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Original Article

Tree species diversity in tropical rainforest of Okomu forest reserve, Nigeria

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ABSTRACT

Nigeria's rainforests are characterised by enormous plant diversity, intricate stand structures, and are potential biodiversity hotspots. Tree species in Nigeria's rainforest, which are essential to life and our environment are vanishing at a disturbing rate. Climate change impacts additionally exacerbate the plights of many indigenous tree species, as it may limit the capability of forest trees to speedily acclimatise. This study focused on the assessment of tree species diversity in Okomu Forest Reserve (OFR). Using a systematic sampling technique, sixty plots of 50 m × 50 m were alternately laid at 200 m intervals on 15 transects (one kilometer each). On each plot, trees with Diameter at Breast Height (DBH, cm) ≥ 10 were identified to species level and enumerated. The stand density (N/ha) was estimated. Based on abundance, species diversities were computed using the Importance Value Index (IVI, %), Shannon-Wiener diversity (H'), Simpson Dominance (D), and Evenness (E) indices. Data were analysed using descriptive statistics and alpha diversity analysis. Eighty-seven tree species belonging to 33 families were identified. The number of stem/ha ranged from 128.0 to 424.0. *Trichilia monadelpha* had the highest IVI (14.29), while *Lannea welwitschii* had the least (0.15). High H' (4.05), D (0.98), and E (0.91) were observed. This study has shown that OFR is better stocked in comparison with other tropical rainforests in Nigeria in terms of species distribution, especially those of the southern part of the country, Nigeria. This study therefore recommends that inventory of OFR should be regularly conducted at least every five years.

K E Y W O R D S : *Climate change , Importance value index, Natural forest, Tree diversity.*

INTRODUCTION

Nigerian forests are one of the 25 biodiversity hotspots of international importance for conservation primacies (Enaruvbe, 2018) and the Nigerian tropical rainforests form a considerable measure of this. Nigeria is indeed endowed with massive area of forest lands such as the swamp forests and tropical rainforest thrilling in the Southern part of the country and savannah in the middle belt. Nigeria ranks amid the countries in the world with abundant forest resources. Mfon *et al.* (2014) recounted that out of Nigerian total land area of about 910,770 km^2, forests covered about 110,890 km^2.

Lowland rainforests in Nigeria are characterised by enormous plant diversity and intricate stand structures. Adekunle *et al.* (2013) reported that these rainforests are potential biodiversity hotspots. Okomu Forest Reserve is a lowland tropical rainforest located in Edo State, south-south Nigeria (Ihenyen *et al.*, 2011). The reserve in 90s comprises of moderately 5 untouched high forest ecosystems in West Africa and is endowed with endemic

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tree species of global importance (Ajayi, 1996). Trees, which are important for the sustenance of life and the health of our planet, are disappearing at an alarming rate (Ezenwenyi *et al.*, 2023). In Nigeria, the impacts of climate change had further aggravated the plights of many indigenous and exotic tree species as climatic variability has limited the ability of forest trees to quickly adapt to the changing climate (Ezenwenyi *et al.*, 2023).

However, despite the biological richness of Okomu Forest Reserve and other tropical forests in Nigeria, these forests are faced with land use pressure mounted by many factors, thereby leading to degradation (Ihenyen *et al.*, 2011). As a result, most of these forests have either been converted to farmland of arable and cash crops or other land uses (Akwaji *et al.*, 2022; Ezenwenyi *et al.*, 2023). The knowledge of the tree species diversity will enable peoples to positively relate with the trees as well as promote the diversity and sustainable management of the tree (Ezenwenyi *et al.*, 2023).

MATERIALS AND METHOD

The study area

This study was conducted in Okomu Forest Reserve (OFR), located in Edo State, Nigeria (6º 09' - 6º32' N; 5º1' - 5º27' E). The map of Okomu Forest Reserve is shown in Figure 1. The forest reserve (FR) has an estimated area of 1,120 km^2 and lies amid rivers Osse and Siluko to the east and west respectively. The vegetation of the OFR is distinctive Guinea–Congo lowland rainforest and is comprised of a mixture of swamp-forest, high forest, secondary forest, and open scrub (BirdLife International, 2011). The OFR comprises of semi-deciduous, moist, lowland rainforest and is archetypal of this fast-vanishing ecosystem of southwestern Nigeria. Freshwater swamp forests are found along the rivers. Okomu has a typical humid tropical climate characterized by two major seasons (rainy and dry). The rainy season lasts from March to October, while dry season lasts from November to February. December and January in Okomu are characterized by Harmattan. The mean annual rainfall of Okomu is 2100 mm with mean temperature of about 30ºC (Enaruvbe, 2018).

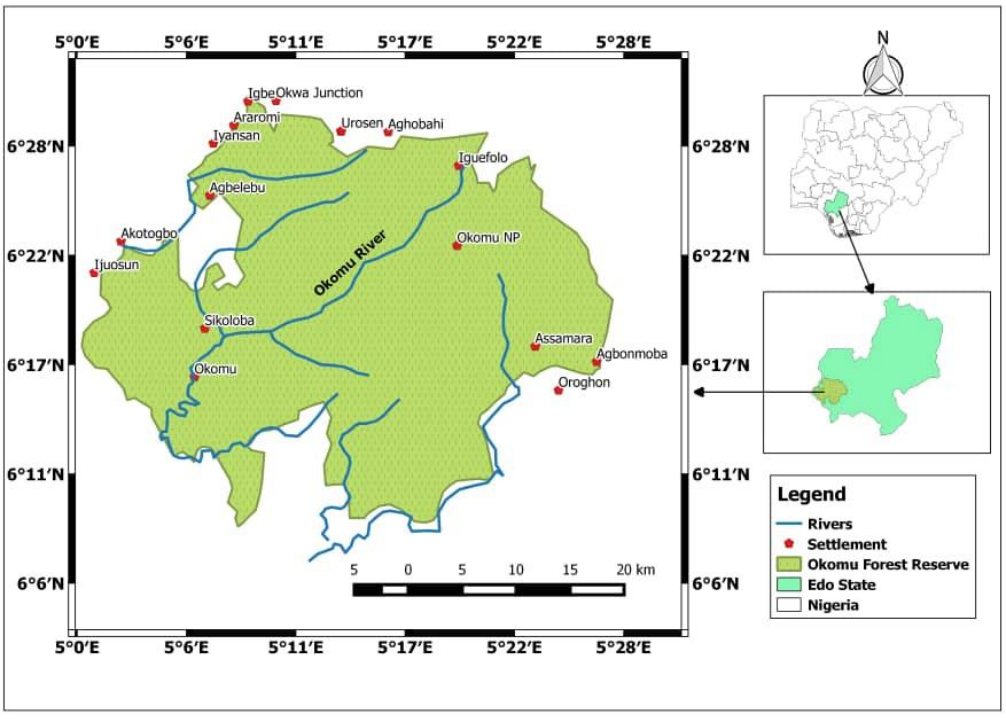

Figure 1: Map of Okomu Forest Reserve, Nigeria

Data Collection

Sampling technique

The data for this study were collected from Okomu Forest Reserve, Nigeria. Systematic (line transect) sampling technique was adopted for plot demarcation in the two management units (locations) within the reserve namely B.C 9 and B.C 10. Line transects of 1 km long situated 600 m apart were established in the two management units of the forest reserve. In location or unit B.C 9, six (6) transects were established with four sample plots of 50 m × 50 m (i.e. 0.25 ha) laid alternately along each transect at 200 m intervals resulting to 24 plots for the 6 transects. In unit B.C 10, Nine (9) transects of the same previously stated distance and plot dimensions were also established, resulting to 36 plots for the 9 transects. The disparity in number of transects was due to different land size areas under each management unit. Hence, sixty sample plots were used in this study. Only trees with diameter at breast height (Dbh) ≥ 10 cm were selected within the sample plots for species identification and recording.

Data processing

Tree species diversity indices computation

Shannon-Wiener diversity index (H'): This is the most widely used index in community ecology. It was calculated to determine the tree species diversity and it's mathematical been expression as:

$$H' = -\sum_{i=1}^{s} P_i \ln P_i \quad (1)$$

Where; H' = Shannon-Wiener index, P_i= is the fraction of individual belonging to the ith species, *ln* = natural log, *i* = 1, 2, . . ., s and s = number of species in the sample. If H' <1, this implies that the tree diversity of the forest is low and vice versa.

Simpson index (D): This is weighted towards the abundance of the commonest species. However, Magurran (2004) stated that Simpson index is one of the most significant and strong diversity measures existing. In essence, it accounts for the differences of the species richness and dispersal.

$$Simpson\ index\ (D) = 1 - \sum_{i=1}^{m} P_i^2 \quad (2)$$

Where, P_i = the proportional abundance of the ith species($P_i = \frac{n_i}{N}$), n_i = individual observation of ith species, N = Total number of all species. i = 1, 2, …, m

Tree density (TD) calculation: The density of trees in a stand (stem density) is an essential measure of forest condition.

$$TD = \frac{N_s}{A} \quad (3)$$

Where, N_s = number of tree stems, A = unit area

Importance Value Index (IVI): this is used to assess the importance of species present in each location. The formula for calculating IVI is expressed as: $IVI = RD + RF + RD_o$ (4)

Where; RD = Relative density (%), FR= Relative frequency (%) and RD_o = Relative Dominance

Data analysis

Tree diversity and exploratory analyses: Alpha diversity method according to Magurran (2004) was used in the analysis of tree diversity for Shannon and Simpson indices while descriptive statistics (frequency, percentage, graphs etc.) was used in analysing the species composition.

RESULTS AND DISCUSSION

Results

Tree species composition

A total of 87 species of 76 genera and 33 families of trees were identified and recorded in the study area (Tables 1). *Strombosia pustulata* Blume (147), *Trichilia monadelpha* Thonn. (147), *Sterculia oblonga* Mast. (146) and *Staudtia stipitata* Warb. (146) species of the families Olacaceae, Meliaceae, Malvaceae and Myristicaceae were most represented in the study area. Species like *Rinorea dentata* P. Beauv., *Mitragyna stipulosa* (D.C) O. Kuntze, *Hylodendron gabunense* Tuub., *Diospyros insculpta* Hutch. and Dalziel, *Diospyros discolor* Willd, *Diospyros barteri* Hiern, *Dacryodes klaineana* (Pierre) H.J. Lam, *Newbouldia laevis* Seem., *Enantia chlorantha* Oliv., and *Lannea welwitsschii* (Hien) Engl. species of families Violaceae,Rubiaceae, Fabaceae, Ebenaceae, Burseraceae, Bignoniaceae, Annonaceae and Anacardiaceae were less represented with very few trees of between 1 to 5 trees across all the sampled plots respectively (Table 1a-1c). *Trichilia monadelpha* Thonn. had the highest Importance Value Index (IVI) value of 14.29. This was followed by *Strombosia pustulata* Blume, *Staudtia stipitata* Warb. and *Sterculia oblonga* Mast. species with IVI values of 13.92, 13.91 and 13.11 respectively while *Lannea welwitsschii* had the least IVI value of 0.15. see Tables 1a-1c for more details.

The number of trees observed and tree Species distribution according to Family

The results of the total number of trees observed according to family are presented in Figure 2. The family Meliaceae had the highest frequency of observation of 422 trees; followed by Malvaceae (291), Fabaceae (261) and Myristicaceae (236). The family Violaceae had the lowest number (1) of observation. The number of tree species distributed according to family as presented in Figure 3 revealed that the family Fabaceae had the highest number of species (11); followed by Meliaceae (8) and Moraceae (6).The families Ulmaceae, Capparidaceae, Cecropiaceae, Clusiaceae, Gentianaceae, Leguminosae, Lycythidaceae, Ochnaceae, Passifloraceae, Rhizophoraceae, Rutaceae, Saptaceae, Simaroubaceae, Urticaceae and Violaceae had the same and lowest number (1) of species each.

Table 1: Tree species and their respective families

Family	Species	Frquency	IVI
Anacardiaceae	*Lannea welwitsschii* (Hien) Engl.	1	0.15
	Spondias mombin L.	7	0.66
Annonaceae	*Annonidium mannii* Oliv.	19	1.67
	Clesistopholis pathens Benth.	38	3.65
	Enantia chlorantha Oliv.	4	0.64
	Monodora myristica (Gaertn.) Dunal	28	2.62
	Monodora tenuifolia	7	0.64
Apocynaceae	*Alstonia boonei* De Wild	25	3.03
	Funtumia elastica P. preuss.	33	3.02
	Mezonerum benthamianum Baill.	8	0.71
	Rauvolfia vomitoria Afzel.	15	1.26
	Vocanga africana Stapt.	25	2.12
Bignoniaceae	*Newbouldia laevis* Seem.	2	0.20
	Spathodea campanulata P. Beauv.	15	1.43
Burseraceae	*Canarium scheweinfurthii* Engl.	11	1.57
	Dacryodes klaineana (Pierre) H.J. Lam	4	0.40
Cannabaceae	*Trema orientalis* (L.) Blume	18	1.59
Capparidaceae	*Buchholzia coriacea* Engl.	37	3.41
Cecropiaceae	*Myrianthus arboreus* P.Beauv.	106	9.95
Clusiaceae	*Allanblackia floribunda* Oliv.	40	3.87
Combretaceae	*Terminalia ivorenesis* A.Chev.	51	7.70
	Terminalia superba Engl. & Diels	30	3.98
Ebenaceae	*Diospyros barteri* Hiern.	3	0.24
	Diospyros crassiflora	114	10.51
	Diospyros discolor Willd.	3	0.30
	Diospyros insculpta Hutch. & Dalziel	5	0.46
Euphorbiaceae	*Macaranga barteri* Roberty	33	2.82
	Ricinodendron heudelotti Baill.	43	5.33
	Drypetes gossweileri S.Moore	25	2.37
Fabaceae	*Albezia zygia* DC.	32	3.36
	Daniella ogea Harms.	26	3.29
	Hylodendron gabunense Tuub.	4	0.46
	Afzelia africana Ex pers.	8	1.12
	Anthonatha macrophylla P. Beauv.	20	1.75
	Distemonanthus benthamianus Baill.	24	3.47
	Baphia nitida Lodd.	17	1.73
	Albizia ferruginea Guill.	9	0.97
	Pentaclethra macrophylla Benth.	65	9.00
	Piptandeniastrum africanum Hook.f.	43	7.10
	Tetrapleura tetraptera Schumach. & Thonn.	13	1.34
Gentianaceae	*Anthocleista vogelii* Planch.	11	1.23
Irvingiaceae	*Irvingia gabonensis*	23	3.14
	Irvingia wombulu Vermoesen	68	8.05
Leguminosae	*Cylicodiscus gabunensis*	33	6.04
Lycythidaceae	*Combretodendran africanum* Welw. Ex Benth.	6	0.56
Malvaceae	*Ceiba pentandra* L.	44	9.35
	Cola rostrata K. Schum.	31	6.55
	Triplochiton scleroxylon K. Schum.	51	2.75
	Bombax buonopozense P. Beauv.	19	4.48
	Sterculia oblonga Mast.	146	13.11
Meliaceae	*Carapa procera* DC.	51	4.64
	Entandrophragma angolense Welw.	40	4.81
	Entandrophragma cylindericum Sprague	43	5.75
	Guarea cedrata A.chev.	32	2.88
	*Guarea thompsoni*i Sprague & Hutch.	32	3.48
	Khaya ivorensis A.Chev.	16	2.24
	Lovoa trichilioides	61	5.56
	Trichilia monadelpha Thonn.	147	14.29

Moraceae	*Antiaris toxicaria* Lesch.	14	1.47
	Ficus exasperata Vahl.	35	3.51
	*Milicia excels*a Welw.	20	2.87
	Musanga cecropoides R.Br.	11	0.99
	Treculia africana Decene	60	5.61
	Treculia obovoidea N.E.Br.	8	0.64
Myristicaceae	*Staudtia stipitata* Warb.	146	13.91
	Psidium guajava	7	0.60
	Pycnanthus angolensis (Welw). Warb	83	10.20
Ochnaceae	*Lophira alata* Banks ex.	37	4.14
Olacaceae	*Coula edulis* Baill.	8	0.73
	Strombosia grandifolia Hook.f.	19	1.57
	Strombosia pustulata Blume	147	13.92
Passifloraceae	*Barteria fistulos*a Mast.	24	1.93
Rhizophoraceae	*Anopyxis Klaineana* (Pierre) Engl.	6	0.73
Rubiaceae	*Cantium gabrifolium*	14	1.22
	Mitragyna stipulosa (D.C) O.Kuntze	3	0.24
	Nauclea diderrichii De Wild.	30	3.33
	Pausinystalia johimbe k. Schum.	22	2.33
	Rothmannia hispida K. Schum.	16	1.29
Rutaceae	*Zanthoxylum zanthoxyloides* Lam.	61	6.50
Sapotaceae	*Chrysophyllum albidum* G.Don.	40	5.12
Simaroubaceae	*Hannoa klainema* Pierre & Engl.	10	0.97
Sterculiaceae	*Sterculia rhinopetela* K.Schum.	73	6.73
	Cola millenii K. Schum.	37	3.33
	Pterogota macrocarpa K.	28	3.15
Ulmaceae	*Celtis zenkeri* Engl.	113	11.25
Urticaceae	*Myrianthus libericus* Rendle	10	1.03
Violaceae	*Rinorea dentata* P. Beauv.	2	0.16

Where: IVI= important value index

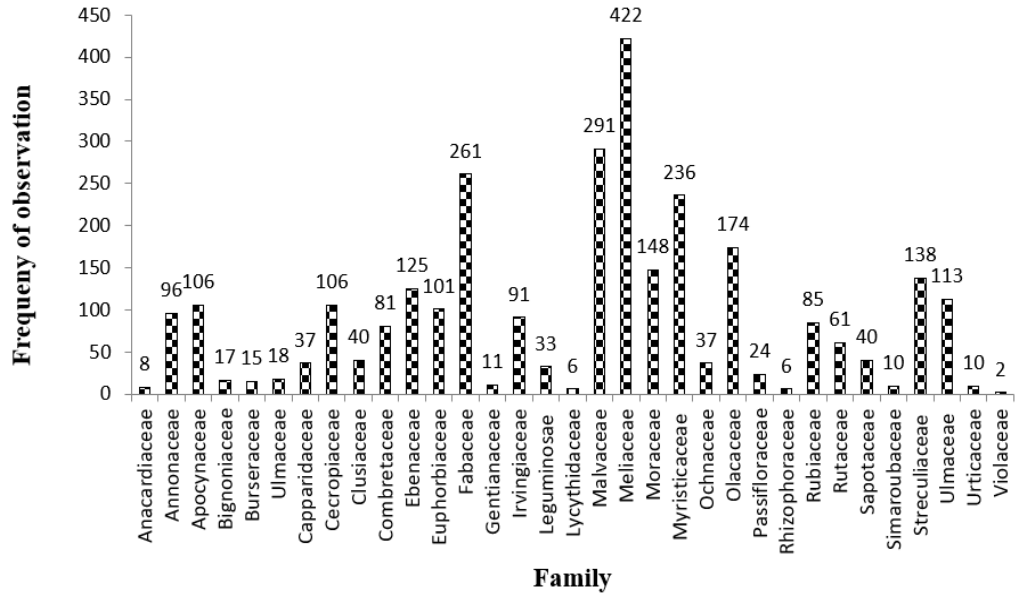

Figure 2: Number of trees observed in the study area according to Family

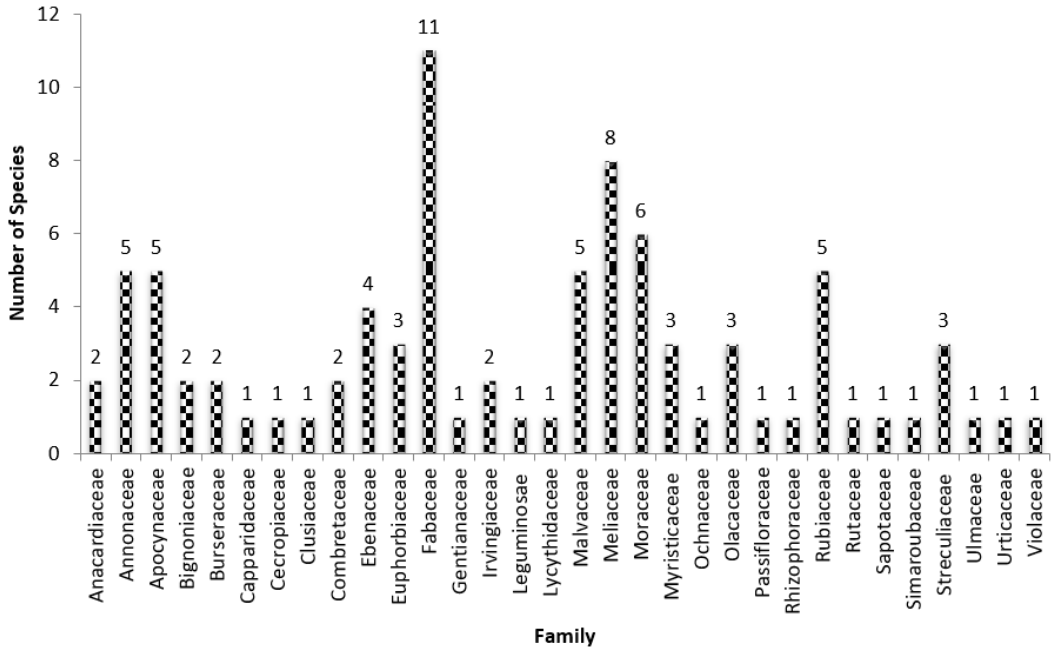

Figure 3: Tree species distribution in the study area according to Family

Species diversity, density and diameter distributions of trees in the study area

A total of 87 species and 76 genera in 33 families was identified and recorded in this study (Table 2). The density of trees per hectare in the study area ranged from 128.0 to 424.0. The result of Shannon-Weiner diversity Index (H') revealed that tree species diversity was 4.05. Simpson index (D) value for species abundance was 0.98 and species evenness (E) was 0.91.

Table 2: Diversity indices

Diversity indices	Values
Number of Trees/ha	128-424
Number of species	87
Number of family	33
Number of Genera	76
Shannon index (H')	4.05
Simpson index (D)	0.98
Species evenness (E)	0.91

Discussion

The tree 87 species in the study area, distributed into 76 genera and 33 families, implies that the vegetation is richer than what was reported by Réjou-Méchain *et al.* (2008) for tropical forest in Central Africa where 73 tree species of 25 families were documented. Also, the result of this study was higher than the report of Bello *et al.* (2013) for Kogo Forest Reserve where 29 species in 25 genera and 16 families recorded. Similarly, the result was also higher than 75 species and 31 families in Tropical Forests in Myanmar noted by Inkyin *et al.* (2017). The variances in the result of this study and the earlier findings may be due to the gradations of anthropogenic activities as well as climate, topographical localities, ecological zones of the diverse forests studied. Bello *et al.* (2013) and Igu and Ezenwenyi (2023) affirmed that unpredictability in terms of anthropogenic activities, ecological zones, climate and weather are major driving factors determining the abundance and distribution of plant species.

In this study, the Fabaceae family had the highest richness of eleven (11) tree species. Other important families in forest reserve include: Meliaceae, Moraceae, Malvaceae, Annonaceae and Apocynaceae. This is similar to the findings of Omorogbe (2004), who reported 14 species from Fabaceae family having the highest family richness in Sakponba Forest Reserve, Edo State, Nigeria. He also reported that Fabaceae was followed by Meliaceae with 7 species; Annonaceae and Sterculiaceae with 6 species each, Moraceae and Apocynaceae had 5 while Euphorbiaceae had 4. The dominance of species in families with high diversity might be owed to their methods of seed distribution and adaptation of these species in these families to the environment. These plants use an explosive mechanism for releasing seeds from their pods and these seeds are then wind dispersed to great distances from their origin. To this end, seeds travel far

from the mother tree and germinate under favourable conditions in the rich luxuriant watershed ecosystem (Ihenyen *et al.*, 2010). Ihenyen *et al.* (2010) and Bello *et al.* (2013) stated similar cases that for some species to be most prevalent in their various areas of studies may be due to adaptation of the species in these families to that environment. Ogunleye *et al.* (2004) also recounted the domination of Fabaceae and Meliaceae in Olokemeji Forest Reserve in Nigeria because they are easily dispersed.

The high values of the diversity indices had shown high species diversity in the study area. The Shannon-Wiener diversity index, Simpson index, Importance value index and species evenness in the study area compared satisfactorily with the standards of Lu *et al.* (2010) and Adekunle *et al.* (2013) who reported high Shannon-Wiener index (3.75), species evenness (0.82) and other diversity indices in their study on tree species diversity and structure of a Nigerian strict nature reserve indicating that the forest is a potential biodiversity hotspot. Olajuyigbe and Jeminiwa (2018) also reported high diversity in their research on tree Species diversity and structure of Eda Forest reserve, Ekiti State, Nigeria. This is also similar to the findings of Igu and Ezenwenyi (2023) who reported species diversity: Shannon index (3.67), Simpson's index (1.06) and evenness (0.79) which showed that the species were much varied and properly distributed accordingly. The number of trees per hectare (128-324) obtained in this study

CONCLUSION AND RECOMMENDATION

This study has shown that Okomu forest reserve is better stocked than most of other tropical rainforests in Nigeria in terms of species distribution especially those of the southern part of the country Nigeria. However, the value was lower than what was obtained in the tropical rainforest in India. This Study therefore, recommends that inventory of forest estate should be regularly conducted and documented at least every five years to provide up-to-date information on the biodiversity and the stocking of the reserve for proper management.

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Authors' Contributions

JUE and OO managed data collection. JUE did the interpretation of the data, writing of the manuscript, material support. JSA reviewed the manuscript. JUE managed the literature searches. JUE managed the development of methodology and data analysis. All Authors read and approved the final manuscript.

Ethical Statement

Not applicable.

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