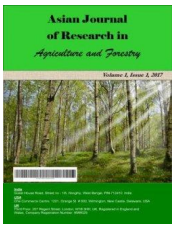

*Asian Journal of Research in Agriculture and Forestry*

*2(1): 1-12, 2018; Article no.AJRAF.42848*

# Tree Species Diversity and Structure of Eda Forest Reserve, Ekiti State, Nigeria

**S. O. Olajuyigbe[1] and M. S. Jeminiwa[2*]**

*[1]Department of Forest Production and Products, University of Ibadan, Oyo State, Nigeria.*
*[2]Southern Guinea Savanna Research Station, Forestry Research Institute of Nigeria, P.O.Box 209, Mokwa, Niger State, Nigeria.*

***Authors' contributions***

*The work was carried out in collaboration between both authors. Author SOO designed the study, performed the statistical analysis and wrote the protocol. Author MSJ wrote the first draft of the manuscript, managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AJRAF/2018/42848
Editor(s):
(1) Dr. Md. Abiar Rahman, Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman- Agricultural University (BSMRAU), Bangladesh.
Reviewers:
(1) Faridah-Hanum Ibrahim, Universiti Putra Malaysia, Malaysia.
(2) Elly Josephat Ligate, Fujian Agriculture and Forestry University, P.R. China.
Complete Peer review History: http://www.sciencedomain.org/review-history/26279

***Original Research Article***

***Received 21 June 2018***
***Accepted 11 September 2018***
***Published 19 September 2018***

## ABSTRACT

Tropical rainforest is continuously threatened by timber exploitation and conversion to other land uses. In this study, tree species diversity and forest structure of Eda Forest Reserve in Ekiti State, Nigeria, were assessed using systematic line transect and purposive sampling techniques for plot demarcation and data collection. Two transects (2000m long) were laid in secondary forest and encroached farmland in the reserve, while the primary forest fragments were sampled purposively. Twenty sample plots (20m×20m) were laid out on each of the vegetation types. All trees >10cm diameter at breast height (dbh) were identified to species level and enumerated for total height and dbh. Data were analyzed using descriptive statistics such as tables, charts, frequency, percentages and diversity index analysis using paleontological statistics software (PAST 2.14). There were 60 species from 22 families, with Sterculiaceae, Caesalpiniaceae and Moraceae being the most abundant families. Individual tree populations were 380 trees/ha, 280 trees/ha and 137 trees/ha in the primary forest, secondary forest and encroached farmland, respectively. Species composition comprised 39, 38 and 19 species in primary forest, secondary forest and encroached farmland,

**Corresponding author: E-mail: jeminiwaoluremi@yahoo.com, Jeminiwaoluremi@gmail.com;*

respectively. *Khaya ivorensis* had the highest relative density in the three vegetation types (19.74%, 24.53% and 27.74%) respectively, while *Ceiba pentandra* had the highest height (53.87m). The mean basal area ranged from 0.36$m^2$/ha (encroach farmland) to 3.18$m^2$/ha (primary forest). Shannon-Wiener Indices were 3.22, 3.14 and 2.51 for the primary forest, secondary forest and encroached farmland, respectively. Eda forest reserve is a heterogeneous ecosystem that had variations in tree population due to anthropogenic activities. The secondary forest and encroached farmland have great potential for recovery if conservation efforts are put in place.

*Keywords: Eda forest reserve; tree species diversity; forest structure; alpha diversity; beta diversity.*

## 1. INTRODUCTION

Approximately, one-third of the earth's land area is covered with forests and nearly 50% of this ecosystem is found in the tropical environments of the world [1]. These rainforests are complex ecosystems mostly dominated by diverse tree species of various sizes. The tropical rainforests also contain a high level of diversity of other flora and fauna which provide a wide variety of food, fodder, fibre and raw materials for people living in and around the forests. They help maintain biological diversity, ameliorate microclimates, influence hydrological processes and nutrient cycling; support soil conservation, as well as improve air and water quality, while serving as habitats for wildlife [1,2]. In Nigeria, 20-25 % of the rainforest zone had been placed under reservation since the late 1920s and '30s. Over the years, the forest reservations have protected natural ecosystems, conserved biodiversity, preserved ecological processes, enhanced scientific research and education, while maintaining genetic resources of flora and fauna [3,4]. However, increased anthropogenic activities in the primary forests of the reserves have resulted in serious deforestation and degradation. Consequently, timber harvesting, forestland encroachment for farming, and the establishment of tree crop plantations are threatening the continued existence of most rainforests [5,4]. The situation is further compounded by the paucity of information on tree species composition and diversity in most of these in–situ conservation areas.

Eda forest reserve is one of the 10 forest reserves in Ekiti state, Nigeria. It is endowed with an array of renewable natural resources that have been subjected to high levels of exploitation through legal and illegal means [6]. A section of the forest reserve had been converted to farmland, exotic and indigenous tree species plantations, while 57.7% is still covered by primary and secondary forests [7]. However, there is limited information on the tree species composition of the remaining primary forest as well as the recovering secondary forest in this forest reserve. Therefore, this study assessed the tree species diversity and forest structure of the encroached farmland, secondary and primary forest areas in Eda forest reserve, Ekiti State, Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Eda forest reserve was gazetted in 1941 (gazette number 37) with the objective of actualizing biological diversity conservation and environmental protection. This tropical humid forest is a high forest located along latitude 7°41'3"N and 7°47'5"N and longitude 5°'36'1"E and 5°37'6"E, at an altitude ranging from 497 to 560 m above sea level (Fig. 1). The reserve is bordered by four towns: Orin/Ara Ekiti (North), Eda-Ile Ekiti (West), Omuo Ekiti (East) and Isinbode Ekiti (South). This 906 ha forest reserve is divided, administratively, into two parts: the 318ha plantation compartment (Eda I), and the 508ha natural forest (Eda II). The natural forest had been initially protected from exploitation but has recently been encroached by subsistence farmers and timber harvesters. The natural forest was highly stocked with many economic tree species and this is evidenced by the level of exploitation that had taken place, resulting in secondary forest regrowth [8]. The forest reserve has an undulating terrain, which is gently sloped in Northeast direction and as ultisol and oxisol soil types. The bedrock material is underlain with basement complex and contains undifferentiated igneous rocks, laterites and white sand. The reserve experiences two seasons with the wet season occurring from April to October while the dry season occurs from November to March. Hence, the average annual temperature ranges from 21°C - 28°C, average precipitation is 1800 mm, while the relative humidity ranges from 56% and 85%. The fragmented primary forest is dense with tree species forming continuous

multilayered canopies, while the lower canopies contain climbers, shrubs and herbaceous plant [7,6].

## 2.2 Sampling Technique and Data Collection

Systematic line transect technique was used to lay sample plots in secondary forest and encroached farmlands, while purposive sampling was used to lay plots in the primary forest, following the method of Duran et al. [9]. Thus, two transects (2,000 m long and 1m wide) were laid in each of the secondary forest and encroached farmland. While, the fragmented nature of the primary forest, resulted in the use of purposive sampling technique for selection of plots. Twenty sample plots (20 m×20 m) were laid in alternate positions along each transect at an interval of 200 m (Fig. 2), while the same number of plots were purposively selected and evaluated in the primary forests. All woody plants with diameter at breast height (dbh) > 10 cm were identified and their total height and dbh measured following the method of Adekunle et al. [10].

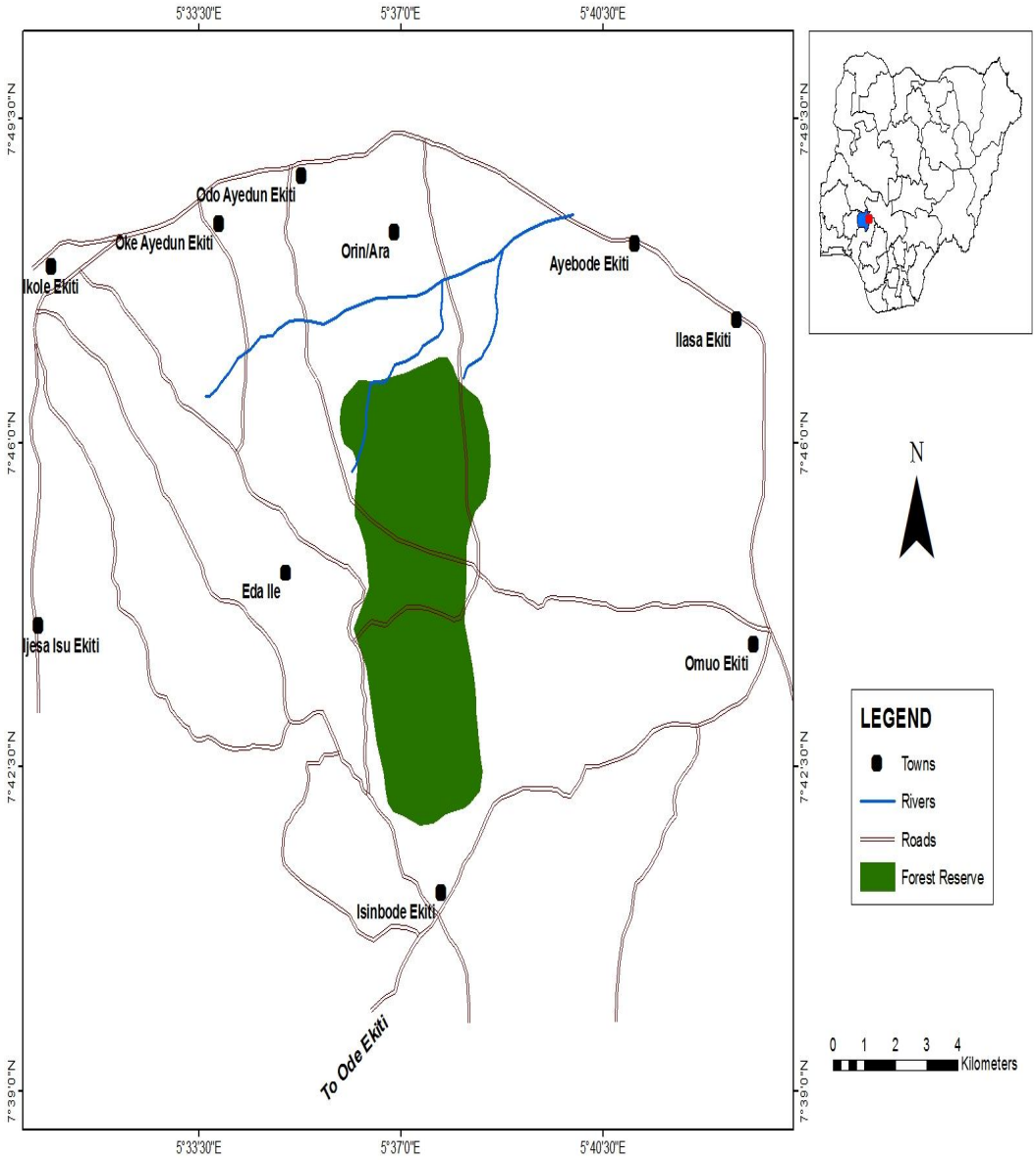


**Fig. 1. Map of Eda forest reserve in Ekiti state, Nigeria**

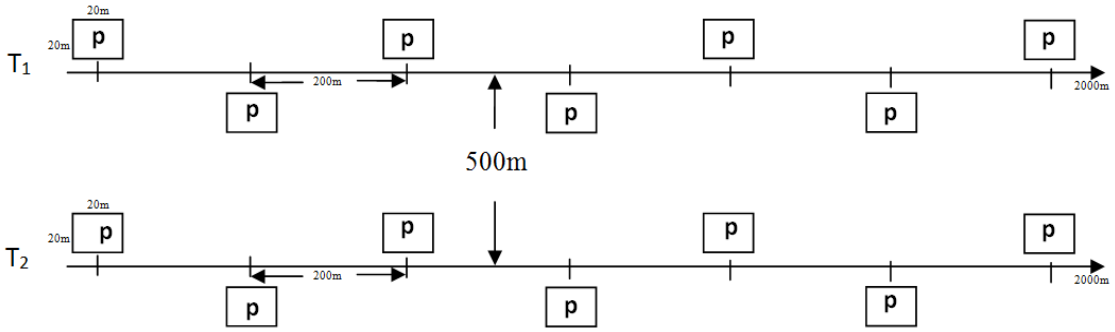


**Fig. 2. Sampling procedure for identification and enumeration in the study area**
*Where: T = Transects, p = Sample plot*

## 2.3 Data Analysis

### 2.3.1 Tree basal area and volume estimation

The basal area (BA $m^2$) of trees was calculated using Eqn. 1:

$$BA = \frac{\pi D^2}{4} \quad (1)$$

Where D = Diameter at breast height (m)

The total basal area for trees in each sample plot was obtained and used to determine the per hectare equivalents.

The volume of individual trees was estimated using the Eqn. 2:

$$V = BAHf \quad (2)$$

Where V = Volume of tree ($m^3$), H = Total Height of tree (m) and $f$ = Form factor. Total plot volumes were obtained by adding the volume of individual trees encountered in each plot and then mean plot volume was calculated. This was also scaled up to per hectare basis.

### 2.3.2 Tree species classification and diversity indices

All trees were identified insitu by an experienced forest taxonomist where possible and samples were compared with voucher specimens in Forest Herbarium Ibadan (FHI), Forestry Research Institute of Nigeria. Tree species were classified into taxonomic families and number of individuals in each family was used for species diversity classification. The frequency of occurrence was used to determine tree species abundance/richness. The diversity indices were determined using paleontological statistics software (PAST 2.14) [11] and some of them were listed as follows:

(i.) Shannon-Wiener diversity index ($H^I$): This determines both the richness and abundance of each tree species in the vegetation types using Eqn. 3 [12]:

$$H^I = \sum_{i=1}^{S} p_i \, Lnp_i \quad (3)$$

Where S = Number of tree species in each vegetation type; $p_i$ = proportion of each tree species to the total number of trees in each vegetation type; Ln = the natural logarithm.

(ii.) Relative Density (RD): This determines the number of individual per hectare in the forest types using Eqn. 4 [10]:

$$RD = \frac{n_i}{N} \, x \, 100\% \quad (4)$$

Where $n_i$ = number of individuals of each tree species i and N = total number of individuals in the entire tree population

(iii.) Relative Dominance ($RD_o$): This determines the level of abundance of individual species over other species in the forest types using Eqn. 5 [10]:

$$RD_o = \frac{(BA_i \, x \, 100\%)}{\sum BA_n} \quad (5)$$

Where $BA_i$ = Basal Area of individual trees belonging to a particular species i and $BA_n$= Total Basal Area.

(iv.) Margalef's index of species richness (M) was determined using Eqn. 6 [13]:

$$M = \frac{(S-1)}{LnN} \quad (6)$$

## 3. RESULTS AND DISCUSSION

### 3.1 Results

#### 3.1.1 Tree species composition and distribution in Eda forest reserve

A total of 60 tree species were encountered during the study and 41 of them were absent in encroached farmland. The primary forest had the highest number of tree species (39), followed by the secondary forest (38) while encroached farmland had the least (19). There were 380 trees/ha in the primary forest while secondary forest and encroached farmlands had 280 trees/ha and 137 trees/ha, respectively (Table 1). *Khaya ivorensis* had the highest number of trees in each vegetation type with 75, 65 and 38 trees/ha in the primary forest, secondary forest and encroached farmland respectively. Similarly, *Milicia excelsa*, *Sterculia rhinopetala* and *Triplochiton scleroxylon* had high representations in all vegetation types (Table 1).

**Table 1. Tree species composition and distribution in Eda Forest Reserve**

| S/N | Species | Family | Primary forest (No./ha) | Secondary forest (No./ha) | Encroached farmland (No./ha) |
|---|---|---|---|---|---|
| 1 | *Afzelia bipindensis* Harms | Caesalpiniaceae | --- | 3 | --- |
| 2 | *Albizia adianthifolia* (Schumach) W. Wight | Mimosaceae | 5 | 3 | 3 |
| 3 | *Alstonia congensis* Engl. | Apocynaceae | 10 | --- | --- |
| 4 | *Alstonia boonei* De Wild. | Apocynaceae | --- | 8 | 3 |
| 5 | *Aningeria robusta* (A. Chev.) Aubrev.& Pellegr | Sapotaceae | 5 | --- | 5 |
| 6 | *Antiaris toxicaria* Lesch. | Moraceae | 10 | 10 | 8 |
| 7 | *Blighia sapida* K. Konig. | Sapindaceae | --- | 13 | 15 |
| 8 | *Bombax buonopozense* P. Beauv. | Bombacaceae | 15 | --- | 3 |
| 9 | *Brachystegia eurycoma* Harms | Caesalpiniaceae | 5 | --- | --- |
| 10 | *Brachystegia kennedyi* Hoyle | Caesalpiniaceae | --- | --- | 3 |
| 11 | *Bridelia atroviridi* Wild. | Euphorbiaceae | --- | 3 | --- |
| 12 | *Ceiba pentandra* (L.) Gaertn. | Bombacaceae | 15 | 8 | 5 |
| 13 | *Celtis zenkeri* Engl. | Ulmaceae | 10 | 8 | 3 |
| 14 | *Chrysophyllum albidum* Linn. | Sapotaceae | 5 | 8 | --- |
| 15 | *Cola gigantea* A. Chev. | Sterculiaceae | --- | 3 | --- |
| 16 | *Cordea millenii* Baker | Bignoniaceae | 5 | --- | --- |
| 17 | *Cynometra megalophylla* Harms | Caesalpiniaceae | 10 | --- | --- |
| 18 | *Dialium guineense* Willd | Caesalpiniaceae | 5 | 3 | --- |
| 19 | *Daniella ogea* (Harms) Rolfe ex. Holland | Caesalpiniaceae | 5 | --- | --- |
| 20 | *Diospyros mespiliformis* Hoshst. | Ebenaceae | 5 | --- | 3 |
| 21 | *Distemona bentamianus* Baill. | Caesalpiniaceae | 5 | --- | --- |
| 22 | *Enantia chlorantha* Oliv. | Annonaceae | --- | 3 | --- |
| 23 | *Entandrophragma angolensis* (Welw.) C. DC. | Meliaceae | --- | 5 | 3 |
| 24 | *Etandrophragma cylindricum* Sprague | Meliaceae | --- | 5 | --- |
| 25 | *Erythrophylum suaveolens* (Guill. & Perr.) Brenan | Caesalpiniaceae | --- | 3 | --- |
| 26 | *Ficus exasperata* Vahl | Moraceae | --- | 8 | --- |
| 27 | *Ficus mucuso* Welw. Ex. Ficalho | Moraceae | 5 | --- | --- |
| 28 | *Funtumia elastica* (Preuss) Stapf. | Apocynaceae | 5 | 3 | --- |
| 29 | *Gossweilodendron balsamiferum* J. | Caesalpiniaceae | --- | 3 | --- |
| 30 | *Hildergardia barteri* (Mast) Kosterm. | Sterculiaceae | 5 | --- | --- |
| 31 | *Hollarrhena floribunda* (G. Don) Dur & Schinz | Apocynaceae | --- | 8 | --- |
| 32 | *Khaya ivorensis* A. Chev. | Meliaceae | 75 | 65 | 38 |
| 33 | *Kigelia africana* (Lam) Benth | Bignoniaceae | 5 | 3 | --- |
| 34 | *Lophira alata* Banks ex. | Ochnaceae | 10 | --- | --- |
| 35 | *Lovoa trichilioides* Harms | Meliaceae | --- | 3 | --- |

| S/N | Species | Family | Primary forest (No./ha) | Secondary forest (No./ha) | Encroached farmland (No./ha) |
|---|---|---|---|---|---|
| 36 | *Mansonia altissima* A. Chev | Sterculiaceae | 5 | 3 | --- |
| 37 | *Milicia excelsa* (Welw.) C.C. Berg. | Moraceae | 25 | 15 | 15 |
| 38 | *Milletia aboensis* (Hook. F.) Baker | Papilionaceae | 5 | --- | --- |
| 39 | *Mitragyna ciliate* Aubrev & Pellegr. | Rubiaceae | --- | 3 | --- |
| 40 | *Monodora myristica* (Gaertn) Dunal | Annonaceae | --- | --- | 3 |
| 41 | *Musanga cecropioides* R. Br. | Moraceae | 5 | 8 | --- |
| 42 | *Nesogordonia papaverifera* (A. Chev.) R. Capuron | Sterculiaceae | 5 | 3 | --- |
| 43 | *Newbouldia laevis* (P. Beauv.) Seem | Bignoniaceae | --- | 3 | --- |
| 44 | *Parinari excelsa* Sabine | Chrysobalanaceae | 5 | --- | --- |
| 45 | *Pentaclethra macrophyla* Benth | Mimosaceae | --- | 3 | --- |
| 46 | *Piptadeniastrum africanum* (Hook F.) Brenan | Mimosaceae | 5 | --- | --- |
| 47 | *Pterocarpus erinaceus* Poir | Papilionaceae | --- | 3 | --- |
| 48 | *Pterygota macrocarpa* K. Schum | Sterculiaceae | 5 | --- | --- |
| 49 | *Pycnantus angolensis* (Welw) Warb. | Myristicaceae | --- | 3 | 3 |
| 50 | *Ricinodendron heudelotii* (Baill) Pierre | Euphorbiaceae | 5 | 8 | --- |
| 51 | *Sterculia rhinopetala* K. Schum | Sterculiaceae | 45 | 25 | 5 |
| 52 | *Sterculia tragacantha* Lindi | Sterculiaceae | 5 | --- | --- |
| 53 | *Strombosia pustulata* Oliv. | Olacaceae | 5 | --- | --- |
| 54 | *Terminalia ivorensis* A. Chev. | Combretaceae | 5 | 5 | 3 |
| 55 | *Terminalia superba* Engl. & Diels | Combretaceae | 10 | --- | --- |
| 56 | *Pterocarpus osun* Craib. | Papilionaceae | 5 | 3 | 3 |
| 57 | *Tetrapleura tetraptera* Taub. | Mimosaceae | 5 | --- | --- |
| 58 | *Triplochiton scleroxylon* K. Schum. | Sterculiaceae | 10 | 10 | 13 |
| 59 | *Xylopia aethiopica* (Dunal) A. Rich | Annonaceae | --- | 3 | --- |
| 60 | *Zanthoxylum zanthoxyloides* (Lam) Zepern | Rutaceae | 5 | 3 | --- |
| | Total | | 380 | 280 | 137 |

### 3.1.2 Family distribution of trees in Eda forest reserve

There were 22 families represented by tree species enumerated in Eda forest reserve (Table 2). Sterculiaceae family (53 trees/ha) had the highest population, followed by Caesalpiniaceae family with 38 trees/ha, while Sapindaceae family had the least of 3 trees/ha. The species from Chrysobalanaceae and Rutaceae families were found only in the primary forest. However, tree species from the Annonaceae, Myristicaceae, Rubiaceae and Sapindaceae families were absent in the primary forest.

### 3.1.3 Relative abundance and diversity indices of tree species in the primary forest of Eda forest reserve

*Khaya ivorensis* had the highest relative density (19.74%), relative dominance (2.42%) and Species Importance Value Index (IVI) (22.16%) in the primary forest (Table 3). This was followed by *Sterculia rhinopetala* with a relative density of 11.84%, relative dominance of 2.30% and IVI of 14.14%. Twenty seven different tree species had the lowest relative density (1.32%). These included *Albizia adianthifolia*, *Brachystegia eurycoma*, *Aningeria robusta*, *Cordea millenii* to mention a few. *Strombosia pustulata* had the least relative dominance (0.23%) and species importance value index (1.55%), along with *Ricinodendron heudelotii* which also had the least species IVI (1.55%).

### 3.1.4 Alpha and beta diversity indices of tree species in Eda forest reserve

Simpson index revealed that the primary forest was the most diverse (0.93), while secondary forest and encroached farmland had indices of 0.92 and 0.87, respectively (Table 4). Similarly, the Shannon Wiener index had the highest value for primary forest (3.22) when compared with secondary forest (3.14) and encroached farmland (2.51). The species evenness revealed that primary forest contained more species (0.88) than the other vegetation types (Table 4). Species richness (Margalef's index) revealed that primary forest was more endowed than other

vegetation types with 39 species/ha, followed by secondary forest with 38 species/ha, while 19 species/ha occurred in encroached farmland. However, the fisher alpha index revealed that secondary forest (11.86) was slightly diverse in species composition than other vegetation types because the values for the primary forest (10.89) and encroached farmland (5.99) were lower.

#### 3.1.5 Growth variables of tree species in Eda forest reserve

The encroached farmland had the highest mean dbh (83.35 ± 9.04 cm), while secondary forest had the least (34.60 ± 3.22 cm) in the forest reserve (Table 5). On the other hand, mean basal area was 3.18 $m^2$/ha, 0.36 $m^2$/ha and 1.68 $m^2$/ha for primary forest, secondary forest and encroached farmland, respectively. The tree volume followed a similar trend with primary forest being the highest (122.44 $m^3$/ha), followed by encroached farmland (53.02 $m^3$/ha) while secondary forest had the lowest (13.20 $m^3$/ha). The mean height varied from 23.87 m - 27.93 m across the vegetation types (Table 5). Trees with dbh < 20.99 cm and 41 - 50.99 cm were only present in secondary forest, while all other diameter class distributions were represented in primary forest and encroached farmland (Fig. 3). The highest frequency was observed for trees in the > 60 cm diameter class which dominated the primary forest.

### 3.2 Discussion

Tree species composition was highest in the primary forest which had a richer and more diverse tree population than other vegetation types. The primary forest was dominated by the light demanding species, characteristic of the emergent layer in a tropical forest. This tall species provide cover for shade tolerant understorey species [10,14]. The primary forest was characterized by an abundance of lianas which entangled the branches and crowns of larger trees. On the other hand, the secondary forest was in the recovery mode with medium size trees, most of which were < 60cm in diameter. This distribution of diameter across the dbh range is an indication of the high level of exploitation that the forest had experienced [4]. In addition, the large trees scattered in the encroached farmland were economic species retained to provide shade and protection for farm crops [5]. The 60 tree species from 22 families in the forest reserve, represent the high level of complexity in terms of structure and function in rainforest ecosystems. Fabaceae, Moraceae, and Sterculiaceae have been consistently reported as dominant plant families in Nigerian tropical forests [10,4].

**Table 2. Family composition and distribution of tree species in Eda forest reserve**

| S/N | Family | Primary forest | Secondary forest | Encroached farmland | No of tree species /ha in each family |
|---|---|---|---|---|---|
| 1 | Annonaceae | --- | 5 | 3 | 8 |
| 2 | Apocynaceae | 10 | 8 | 3 | 21 |
| 3 | Bignoniaceae | 10 | 5 | --- | 15 |
| 4 | Bombacaceae | 10 | 3 | 5 | 18 |
| 5 | Caesalpiniaceae | 25 | 10 | 3 | 38 |
| 6 | Chrysobalanaceae | 5 | --- | --- | 5 |
| 7 | Combretaceae | 10 | 3 | 3 | 16 |
| 8 | Ebenaceae | 5 | --- | 3 | 8 |
| 9 | Euphorbiaceae | 5 | 5 | --- | 10 |
| 10 | Meliaceae | 5 | 10 | 5 | 20 |
| 11 | Mimosaceae | 15 | 5 | 3 | 23 |
| 12 | Moraceae | 20 | 10 | 5 | 35 |
| 13 | Myristicaceae | --- | 3 | 3 | 6 |
| 14 | Ochnaceae | 5 | --- | --- | 5 |
| 15 | Olacaceae | 5 | --- | --- | 5 |
| 16 | Papilionaceae | 10 | 5 | 3 | 18 |
| 17 | Rubiaceae | --- | 5 | --- | 5 |
| 18 | Rutaceae | 5 | --- | --- | 5 |
| 19 | Sapotaceae | 10 | 5 | 5 | 20 |
| 20 | Sterculiaceae | 35 | 13 | 5 | 53 |
| 21 | Ulmaceae | 5 | 3 | 3 | 11 |
| 22 | Sapindaceae | --- | 1 | 2 | 3 |
| | **Total** | **195** | **99** | **54** | **348** |

**Table 3. Diversity indices of tree species in the primary forest in Eda forest reserve**

| S/N | Species name | Family | Mean height (m) | Mean DBH (cm) | Number of trees (/ha) | Relative density (%) | Relative dominance (%) | Species impotance value (%) | Volume ($m^3$/ ha) | Basal area ($m^2$ /ha) | Shannon wiener ($H^I$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Albizia adiantifolia* | Mimosaceae | 16.7 | 115.8 | 5 | 1.32 | 0.48 | 1.80 | 10.03 | 0.60 | 0.057 |
| 2 | *Alstonia congensis* | Apocynaceae | 26.7 | 56 | 10 | 2.63 | 3.07 | 5.70 | 114.45 | 3.80 | 0.096 |
| 3 | *Aningerea robusta* | Sapotaceae | 21.8 | 31 | 5 | 1.32 | 1.26 | 2.57 | 33.98 | 1.56 | 0.057 |
| 4 | *Antiaris toxicaria* | Moraceae | 49 | 134.6 | 10 | 2.63 | 10.17 | 12.80 | 616.90 | 12.60 | 0.096 |
| 5 | *Bombax buonopozense* | Bombacaceae | 46.77 | 101.2 | 15 | 3.95 | 6.14 | 10.08 | 350.25 | 7.60 | 0.128 |
| 6 | *Brachystegia eurycoma* | Caesalpiniaceae | 32.3 | 40.1 | 5 | 1.32 | 7.28 | 8.59 | 291.17 | 9.01 | 0.057 |
| 7 | *Ceiba pentandra* | Bombacaceae | 53.87 | 38.5 | 15 | 3.95 | 13.89 | 17.83 | 936.85 | 17.20 | 0.128 |
| 8 | *Celtis zenkerii* | Ulmaceae | 25.25 | 27.4 | 10 | 2.63 | 1.98 | 4.61 | 61.50 | 2.45 | 0.096 |
| 9 | *Chysophylum albidum* | Sapotaceae | 32 | 71 | 5 | 1.32 | 1.60 | 2.91 | 63.36 | 1.98 | 0.057 |
| 10 | *Cordea millenii* | Bignoniaceae | 23.4 | 201.7 | 5 | 1.32 | 0.99 | 2.31 | 28.82 | 1.23 | 0.057 |
| 11 | *Cynometra megalophylla* | Caesalpiniaceae | 16.2 | 77 | 10 | 2.63 | 0.61 | 3.24 | 12.05 | 0.75 | 0.096 |
| 12 | *Dalium guinensis* | Caesalpiniaceae | 16.8 | 64.6 | 5 | 1.32 | 0.37 | 1.68 | 7.63 | 0.45 | 0.057 |
| 13 | *Daniella ogea* | Caesalpiniaceae | 38.5 | 65.2 | 5 | 1.32 | 3.13 | 4.44 | 149.10 | 3.87 | 0.057 |
| 14 | *Diospyros mespiliformis* | Ebenaceae | 18.8 | 34.7 | 5 | 1.32 | 1.20 | 2.51 | 27.84 | 1.48 | 0.057 |
| 15 | *Distemona bentamianus* | Caesalpiniaceae | 16.1 | 32.5 | 5 | 1.32 | 0.33 | 1.65 | 6.68 | 0.41 | 0.057 |
| 16 | *Ficus mucuso* | Moraceae | 18.4 | 168 | 5 | 1.32 | 0.38 | 1.70 | 8.70 | 0.47 | 0.057 |
| 17 | *Funtumia elastic* | Apocynaceae | 28.6 | 101.2 | 5 | 1.32 | 1.88 | 3.20 | 66.60 | 2.33 | 0.057 |
| 18 | *Hildergadia baterii* | Sterculiaceae | 19.6 | 64.9 | 5 | 1.32 | 1.06 | 2.38 | 25.81 | 1.32 | 0.057 |
| 19 | *Khaya ivorensis* | Meliaceae | 34.03 | 132.7 | 75 | 19.74 | 2.42 | 22.16 | 114.70 | 3.00 | 0.320 |
| 20 | *Kigelia Africana* | Bignoniaceae | 21.3 | 96.4 | 5 | 1.32 | 1.15 | 2.46 | 30.22 | 1.42 | 0.057 |
| 21 | *Lophira alata* | Ochnaceae | 37.35 | 61.1 | 10 | 2.63 | 3.67 | 6.31 | 171.15 | 4.55 | 0.096 |
| 22 | *Mansonia altissima* | Sterculiaceae | 17.6 | 227.8 | 5 | 1.32 | 0.89 | 2.21 | 19.49 | 1.11 | 0.057 |
| 23 | *Melicia excels* | Moraceae | 45.68 | 57.9 | 25 | 6.58 | 5.69 | 12.27 | 331.70 | 7.05 | 0.179 |
| 24 | *Milletia aboensis* | Papilionaceae | 14.4 | 39.1 | 5 | 1.32 | 0.36 | 1.68 | 6.42 | 0.45 | 0.057 |
| 25 | *Musanga cecropioides* | Moraceae | 9.2 | 80.5 | 5 | 1.32 | 0.38 | 1.69 | 4.28 | 0.46 | 0.057 |
| 26 | *Nesogodonia papaverifera* | Sterculiaceae | 27 | 101.2 | 5 | 1.32 | 3.20 | 4.52 | 107.11 | 3.97 | 0.057 |
| 27 | *Parinari excels* | Chrysobalanaceae | 16.1 | 71 | 5 | 1.32 | 1.51 | 2.83 | 30.11 | 1.87 | 0.057 |
| 28 | *Piptadeniastrum africanum* | Mimosaceae | 28.4 | 34 | 5 | 1.32 | 1.93 | 3.24 | 67.86 | 2.39 | 0.057 |

| S/N | Species name | Family | Mean height (m) | Mean DBH (cm) | Number of trees (/ha) | Relative density (%) | Relative dominance (%) | Species impotance value (%) | Volume ($m^3$/ ha) | Basal area ($m^2$ /ha) | Shannon wiener ($H^l$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | *Pterocarpus osun* | Papilionaceae | 21.4 | 196.9 | 5 | 1.32 | 0.51 | 1.83 | 13.52 | 0.63 | 0.057 |
| 30 | *Pterygota macrocarpa* | Sterculiaceae | 29.3 | 134.6 | 5 | 1.32 | 1.71 | 3.03 | 62.17 | 2.12 | 0.057 |
| 31 | *Ricinodendron heudelotii* | Euphorbiaceae | 16.7 | 121.9 | 5 | 1.32 | 0.24 | 1.55 | 4.92 | 0.29 | 0.057 |
| 32 | *Steculia rhinopetala* | Sterculiaceae | 29.88 | 172.1 | 45 | 11.84 | 2.30 | 14.14 | 94.35 | 2.85 | 0.253 |
| 33 | *Steculia tragacanta* | Sterculiaceae | 46.8 | 108.2 | 5 | 1.32 | 2.95 | 4.26 | 170.81 | 3.65 | 0.057 |
| 34 | *Strombosia pustulata* | Olacaceae | 14 | 92.6 | 5 | 1.32 | 0.23 | 1.55 | 4.01 | 0.29 | 0.057 |
| 35 | *Terminalia ivorensis* | Combretaceae | 47.8 | 33.7 | 5 | 1.32 | 5.53 | 6.84 | 327.11 | 6.84 | 0.057 |
| 36 | *Terminalia superb* | Combretaceae | 29 | 34.4 | 10 | 2.63 | 3.47 | 6.10 | 128.80 | 4.30 | 0.096 |
| 37 | *Tetrapleura tetraptera* | Mimosaceae | 17 | 155.6 | 5 | 1.32 | 1.39 | 2.71 | 29.26 | 1.72 | 0.057 |
| 38 | *Triplochyton scleroxylon* | Sterculiaceae | 43.35 | 103.7 | 10 | 2.63 | 4.36 | 6.99 | 240.10 | 5.40 | 0.096 |
| 39 | *Zanthoxylum zanthoxyloides* | Rutaceae | 14.7 | 132 | 5 | 1.32 | 0.30 | 1.62 | 5.55 | 0.38 | 0.057 |

**Table 4. Diversity indices of tree species in Eda forest reserve, Ekiti state, Nigeria**

| Diversity indices | Primary forest | Secondary forest | Encroached farmland |
|---|---|---|---|
| Simpson index (D) | 0.93 | 0.93 | 0.87 |
| Shannon Wiener index (HI) | 3.22 | 3.14 | 2.51 |
| Mergalef's index (d) | 6.39 | 6.57 | 3.66 |
| Evenness index (E) | 0.88 | 0.86 | 0.85 |
| Menhinck index | 2.00 | 2.27 | 1.62 |
| Fisher alpha index | 10.89 | 11.86 | 5.99 |
| Dominance index (C) | 0.07 | 0.08 | 0.12 |

**Table 5. Growth characteristics of trees in Eda forest reserve, Ekiti state, Nigeria**

| Growth variable | Primary forest | Secondary forest | Encroached farmland |
|---|---|---|---|
| Mean dbh (cm) | 78.58 ± 6.93 | 34.61±3.22 | 83.35±9.04 |
| Dominant dbh (cm) | 82.00 | 30.00 | 140.00 |
| Mean height (m) | 27.23 ± 1.90 | 23.87±1.54 | 27.93±1.59 |
| Dominant Height (m) | 16.70 | 17.40 | 28.00 |
| Mean Basal Area ($m^2$/ha) | 3.18±0.57 | 0.36±0.08 | 1.68±0.39 |
| Total Basal Area ($m^2$/ha) | 123.86 | 13.68 | 31.87 |
| Mean Volume ($m^3$/ha) | 122.44±29.92 | 13.20±4.06 | 53.02±14.67 |
| Total Vol./ha ($m^3$/ha) | 4775.32 | 501.49 | 1007.31 |

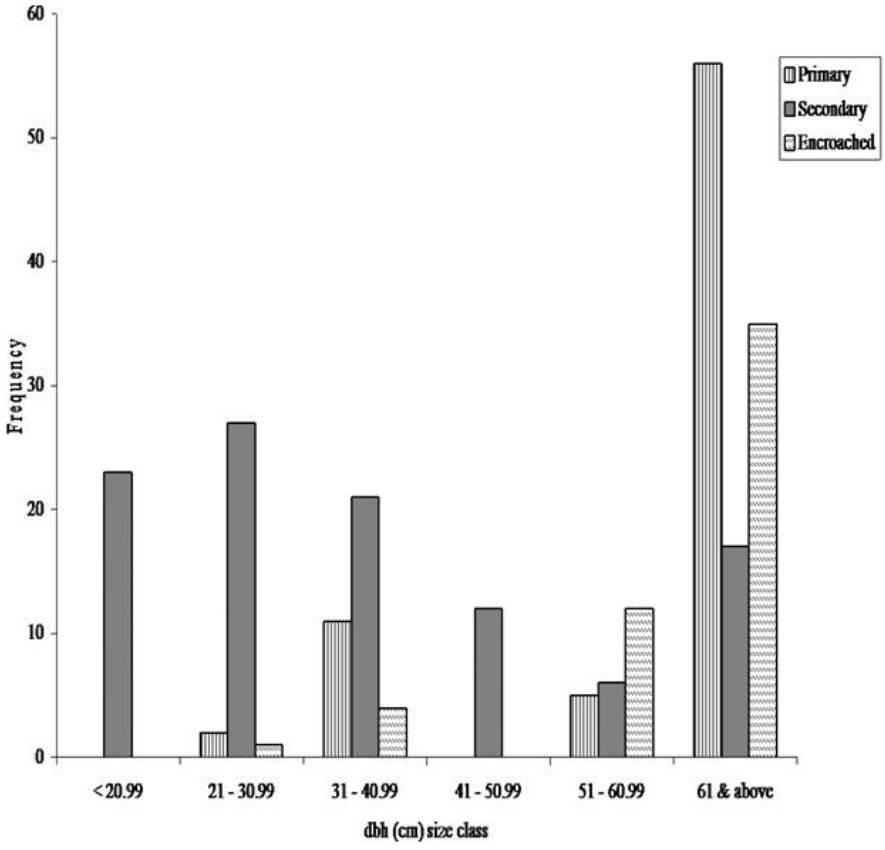


**Fig. 3. Diameter (Dbh) distribution pattern of Eda forest reserve**

*Khaya ivorensis* had the highest relative density of 19.74% and could be regarded as the most abundant species in the forest reserve. The dominance of emergent layer species (such as *Khaya ivorensis, Millicia excelsa*) highlights the fact that the forest was a climax old growth forest

before exploitation and opening of the forest canopy [15]. The importance value index (IVI), which combines the attributes of relative density, relative frequency and relative dominance; measures the relative importance of a species in a forest [16]. This study revealed that *Khaya ivorensis* had the highest IVI (22.16%) indicating that this species was the most abundant in the forest reserve and was closely followed by *Ceiba pentandra (*IVI of 17.83%). This species also had the highest relative dominance value of 13.89% which also presented the species as the indicator species in the reserve. This was followed by *Antiaris africana with* 10.17% and the least relative dominance value of 0.23% was contributed by *Strombosia pustulata*.

The highest mean height (53.87 m) was recorded for *Ceiba pentandra* which is an indicator species in tropical rainforest ecosystems. On the other hand, the least height (9.2 m) was recorded for *Musanga cecropioides* which is a pioneer species that colonizes clearings and abandoned farmlands [4]. The study revealed that despite the high level of exploitation, Eda forest reserve was a repository of many indigenous tropical hardwood species and had high potential for germplasm conservation.

The Shannon diversity index ($H^I$) which characterizes the level of diversity in tropical forests ecosystems has a general limit of 1.5 – 3.5 [9]. Hawthorne et al. [15] opined that the $H^I$ index was an indication of the high species diversity and reflected the dominance of a few tree species in the forest. The $H^I$ value for the primary forest was slightly lower than other tropical rainforests. For instance, Parthasarathy [2] reported $H^I$ = 3.89, while Adekunle and Olagoke [17] reported $H^I$ = 4.02, for rainforests in India and Nigeria, respectively. Nevertheless, Alpha diversity index was highest in the primary forests (Simpson index = 0.93 and $H^I$ = 3.22). The Sorensen's index indicated the species similarities among vegetation types [18]. Primary forest had a lower Sorensen's index (0.19), indicating it was more similar to secondary forest (0.23) than encroached farmland (0.28). This is evidenced by higher tree population (380 trees/ha) in primary forest when compared to encroached farmland (137 trees/ha). This finding agrees with similar studies such as Sanwo et al. [12] who reported 335 trees/ha from 63 species and belonging to 25 families in a tropical rainforest in southern Nigeria. Also, Aigbe et al. [13] documented 323 trees/ha from 68 species in Afi River forest reserve, Nigeria. However, the stand density of Eda forest reserve was lower than that of tropical Amazonia forests with approximately 1720 trees/ha [19].

The dbh class distribution revealed the structure of a degraded forest (encroached farmland), a secondary and old growth forest. The presence of more trees in the lower dbh classes (Fig. 3), highlighted the process of recovery of the tree vegetation in the secondary forest [20,14]. This implies that the secondary forest has relatively good regeneration and recruitment potential which are indications of forest health and vigour.

## 4. CONCLUSION

This study revealed the level of exploitation that had influenced the tree species composition in different vegetation types in Eda forest reserve. Human disturbances had influenced the tree species composition and structural complexity of the forest reserve. Hence, the removal of large trees resulted in tree density and volume fluctuations in secondary forest and encroached farmland. Notwithstanding, comparably high floristic composition and diversity were observed in the secondary forest. Thus, the degraded areas have potential for recovery if encroachment and uncontrolled exploitation are curbed. Hence, there is a need for a reconciliation of the demands for conservation with social and economic expectations from Eda forest reserve. Furthermore, interventions such as enrichment planting, and regulated resource utilization could aid the restoration of encroached farmlands.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Food and Agriculture Organisation, (FAO). Global Forest Resources Assessment. Desk Reference FAO, Rome, Italy; 2015.
2. Parthasarathy N. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Current Science. 2001;80(3):389-393.
3. Awotoye O, Adebola S. The changing structural face of Little-Ose forest reserve South-West Nigeria. Journal of Biological

and Chemical Research. 2013;30(2):875-886.
4. Olajuyigbe SO, Adaja AA. Floristic composition, tree canopy structure and regeneration in a degraded tropical humid rainforest in southwest Nigeria. Tanzania Journal of Forestry and Nature Conservation. 2014;84:6-23.
5. Oke DO, Odebiyi KA. Traditional cocoa-based agro forestry and forest species conservation in Ondo State, Nigeria. Agriculture, Ecosystems and Environment. 2007;122:305-311.
6. EKFD. Reports on the contribution of forest products to commercial activities and income generation in Ekiti State. Ekiti State Forestry Department (EKFD), Ado-Ekiti, Nigeria. Annual Report on Forest Products. 2006;2(3):8–21.
7. Alo AA, Akindele SO, Onyekwelu JC. Development of land use map of Eda forest reserve in Ekiti State, Nigeria. Applied Tropical Agriculture. 2014;20:19-23.
8. EKFD. Report on the update of forest reserves statistics and status in Ekiti state. Ekiti State Forestry Department (EKFD), Ado Ekiti, Nigeria. Annual Report on Forest Reserves. 2012;4(1):17–28.
9. Duran E, Meave JA, Lott DJ, Segura G. Structure and tree diversity patterns at landscape level in a Mexican tropical deciduous forest. Boletin de Sociedad Botanica de Mexico. 2006;79:43-60.
10. Adekunle VAJ, Olagoke AO, Akindele SO. Tree species diversity and structure of a Nigerian strict nature reserve. Tropical Ecology. 2013;54(3):275–289.
11. Hammer O, Harper DAT, Ryan PD. Past: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica. Geosciences e – Journal. 2001;20(2):324–336.
12. Sanwo SK, Ige PO, Sosanya OS, Ogunlaye OG. Tree species diversity and forest stand dynamics in a tropical rainforest in Southern, Nigeria. Malaysian Applied Biology. 2015;44(2):65–73.
13. Aigbe HI, Akindele SO, Onyekwelu JC. Tree species diversity and density pattern in Afi river forest reserve, Nigeria. International Journal of Scientific and Technology Research. 2014;3(10):178–185.
14. Bobo KS, Waltert M, Sainge M, Njokagbor J, Fermon H, Mühlenberg M. From forest to farmland. ǁ species richness patterns of trees and under storey plants along a gradient of forest conversion in South-western Cameroon. Biodiversity and Conservation. 2006;15:4097-4117.
15. Hawthorne WD, Marshall CAM, Juam MA, Agyeman VK. The impact of logging damage on tropical rainforest, their recovery and regeneration. An Annotated Bibliography. 2011;47-121.
16. Anning A, Akyeampong S, Addo-Fordjour P, Anti K, Kwarteng A, Tettey Y. Floristic composition and vegetation structure of the KNUST Botanic Garden, Kumasi, Ghana. Journal of Science and Technology. 2009; 28(3):103-122.
17. Adekunle VAJ, Olagoke AO. The impacts of timber harvesting on residual trees and seedlings in a tropical rain forest ecosystem, southwestern Nigeria. International Journal of Biodiversity Science. Ecosystem Services and Management. 2010;6(3-4):131–138.
18. Ihuma JO, Chima VD, Chapman HM. Tree species diversity in a Nigerian montane forest ecosystem and adjacent fragmented forest. Journal of Agricultural and Biological Science. 2011;17-22.
19. Campbell DG, Stone JL, Rosas JA. A comparison of the phytosociology and dynamics of three flood plain forests of known ages, Rio Jurua, western Brazilian Amazon. Botanical Journal of the Linnaean Society. 1992;108:213-237.
20. Boubli JP, Eriksson J, Wich S, Hohmann G, Mesoscale BF. Transect sampling of trees in the Lomako-Yekokora interfluviumǁ, Democratic Republic of the Congo. Biodiversity and Conservation. 2004;13:2399-2417.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sciencedomain.org/review-history/26279*