Research Article
Open Access
CrossMark

Forest Structure, Tree Species Diversity, and Distribution in Ukpon River Forest Reserve, Cross River State, Nigeria

Abstract

For effective conservation management, it is crucial to comprehend the diversity, abundance, and distribution of the forest as wildlife habitat. The fundamental composition of the forest is significantly influenced by the ecological features of the sites, species diversity, and rate of tree species regeneration. This finding aimed to assess the diversity, abundance, and distribution of tree species as suitable habitat for wildlife species and for sustainable forest management, climate change mitigation, and environmental resilience. The study was conducted in dry season (between 5th September, 2021 and April, 2022). Purposive sampling techniques and systematic line transects were used for data collection and plot delineation. There were laid 8 transects, each 1000 meters long and 500 meters apart. Descriptive statistics such as mean, frequencies, and percentages were used to analyze the data. Correlation analyses and diversity indices were carried out using the R programming software. In the study area, 68 tree species from 34 families were found. *Meliacea* (6 trees per ha), *Caesalpiniceae*, and *Moracea* (5 trees per ha) were the three most common tree species in the study area. *Melicia excelsa* showed the highest relative frequency (2.256%) and (2.241%). The species *Bialonella toxisperma* had the highest relative dominance (4.970%). In *Melicia excelsa*, IVI recorded the highest value (4.970%). The tallest tree and Dbh (Diameter at Breast Height) measured 80.5 cm and 68.3m). The *Margelef* index was 36.10, the Shannon Wiener index was 5.058, and species richness was 68. However, the high proportion of smaller-diameter trees in the forest reserve implies that, it is strong and healthy. Since natural areas play a critical role in slowing down climate change, strict oversight of these areas should be strongly encouraged.

Keywords: tree species, diversity, distribution, abundance, okpon river

Volume 7 Issue 2 - 2023

Esor PE,[1] Amonum JI,[2] Agera SIN[2]
[1]Department of Forestry and Wildlife Management, Cross River University of Technology Calabar, NIgeria
[2]Department of Forest Production and products, College of Forestry and Fisheries, Joseph Sarwuan Tarka University Makurdi, Nigeria

Correspondence: Esor PE. Department of Forestry and Wildlife Management Cross River University of Technology Calarba, Nigeria, Email esorpeterekpo@yahoo.com

Received: February 24, 2023 | **Published:** May 04, 2023

Introduction

Understanding the forest stands' structure, diversity, abundance, and distribution is essential for conservation management. The ecological characteristics of the sites, species diversity, and the rate of tree species regeneration all play a significant role in the fundamental structure of the forest. Tree species abundance and diversity are essential to the overall biodiversity of forests because trees provide resources such as food, traditional medicine, timber, shade, and habitats for fauna Sushma et al.,[1] Due to numerous anthropogenic factors, the extent of species decline in the second half of the 20th century became a universal or global problem.[2] The provision and protection of biodiversity services are crucial to describing the pattern of forest structure in order to control or manage the increasing rate of anthropogenic activities within the forest estate.[3] The variation in tree species diversity among forest reserves has been attributed to a variety of factors. According to Malhil et al.,[4] and Lippok et al.,[5] topography has a significant impact on the local endemism of plant species. Franscico et al., reported that disturbance has an impact on diversity and regeneration, including changes in tree growth, tree mortality, understory development in relation to forest reserves, and habitat heterogeneity. Forests are one of the main vegetative elements in India (as well as Nigeria), and they serve as a priceless repository for numerous economically significant species as well as the genetic material for many crop plants and their wild relatives.[5] Basic understanding of key elements' spatial and temporal ranges as well as the main environmental factors that influence their survival and distribution is necessary for sustainable conservation management.[6]

Materials and methods

The study area

Okpon River Forest Reserve was gazetted by Cross River State in 1930. The reserve occupied a land mass of 31,300 hectares, covering two local government areas, Obubra and Yakurr, respectively. The Reserve lies between Latitudes 5^0 . 40^1 ,$5^0.50^1$ and $6^0.00^1$, 6^0 .10^1 North of the Equator and Longitude 8^0. 10^1 ,8^0. 20^1 and $8^0.30^1$, 8^0. 40^1 East of the Greenwich Meridian Figure 1. The reserve is bounded in the north by Etung and Ikom LGAs, south by Baise LGA, west by Abi LGA, and east by Eboyi State.

Sampling techniques/procedure

Transects and plots were selected using systematic and purposeful sampling techniques. For the purpose of counting the species of plants, eight (8) transects were set up. At regular intervals of 250 m along the transects, four plots of 50 m x 50 m (0.25 ha) size were systematically placed alternately along each transect. A hundred metres separated each transect. All woody plants with a diameter at breast height (dbh) less than 10 cm were the only ones eligible for measurement and identification.

Data collection and analyses

The study was conducted in dry season (between September, 2021 and April, 2022). Data collected was based on Dbh (≥10 cm). The height of each individual tree was measured using a sunto clinometer, while the diameter of the trees was measured using a diameter tape.

The diameter at breast height (> 10 cm dbh), importance value index (IVI), relative frequencies, relative dominance, relative density, and height of the entire individual tree were all calculated.

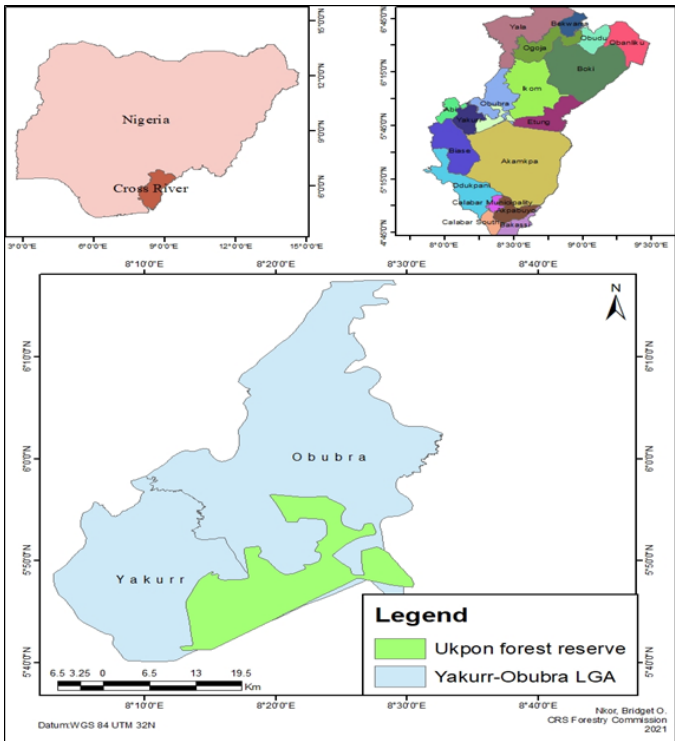

Figure 1 Map of Okpon river forest reserve.

The 2017 version of the Microsoft Word and Excel package was used to impute the collected data. We used descriptive statistics like means, percentages, tables, and charts. Using diversity indices, the RF, RD, RDO, and IVI of tree species were calculated. The threshold for statistical significance was (P 0.005%). In the "R" software, correlation analysis and diversity indices were both carried out.

Basal areas: of all trees in the samples plots were calculated using the formula:

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

B.A= Basal Area (m^2), D= Diameter at Breast Height (cm) and π =(3.142). .

Species Relative density (RD %):

$$RD = \frac{ni \times 100}{N} \quad (2)$$

RD = Relative density of the species, ni = Number of individuals per species and N = Total number of all individual tree of all species in the entire population.

Species Relative Dominance (%) was estimated using the following equation:

$$RD_0 = \frac{\sum B\alpha_1 \times 100}{\sum B\alpha_n} \quad (3)$$

Ba_1 = Basal area of individual tree belonging to the i^{th} species and Ba_n = Stand basal area.

Shannon – wiener diversity index was calculated using the following equation:

$$H = -\sum_{1=1} P_1 In(P_1) \quad (4)$$

H' = Shannon diversity index, S = the total number of species in the community, P_1= Proportion S (species in the family) made *u* to the i^{th} spp and In = natural logarithm.

Important Value Index:

IVI =RF+RD+RD (5)

RD = Relative density of the species; RD_O = relative dominance

Results

Forest Structure of the Ukpon River Forest Reserve

Table 1 shows the diameter of breast height and the total height of species at the Okpon Forest Reserve. The maximum and minimum diameters at the base were recorded as 80.5 cm and 10.1 cm, with a mean of 25.1 cm and SD of 13.2. The mean total height was 28.6 m, with a standard deviation of 14.1 m. A minimum total height of 5.2 and a maximum of 68.3 m, with a mean of 28.6 m, were recorded in the study area. The diameter distribution in Figure 2 revealed that tree species within the diameter at breast height (dbh) distribution ranged from 10 cm to 70 cm. Fifty-five (55) trees belonged to the Dbh class (10 cm to 20 cm) and were the most frequently occurring in the area, representing 47%. This was followed by trees in the diameter class of 20cm – 40cm with twenty five (25) trees/ha representing 17.10%. the least number of stem (15tree/ ha) and (10 trees/ha) falls under diameter class of 40cm – 50cm and 50cm to 60cm representing 11.1% and 5.0% respectively while the least species within the diameter range of 60 cm > 70 cm represented 11.1 % and 5.0% respectively. Based on the result of this finding Figure 3, the total height of tree species in the study area ranged from 10 to 70 m. Forty trees (40/ ha) belonged to the tree height class of 20–30 m, representing 35%, followed by the tree height class of 30–50 m, with 25 trees representing 39.4%. Similarly, 20 trees/ha falls between the height classes of 50 – 60m trees represented 12.8% of the entire tree species in the study location. Ten trees belonged to the height class between 60 and 70 m, representing 7.6%, while 5 trees per ha belonging to the height classes of 10 to 20 m and > 70 m were in the range of 2.6 each.

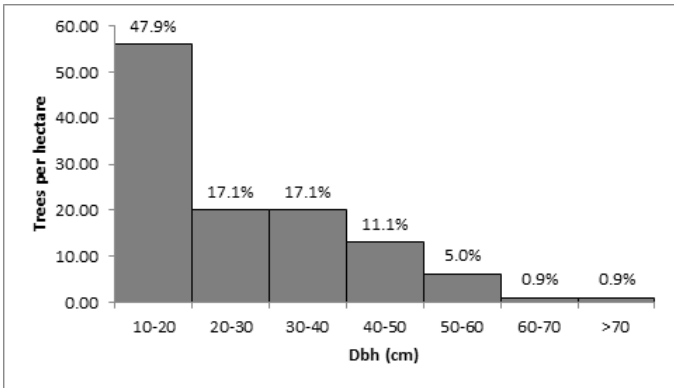

Figure 2 Diameter at breast height distribution of tree species in Okpon river forest reserve.

Tree species diversity and distribution in okpon river forest reserve

The results of this study recorded 248 tree species belonging to 55 families. Caesalpinaceae had the highest number of species (24

trees per ha), followed by *Moraceae* (20 trees per ha), *Euphorbiaceae* (15 trees per ha), *Apocynaceae* and *Steculiaceae* (12 trees per ha), *Leguminocea* (10 trees per ha), *Annonaceae* (9 trees per ha), and Rutaceae (8 trees per ha). These families were regarded as the most dominant in the forest reserve. *Sapindaceae* and *Ebeneceae* had 7 species each, Rubiaceae had 6 species, Mimosaceae and *Ulmaceae* 5 tree Sapotaceae and *Anacardiaceae* 4 species, *Gentianaceae* and *Lauraceae* families 3 species. Eleven families recorded two species, while twenty (20) families recorded one species each (Table 2).

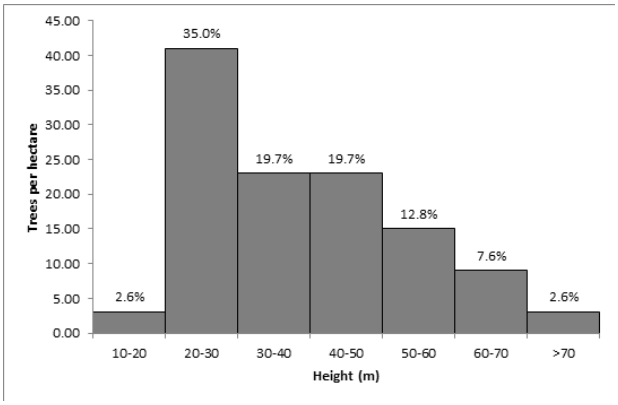

Figure 3 Total height distribution of trees at the okpon river forest reserve.

Table 1 Summary statistics of growth variables in Okpon river forest reserve

Parameters	Dbh (cm)	Ht (m)
Minimum	10.1	5.2
Max	80.5	68.3
Mean	25.1	28.6
Standard deviation	13.2	14.1
Sample Size	937	937

Relative Frequency, Relative Density, Relative Dominance, and Importance Value Index (IVI) of Tree Species at Okpon Forestry Reserve

The result indicates that *Brachystegia eurycoma* and *Melicia excelsa* had the highest relative frequency of (2.266) followed by *Khaya ivorensis* (1.933%), *Diospyros mespiliformis, Funtumia elastic, and Lophira alata, which* recorded the same relative frequency of (1.826%). The least relative frequency of (0.107 %) were recorded in 107 tree species Table 2. The results of the relative density of tree species at the Okpon forestry reserve presented in Table 2 showed that *Brahystegia erycoma* recorded the highest relative density of (2.241%), closely followed by *Khaya ivorensis and Milicia excelsa* that recorded the same value (2.028%), *Lophira alata* (1.814%), and *Entandrophragma utile* (1.708%), while the least relative density of (0.107%) was recorded in ninety-six (96) tree species.

Milicia excelsa recorded the highest relative dominance (4.970%), followed by *Piptadeniastrum africana* (4.643%), and *Brachystegia erycoma* (3.089%). The least relative dominance was obtained in *Kigela africana* (0.016%). *Brachystegia erycoma recorded* the highest IVI of 10.66%, followed by *Milicia excelsa* (9.46%) and *Khaya ivorensis* (6.865%). The lowest IVI of 0.228% was in *Ficus muccuso and Mansonia altissima (*Table 2).

Table 2 Species composition, abundance, and IVI at Okpon river forest reserve CRS, Nigeria

S/No	Species	Family	RF(%)	RD(%)	RDo(%)	IVI
1	*Acioa pallescens*	*Chysobalana*	0.322	0.32	0.177	0.819
2	*Aeglopsis chevalieri*	*Rutaceae*	0.43	0.427	0.268	1.125
3	*Afrormosia elata*	*Leguminosae*	0.644	0.64	0.312	1.597
4	*Afrostyrax lepidophyllus*	*Styraceae*	0.107	0.107	0.039	0.253
5	*Afzelia africana*	*Caesalpinaceae*	0.322	0.32	0.267	0.909
6	*Afzelia bella*	*Caesalpinaceae*	0.322	0.32	0.295	0.937
7	*Afzelia bipindensis*	*Leguminosae*	0.43	0.427	0.161	1.018
8	*Afzelia pachyloba*	*Caesalpinaceae*	0.107	0.107	0.053	0.267
9	*Albizia lebbeck*	*Leguminosae*	0.107	0.107	0.023	0.237
10	*Albizia adianthitolia*	*Mimosaceae*	0.107	0.107	0.027	0.242
11	*Albizia ferruginea*	*Leguminosae*	0.43	0.427	0.177	1.033
12	*Albizia gummifera*	*Leguminosae*	0.215	0.213	0.094	0.523
13	*Albizia zygia*	*Leguminosae*	0.43	0.427	0.333	1.19
14	*Alchornea cordifolia*	*Euphorbiaceae*	0.215	0.213	0.054	0.482
15	*Alchornea laxiflora*	*Euphorbiaceae*	0.43	0.427	0.085	0.942
16	*Allanblackia floribunda*	*Cluciaceae*	0.644	0.64	0.509	1.794
17	*Allophylus africana*	*Sapindaceae*	0.107	0.107	0.127	0.342
18	*Alophyllus africanum*	*Sapindaceae*	0.107	0.107	0.056	0.27
19	*Alstonia boonei*	*Apocynaceae*	0.967	0.961	0.969	2.896
20	*Alstonia congensis*	*Apocynaceae*	0.859	0.854	0.965	2.678
21	*Amphimas pterocarpoides*	*Leguminosae*	0.43	0.427	0.209	1.065
22	*Angylocalyx oligophyllus*	*Leguminosae*	0.43	0.427	0.279	1.136
23	*Aningeria robusta*	*Sapotaceae*	0.215	0.213	0.03	0.459
24	*Anonidum mannii*	*Annonaceae*	0.107	0.107	0.042	0.256
25	*Anthocleista djalonesis*	*Gentianaceae*	0.107	0.107	0.134	0.348

Citation: Esor PE, Ammonum JI, Agera SIN. Forest Structure, Tree Species Diversity, and Distribution in Ukpon River Forest Reserve, Cross River State, Nigeria. *Int J Avian & Wildlife Biol.* 2023;7(2):46–54. DOI: 10.15406/ijawb.2023.07.00189

Table 2 Continued...

S/No	Species	Family	RF(%)	RD(%)	RDo(%)	IVI
26	*Anthocleista nobilis*	*Gentianaceae*	0.107	0.107	0.032	0.246
27	*Anthocleista vogelii*	*Gentianaceae*	0.107	0.107	0.12	0.334
28	*Anthonotha macrophylla*	*Caesalpinacea*	0.107	0.107	0.101	0.315
29	*Antiaris africana*	*Apocynaceae*	0.107	0.107	0.053	0.267
30	*Antiaris toxicaria*	*Moraceae*	0.644	0.64	0.216	1.501
31	*Antiaris welwitschii*	*Moraceae*	0.215	0.213	0.051	0.48
32	*Antidesma laciniatum*	*Euphorbiaceae*	0.215	0.213	0.097	0.525
33	*Antrocaryon micraster*	*Anacardiaceae*	0.107	0.107	0.017	0.231
34	*Aubregrinia taiensis*	*Mimosaceae*	0.215	0.213	0.037	0.466
35	*Avicennia africana*	*Avienniaceae*	0.43	0.427	0.209	1.066
36	*Azadirachta indica*	*Meliaceae*	0.322	0.32	0.192	0.835
37	*Baillonella toxisperma*	*Sapotaceae*	1.504	1.494	3.672	6.67
38	*Balanites wilsoniana*	*Balanitaceae*	0.322	0.32	0.147	0.789
39	*Baphia maxima*	*Papiloniaceae*	0.537	0.534	0.2	1.271
40	*Baphia nitida*	*Papiloniaceae*	0.537	0.534	0.247	1.318
41	*Barteria fistulosa*	*Passifloraceae*	0.215	0.213	0.036	0.464
42	*Barteria nigritana*	*Passifloraceae*	0.322	0.32	0.263	0.906
43	*Beilschmiedia gaboonensis*	*Lauraceae*	0.322	0.32	0.182	0.825
44	*Beilschmiedia mannii*	*Lauraceae*	0.107	0.107	0.042	0.256
45	*Berlinia auriculata*	*Caesalpinaceae*	0.215	0.213	0.164	0.592
46	*Berlinia bracteosa*	*Caesalpinaceae*	0.107	0.107	0.017	0.231
47	*Blighia sapida*	*Sapindaceae*	0.215	0.213	0.163	0.592
48	*Blighia unijugata*	*Sapindaceae*	0.215	0.213	0.098	0.526
49	*Blighia welwitschii*	*Sapindaceae*	0.107	0.107	0.032	0.246
50	*Bombax buonopozense*	*Bombaceae*	1.611	1.601	2.071	5.283
51	*Bosqueia angolensis*	*Moraceae*	0.537	0.534	0.339	1.41
52	*Bosquiea phoberos*	*Moraceae*	0.322	0.32	0.07	0.713
53	*Brachystegia eurycoma*	*Caesalpinaceae*	2.256	2.241	6.17	10.667
54	*Brachystegia kennedy*	*Caesalpinaceae*	0.107	0.107	0.115	0.33
55	*Brachystegia nigerica*	*Leguminosae*	1.289	1.281	3.089	5.659
56	*Brenania brieyi*	*Rubiaceae*	0.215	0.213	0.255	0.683
57	*Bridelia atroviridis*	*Euphorbiaceae*	0.107	0.107	0.087	0.301
58	*Bridelia ferruginea*	*Euphorbiaceae*	0.322	0.32	0.188	0.831
59	*Caloncoba glauca*	*Flacourtiaceae*	0.537	0.534	0.231	1.301
60	*Calpocalyx brevibracteatus*	*Mimosaceae*	0.43	0.427	0.258	1.115
61	*Calpocalyx spp*	*Mimosaceae*	0.107	0.107	0.016	0.23
62	*Carapa procera*	*Apocynaceae*	0.43	0.427	0.171	1.027
63	*Carpolobia alba*	*Apocynaceae*	0.107	0.107	0.043	0.258
64	*Carpolobia lutea*	*Apocynaceae*	0.107	0.107	0.049	0.263
65	*Casearia barteri*	*Salicaceae*	0.107	0.107	0.053	0.267
66	*Cassipourea congoensis*	*RPhizophoraceae*	0.107	0.107	0.024	0.238
67	*Ceiba pentandra*	*Bombaceae*	1.826	1.814	2.635	6.275
68	*Celtis mildbraedii*	*Ulmaceae*	0.107	0.107	0.105	0.32
69	*Celtis zenkeri*	*Ulmaceae*	0.107	0.107	0.022	0.237
70	*Chrysophyllum albidum*	*Sapotaceae*	1.396	1.387	1.387	4.171
71	*Chrysophyllum spp*	*Sapotaceae*	0.215	0.213	0.15	0.579
72	*Chrysophyllum subnudum*	*Sapotaceae*	0.752	0.747	0.707	2.206
73	*Chytranthus ellipticus*	*Sapindaceae*	0.322	0.32	0.535	1.177
74	*Cinnamomum zeylanicum*	*Lauraceae*	0.43	0.427	0.186	1.043
75	*Citrus spp*	*Rutaceae*	0.644	0.64	0.178	1.463
76	*Cleistanthus polystachyus*	*Euphorbiaceae*	0.215	0.213	0.157	0.585
77	*Cleistopholis patens*	*Annonaceae*	0.215	0.213	0.08	0.508
78	*Cola acuminate*	*Steruliaceae*	0.537	0.534	0.169	1.239
79	*Cola digitate*	*Steruliaceae*	0.215	0.213	0.15	0.579
80	*Cola gigantean*	*Steruliaceae*	0.859	0.854	0.461	2.174
81	*Cola heterophylla*	*Steruliaceae*	0.322	0.32	0.296	0.939
82	*Cola hispida*	*Steruliaceae*	0.322	0.32	0.282	0.924
83	*Cola nigerica*	*Steruliaceae*	0.107	0.107	0.102	0.317
84	*Cola nitida*	*Steruliaceae*	0.43	0.427	0.204	1.061
85	*Cola reticulata*	*Steruliaceae*	0.107	0.107	0.031	0.245

Citation: Esor PE, Ammonum JI, Agera SIN. Forest Structure, Tree Species Diversity, and Distribution in Ukpon River Forest Reserve, Cross River State, Nigeria. *Int J Avian & Wildlife Biol.* 2023;7(2):46–54. DOI: 10.15406/ijawb.2023.07.00189

Table 2 Continued...

S/No	Species	Family	RF(%)	RD(%)	RDo(%)	IVI
86	*Combretodendron macrocarpum*	*Lecythidaceae*	0.107	0.107	0.087	0.301
87	*Cordia millenii*	*Bignoniaceae*	0.107	0.107	0.032	0.246
88	*Cynometra mannii*	*Caesalpinaceae*	0.215	0.213	0.145	0.573
89	*Cynometra megalophylla*	*Caesalpinaceae*	0.107	0.107	0.04	0.254
90	*Dacryodes edulis*	*Burseraceae*	1.611	1.601	2.057	5.27
91	*Dacryodes klaineana*	*Burseraceae*	0.322	0.32	0.366	1.008
92	*Daniellia ogea*	*Ceasalpinaceae*	0.644	0.64	0.56	1.845
93	*Dennettia tripetala*	*Annonaceae*	0.215	0.213	0.042	0.47
94	*Detarium senegalense*	*Caesalpinaceae*	0.107	0.107	0.154	0.368
95	*Dialium dinklagei*	*Caesalpinaceae*	0.107	0.107	0.132	0.346
96	*Dialium guineense*	*Caesalpinaceae*	1.611	1.708	1.439	4.758
97	*Dichaetanthera Africana*	*Melastomataceae*	0.215	0.213	0.064	0.492
98	*Dichapetalum spp*	*Melastomataceae*	0.107	0.107	0.026	0.24
99	*Didelotia Africana*	*Ceasalpinaceae*	0.215	0.213	0.165	0.593
100	*Diospyros abyssinica*	*Ebenaceae*	0.107	0.107	0.121	0.335
101	*Diospyros barteri*	*Ebenaceae*	0.215	0.213	0.052	0.481
102	*Diospyros dendo*	*Ebenaceae*	0.43	0.427	0.193	1.05
103	*Diospyros mannii*	*Ebenaceae*	0.322	0.32	0.387	1.029
104	*Diospyros mespiliformis*	*Ebenaceae*	1.826	1.814	1.137	4.777
105	*Diospyros nigerica*	*Ebenaceae*	0.215	0.213	0.109	0.538
106	*Diospyros preussi*	*Ebenaceae*	0.322	0.32	0.169	0.811
107	*Diospyrus spp*	*Ebenaceae*	0.107	0.107	0.206	0.42
108	*Distemonanthus benthamianus*	*Caesalpinaceae*	0.107	0.107	0.025	0.239
109	*Dracaena arborea*	*Dracaenaceae*	0.43	0.427	0.283	1.139
110	*Drypetes chevalieri*	*Euphorbiaceae*	0.107	0.107	0.144	0.358
111	*Ekebergia senegalesis*	*Meliaceae*	0.215	0.213	0.072	0.5
112	*Enantia chlorantha*	*Annonaceae*	0.107	0.107	0.031	0.245
113	*Entandrophragma angolense*	*Meliaceae*	1.611	1.601	2.604	5.816
114	*Entandrophragma cylindricum*	*Meliaceae*	1.719	1.708	2.672	6.098
115	*Entandrophragma utile*	*Meliaceae*	0.537	0.534	0.774	1.845
116	*Eribroma oblonga*	*Malvaceae*	0.215	0.213	0.082	0.51
117	*Eriocoelum macrocarpum*	*Sapindaceae*	0.215	0.213	0.212	0.641
118	*Erythrina vogelii*	*Caesalpinaceae*	0.322	0.32	0.257	0.899
119	*Erythrophelum suaveolens*	*Caesalpinaceae*	0.107	0.107	0.09	0.304
120	*Erythroxylum mannii*	*Erthroxylaceae*	0.215	0.213	0.124	0.552
121	*Ficus capensis*	*Moracaae*	0.752	0.747	0.157	1.656
122	*Ficus congensis*	*Moraceae*	0.537	0.534	0.149	1.22
123	*Ficus exasperate*	*Moraceae*	1.182	1.174	0.431	2.786
124	*Ficus mucuso*	*Moraceae*	0.107	0.107	0.014	0.228
125	*Ficus vogeliana*	*Moraceae*	0.43	0.427	0.091	0.947
126	*Funtumia elastica*	*Apocynaceae*	1.826	1.814	0.789	4.43
127	*Garcinia kola*	*Moraceae*	1.074	1.067	0.359	2.501
128	*Garcinia livingstonei*	*Moraceae*	0.215	0.213	0.047	0.475
129	*Garcinia manii*	*Apocynaceae*	0.859	0.854	0.446	2.16
130	*Gilbertiodendron dewevrei*	*Caesalpinaceae*	0.215	0.213	0.18	0.608
131	*Gmelina arborea*	*Verbenaceae*	1.182	1.174	1.948	4.303
132	*Grewia coriacea*	*Tillaceae*	0.215	0.213	0.077	0.505
133	*Guarea glomerulata*	*Meliaceae*	0.43	0.427	0.172	1.028
134	*Hannoa klaineana*	*Simaroubaceae*	0.752	0.747	0.474	1.973
135	*Harungana madagascariensis*	*Guttiferae*	0.322	0.32	0.182	0.824
136	*Heinsia crinata*	*Myristicaceae*	0.107	0.107	0.019	0.233
137	*Hevea brasiliensis*	*Euphorbiaceae*	0.537	0.534	0.136	1.207
138	*Hexalobus crispiflorus*	*Annonaceae*	0.107	0.107	0.027	0.241
139	*Hildegardia barteri*	*Sterculiaceae*	0.107	0.107	0.031	0.245
140	*Holarrhena floribunda*	*Apocynaceae*	0.215	0.213	0.066	0.495
141	*Holoptelea grandis*	*Ulmaceae*	0.107	0.107	0.019	0.234
142	*Homalium lelestui*	*Salicaceae*	0.322	0.32	0.073	0.716
143	*Hunteria eburnean*	*Apocynaceae*	0.322	0.32	0.105	0.747
144	*Hylodendron gabunense*	*Caesalpiniaceae*	0.43	0.427	0.133	0.99
145	*Hymenodictyon biafranum*	*Myristicaceae*	0.215	0.213	0.162	0.591

Table 2 Continued...

S/No	Species	Family	RF(%)	RD(%)	RDo(%)	IVI
146	*Hymenostegia afzelia*	*Caesalpinaceae*	0.107	0.107	0.213	0.427
147	*Irvingia gabonensis*	*Irvingiaceae*	1.504	1.494	2.669	5.667
148	*Irvingia grandifolia*	*Meliaceae*	0.107	0.107	0.059	0.273
149	*Irvingia wombolu*	*Irvingiaceae*	0.859	0.854	1.32	3.033
150	*Khaya grandifoliola*	*Meliaceae*	0.967	0.961	1.142	3.069
151	*Khaya ivorensis*	*Meliaceae*	1.933	2.028	2.903	6.865
152	*Kigelia Africana*	*Bignoniaceae*	0.107	0.107	0.016	0.23
153	*Klainedoxa gabonensis*	*Irvingiaceae*	0.322	0.32	0.873	1.515
154	*Lannea welwitschii*	*Anacardiaceae*	0.107	0.107	0.032	0.246
155	*Lecaniodiscus cupanioides*	*Sapindaceae*	0.107	0.107	0.02	0.234
156	*Leonardoxa Africana*	*Caesalpiniaceae*	0.107	0.107	0.059	0.273
157	*Lepidobotrys staudtii*	*Linaceae*	0.215	0.213	0.119	0.547
158	*Leptonychia pallid*	*Sterculiaceae*	0.215	0.213	0.041	0.469
159	*Lophira alata*	*Ochnaceae*	1.826	1.814	1.657	5.297
160	*Lovoa trichilioides*	*Meliaceae*	1.504	1.601	1.902	5.006
161	*Macaranga barteri*	*Euphorbiaceae*	0.107	0.213	0.043	0.364
162	*Maesobotrya staudtii*	*Euphorbiaceae*	0.107	0.107	0.032	0.246
163	*Magnifera indica*	*Anacardiaceae*	0.215	0.213	0.492	0.92
164	*Mallotus oppositifolius*	*Euphorbiaceae*	0.107	0.107	0.026	0.24
165	*Mammea Africana*	*Guttiferae*	0.322	0.32	0.224	0.867
166	*Mangifera indica*	*Anacardiaceae*	0.43	0.427	0.529	1.385
167	*Mansonia altissima*	*Sterculiaceae*	0.107	0.107	0.014	0.228
168	*Markhamia tomentosa*	*Bignomaceae*	0.107	0.107	0.105	0.32
169	*Massularia acuminate*	*Rubiaceae*	0.107	0.107	0.044	0.258
170	*Microberlinia bisulcata*	*Caesalpiniaceae*	0.215	0.213	0.156	0.584
171	*Microdesmis puberula*	*Pandaceae*	0.107	0.107	0.064	0.278
172	*Milicia excels*	*Moraceae*	2.256	2.241	4.97	9.467
173	*Millettia macrophylla*	*Papiloniaceae*	0.215	0.213	0.075	0.503
174	*Mitragyna ledermannii*	*Rubiaceae*	0.107	0.107	0.181	0.396
175	*Moringa oleifera*	*Moringarceae*	0.43	0.427	0.705	1.562
176	*Morus mesozygia*	*Moraceae*	0.322	0.32	0.211	0.854
177	*Musanga cecropioides*	*Urticaceae*	1.182	1.281	2.315	4.778
178	*Myrianthus preussii*	*Cecropiaceae*	0.107	0.107	0.027	0.241
179	*Napoleonaea vogelii*	*Lecythidaceae*	0.43	0.534	0.278	1.242
180	*Nauclea diderrichii*	*Rubiaceae*	1.182	1.174	1.486	3.842
181	*Newbouldia laevis*	*Bignomaceae*	0.859	0.854	0.454	2.167
182	*Newtonia duparquetiana*	*Mimosaceae*	0.107	0.107	0.04	0.254
183	*Octoknema affinis*	*Olacaceae*	0.322	0.32	0.163	0.805
184	*Omphalocarpum elatum*	*Sapotaceae*	0.107	0.107	0.023	0.237
185	*Oubanguia alata*	*Scytopetalacea*	0.107	0.107	0.042	0.256
186	*Oxystigma mannii*	*Caesalpiniaceae*	0.215	0.213	0.167	0.595
187	*Parinari chrysophylla*	*Rubiaceae*	0.107	0.107	0.025	0.239
188	*Parkia bicolor*	*Mimosaceae*	0.537	0.534	0.487	1.557
189	*Paropsia guneensis*	*Passifloraceae*	0.107	0.107	0.021	0.235
190	*Pausinystalia talbotiic*	*Rutaceae*	0.107	0.107	0.054	0.268
191	*Pentaclethra macrophylla*	*Mimosaceae*	1.504	1.494	1.842	4.839
192	*Persea Americana*	*Lauraceae*	0.537	0.534	0.811	1.882
193	*Piptadeniastrum africanum*	*Mimosaceae*	1.396	1.387	4.643	7.427
194	*Poga oleosa*	*Rhizophoraceae*	0.107	0.107	0.128	0.342
195	*Psidium guajava*	*Myrtaceae*	0.215	0.213	0.034	0.462
196	*Pterocarpus mildbraedii*	*Papiloniaceae*	0.107	0.107	0.043	0.257
197	*Pterocarpus osun*	*Mimosaceae*	0.43	0.427	0.27	1.127
198	*Puasinystalia talbotii*	*Rutaceae*	0.107	0.107	0.054	0.268
199	*Pycnanthus angolensis*	*Myristicaceae*	0.644	0.64	0.868	2.153
200	*Pycnanthus microcephalus*	*Myristicaceae*	0.107	0.107	0.033	0.247
201	*Randia longiflora*	*Rubiaceae*	0.43	0.427	0.186	1.043
202	*Raphia hookeri*	*Arecaceae*	0.215	0.213	0.109	0.537
203	*Rauvolfia vomitoria*	*Apocynaceae*	0.107	0.107	0.087	0.301
204	*Rhaptopetalum beguei*	*Scytopetalaceae*	0.107	0.107	0.019	0.234
205	*Ricinodendron heudelotii*	*Euphorbiaceae*	0.967	0.961	0.437	2.364

Citation: Esor PE, Ammonum JI, Agera SIN. Forest Structure, Tree Species Diversity, and Distribution in Ukpon River Forest Reserve, Cross River State, Nigeria. *Int J Avian & Wildlife Biol.* 2023;7(2):46–54. DOI: 10.15406/ijawb.2023.07.00189

Table 2 Continued...

S/No	Species	Family	RF(%)	RD(%)	RDo(%)	IVI
206	*Rinorea dentate*	*Violaceae*	0.107	0.107	0.054	0.268
207	*Roystonea regia*	*Palmae*	0.107	0.107	0.017	0.231
208	*Santiria trimera*	*Burseraceae*	0.107	0.107	0.043	0.258
209	*Sapium ellipticum*	*Euphorbiaceae*	0.107	0.107	0.086	0.3
210	*Scyphocephalum mannii*	*Myristicaceae*	0.107	0.107	0.105	0.319
211	*Spondias mombin*	*Annacardiaceae*	0.752	0.747	0.567	2.066
212	*Stemonocoleus micranthus*	*Papiloniaceae*	0.107	0.107	0.017	0.231
213	*Strombosia grandifolia*	*Olacaceae*	0.107	0.107	0.021	0.235
214	*Strombosia scheffleri*	*Olacaceae*	0.107	0.107	0.129	0.343
215	*Tabernaemontana crassa*	*Apocynaceae*	0.107	0.107	0.017	0.231
216	*Tabernaemontana pachysiphon*	*Apocynaceae*	0.107	0.107	0.087	0.301
217	*Tectona grandis*	*Verbenaceae*	0.322	0.32	0.631	1.274
218	*Terminalia ivorensis*	*Combretaceae*	0.859	0.854	0.906	2.619
219	*Terminalia superb*	*Combretaceae*	0.537	0.534	0.705	1.776
220	*Tetrapleura tetraptera*	*Mimosaceae*	0.752	0.747	0.66	2.159
221	*Thecacoris leptobotrya*	*Euphorbiaceae*	0.107	0.107	0.119	0.333
222	*Theobroma cacao*	*Malvaceae*	0.322	0.32	0.064	0.706
223	*Treculia Africana*	*Moraceae*	1.289	1.281	2.462	5.031
224	*Treculia obovoidea*	*Moraceae*	0.215	0.213	0.165	0.594
225	*Trema guineensis*	*Ulmaceae*	0.107	0.107	0.02	0.234
226	*Trema orientalis*	*Ulmaceae*	0.215	0.213	0.149	0.577
227	*Trichilia welwitschii*	*Meliaceae*	0.322	0.32	0.067	0.71
228	*Trichillia gilgiana*	*Meliaceae*	0.107	0.107	0.018	0.232
229	*Trilepisium madagascariense*	*Moraceae*	0.107	0.107	0.149	0.363
230	*Triplochiton scleroxylon*	*Sterculiaceae*	0.322	0.32	0.137	0.779
231	*Uapaca acuminata*	*Euphorbiaceae*	0.107	0.107	0.032	0.246
232	*Uapaca heudelotii*	*Euphorbiaceae*	0.107	0.107	0.214	0.428
233	*Uapaca togoensis*	*Euphorbiaceae*	0.43	0.427	0.311	1.167
234	*Uvariastrum elliotianum*	*Annonaceae*	0.107	0.107	0.111	0.326
235	*Uvariopsis bakeriana*	*Annonaceae*	0.107	0.107	0.03	0.244
236	*Vernonia conferta*	*Asteraceae*	0.43	0.427	0.179	1.036
237	*Vitex doniana*	*Verbenacea*	0.537	0.534	0.14	1.211
238	*Voacanga africana*	*Apocynaceae*	0.215	0.213	0.067	0.496
239	*Xylopia acutiflora*	*Annonaceae*	0.107	0.107	0.017	0.231
240	*Xylopia aethiopica*	*Annonaceae*	0.107	0.107	0.137	0.352
241	*Xylopia africana*	*Annonaceae*	0.107	0.107	0.032	0.246
242	*Xylopia staudtii*	*Annonaceae*	0.107	0.107	0.039	0.253
243	*Xylopia talbotii*	*Annonaceae*	0.322	0.32	0.353	0.995
244	*Zanthoxylum gilletii*	*Rutaceae*	0.107	0.107	0.015	0.229
245	*Zanthoxylum macrophylla*	*Rutaceae*	0.215	0.213	0.314	0.743
246	*Zanthoxylum rubescens*	*Rutaceae*	0.107	0.107	0.03	0.244
247	*Zanthoxylum zanthoxyloides*	*Rutaceae*	0.107	0.107	0.017	0.231
248	*Zenkerella citrine*	*Leguninosae*	0.107	0.107	0.035	0.249

RF, relative frequency; RD, relative density; RDo, rselative dominance; IVI, importance value index

Species diversity in the sampled transect of okpon river forest reserve

The results in Table 3, across tree species diversity in the sampled transects indicate that Transect (T_5) had the highest number of individual tree species (145) and had Shannon wiener index of 4.563 with species richness of 106 closely followed by Transect seven (T_7) with one hundred and twenty one (121) number of individual species, Shannon wiener index and species richness of 4.203 and 75 respectively. Transects one and three (T_1 and T_3) recorded the same number of individual tree species (118); the Shannon-Wiener indices were 4.405 and 4.079, with species richnesses of 88 and 67, respectively. The least number of species, 93, with a Shannon number of 3.925 and a species richness of 57, was recorded in Transects 8 (Table 3). The summary of diversity indices across the sampled transects at the Okpon River Forest Reserve presented in Table 4 shows that the Shannon Weiner index minimum and maximum values were 3.925 and 4.563 with a mean value of 4.287, while species richness had a minimum and maximum of 57 and 106 with an average value of 81.75. Both the Shannon Weiner index and species richness had standard deviations of 0.212 and 15.508, respectively. Table 5 indicates species diversity indices in the study area; Shannon weiner index recorded (5.058), Simpson's index (0.991), Pielou eveness index (0.917) and Margelef index recorded (36.097). The results of species richness recorded 248 trees in the study sites. Table 5

Table 3 Species diversity in the sampled transects at Okpon river forest reserve

Transects	Number of Individuals	Shannon-Weiner Index(HI)	Species Richness
Transects 1	118	4.079	67
Transects 2	111	4.261	79
Transects 3	118	4.405	88
Transects 4	117	4.432	92
Transects 5	145	4.563	106
Transects 6	114	4.431	90
Transects 7	121	4.203	75
Transects 8	93	3.925	57

Table 4 Summary statistic of diversity indices across the sampled Transects at Okpon river forest reserve

Statistic parameters	Shannon-Weiner index	Species richness
Mean	4.287	81.75
Standard deviation	0.212	15.508
Minimum	3.925	57
Max	4.563	106
Number of transects	8	8

Table 5 Overall species diversity in the study area

Diversity indices	Index value
Shannon-Weiner index	5.058
Simpson's index	0.991
Pielou evenness index	0.917
Margalef index	36.097
Richness	248

Discussion

Forest Structure of Ukpon River Forest Reserve

Diameter and height distributions reflect the horizontal structure and vertical pattern of the forest; these are indications that the forest has the potential for continuous growth. However, the presence of large trees has been reported to be a sign of mature tropical rainforest Zang et al. According to Adekunle et al.,[7] 222 tree stands were found to be in the lower Dbh class of 10–20 cm, followed by 21–30 cm, which had 78 tree stands, and 72 tree stands in the higher Dbh class of 81 cm. Hence, he reported that the diameter distribution indicated healthy recruitment potentials. The lower-class diameter tree stands could develop into mature trees and replace the old ones in the future if proper conservation efforts are sustained. Thus, this structure is typical of a natural forest.[8,9] The minimum and maximum Dbh of trees in the study area were 10.1 m and 80.5 m, respectively. The forest reserve was characterized by an abundance of trees with small Dbh, which is not unusual for tropical rainforests. Similar results have been reported by previous workers in other tropical rainforests in Nigeria.[10] The reason for relatively fewer number of individual trees with large Dbh values greater than >0.70 (Dbh>70) could be attributed to forest degradation activities which may have removed large individuals as well as the facts that some large-sized trees would have been removed through logging operation for some uses in the past.[11]

Tree species diversity and distribution in okpon river forest reserve

The results of this study recorded 68 tree species belonging to 34 families. *Caesalpinceae, Moracea and Meliacea* were the most abundance families. The area is rich in terms of tree species composition. However, the number is lower when compared with the 99 tree species belonging to 36 families recorded in the Takamanda Rainforest of Southwest Cameroon.[12] Similarly, it is lower than 118 tree species reported by Adeyemi et al.,[13] for the Oban Division of the Cross River National Park in Nigeria. A higher number of tree species increases the number of ecological niches for fauna and understory flora. Thus, the presence of numerous tree species on a stand conserves not only more trees but other organisms as well. Comparing the results of this study to a similar study by Oluwatosin et al., in Onigambari forest reserve, Ondo State, Nigeria, they obtained a higher number of families (54) of tree species, while Miazu.[14] reported four families in Kuyambana forest reserve, Zamfara State, Nigeria, even lower than the presence study of 34 families recorded in Okpon river forest reserve. He reported the dominance of the *Caesalpinaceae, Mimosaceae,* and *Combretaceae* families. This finding corroborated the works of Adekunle (2013), who reported that the tropical rainforest ecosystems of southwest Nigeria are dominated by some specific families such as the *Sterculiaceae, Meliaceae, and Moraceae.* In this present study, Okpon River Forest Reserve was dominated by the Caesalpiniaceae, *Meliaceae, and Moraceae families.*

Fabaceae, Melicea, and C*aesalpiniacea* have been reported as dominant plant families in Nigerian tropical forests.[10] The effect of anthropogenic activities on the growth and distribution of tree species may have played a role in the status of these species in the ecosystem, threatening the occurrence and development of certain species while favouring others. The *Caesalpinaceae, Meliaceae, Moraeceae,* and *Euphorbiaceae* were the most prevalent families in the study area. This could be due to their fast regeneration ability associated with symbiotic properties, which may have enabled the species to easily establish within different habitat types. Deka *et al.* (2012) reported that legumes were the most prominent species recorded in Takamanda forest. This may not be far from the fact that the two forest reserves share some ecosystem characteristics and geographic boundaries.

The value of the Shannon Wiener index for tree species in this present study was (5.05). The value recorded in this study is higher than what was reported in other forest reserves; for instance, Parthasarathy (2001) reported H_1 3.89, while Adekunle and Olagoke (2010) reported H_1 4.02 for rainforest in India and Nigeria, respectively. This result is also in line with the findings of Bhat and kaveriappa (2013) who obtained among the fresh water swamp forest of kulathupazha, Anchal, Shendumeg, Karthakani, Pilarlarkan and Charmady Karnataka, Shannon wiener of (2.53), (3.69), (2.46), (4.04), (3.25) and (4.90) were recorded respectively. The reason for the high Shannon wiener in this present study could probably be due to the existing management practices, enacted law enforcements programs and anthropogenic activities.

Important value index for tree species

The tree with the highest importance value in the reserve was *Brachystegia eurycoma* (10.6%) followed by *Milicia excelsa* (9.4%). This is consistent with the works of Soumana et al., who reported that, most tree species could grow best in loamy sandy soils. The tree with the lowest importance index in the study area was *Pterocarpus* osun (1.1%). This could likely be due to the multi-purpose usefulness (commercial and medicinal uses) of the tree, which is very important to the local economy. According to Curtis and Mcintosh (1951), a high importance value index IVI of a species indicates its dominance and ecological success, its good power of regeneration, and a greater ecological amplitude; these plants also need conservation management, while species that were grouped as

having a low importance value therefore need high conservation effort Abdullahi, Abba. The highest regeneration potentials were recorded in *Treculia africana* (0.025%), which is quite lower in value than the 0.189% *Culcacia saxatilis* species obtained in the Onigambari forest reserve in Oyo State, Nigeria, by Salami et al. (2016). The differences in value could be attributed to the management practises adopted in the forest reserve. The regeneration potential in the study area was generally very poor. This has a serious implication on the regeneration and conservation of the various species encountered on the renewal of the forest in general. Wale et al. (2012) also noted that lack of adequate regeneration is an issue recognised by foresters and ecologists. Malik and Bhat (2016) also observed limited regeneration and subsequently declining populations of some dominant native species. Jaya Kumar and Nair (2013) observed in their study that only 101 species regenerate well, with one of the dominant species having no seedlings, which is an indication of poor regeneration.[15–21]

Conclusion and recommendation

Based on the results of this finding, a total of 68 tree species from 34 families were encountered in the study area. The results indicate that, *Meliaceae* had the highest number (6) of tree species, *Caesalpiniceae* had 5 species. There was low tree species density and high species diversity in the study area. The dominant height in the reserve was 40 m, with a Dbh class of 10–20 cm, which tends to dominate. To ensure suitable habitat for sustainable wildlife management and to prevent the extinction of some tree species in the area, there is a need to restrict logging activities and other illegal activities that have a negative effect on stand density and species distribution and abundance. Also, tight control of natural areas should be highly promoted because it is impossible to overstate how much they contribute to preventing climate change in the Ukpon area of Nigeria's Cross River State.

Acknowledgments

None.

Conflicts of interests

Authors declare that there are no conflicts of interest.

References

1. Sushma S, Subair A, Chandra M, et al. Tree species richness, diversity and regeneration status in different oak (Quercus spp) dominated forest of garhwal himalaya India. *Journal of Asia Pacific Biodiversity*. 2016;9:293–300.
2. Malik ZA, Hussan A, Igbal,K. Species Richness and diversity along the distribution gradient in Kadonath Wildlife Sanctuary and its adjourning areas in Garhwal Himalaya, India. *International journal of Current Research;* 2014.
3. Neelo JD, Teketay K, Kashe, et al. Stand structure, diversity and regeneration status of woody species in open and ex close dry wood land sites around molapo farming areas of the Okavango delta, Norlheasterm Botswana. *Open Journal of Forest*. 2015;5 (4):313–228.
4. Malhi Y, Lewis SL, Mayaux P, et al. African rainforests; past; present and future. *Philosophical transactions of the rayal society Biological Science*; 2013.
5. Pushpangadam P. Economic evaluation of biodiversity in context of CBD and IPR regimes. In: regional training programed on biodiversity systematics evaluation and monetary with emphasis on medicinal plants. National Botanical Research Institute: Lucknow India; 2001.
6. Gillison AN. Biodiversity assessment in the north bank landscape, North East India: a preliminary survey; 2004.
7. Adekunle VAJ. Olagoke AO, Akindele SO. Tree species diversity and structure of a nigeria strict nature reserve. *Tropical Ecology*. 2013;54(3):275–289.
8. Ogana FN, Gorgoso, Varela JJ. Comparison of estimation methods for fitting meibull distribution to the natural stand of oluwa forest reserve, Ondo State, Nigeria. *Journal of Research in Forestry. Wildlife and Environment*. 2015;7(2):81–90.
9. Dau JH, Vange T, Amonum JI. Growth space requirements models for *Daniellia Oliverii* (*Rolfe) hutch and Daviz* tree in Makurdi, Nigeria. *International Journal of Forestry and Horticulture (IJFH)*. 2016;2(3):31–39.
10. Adekunle VAJ, Olagoke AO. Diversity and bio volume of tree species in natural forest ecosystem in the bitumen – producing area of Ondo state, Nigeria. *Baseline study Biodiversity and Conservation*. 2008;17:2735–2755.
11. Hadi S, Zieglar T, Waltert M, et al. Tree diversity and forest structure in northern Siberut, Mentawai island, Indonesia. *Tropical Ecology*. 2009;50(2):315–327.
12. Egbe EA, Chuyong GB, Fonge BA, et al. Forest disturbance at korup national park. Cameroon. *International Journal of Biodiversity Conservation*. 2012;4(11):377–384.
13. Adeyemi AA, Jimoh SO, Adesoye PO. Assessment of tree diversities in oban division of the cross river nation park (CRNP), Nigeria. *Journal of Agriculture, Forestry and the Social Sciences*. 2013;11(1):216–230.
14. Miazu A. *Woody plants genetics resources of kuyambana forest reerve, Mara zamfara state*. Dissertation on department of biological sciences, Usman danfodiyo university, Sokoto; 2010.
15. Abdulahi MB. *Phytosociological studies and community rural appraisal towards biodiversity conservation in yankari: Game reserve, Bauchi state, Nigeria.* Abubakar Tafawa Belawa University, Bauchi, Nigeria; 2010.
16. Adekunle VAJ, Olagoke AO, Ogundare LF. Rate of timber production in a tropical rainforest ecosystem of southwest nigeria and its implications on sustainable forest management. *Journal of Forestry Research*. 2010;21:225–230.
17. 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.
18. Dekka J, Tripath PO, Khan LM. High dominance of shorea robusta gaertn in alluvial plain kammp sal forest of Assam, North Eastern. *India International Journal of Ecosystem.* 2002;2(4):67–73.
19. Haby VA, Marvin L, Baker, et al. V*egetables growers handbook.* 4th edition. Compiled by Joseph GM, Frank JD (Emeritus). Texas A & M University. Horticultural and Forestry Science Building College Station, Texas; 2009.
20. Lippork D, Beck SG, Renson D, et al. Topography and edge effects are more important than elevation as derives of vegetation patterns in a neotropical montane forest. *Journal of Vegetation Science.* 25;724–733.
21. Parthasarathy N. Changes in forest composition and structure in three sites of tropical evergneen forest around sengaltheri, western ghats. *Current Science*. 2015;80(3):389–393.