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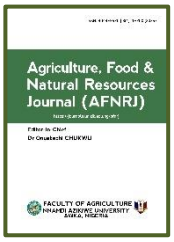

Original Article

Tree species composition and diversity across three forest reserves in Oyo State, Nigeria

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A B S T R A C T

Forest reserves play a crucial role in biodiversity conservation and ecosystem stability, yet increasing exploitation threatens their ecological integrity. Tree species composition and diversity were assessed at Ijaye, Osho, and Onigambari forest reserves, Oyo State, Nigeria. A systematic sampling design was employed, and two lines transect, each 1000 m long and separated by 500m. Four temporary sample plots of 20×40m sizes were laid along each transect at 250m intervals. Diameter at breast height was measured from each of the trees in each plot; this was used to compute basal area, relative frequency, and relative dominance, and habitat occupancy was obtained and compared. Shannon-Weiner and species evenness indices were used to assess tree species diversity and abundance. The result shows that a total of 206 different tree species from six (6) families were encountered in Ijaye forest reserve, 177 trees from 12 families for Osho Forest reserve, while 189 trees from 17 families were encountered at Onigambari forest reserve. Shannon-Weiner values obtained were 1.95, 2.69, and 3.20 for Ijaye, Osho, and Onigambari forest reserves, while species evenness indices were 0.74, 0.91, and 0.88 for Ijaiye, Osho, and Onigambari forest reserves. Out of 36 tree species encountered in the three forest reserves, only 8 species had regeneration potential >1, which is regarded as low regeneration potential. The study concluded that exploitation has affected species diversity in the ecosystem and subsequently the roles of trees in environmental conservation are affected. Implementing silvicultural treatments is therefore recommended in order to improve species growth and facilitate natural regeneration.

K E Y W O R D S : *Abundance, Diversity, Exploitation, Regeneration potentials, Tree composition*

INTRODUCTION

Forests are complex ecosystems that support a rich diversity of plants, animals, and microbes, all of which interact with non-living abiotic factors (FAO, 2007). These ecosystems play vital roles, such as providing timber, preserving biodiversity, acting as carbon sinks, and supporting indigenous communities. Forests also function as social-ecological systems, offering essential ecosystem services (Chazdon *et al*., 2016).

Beyond their ecological significance, forests are crucial to global energy supply, particularly in rural areas. They also provide essential materials for construction, paper production, and non-timber products such as food, fodder, and medicine.

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Additionally, forests offer significant cultural, spiritual, and recreational benefits to millions of people (Agbogidi & Eshegbeyi, 2008).

Despite these numerous benefits, forests are being lost at an alarming rate, with around 13 million hectares of tropical forest disappearing each year, primarily due to agricultural expansion (FAO, 2015). In Africa, the total forest area was estimated at 635 million hectares in 2005, with a net annual loss of approximately 4 million hectares from 2000 to 2005, accounting for nearly 55% of the global reduction in forest cover (FAO, 2007). The most significant losses have occurred in countries with the largest forest areas, such as Nigeria, which is a leading contributor to deforestation in West Africa (FAO, 2007).

In many developing countries, including Nigeria, land-use practices are often poorly planned, leading to unsustainable agricultural, forestry, and urban development. Nigeria, covering a total area of 92.4 million hectares, has about 9.7 million hectares (roughly 10% of the country) designated as forest reserves (Dankumo *et al*., 2015). However, only a small portion of these reserves are made up of lowland rainforest (Dankumo *et al*., 2015). By the late 1990s, only around 1.19 million hectares of lowland rainforest remained, with 288,000 hectares officially protected as forest reserves (ITTO, 2011). Similar to forests in other countries, Nigeria's forests provide a wide range of wood and non-wood products and offer critical environmental and social services. However, the growing demand for these resources has placed significant pressure on forest ecosystems, leading to over-exploitation and degradation (Onuoha, 1999; Oyebo, 2002). Human activities have intensified the pressure on forests, contributing to biodiversity loss, land and water degradation, and the release of substantial amounts of carbon into the atmosphere (Ajake, 2008). The greatest threats, particularly deforestation, are concentrated in developing countries within tropical ecosystems (FAO, 2007).

Effective forest management is essential to mitigate these impacts, and understanding stand density is crucial for assessing overcrowding and competition between trees in forest stands. Accurate quantitative and qualitative ecological data are necessary for guiding forest owners and managers in developing sustainable management strategies. The aim of this study is to provide baseline data on forest composition and regeneration potential, comparing these factors across three selected forest reserves in Nigeria. By assessing these reserves, the research will contribute to a better understanding of the current state of these ecosystems and offer insights into potential conservation and management strategies.

METHODOLOGY

The study was carried out in Oyo State, Nigeria. Oyo State is located in Southwestern part of Nigeria occupying about 2,650,000 ha (National Bureau of Statistics: (2012)). It is bounded in the North by Kwara State, in the East by Osun State, in the South by Ogun State and in the West partly by Ogun State and partly by the Republic of Benin. Oyo State is situated between latitudes 7° 3'0.26"N and 9°11'6.10"N and longitudes 2°42'25.14"E and 4°33'23.84"E respectively. The study was carried out in three (3) selected forest reserves within Oyo State. The selected forest reserves for this research were Ijaiye forest reserve between latitudes 7°45′ and 7°43′ N and longitudes 3°46′ and 3°48′ E., Onigambari forest reserve between latitude 7°26′ N and longitude 3°51′ E and Osho forest reserve latitude between 6°50′ N and longitude 4°30′ E.

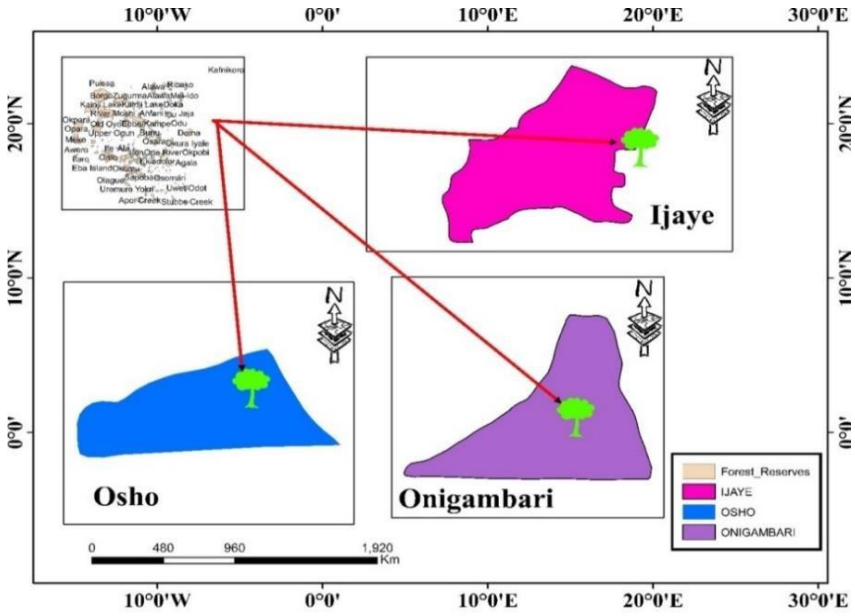

Figure 1: Map of Oyo State Showing the Study Forest Reserves

Sampling procedure

A systematic line transect was employed in the laying of the plots. Two transects of 1000m in length with a distance of at least 500m between the two parallel transects were used in each of the study sites. Sample plots of 20m x 40m in size was laid in alternate along each transect at 250m intervals and thus summing up to 4 sample plots per 1000m transect and a total of 8 sample plots under each of the selected forest sites and 24 sample plots for this study.

Data Computation and Analysis

Based area calculation

The basal area of all trees in each of the sample plot was calculated using equation 1:

$BA = \pi D^2/4$ (1)

Where BA = Basal area (m^2); D = Diameter at breast height (cm) and π = Pi (3.142).

The total basal area for each sample plot was obtained by adding the basal areas of all the trees in the plot per hectare basis. All tree species were classified into families using Keay (1989) as a guide.

The following biodiversity indices were computed;

(a). **Species relative dominance ((RDo (%)):** This was obtained using the formula given by Brashear's *et al.*, (2004):

$RDo = (\Sigma Ba_i * 100)/\Sigma Ba_n$ (2)

Where RDo = Relative Dominance, Ba_i= Basal area of individual tree belonging to tree species ith, Ba_n = Stand basal area

(b). **Important Value Index (IVI)**: Important value index was obtained by summing the Relative density and Relative dominance, and then dividing it by 2 as given by equation

$$IVI = \frac{RD + RDo}{2} \quad (3)$$

(c). **Species Relative Density (RD)**: Species relative density refers to the number of individuals of a given species divides by the total number of individuals of all species. It is given by equation 3 (eqn. 3)

$RD = n_i/N*100$ (4)

Where RD = relative density, n_i= number of individual species, N = total number of individuals in the entire population

(d). The Shannon-Weiner diversity index (H'): This was used to calculate ecosystems diversity index because it takes into account the species richness and abundance of each species in different ecosystems (Price, 1997). The equation that will be used is (eqn. 4):

$H = \Sigma^s_{i=1}$ pi ln(pi) (5)

H = Shannon diversity index, S = the total number of species in the habitat, Pi = proportion S (species in the family) made up of the i^{th} species, ln = natural logarithm

(e). **Species evenness (E)**: This was calculated by adopting Shannon's equitability (E_H) as stated by Kent & Coker (1992) (eqn. 6):

$$E_H = \frac{\sum_{i=1}^{s} p_i \ln(p_i)}{\ln(S)} \quad (6)$$

(f). Sorensen's species similarity index (SI) of Nath *et al*., (2005) was adopted in calculating the similarity of species between any two sites:

SI = (2C/a+b) *100 (7)

Where C = number of species in sites a and b; a, b = number of species at sites a and b; The data collected from the experiments were analyzed using Statistical Package for Social Sciences. The data were also subjected to correlation analysis to determine the significance difference between different species across the three forest reserves and their interactions at 0.05 level of significance.

RESULTS

Tree Species Diversity at Ijaye, Osho and Onigambari Forest Reserve.

Floristic composition results of this study showed the level of plant species diversity, richness, and distribution in a typical tropical rainforest ecosystem. Result in table 1 shows that, a total of 206 individuals per hectare representing 15 species and 9 families were identified at the Ijaye forest reserve. While a total of 145 individuals trees representing 18 different tree species and 13 families were identified at the Osho Forest reserve and 189 individuals belonging to 19 families were identified at Onigambari forest reserve (Table 1)

In Ijaye forest reserve, *Vitellaria paradoxa* with abundance of 69 individuals per hectare was the most common species encountered in the site, followed by *Daniella Oliveri* with abundance of 50 individual trees per hectare, which was directly followed by Tectona grandis with 30 individuals and *Vitalleria lanceolate* with 15 individuals per hectare (Table 2). The least encountered species were *Acacia spectabilis*, *Newbouldia laevis* and *Parkia biglobosa* with each species being represented by (1) respectively. *Newbouldia laevis* had the highest basal area ($0.14m^2$/ha), followed by *Cassia siamea* and *Chromolaena odorata* both represented by basal area of $0.12m^2$/ha each, while the least basal area was recorded for *Vitex donialla* and *Trichilia roka* with $0.05m^2$/ha each. The result shows that majority of the species in Ijaye forest reserve were in low diameter class. At Ijaye forest resereve, relative dominance ranged from 0.36% to 0.85%. While relative density varied from 0.49% to 33.50%.

The result in table 2 revealed that *Khaya grandifoliola* (19) was the most abundant individual on Osho Forest reserve, followed by *Albizia zygia*, *Celtis zenkeri* and *Tectona grandis* that were all represented by 14 individuals per hectare on the forest reserve. Tree species such as *Ficus nitida*, *Pycnanthus angolensis* and *Rauvolfia vomitoria* had 1 individual per hectare each respectively. The species with the highest basal area (0.13m^2/ha) was *Blighia sapida*, followed by *Securinega virosa* and *Anogeissus schimperi* (0.12m^2/ha) each respectively. *Ficus nitida* had the highest mean dbh (17.10cm), followed by *Pterocarpus erinaceus* (16.45cm), *Rauvolfia vomitoria* (16.20cm) while the least mean dbh were recorded for *Tectona grandis* (11.61cm) and *Anogeissuss chimperi* (11.50cm). Thus, the result shows that 83% of the species enumerated were in the diameter class of 10-15cm while less than 5% of the species were encountered in the diameter class of 21-25cm respectively. Showing that majority of the species encountered on the site were small diameter trees.

At Onigambari forest reserve, 75% of the species enumerated were found at diameter class of 10-20cm indicating majority of the trees were small diameter trees, while 25% of the species were encountered at the diameter class of 21-45cm. The result presented on Table 2 showed that the most occurrent species on the site were *Bligia sapida* (27), *Newbouldia laevis* (16), *Cola gigantia* (14) and *Cola millenii* (12) and tree species with the lowest number of individuals per hectare include *Albizia lebbeck*, *Baphia nitida*, *Clausena anisata*, *Ficus lutea*, *Lecaniodiscus cupanioides*, *Morinda lucida*, *Phylocentrum jollyantin*, *Pterocarpus erinaceus*, and *Pycnanthus angolensis* which recorded a single tree species respectively.

Table 1: Parameters measured at the three Forest Reserves

Forest Reserves	Individuals/ Hectare	No/ species	Families	H/BA (m^2/ha)	H/RDo (%)	H/RD (%)	H/IVI (%)	H/mdbh (cm)
IJAYE	206	15	9	0.14	0.85	33.50	17.11	17.23
OSHO	145	18	13	0.13	0.97	13.10	6.88	17.10
ONIGAMBARI	189	38	19	0.64	1.04	14.29	7.66	24.84

H/BA=Highest Basal Area, H/RDo =Highest Relative Dominance, H/RD= Highest Relative Density, H/IVI =Highest Important Value Index, H/mdbh= Highest mean dbh

Table 2: Tree Species Distribution and Diversity of some selected species at Osho Forest Reserve.

Family	Tree species	Abun / ha	RDO	RD	RF	IVI	Mdbh	PiLnpi	BA/ha (m^2)
			Ijaye Forest Reserve						
Fabaceae	*Daniellia oliveri*	50	0.43	24.27	0.243	12.35	13.38	-0.34	0.08
Lamiaceae	*Tectona grandis*	30	0.46	14.56	0.146	7.51	13.89	-0.28	0.08
Sapotaceae	*Vitalleria lanceolate*	15	0.36	7.28	0.073	3.82	13.98	-0.19	0.07
Sapotaceae	*Vitellaria paradoxa*	69	0.72	33.5	0.335	17.11	13.03	-0.37	0.09
			Osho Forest Reserve						
Fabaceae	*Albizia zygia*	14	0.77	9.66	0.1	5.21	12.79	-0.23	0.09
Cannabaceae	*Celtis zenkeri*	14	0.54	9.66	0.1	5.1	13.77	-0.23	0.08
Fabaceae	*Khaya grandifoliola*	19	0.66	13.1	0.13	6.88	12.44	-0.27	0.1
Lamiaceae	*Tectona grandis*	14	0.93	9.66	0.1	5.29	11.61	-0.23	0.2
			Onigambari Forest Reserve						
Sapindaceae	*Bligia sapida*	27	1.04	14.29	0.14	7.66	14.99	-0.28	0.06
Malvaceae	*Cola gigantia*	14	0.35	7.41	0.07	3.88	16.54	-0.19	0.05
Sterculiaceae	*Cola millenii*	12	0.45	6.35	0.06	3.4	12.52	-0.18	0.09
Bignoniaceae	*Newbouldia laevis*	16	0.51	8.47	0.08	4.49	19.51	-0.21	0.26

Abun/ha= Abundance per hectar, PiLNPi= Shannon-wienner index, BA/ha= Basal area per hectar, RDo= Relative Dominance, RD= Relative Density, RF= Relative Frequency, IVI= Important Value Index, Mdbh= Mean DBH.

Family Diversity at the Different Study Sites

A total of 22 plant families were encountered across the three forest reserves. Nine (9) families were found at Ijaye, 15 at Osho while 16 families were encountered at Onigambari forest reserve respectively. The families with highest number of tree species in all the study sites were *Fabaceae, Moraceae* and *Sapindaceae* with 18, 8 and 4 respectively, while the least recorded family with the lowest species were *Anacardiaceae, Icacinaceae, Leguminosae, Myrtaceae*, and *Sterculiaceae* with 1 tree species respectively. Table 3 presents families that were encountered at the three forest reserves which were *Bignoniaceae, Fabaceae, Meliaceae* and *Moraceae* were represented with one or more species across the three forest reserves. *Bignoniaceae* family had a single tree species across the three forest reserves respectively, *Fabaceae* had 5 tree species at Ijaye forest reserve, 4 at Osho and 9 species at *Onigambari forest reserve. Meliaceae* family had a single tree species across the three forest reserves respectively. *Moracea* family was represented with 1 trees specie at Ijaye and Osho Forest reserves while 6 tree species were encountered at Onigambari forest reserve.

Table 3: Distribution of some selected tree families at the different study sites

S/N	Family	Ijaye forest reserve	Osho forest reserve	Onigambari forest reserve	Total
		No of Species	No of Species	No of Species	
1	*Bignoniaceae*	1	1	1	3
2	*Fabaceae*	5	4	9	18
3	*Meliaceae*	1	1	1	3
4	*Moraceae*	1	1	6	8

Regeneration Potential of the Study Sites

According to the result, a total of 240 wildlings were enumerated at Ijaye forest reserve, with the regeneration potential ranging from 0.20 to 18.09 and the frequency ranged from 7 to 60 of the species encountered. During the enumeration, Vitalleria lanceolate had the highest number of individuals of 60 at Ijaye forest reserve. Other abundant species were *Vitellaria paradoxa* (54), *Daniellia oliveri* (52), *Trichili roka* (33), *Chromolaena odorata* (24), and *Vitex donialla* (7). The result further revealed that Sapotaceae (*Vitellaria paradoxa* and *Vitalleria lanceolata*) had the highest number of family occurrence. At Osho Forest reserve, a total of 118 wildlings were found which has the ability to regenerate in the nearest future. All the families encountered at Osho Forest reserve were represented with 1 family each. The regeneration value ranges between 0.02 and 4.90. The tree species with the highest regeneration potential includes *Albizia zygia* having 4.90 and 62 wildlings/ha, followed by *Khaya grandifoliola* with 1.18 and 11 wildlings/ha, Adansonia digitata with 1.15 and 34 wildlings/ha. The result further revealed that Ficus nitida has the lowest regeneration potential with 0.02 and 4 wildling/ha. At Onigambari forest reserve a total of 13 families were encountered at, Fabaceae has the highest with 3 families while families like Malvaceae and Meliaceae had 2 families represented respectively while all others had 1 family respectively.

A total of 121 wildlings were found at Onigambari forest reserve. The result further revealed the frequencies of wildlings which ranged between 1 and 27. Blighia sapida had the highest frequency of 27 wildlings, followed by *Newbouldia laevis* (16), and *Cola gigantia* (14) etc. Some species such as *Clausena anisata* and *Phylocentrum jollyantin* had relatively low occurrence of (1) wildlings each. The regeneration value ranges between 0.02 and 2.46 in the site. The tree species with highest regeneration potential were Newbouldia laevis having 2.46 and 29 wildlings/ha, followed by *Bligia sapida* with 2.43 and 17 wildlings/ha. The result revealed that *Spondia monbin* had the lowest regeneration potential with 0.02 and 1 wildling/ha.

DISCUSSION

Comparison of Trees Species Diversity in the Study Area

Research revealed that the tropical rainforest ecosystem is among the most complex and species rich ecosystem of the world, and there is a wide variation in the composition and abundance of species between various tropical forests (Bhat *et al*., 2000). The tropical rainforest supports the greatest tree species diversity, with Ijaye and Onigambari reserves dominated by Fabaceae, Moraceae, and Sapindaceae families, while Osho had the least diversity. The least represented families across all reserves included Anacardiaceae, Icacinaceae, Leguminosae, Myrtaceae, and Sterculiaceae. Adekunle (2006) observed that tropical rainforests house more tree species than any other forest community, regardless of plot size. Result of basal area revealed *Vitalleria lanceolata* (0.09) as dominant in Ijaye, *Blighia sapida* (0.13) in Osho, and Nesogordonia papaverifera (0.64) in Onigambari.

Most trees were in the lower diameter class (10–30 cm), aligning with findings from Jimoh *et al*., (2012) and Adekunle *et al*., (2013) for Oban division of Cross River National Park, Nigeria and Queen's plot in Akure forest reserve, Nigeria. These trends may result from climatic variability, logging, farming, or overgrazing (Zankan *et al*., 2019). The Shannon-Wiener diversity indices for Ijaye, Osho, and Onigambari were 1.95, 2.60, and 3.20, respectively, with higher values linked to

proper monitoring (Pande *et al*., 1996). Species evenness values of 0.70 (Ijaye), 0.90 (Osho), and 0.88 (Onigambari) with Osho having the highest value, indicates more uniform species distribution in Osho (Onyekwelu *et al*., 2008). Sorensen's similarity index revealed low similarity between reserves, with Ijaye and Osho having a similarity index of 0.17, while Ijaye and Onigambari had the lowest at 0.01. This low similarity reflects distinct environmental heterogeneity influenced by human activities such as logging and overgrazing (Ekta, 2012).

Regeneration potential in the Study Area

The result shows that the regeneration potential of the sample plots was poor. It therefore has a great implication on the regeneration and conservation of the various species encountered. The regeneration per hectare revealed that Vitellaria lanceolata had the highest regeneration of 18.09 juvenile trees in Ijaye forest reserve, *Albizia zygia* (4.90) in Osho Forest reserve and *Newbouldia laevis* (2.46) had the highest regeneration potential at Onigambari forest reserve. It was observed that Ijaye forest reserve had the highest number of possible regeneration potential. Generally, the regeneration potential of the species was found to be poor in the three forest reserves, this could be as a result of human activities, soil degradation, competition from invasive species, lack of seed dispersals among others. Similarly, Oduwaiye *et al*., (2002) also indicated that the regeneration potential of Okomu forest was poor and most of the economically important plants had zero regeneration potential. This may affect the conservation of such species. However, species with high regeneration rates were found to be widely distributed. Therefore, the future of this reserve relies on effective management of these species.

Threatened and endangered species, according to FORMECU (1999) that were identified in the course of this study in Ijaye forest reserve were *Acacia spectabilis, Newbouldia laevis* and *Parkia biglobosa.* In Osho Forest reserve, *Ficus nitida, Pycnanthus angolensis* and *Rauvolfia vomitoria* were threatened and endangered, while *Albizia lebbeck, Baphia nitida, Clausena anisata, Ficus lutea, Lecaniodicus cupanioides, Morinda lucida, Phylocentrum jollyantin, Psidium guajava, Pycnanthus angolensis* and *Pterocarpus erinaceus* were found at Onigambari forest reserve. All of these species were encountered once in the study sites. Apart from the impacts of logging on tree species diversity, the resultant effect of logging on the environment is great. Fuwape (2001) highlighted that forest exploitation in Nigeria is often poorly planned and executed, resulting in harmful environmental impacts. The extinction of several economically valuable tree species in Nigeria is a well-known phenomenon (Adekunle & Akinlembola, 2008). If forests are degraded indiscriminately, the different uses and roles associated with them will be lost.

CONCLUSION AND RECOMMENDATION

This study highlights the severe threats posed by forest exploitation in Ijaye, Osho, and Onigambari forests, which endanger biodiversity and ecosystem stability. With only 22% of surveyed species exhibiting adequate regenerative potential, natural regrowth alone is insufficient to counteract the pressures of resource extraction.

To address these challenges, it is essential to implement silvicultural treatments that enhance species growth and support natural regeneration. Additionally, strengthening protective measures is crucial in curbing exploitation and preserving forest integrity. Furthermore, promoting reforestation initiatives plays a vital role in restoring degraded landscapes, enhancing biodiversity, and ensuring long-term ecological balance.

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Authors' Contribution

OJA & AAA managed data collection, interpretation of data, literature searching, writing the manuscript. NO & SAA managed the development of methodology, and revised the manuscript. All authors read and approved the final manuscript

Ethical Statement

Not applicable

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