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SPECIES DIVERSITY, VOLUME DETERMINATION AND STRUCTURE OF PROTECTED FORESTS FOR *IN-SITU* BIODIVERSITY CONSERVATION

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Abstract

This study was designed to determine tree species composition, vegetation structure and the potentials of these protected forests for in-situ biodiversity conservation. The study areas were stratified into two different forest types (primary forest and sacred forest). Data were collected from eight 25m plots situated in these four forest areas (Akure Strict Nature Reserve, Eda Forest Reserve, Osun Osogbo Sacred Grove and Igbo Olodumare Sacred Grove) all located in southwestern Nigeria using a simple random sampling method. The results showed that the forest ecosystem included 57 tropical hardwood species belonging to 29 families. The highest tree species, diversity index and species evenness were found at Osun Osogbo sacred grove. This followed closely by Akure primary forest and Eda primary forest while Igbo Olodumare sacred grove had the least species composition species diversity index and species evenness. These findings confirmed that both the primary forests and sacred grove forests are important indicators of in-situ biodiversity conservation and structural improvement of the forest ecosystem. Despite the neglect of traditional methods of conservation, it has proved to be most effective method with high potentials for forests in-situ biodiversity conservation and this enhance ecosystem management.

Keywords*: Biodiversity indices; Forest structure; Primary forest; Protected areas; Sacred grove; Tree diversity; Tree structure.*

Introduction

Tropical rainforests ecosystems are unique with high level of flora and fauna diversity and species richness. Tropical rainforest habitats cover just 7% of the dry surface of the earth and contain nearly 70% of the world's plant and animal species [1, 2]. Tropical rainforest is known to house hundreds of tree species within a hectare and support ecosystem services to the environment as regulator of carbon dioxide level in the atmosphere through photosynthesis, recycle water and play important role in keeping plant and animals alive and healthy [2-5].

Protected forests are established to conserves biodiversity *in-situ* and preserve the natural forest ecosystems for ecosystems sustainability and conservation. Protected forests absorb carbon dioxide from the atmosphere during the photosynthesis process and recycle carbon via the carbon sequestration process. Protected areas include forest reserves that are less than 20% of the region planned for protection [6]. These protected areas (PA), primary forest reserves and sacred groves are dispersed in the Federation's 36 states and are controlled locally

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by their respective state governments through Nigeria's Department of Forestry and Wildlife Conservation [6].

Sacred groves are forest areas that are preserved specifically by religious activities or taboo with important reference to particular culture and tradition of the people. Primary forests are forest of peculiar or native tree species where human activities are restricted or curtain and the ecological processes of the forest are not disturbed.

Determining the contribution of protected forests to the conservation of biodiversity in situ can be a significant boost for micro- and macro-environmental protection. Protected forests particularly sacred groves is attracting increasing interest in international organizations and conservation organizations such as UNESCO and WWF as the effective tradition model for conservation and sustainable use of biological diversity [7, 8]. Protected areas management is an essential aspect of biodiversity conservation activities and the efficacy will depend on the positions of the respective countries federal and state governments. However, due to high population growth and land tenure system in Nigeria, many protected forests are threatened by encroachers with high level of deforestation for arable crops cultivation. This tends to partly responsible for the pressure and overexploitation of resource (vegetation structure and composition) which they have been subjected to for decades [2, 9]. Therefore, basic aims of this study are to: (a) assess the composition and structure of the species; (b) evaluate the level contribution of growth variables and increase in volume yield to the ecosystem in protected forests.

Materials and Methods

Study areas

Locations of study were selected from the southwest Nigerian rainforest region, two primary forests (Akure and Eda reserves) and two sacred groves (Osun Osogbo and Igbo Olodumare groves). The area's climate is sub-tropical humid, indicating that it is essentially within the tropical rainforest zone. It is dominated by wide-leaved hardwoods forming dense, layered stands. The average annual temperature is around 27°C (minimum 20°C and maximum 34°C) and the rainy season lasts eight months per year, between March and October (about 2500mm), while the dry seasons typically last four months, between November and February.

The sacred grove Osun-Osogbo is located outside the town of Osogbo in Osun State and dedicated to the goddess of Osun. It is filled with 40 sanctuaries and shrines, two palaces and several sculptures and works of art in memory of the goddess Osun and other gods [2]. The Sacred Grove is a National Monument of Nigeria and a UNESCO World Heritage Site from 2005. This covers an area of 75 hectares and is encircled by a 47ha buffer zone [8]. On the other, Igbo Olodumare sacred grove is located in the town of Oke-Igbo/Ile-Oluji Local Government Area (LGA) of Ondo State. It covers an area of 7ha and is renowned for its spiritual value [2].

Akure Forest Reserve is one of the primary forests in southwestern Nigeria with no record of human activity [6]. It was established in 1934 and planned as a strict nature reserve by the Nigerian Forestry Research Institute in 1954 and covers an area of 600ha. [6]. This reserve is managed by the Federal Government of Nigeria (FGN) through the Ministry of Environment under the supervision of Forestry Research Institute of Nigeria (FRIN), Ibadan. Eda Forest Reserve is situated in Ekiti East Local Government Area (LGA) of Ekiti State, Nigeria, town Eda-Ile. The forest reserve being a primary forest harbors economically important tropical hardwood tree species. This natural forest reserve is one of Nigeria's declared reserves and it is managed by the Government of Ekiti State.

Data Collection

In the four protected forests every forest area was divided into plots of 25×25m and selected 8 sample plots. The total plots selected for this study in the four forests were 32 plots. The simple random sampling technique was adopted in the collection of samples in all forests of the kind protected.

Measurement and identification were restricted to all woody plants (diameter at breast height - *dbh* - around 10 cm) within each sample plot as done by [6, 9-13]. For further study, the following tree data were collected: (1) diameter at breast height (dbh); this is the diameter of the stem at 1.3m above ground level; (2) diameters at the base, middle and top, using a Spiegel Relaskop; (3) total height using a Spiegel Relaskop; total height of trees refers to the vertical height from the ground to the tip of the crown [14]. These data were used for further analysis of tree species diversity and structure.

Data Analysis

Indices of Arboreal Diversity

The following indices have been employed [9, 13, 15-17]. The importance value index (IVI) for trees was determined from the values of relative density and relative dominance for trees. The species diversity index was calculated following Shannon-Wiener diversity index:

$$H' = -\Sigma(ni/N) \ln ni/N, \quad (1)$$

where: H' = Shannon-Wiener index of general diversity, ni = importance value index of ith species, N = sum of importance value index of all the species.

Sorensen's species similarity index between two sites was calculated using equation:

$$SI = [2C/(a+b)]\times 100, \quad (2)$$

where: C = number of species at sites *a* & *b* and *a*, *b* = number of species at sites *a* and *b*.

The species dominance index was calculated by the formula given by Simpson:

$$Cd = \Sigma (ni/N)^2 \quad (3)$$

where: ni = importance value index of ith species, N = sum of importance value index of all the species.

Forest Structure Analysis

Based on the [6, 18-19] forest structural analysis, the size class distributions were classified into three distinct categories, that is, smaller; medium and upper. The stems were further graded into nine diameters and seven height groups to display respectively the graphical trend of tree population distribution and vertical stratification. The calculation of basal area and volume was based on the method used [9] to determine basal area and volume for this study. The basal area of each individual tree species was calculated as:

$$ba = \pi(1/2\times dbh)^2 \quad (4)$$

where: ba = basal area (m^2), dbh = diameter at breast height (cm) and $\pi = 3.142$. Total basal area of the plot was obtained by adding the basal area in the plots of individual trees. Mean basal area for sample plots was calculated by dividing total basal area by sample plot number (8 plots). Basal area per hectare was obtained by multiplying mean basal area per plot with the number of 25×25m plots in a hectare (16 plots).

The volume of individual tree species was calculated using equation (5) [20]:

$$V = (h/6)(A_b+4A_m+A_t) \quad (5)$$

where: V = tree volume (m^3), $\pi = 3.142$, h = tree height (m) measurement, A_b, A_m and A_t = tree cross-sectional area (m^2) at the base, middle and top of merchantable height, respectively, and h = total height (in meters). The total volume of the plot was obtained by adding the volume of single trees to the plots. Mean volume for sample plots was calculated by dividing the total plot volume by the number of sample plots (8 plots). Volume per hectare was calculated by multiplying average volume per plot with the number of plots 25×25m per hectare (16 plots).

Correlation Analysis

The correlation matrix for tree growth variables was constructed and main component analysis (PCA) was constructed to examine the relationship between the growth variables [9]. To evaluate the main components, selected and extracted only main components with their own values greater than 1. Each extracted factor has been selected and called significant variables with coefficients of ±0.70. Nonetheless, to determine the basic growth variables that maintain these interrelationships, the component variables with the highest loads (coefficients of correlation) for each extracted main growth factor were selected to represent the extracted components because they provide the best relationship [13].

Results and discussion

Forest Structure in the four protected forests

Figure 1 shows the diameter distribution which represents the vertical structure of the four protected forests. There is proof that the highest proportions of trees per hectare were in the lowest diameter class while the lowest was in the 71÷90cm class. The curves of all the four protected forests had the J-shaped form inverse. This was expected of any natural forest ecosystem mature and undisturbed. The class of height distribution shows the physiognomy of the four protected forests (Figure 1). This was consistent with the tree height distribution in the forests. The result indicated that the highest number of trees occurred in the 11÷15m (middle stratum) height class, whereas the lowest was in the 21÷30m (upper stratum class).

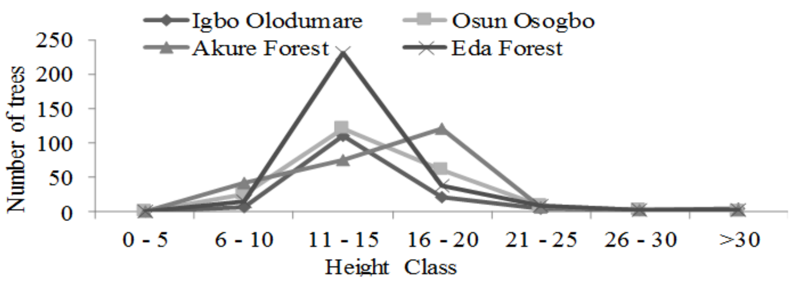

Fig. 1. Height distribution of trees in the four protected forests

In the four protected forests, there are 37.8% trees per hectare that could be referred to as emerging (>40cm). In the middle stratum the Akure primary forest had the highest percentage of trees than the other three forest types.

Variable arboreal growth and volume yield in the four forests protected

Figure 2 and Table 1 indicates the effect of tree-growth variables for the four protected forests. Highest mean DBH of 45.60cm was recorded in OOSG, followed by 40.65cm for EDPF, while 40.54cm for IOSG and 37.13cm for AKPF. The tree dominant DBH of 105.70cm for EDPF, followed by AKPF of 102.10 cm, while 96.00 cm for IOSG and 89.60 cm for OOSG. AKPF has the highest mean height 14.70m, followed by 13.74m recorded for IOSG, while 13.42m for OOSG and 13.27m for EDPF. The highest dominant tree height of 22.80 m was recorded for AKPF, followed closely by EDPF of 22.60m, while 21.80m for IOSG and OOSG has the least 19.50m. The highest basal area and volume per hectare of 70.10m^2 and 990.74m^3 was reported for OOSG, followed by AKPF with 50.00m^2 and 810.10m^3 as the basal area and volume per hectare, while EDPF has 40.68m^2 and 630.27m^3 as the basal area and volume and IOSG has the lowest basal area (40.58m^2) and volume (620.86m^3). The results of the one-way analysis of variance revealed that there is no significant difference ($p < 0.05$) in the phytosociological characteristics of these protected forests.

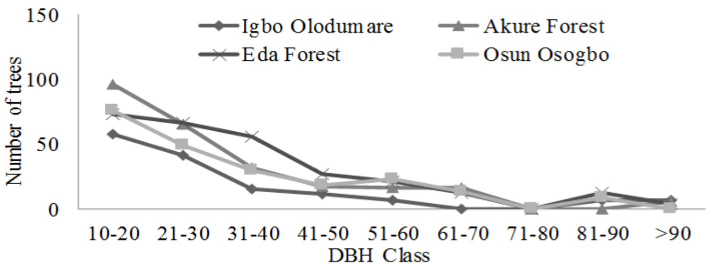

Fig. 2. Diameter at Breast Height curves for the four protected forests

Table 1. Summary of tree growth variables in the selected four protected forest

Biodiversity Index	Sacred Grove		Primary Forest	
	Osun Osogbo	**Igbo Olodumare**	**Akure**	**Eda**
Mean DBH (cm)	45.60 ± 2.85	40.54 ± 4.45	37.13 ± 3.60	40.65 ± 4.49
Dominant DBH (cm)	89.60	96.00	102.10	105.70
Mean Height (m)	13.42 ± 0.43	13.74 ± 0.52	14.70 ± 0.57	13.27 ± 0.46
Dominant Height (m)	19.50	21.80	22.80	22.60
Basal area/ha (m^2)	70.10	40.58	50.00	40.68
Volume/ha (m^3)	990.74	620.86	810.10	630.27

Tree species diversity and Abundance

Shannon–Wiener diversity index ranged from Igbo Olodumare (2.30), Eda primary forest (2.58), Akure primary forest (3.20) and the highest in Osun Osogbo sacred grove (3.26) in the four sites. Shannon–Wiener diversity index ranged from 2.30 to 3.26 in all sites, with Osun Osogbo sacred grove and Igbo Olodumare sacred grove having the highest and lowest values respectively. Species diversity index were similar in all the four protected forest areas used for this study. Simpson's index for species evenness ranged from 0.45 to 0.61 and was also similar in all the four protected forests. Shannon-Wiener diversity index (H′) followed the order Osun Osogbo sacred grove > Akure primary forest > Eda primary forest > Igbo Olodumare sacred grove while Shannon's maximum diversity index (Hmax) followed the order Eda primary forest > Akure primary forest > Osun Osogbo sacred grove > Igbo Olodumare sacred grove (Table 2).

Table 2. ANOVA of tree growth variable and biodiversity indices of the protected areas

Biodiversity Index (ha^{-1})	Sacred Grove		Primary Forest	
	Osun Osogbo	**Igbo Olodumare**	**Akure**	**Eda**
Number of Families	19ab	16b	20ab	17b
Number of tree spp	38a	27b	35a	28b
Number of Individual stems	217	146	248	301
Number of endangered spp	11 (28.9%)	13 (48.2%)	15 (42.9%)	12 (42.9%)
Spp diversity index (H′)	3.26a	2.30b	3.20a	2.58b
Spp evenness (E_H)	0.61a	0.46b	0.58ab	0.45b
Max diversity index (Hmax)	5.38ab	4.98b	5.51ab	5.71ab

Values in brackets are percentages of the number of endangered species to total species;
Values followed by the same letter within the same row are not significantly different ($p<0.05$).

Results of Shannon's equitability (E_H) revealed that species evenness in the four protected forest areas were similar, which was confirmed by the difference between H′ and Hmax for the four sites. It has been shown that the lower the difference, the more the evenness of species. Results of species similarity index 54.8%, 52.3%, 49.1%, 43.8%, 39.7% and 37.9% between Akure primary forest and Igbo Olodumare; Osun Osogbo sacred grove and Igbo Olodumare; Eda primary forest and Igbo Olodumare; Osun Osogbo sacred grove and Akure primary forest; Eda primary forest and Akure primary forest respectively. This revealed that tree species in Akure primary forest and Igbo Olodumare sacred grove are more similar than any other site combinations.

Tree species diversity and Abundance

The sum of 57 species were enumerated in the four protected forest areas, with Osun Osogbo sacred grove having the highest number of species (38), followed closely by primary forest at Akure (35), Eda had (28) and Igbo Olodumare sacred grove had (27) per hectare Table 2. We enumerated 29 families in the four sites as follows: a total of 20 families in primary forest at Akure, then 19 families in Osun Osogbo sacred grove, 17 in Eda primary forest and 16 in Igbo Olodumare sacred grove. Families with high numbers of different species are Sterculiaceae, Apocynaceae, Ulmaceae, Meliaceae, Ebenaceae, Moraceae and Caeslpiniodeseae. Four tree species are common species and were found in the four sites (primary forests Akure and Eda; sacred groves Igbo Olodumare and Osogbo). The distribution of species throughout the four protected forests revealed that 44.53% of the species occurred in all four sites (habitat generalist), 49.22% in the primary forest and the maximum 50.78% in the sacred grove. According to the classification of [35], 15 (42.9%), 13 (48.2%), 12 (42.9%) and 11 (29.0%) of trees species are endangered in Akure primary forest, Igbo Olodumare sacred grove, Eda primary forest and Osun Osogbo sacred grove respectively.

These tree species are also listed under the (IUCN 2005, Onyekwelu & Olusola 2014) threatened tree species. The total numbers of individual trees (≥ 10cm dbh) in the Akure primary forest were 248 stems·ha^{-1} and 301 stems·ha^{-1} were recorded for Eda primary forest Table 3. Igbo Olodumare sacred grove has 146 stems·ha^{-1} and 217 stems·ha^{-1} in the Osun Osogbo sacred grove. The percentage distribution of individual tree stems represented by single individual was 2.02%·ha^{-1}, for 2~5 individual stems it was 24.60% and 73.38% represented by more than five individual stems ha^{-1} in Akure primary forest reserve. Eda primary forest reserve has 3.32% which represented single individual stem·ha^{-1}, for 2~5 individual stems it was 6.98% and 89.70% by more than five individual stems·ha^{-1}. Osun Osogbo sacred grove has 3.69% which represented single individual stems·ha^{-1}, 29.03% for 2~5 individual stems and 67.28% by more than five individual stems·ha^{-1}. Igbo Olodumare sacred grove has 7.41% which represented single individual stems·ha^{-1}, 62.96% for 2~5 individual stems and 29.63% by more than five individual stems·ha^{-1}. In the Ulmaceae family, *Celtis zenkeri* had the highest frequency of 60/ha in the four locations. This was followed by the Moraceae family's Ficus capensis with a stand density of 33/ha in OOSG, whiles the Apocynaceae 26/ha Holarrhena floribunda was reported for IOSG and Celtis zenkeri in the Ulmaceae family with 22 individual stems per hectare in the AKPF Table 3.

Relationship among tree growth variables in four protected forests using PCA

The various growth variables were examined using Principal Component Analysis (PCA) to identify the critical growth factors that contribute to ecosystem structure and enhancement. Component loadings (coefficients of correlation) and variances (eigen values) were determined for the different growth variables, and the results were presented in Table 4. Growth variables PCA tests have their own values that were less than one. Parameters greatly contributed to the development of the forests (diameter at breast height – 0.996, basal area – 0.969, volume – 0.955 and height – 0.553), as they were heavily loaded on part 1. This portion represented 58 per cent of the growth parameters ' total variance. The major contributor of the growth variable for component 2 was in EDPF and OOSG height, while others were not important since their own vectors were less than ±0.70 Table 4.

Table 3. Species diversity, abundance and families in the four protected forests

S/N	TREE SPECIES	Family	EDPF	IOSG	OOSG	AKPF
1	*Afzelia Africana*	Caesalpinoideae	2	0	3	0
2	*Albezia lebbeck*	Mimosoidaceae	0	0	5	0
3	*Albizia ferruginea*	Mimosoidaceae	1	0	0	1
4	*Albizia zygia*	Mimosoidaceae	1	1	9	0
5	*Alstonia booneii*	Apocynaceae	1	0	0	5
6	*Anthocleista nobilis*	Apocynaceae	0	0	16	0
7	*Antiaris Africana*	Moraceae	0	0	0	4
8	*Baphia nitida*	Papilionioideae	0	0	0	3
9	*Blighia sapida*	Sapidaceae	0	0	1	0
10	*Bombax buonopozense*	Bombacaceae	1	0	7	0
11	*Boscueia angolensis*	Moraceae	0	6	1	0
12	*Bosqueia angolensis*	Moraceae	46	0	0	0
13	*Brachystegia enricoma*	Fabaceae	0	11	10	5
14	*Bridelia micrantha*	Euphorbiaceae	24	3	5	0
15	*Buchholzia coriacea*	Capparaceae	0	2	0	0
16	*Ceiba pentandra*	Bombacaceae	1	3	3	0
17	*Celtis zenkeri*	Ulmaceae	60	4	15	22
18	*Chrysophyllum albidum*	Sapotaceae	5	0	0	2
19	*Cola gigantia*	Sterculianceae	12	0	3	0
20	*Cola hipsida*	Sterculiaceae	0	0	2	0
21	*Cola millenii*	Sterculiaceae	0	2	13	19
22	*Cola nitida*	Malvaceae	0	0	4	0
23	*Cordia millenii*	Boraginaceae	0	5	0	1
24	*Delonix regia*	Caesalpinioideae	0	0	6	0
25	*Diospyrous barteri*	Ebeneceae	0	3	0	6
26	*Diospyrous barteri*	Ebeneceae	4	0	3	0
27	*Entandrophragma angolense*	Meliaceae	9	0	0	22
28	*Eucalyptus torreliana*	Fabaceae	0	0	1	0
29	*Fagara xanthoxyloides*	Rutaceae	0	5	0	0
30	*Ficus capensis*	Moraceae	0	33	0	0
31	*Ficus capensis*	Moraceae	0	0	5	0
32	*Ficus exaspirata*	Moraceae	1	5	3	0
33	*Ficus thonningii*	Moraceae	0	5	1	0
34	*Funtumia elastic*	Apocynaceae	2	6	4	16
35	*Gliricidia sepium*	Fabaceae	0	0	8	0
36	*Hildegardia barteri*	Meliaceae	0	4	0	0
37	*Holarrhena floribunda*	Apocynaceae	0	0	26	0
38	*Holoptelea grandis*	Ulmaceae	0	0	0	12
39	*Hunteria umbellate*	Simaroubaceae	25	0	0	3
40	*Khaya grandifoliola*	Meliaceae	1	3	0	1
41	*Khaya ivorensis*	Meliaceae	0	7	0	0
42	*Khaya senegalensis*	Meliaceae	0	0	0	4
43	*Lannea welwitschii*	Anacardiaceae	0	0	0	18
44	*Lecaniodiscuss cupanioides*	Sapindaceae	0	0	18	0
45	*Malacantha alnifolia*	Sapotaceae	0	0	0	16
46	*Mansonia altisima*	Sterculiaceae	0	4	0	9
47	*Milicia excels*	Moraceae	0	2	4	0
48	*Milicia regia*	Moraceae	3	3	7	0
49	*Monodora myristica*	Annonaceae	0	0	0	11
50	*Morinda lucida*	Rubiaceae	0	0	1	0
51	*Musanga cecropioides*	Aquifoliaceae	1	3	1	0
52	*Piptadeniastrum africanum*	Mimosoideae	2	0	4	0
53	*Pterocarpus osun*	Papilionioideae	3	0	0	1
54	*Pterparygota macrocarpa*	Sterculiaceae	0	0	3	10
55	*Pterparygota macrocarpa*	Sterculiaceae	0	6	0	0
56	*Pycnanthus angolensis*	Inyristicaceae	1	3	1	3
57	*Rauvolfia vomitoria*	Apocynaceae	0	0	0	1
58	*Ricinodendron heudelotti*	Euphorbiaceae	9	5	11	1
59	*Rothimannia hispida*	Rubiaceae	0	0	0	5
60	*Senna siamea*	Caesalpiniodeae	0	0	0	2
61	*Spathodea campanulata*	Bignoniaceae	2	0	2	0
62	*Spondas mombin*	Anacardiaceae	0	1	3	0
63	*Sterculia oblonga*	Sterculiaceae	0	5	4	0
64	*Sterculia rhinopetala*	Sterculianceae	7	0	1	8
65	*Strombosia pustulata*	Olacaceae	21	0	3	2
66	*Terminalia superba*	Combretaceae	0	0	0	4
67	*Tetrapleura tetraptera*	Mimosoideae	0	0	0	3
68	*Trichilia monadelpha*	Meliaceae	0	0	0	4
69	*Triplochiton scleroxylon*	Sterculianceae	33	0	0	13
70	*Xylopia aethiopica*	Annonaceae	24	0	0	5
71	*Zanthoxylum xanthoxyloides*	Rutaceae	1	0	0	4

Note: EDPF - Eda Primary Forest, IOSG - Igbo Olodumare Sacred Grove, OOSG - Osun Osogbo Sacre Grove, AKPF - Akure Primary Forest.

Table 4. Principal Component Analysis of growth variables of the four protected forests

Growth Variables	PC for EDPF		PC for IOSG		PC for AKPF	PC for OOSG
	1	2	1	2	1	1
Dbh (cm)	0.996	0.263	0.995	-0.330	0.985	0.981
Height (m)	0.553	0.991	0.105	0.994	0.585	0.436
Basal area (m^2)	0.969	0.178	0.970	-0.113	0.943	0.973
Volume (m^3)	0.955	0.155	0.976	0.070	0.945	0.946
LNBA	0.947	-0.204	0.973	-0.079	0.961	0.952
LNVol.	0.960	0.011	0.973	0.100	0.965	0.979
Eigen Values	4.51	2.56	3.69	1.78	4.22	3.42
% Variance	57.70	13.30	47.16	15.70	57.70	56.89
Cumulative explanation	62.48	75.42	49.80	80.95	68.54	62.57

Discussion

Tree species Diversity and conservation

Tropical rainforest environment includes the most diverse species of all habitats, plant genetic materials and ecological processes. Forest ecosystems play an important role in the functioning of the biosphere since they are the host of many plants and animals cultivated [21]. Forest reservations (primary forest and sacred groves) are traditionally known methods of in-situ biodiversity conservation which are needed to control, monitor and protect tree species from anthropogenic disturbances. The findings of tree species evaluation showed that all trees observed in the four identified protected forests were indigenous tropical hardwood species with less exotic species found in the sacred grove of Osun Osogbo.The dominated families and species in this research were Sterculiaceae (*Triplochiton scleroxylon, Sterculia* spp., *Mansonia altisima*, *Cola* spp., *Pterygota macrocarpa*), Moraceae (*Bosqueia angolensis Antiaris africana, Ficus* spp.), Ulmaceae (*Celtis* spp., *Holoptelea grandis*), Meliaceae (*Entandrophragma angolensis*, *Khaya ivorensis*). This finding is consistent with the researches of [2, 6, 9, 13, 22].

However, our results indicate that members of the families Apocynaceae (*Funtumia elastica*, *Anthocleista nobilis*, *Hunteria umbellate*), Euphorbiaceae (*Bridelia micrantha*, *Ricinodendron heudelotii*) are the most widespread and species such as *Khaya* spp., *Diospyros* spp., *Triplochiton scleroxylon* and *Strombosia pustulata* are important components of the study site floristic composition. Trees species richness in the study sites were similar to this range (100 to 300ha^{-1}) given by [3-4] and also within the range reported for some rainforest sites in Nigeria [2, 6, 9, 13] and higher than some sites in India [23-25]. The results of this study revealed that many indigenous tropical hardwood tree species in various families were housed in protected forests (primary forests and sacred groves). This is illustrated by the 912stems·ha^{-1} (dbh = 10cm) belonging to 57 indigenous hardwood species and 29 large families in these four protected forests. Higher number of tree species has been reported in some protected sites in Sierra Leone and India [9, 26-27] than in protected areas in south western Nigeria.

Species richness values in Akure primary forest (35spp·ha^{-1}) and Osun Osogbo sacred grove (38spp·ha^{-1}) which is the highest in these four sites are relative low compared to some rainforest sites in Nigeria, [28-29] confirmed that 56, 55 and 54 tree species ha^{-1} were found in forest reserves of Sapoba, Shasha and Ala, respectively. Lower tree species richness in these protected forest areas could be as a result of management practices rather site and ecological status of the areas. Researches have proved that tropical rainforests of south-western Nigeria are inherently poor in tree species, with number of tree species rarely more than 70ha^{-1} [2, 6, 22, 30]. This is an indication that these methods of *in-situ* biodiversity conservation could be improved and it could completely decrease the intensity of forest degradation in south western Nigeria. Determination of tree stem volume has been identified as the most significant criteria for forest management and its acquisition is very time-consuming, labor intensive and expensive due to the involvement of field surveys in data collection [6, 9, 31].

The volume obtained for these four protected forest sites are relatively similar to that obtained in earlier researches [9, 32] and also close to the amount collected from the Italian Alps ' multilayer forest areas [31]. The findings reported in this research suggest that all volume estimation methods are equal and reliable. Volume could be determined (form factor was used by [32] airborne laser scanning was used by [31]. Newton's volume estimation formula was used in this study [20] which has been adjudged to be the most accurate method of tree stem volume estimation as reported by [9, 13]. The management methods practice in Nigeria could be effective and adequate with proper funding and monitoring of these protected areas for *in-situ* biodiversity conservation.

In their previous research [33-34] it was noted that various management regimes had a significant influence on the composition and richness of plant species and on the entire site structure. The results of volume yield and tree species diversity indicated that both primary forest and sacred grove are effective traditional methods of forest conversation and management for higher species diversity and volume estimation.

Conclusions

The current level of forest degradation in south western Nigeria is the biggest challenge for conservationist and forest managers. It is therefore imperative to intensify effort in sustaining the current methods of protecting the forest through the establishment of more protected areas for *in-situ* biodiversity conservation. The current status of these protected areas in terms of the abundance, evenness, productivity and structure of tree species shows the effectiveness of conservation strategies for in-situ biodiversity management. The indices of biodiversity were high, and the forest structure suggests that forests will continue to grow until they become mature and stable forests, if these methods of protection and management are retained. These protected forest sites are potential biodiversity hotspot requiring better protection, careful monitoring and effective management measures, with intensive research of all indicators of biodiversity to keep the sites from destruction and encroachment. The endangered species should be treated as rare species and extensive conservation efforts should be pursued by all stakeholders to avoid the extinction of such species. It is recommended that more protected forests should be demarcated to protect the forest sites from degradation and endangered species from extinction. Also, these traditional methods of *in-situ* biodiversity conservation should be improved for the enhancement, management and conservation of all the existing protected forests to guard against anthropogenic activities.

References

[1] T.E. Lovejoy, *Biodiversity: what is it?*, **Biodiversity II: Understanding and Protecting our Natural Resource**, (Editors: M.L. Reaka-Kudla , D.E. Wilson, E.O. Wilson, F.M. Peter), Joseph Henry Press, Washington DC, 1996, pp. 7-14, ISBN 978-0-309-05584-0.

[2] J.C. Onyekwelu, J.A. Olusola, *Role of Sacred Grove in in-situ biodiversity conservation in rainforest zone of South Western Nigeria*, **Journal of Tropical Forest Science, 26**(1), 2014, pp. 5–15.

[3] P. Sollins, *Factors influencing species composition in tropical lowland rain forest: does soil matter?,* **Ecology**, **79**(1), 1998, pp. 23–30.

[4] N.C.A. Pitman, C.E. Ceron, C.I. Reyes, M. Thurber, J. Arellano, *Catastrophic natural origin of a species-poor tree community in the world's richest forest,* **Journal of Tropical Ecology**, **21**, 2005, pp. 559–568, part 5.

[5] A.D. Agbelade, S.O. Akindele, *Land use mapping and tree species diversity of Federal University of Technology, Akure*, **American International Journal of Contemporary Research**, **3**(2), 2013, pp. 104-113.

[6] V.A.J. Adekunle, A.O. Olagoke, S.O. Akindele, *Tree species diversity and structure of a Nigerian strict nature reserve,* **Tropical Ecology**, **54**(3), 2013, pp. 275-289.

[7] D.D. Daye, J.R. Healey, *Impacts of land-use change on sacred forests at the landscape scale,* **Global Ecology and Conservation**, **3**, 2015, 349–358.

[8] IUCN (International Union for Conservation of Nature), *Nomination to the World Heritage List OSUN-OSOGBO SACRED GROVE Osogbo, Osun State*, file number no. 1118 in **Evaluations of Cultural Properties, UNESCO World Heritage Convention**, 2005, pp. 1–43, https://whc.unesco.org/uploads/nominations/1118.pdf

[9] V.A. Adekunle, N.K. Nair, A.K. Srivastava, N.K. Singh, *Volume yield, tree species diversity and carbon hoard in protected areas of two developing countries,* **Forest Science and Technology**, **10**(2), 2014, pp. 89-103, DOI:10.1080/21580103.2013.860050

[10] D.U.U Okali, B.A. Ola-Adams, *Tree population changes in treated rainforest at Omo Forest Reserve, south-western Nigeria*, **Journal of Tropical Ecology**, **3**(4), 1987, pp. 291-313.

[11] M.B. Swaine, J.B. Hall, *Forest Structure and Dynamics,* **Plant Ecology in West Africa–Systems and Processes**, (Editor G.W. Lawson), John Willey and Sons Ltd Publisher, Chichester, UK, 1986, pp. 47–93.

[12] J.S. Hall, D.J. Harris, V. Medjibe, P.M.S. Ashton, *The effects of selective logging on forest structure and tree species composition in a Central African forest: implications for management of conservation areas,* **Forest Ecology and Management**, **183**(1-3), 2003, pp. 249–264.

[13] A. Lawal, V.A.J. Adekunle, *A silvicultural approach to volume yield, biodiversity and soil fertility restoration of degraded natural forest in South-West Nigeria*, **International Journal of Biodiversity Science Ecosystem Services & Management**, **9**(3), 2013, pp. 201-214, DOI:10.1080/21513732.2013.823464

[14] FAO - Food and Agricultural Organization, **Global Forest Resources Assessment 2005 - Progress towards sustainable forest management**, FAO Forestry Paper 147, Rome, Italy, 2006, ISBN 92-5-105481-9

[15] M. Kent, P. Coker, **Vegetation description and analysis. A practical approach**, London: Belhaven Press, London, UK, 1992, ISBN 0-471-94810-1

[16] A.E. Magurran, **Measuring Biological Diversity**, Blackwell Publishing, Oxford, UK, 2004, ISBN 0-632-05633-9

[17] X.T. Lu, J.X. Yin, J.W. Tang, *Structure, tree species diversity and composition of tropical seasonal rainforests in Xishuangbanna, south-west China*, **Journal of Tropical Forest Science**, **22**(3), 2010, pp. 260–270.

[18] J. Proctor, J.M. Anderson, P. Chai, H.W. Vallack, *Ecological studies in four contrasting lowland rainforests in Gunung Mulu National Park, Sarawak: I. Forest environment, structure and floristic*, **Journal of Ecology**, **71**(1), 1983, pp. 237–260.

[19] D.M. Newbery, *Floristic variation within Kerangas (heath) forest - reevaluation of data from Sarawak and Brunei*, **Vegetation**, **96**(1), 1991, pp. 43–86.
[20] B. Husch, T.W. Beers, J.A. Kershaw Jr., **Forest Mensuration**, 4th edition, John Wiley & Sons Inc. Publishing, New Jersey, USA, 2003, ISBN 0-471-01850-3
[21] **Forest Biodiversity as a Challenge and Opportunity for Climate Change Adaptation and Mitigation**, Presidency background paper presented at the Informal Meeting of EU Environment Ministers, April 11th –13th, 2008, Ljubljana/Brdo.
[22] J.C. Onyekwelu, R. Mosandl, B. Stimm, *Tree species diversity and soil status of primary and degraded tropical rainforest ecosystems in south-western Nigeria,* **Journal of Tropical Forest Science**, **20**(3), 2008, pp. 193–204.
[23] U.M. Chandrashekara, *Assessment of level of human disturbance in village-adjacent natural forest plots in the Kerala Part of Nilgiri Biosphere Reserve*, **International Journal of Ecology and Environmental Sciences**, **39**(4), 2013, pp. 211-221.
[24] P. Pushpangadan, *Economic Evaluation of Biodiversity in context of CBD and IPR regimes,* proceeding of regional training programme on **Biodiversity systematics: Evaluation and Monitoring with emphasis on medicinal plants**, National Botanical Research Institute, Lucknow, India. September 3rd–13th, 2001.
[25] M. Rajkumar, N. Parthasarathy, *Tree diversity and structure of Andaman Giant Evergreen Forests, India*, **Taiwania, 53**(4), 2008, pp. 356–368.
[26] A.R. Lebbie, R.P. Guries, *Ethnobotanical value and conservation of sacred groves of the Kpaa Mende in Sierra Leone*, **Economic Botany**, **49**, 1995, pp. 297–308.
[27] M. Rajendraprasad, P.N. Krishnan, P. Pushpangadan, *The role of sacred groves of Kerala on the sustainable management of nutrients and hydrological cycles,* in **Proceedings of the 7th Kerala Science Congress**, State Committee on Science, Technology and Environment, Thiruvananthapuram, Kerala, 1998, pp.125-126.
[28] R.G. Lowe, *Volume increment of natural moist tropical forest in Nigeria*, **The Commonwealth Forestry Review**, **76**(2), 1997, pp. 107−113.
[29] V.A.J. Adekunle, *Conservation of tree species diversity in tropical rainforest ecosystem of south-west Nigeria*, **Journal of Tropical Forest Science**, **18**(2), 2006, pp. 91−101.
[30] V.A.J. Adekunle, A.O. Olagoke, *Diversity and biovolume of tree species in natural forest ecosystem in the bitumen-producing area of Ondo state, Nigeria: a baseline study*, **Biodiversity and Conservation**, **17**(11), 2008, pp. 2735-2755.
[31] S. Tonolli, M. Dalponte, L. Vescovo, M. Rodeghiero, L. Bruzzone, D. Gianelle, *Mapping and modeling forest tree volume using forest inventory and airborne laser scanning*, **European Journal of Forest Research**, **130**(4), 2011, pp. 569–577.
[32] F. Wittmann, B.T. Zorzi, F.A.T. Tizianel, M.V.S. Urquiza, R.R. Faria, N. Machado e Sousa, E.D.S. Modena, R.M. Gamarra, A.L.M. Rosa, *Tree species composition, structure, and aboveground wood biomass of a riparian forest of the lower Miranda river, southern Pantanal, Brazil*, **Folia Geobotanica**, **43**(4), 2008, pp. 397-411.
[33] T. Banda, M.W. Schwartz, T. Caro, *Woody vegetation structure and composition along a protection gradient in a Miombo ecosystem of Western Tanzania*, **Forest Ecology and Management**, **230**(1-3), 2006, pp. 179–185.
[34] P.K.T. Munishi, T.C. Ruwa-Aichi, G. Soka, *Plant communities and tree species associations in a Miombo ecosystem in the Lake Rukwa basin, Southern Tanzania: Implications for conservation,* **Journal of Ecology and the Natural Environment, 3**(2), 2011, pp. 63–71.

[35] * * *, *Forest Resources Study, Nigeria,* **Revised National Report**, Volume 2, prepared for FORMECU by Beak and Geomatics International, 1999, p. 224.

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