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

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Original Research Article

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,

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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 0.36m^2/ha (encroach farmland) to 3.18m^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 (FAO, 2015). 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 (FAO, 2015; Parthasarathy, 2001). 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 (Awotoye and Adebola, 2013; Olajuyigbe and Adaja, 2014). 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 (Oke and Odebiyi, 2007; Olajuyigbe and Adaja, 2014). 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 (EKFD, 2006). 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 (Alo *et al.,* 2014). 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 906ha 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 (EKFD, 2012). 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 1800mm, 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 (Alo *et al.,* 2014; EKFD, 2006).

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.* (2006). Thus, two transects (2,000m 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 (20m×20m) were laid in alternate positions along each transect at an interval of 200m (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*. (2013).

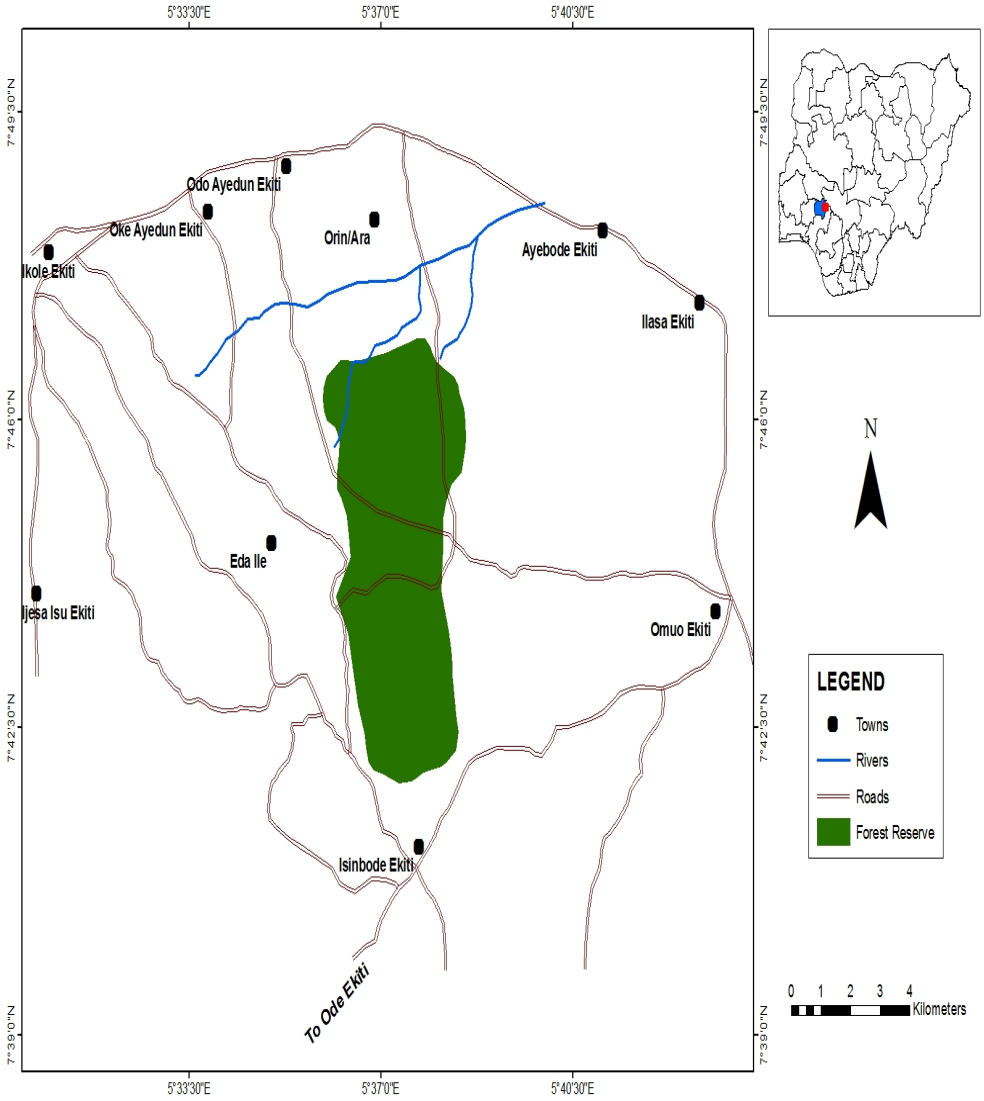

Fig. 1. Map of Eda Forest Reserve in Ekiti State, Nigeria

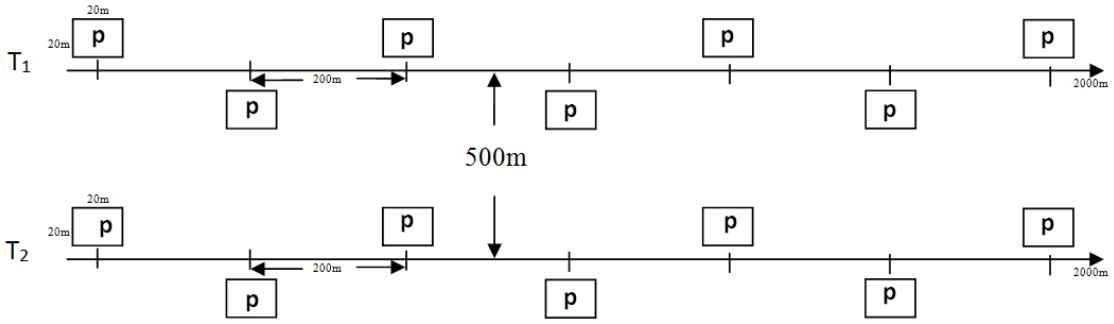

Fig. 2. Sampling procedure for identification and enumeration in the study area
Where: T = Transects, p = Sample plot

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) (Hammer *et al.,* 2001) 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 (Sanwo *et al.,* 2015):

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

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 (Adekunle *et al.,* 2013):

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

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 (Adekunle *et al.,* 2013):

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

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 (Aighe *et al.,* 2014):

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

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 (122.44m^3/ha), followed by encroached farmland (53.02m^3/ha) while secondary forest had the lowest (13.20m^3/ha). The mean height varied from 23.87m - 27.93m across the vegetation types (Table 5). Trees with dbh < 20.99cm and 41 - 50.99cm 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 > 60cm 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 (Adekunle *et al.,* 2013; Bobo *et al.,* 2006). 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 (Olajuyigbe and Adaja, 2014). In addition, the large trees scattered in the encroached farmland were economic species retained to provide shade and protection for farm crops (Oke and Odebiyi, 2007). 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 (Adekunle *et al.* 2013; Olajuyigbe and Adaja, 2014).

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^l)
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

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)
28	*Piptadeniastrum africanum*	Mimosaceae	28.4	34	5	1.32	1.93	3.24	67.86	2.39	0.057
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

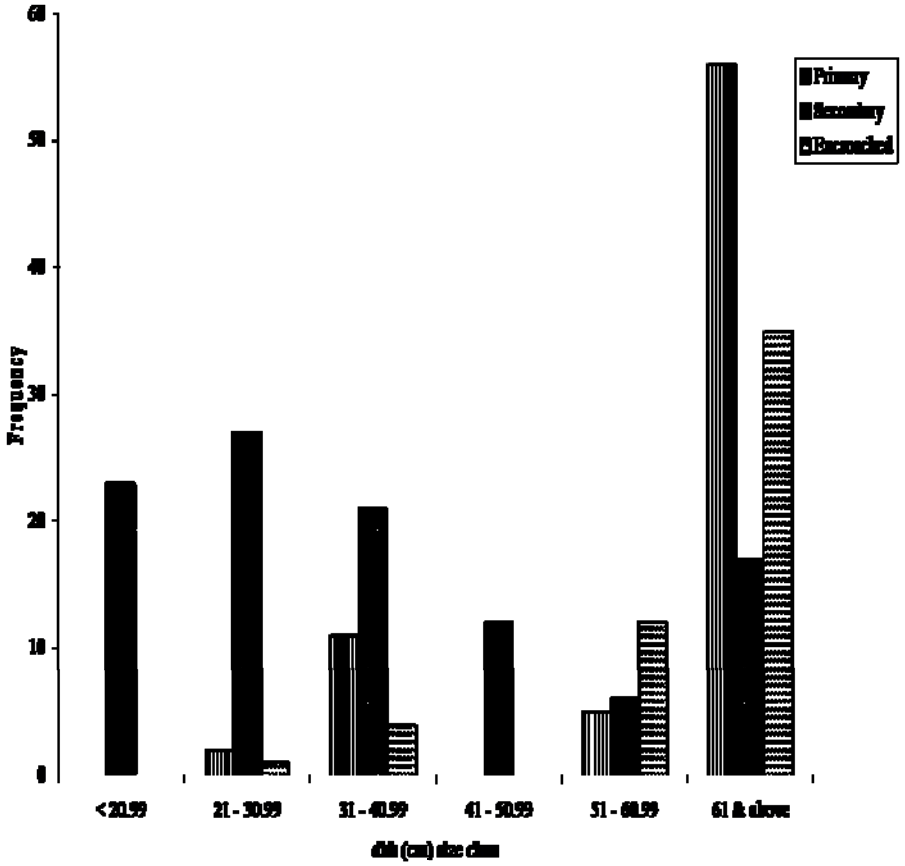

Fig. 3. Diameter (Dbh) distribution pattern of Eda Forest Reserve

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 (Hawthorne *et al*., 2011). 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 (Anning *et al.* 2009). 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 (53.87m) was recorded for *Ceiba pentandra* which is an indicator species in tropical rainforest ecosystems. On the other hand, the least height (9.2m) was recorded for *Musanga cecropioides* which is a pioneer species that colonizes clearings and abandoned farmlands (Olajuyigbe and Adaja, 2014). 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 (Kent and Coker 1992). Hawthorne *et al*. (2011) 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 (2001) reported H^I = 3.89, while Adekunle and Olagoke (2010) 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 (Ihuma *et al*., 2011). 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*. (2015), who reported 335 trees/ha from 63 species and belonging to 25 families in a tropical rainforest in southern Nigeria. Also, Aigbe *et al.* (2014) 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 (Campbell *et al.,* 1992).

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 (Boubli *et al*., 2004; Bobo *et al.,* 2006). 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.

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