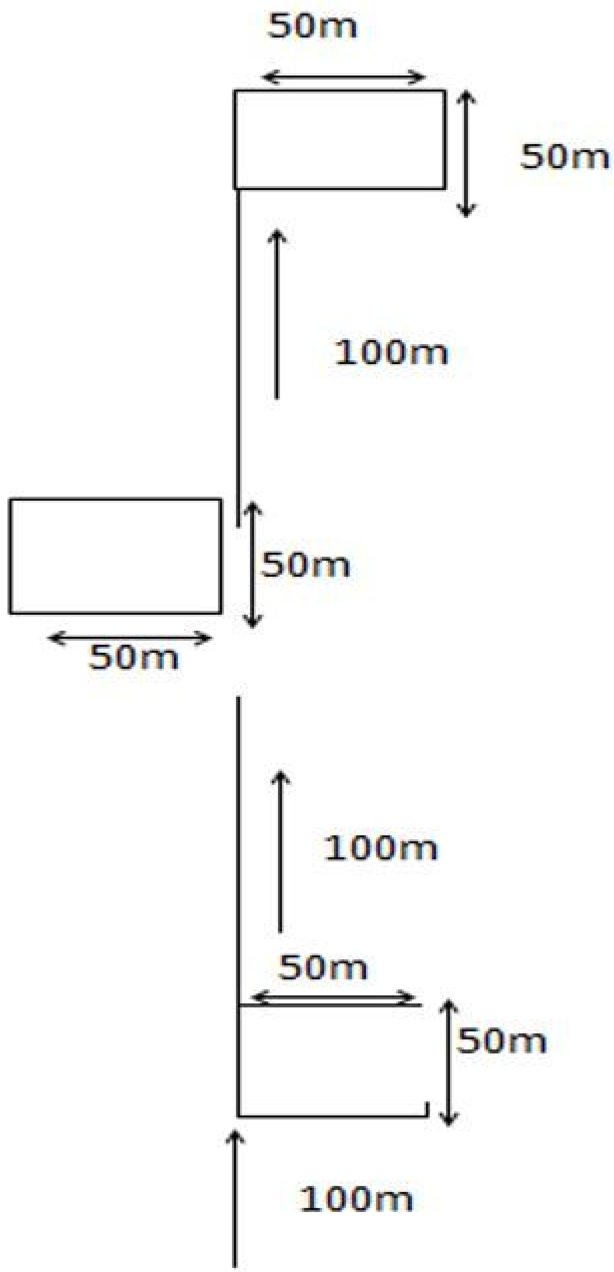



**Figure 3**

Systematic line transects sampling technique for plot layout of each study sites.

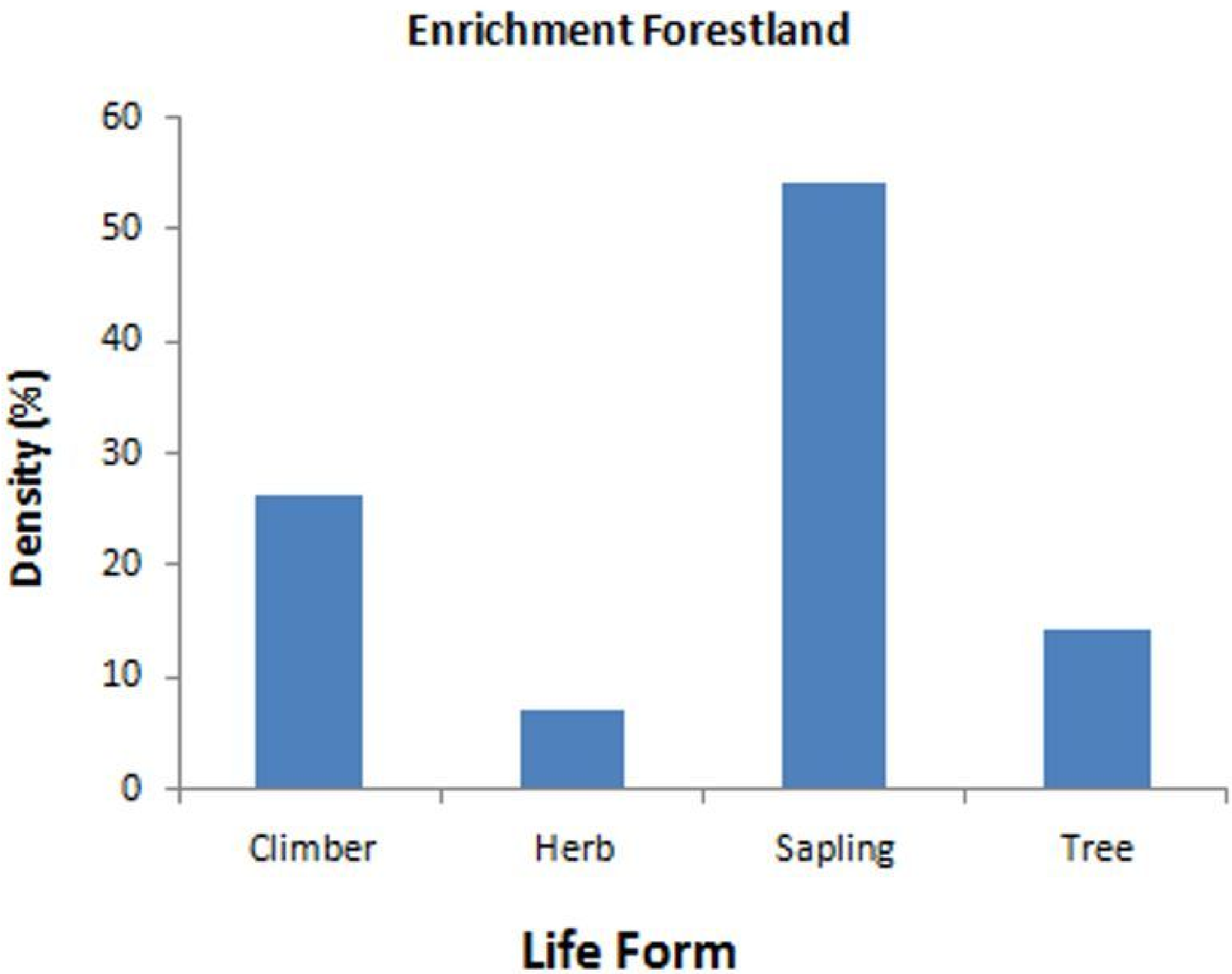
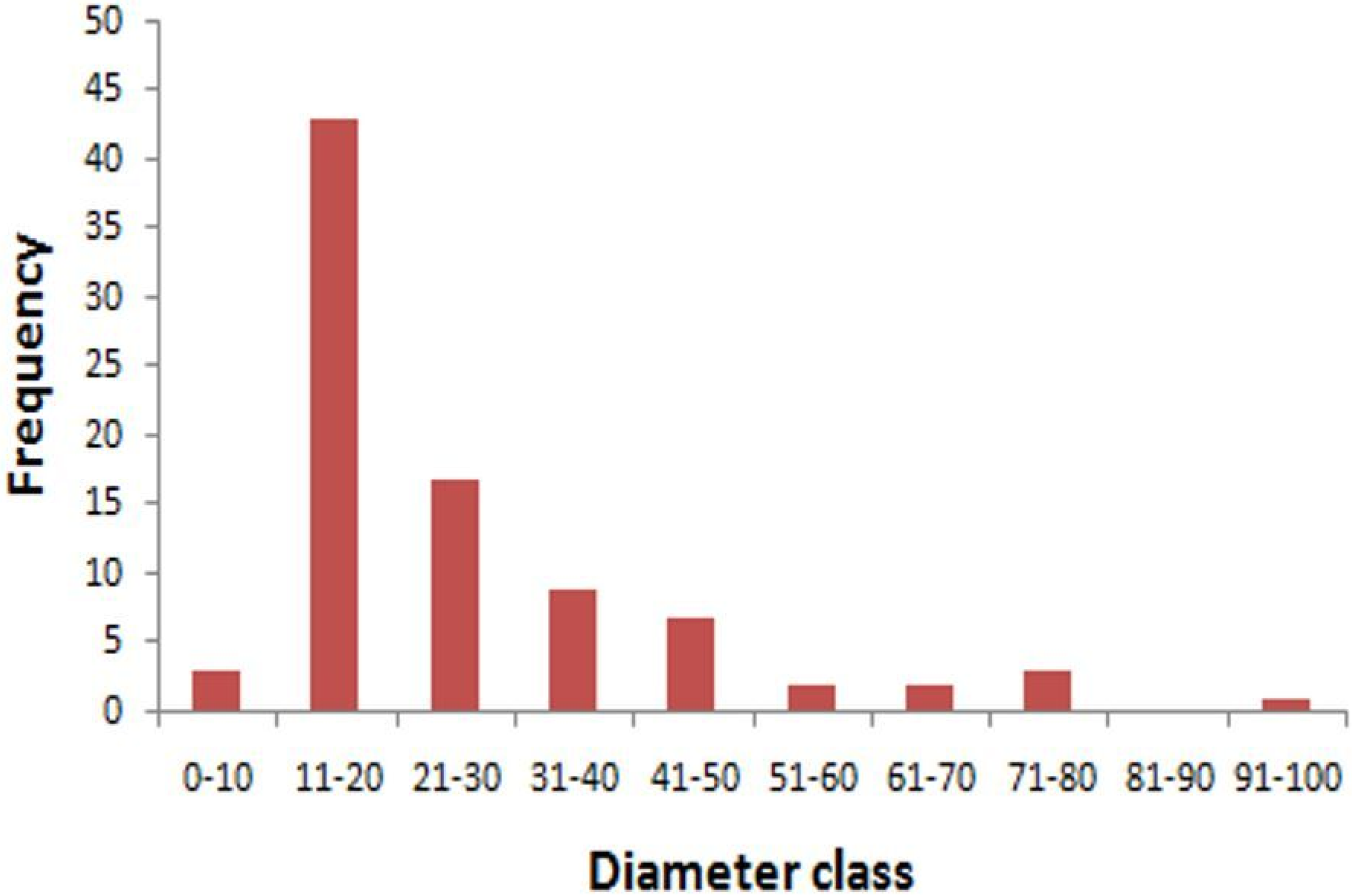



**Figure 4**

Showing the different undergrowths of enrichment forestland.




### Figure 5

Diameter classes distribution of mature woody species.