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**Research article**

# Volume yield and tree species diversity of three protected areas in Akure forest reserve, Ondo State, Nigeria

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**Abstract:** The roles of protected areas in biodiversity conservation were assessed in this study. This was achieved by assessing tree species diversity and volume yield of three protected areas in Akure Forest Reserve, Ondo State, Nigeria. Two sampling plots of 50 m × 50 m were laid in each of the sites using systematic line transect. Trees with DBH >10cm were identified in each plot, their frequency of occurrence were ascertained and categorized into families. All tree growth variables were measured in each of the study sites. The results obtained from this study indicated that the three selected protected areas within the forest reserve are rich in trees species. A total of 264 stems $ha^{-1}$ were observed in the SNR, 198 stems $ha^{-1}$ were recorded in the Buffer zone and Enrichment Planting had 72 stems $ha^{-1}$. The number of tree species observed in SNR, Buffer Zone, Enrichment Planting followed the order of 37> 31 >25. Shannon Weiner index of 2.97, 3.10 and 3.00 were obtained in the buffer zone, SNR and Enrichment planting site respectively. SNR had the highest volume of 461.74 $m^3$ $ha^{-1}$, this was followed by the Buffer zone with 424.46 $m^3$ $ha^{-1}$ and the Enrichment planting (138.28 $m^3$ $ha^{-1}$). The high biodiversity indices are indication that biodiversity can be conserved through *in situ* method if proper managerial actions are put in place. The study therefore recommended that the remaining protected areas should be safeguarded from anthropogenic activities and more protected areas be established.

**Keywords:** Protected area, Conservation, Biodiversity, Volume.

## INTRODUCTION

Forest biodiversity protection relies on the ability to assess hot spots, quantify and predict spatial and temporal trends of key species, maintain a natural disturbance regime and limit harmful human activities (Stohlgren *et al*., 1999). They are geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008).

Protected areas was defined by the International Union for Conservation of Nature (IUCN) as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN, 1994). Forest protected areas help conserve ecosystems that provide habitat, shelter, food, raw materials, genetic materials, a barrier against disasters, a stable source of resources and many other ecosystem goods and services and thus can have an important role in helping species, people and countries adapt to climate change. They can thus continue to serve as a natural storehouse of goods and services into the future. They help in the conservation of indigenous species that are resistant to pests, diseases and pathogens, environmental stresses and nutrient loss.

Biological diversity is critical for the maintenance of ecosystem. Each species in the forest plays a fundamental role in the maintenance of the forest ecosystem. Tropical forests are one of the main repositories of global biodiversity (Rennolls & Reynold, 2007; Sarkar & Devi, 2017). Unfortunately, this biodiversity is under threat as a result of forest degradation and deforestation. The likely impact of degradation and deforestation in tropical rainforest has direct environmental and biological implications (Barua *et al.*, 2018).

It is important to quantify the tree species diversity of protected areas so as to provide useful information on the genetic resources available, estimate the level of adaptation to the environment, their ecological significance and the efficacy of these protected areas in biodiversity conservation. For the protection of forests from degradation and deforestation, it is vital to investigate the present status of species diversity as it will provide direction for the management of forest areas (Bajpai *et al.*, 2012; Nurudeen *et al.*, 2017; Bajpai *et al.*, 2018). Information from this quantitative inventory will provide a valuable reference for forest assessment and improve our knowledge in identification of ecologically useful species as well as species of special concern. Therefore, this study was carried out to assess the present status of protected areas in Akure Forest Reserve and their efficacy as biodiversity hotspot. This was achieved through field inventory and on-the-spot tree diversity assessment.

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## METHODOLOGY

### *The study area*

The three protected areas *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP) are located in Akure forest Reserve. The reserve is geographically located in a humid rainforest zone of Akure South Local government area of Ondo State, Nigeria. It lies between latitudes7°16′ and 7°18′ N of the Equator and longitudes 5° 9′ and 5°11′ E of the Greenwich Meridian. It was constituted as a reserve in 1936 and the total land area covered is 69.93 $km^2$. Politically, it lies in Ondo State in Southwestern Nigeria. The relief pattern is low lying, elevation ranges from 216 m to 504 m and gently undulating in southern part while the northern part is hilly rock outcrops occurring at close intervals. The underlying rock is crystalline and gneiss. It is slightly neutral; pH of 6.7-7.3 and sandy-loam in nature. The dry season lasts from November to March while the wet season commences from April and ends in October with the highest rainfall records between July and August, Average daily temperature ranges between 21ºC and 29ºC almost throughout the year. The mean annual rainfall varies from 2000 mm in southern area to 1500 mm in northern area with relative humidity of 80-85% annually experienced in south-west.

### *Data collection*

*Sample plots demarcation*

Systematic sampling design (systematic line transects) was used in plot layout. Two equal plots of size 50 m × 50 m were alternatively laid on the transect. All woody plants within the transect were enumerated.

*Tree enumeration*

All Woody plants with DBH greater than 10 cm were enumerated. Tree growth variables such as the diameter at the base ($D_b$), Diameter at breast height (DBH), diameter at the middle ($D_m$), Diameter at the top ($D_t$) and height were measured for basal area and volume estimation.

*Biodiversity indices and tree species classification*

The botanical name of every living trees encountered in each sample plot was recorded. Where a tree’s botanical name is not known immediately, such a tree was identified by its commercial or local name. Such commercial or local names were translated to correct botanical names using Gbile (1984) and Keay (1989). Frequencies of occurrence were obtained for species abundance or richness. This was repeated for all the trees encountered in the sample plots. All trees were assigned to families and the number of species in each family were obtained.

### *Method of data analysis*

*Basal area estimation*

Basal area per hectare was obtained by multiplying the mean plot basal area by the number of plots per hectare

$$\mathrm{BA} = \frac{\pi \mathrm{D}^2}{4}$$

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

*Volume estimation*

The volume of individual trees was estimated using the Newton formula (Husch *et. al*., 2003).

$$\mathrm{V} = \frac{\pi \mathrm{h}}{24}(\mathrm{D}_\mathrm{b}^2 + 4\mathrm{D}_\mathrm{m}^2 + \mathrm{D}_\mathrm{t}^2)$$

Where, V= Volume of tree ($m^3$); $D_b$= Diameter at the base (m); $D_m$= Diameter at the middle (m); $D_t$= Diameter at the top (m); H= height (m).

Volume per hectare was obtained by multiplying the number of plots per hectare.

### *Biodiversity indices*

*Important value index*

Important value index was computed as,

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

Where, RD= Relative density of the Species; $RD_o$= Relative dominance of Species.

*Species relative density (RD)*

Species relative density, which is an index for assessing species relative distribution, was computed as,

$$\mathrm{RD} = \frac{\mathrm{n_i}}{N} \times 100$$

Where, RD= Relative density of the species; $n_i$= Number of individuals per species; $N$= Total number of all individual trees of all species in the entire population.

*Species relative dominance*

Species relative dominance was estimated as,

$$\mathrm{RDo} = \frac{\sum \mathrm{Ba_i}}{\sum \mathrm{Ba_n}} \times 100$$

Where, $Ba_i$= basal area of individual tree belonging to the $i^{th}$ species; $Ba_n$= stand basal area.

*Shannon-Wiener Diversity Index*

Species diversity index was calculated using the Shannon-Wiener diversity index,

$$\mathrm{H'} = -\sum_{i=1}^{S} P_i \ \mathrm{In}\ (P_i)$$

Where, H'= Shannon diversity index; S= Total number of species in the community; $P_i$= Proportion S (species in the family) made up of the ith species; ln= Natural logarithm.

*The Species evenness (E)*

Species evenness in each plot was determined using Shannon's equitability ($E_H$),

$$\mathrm{E_H} = \frac{\mathrm{H'}}{\mathrm{H_{Max}}} = \frac{\sum_{i=1}^{S} P_i \ \mathrm{In}\ (P_i)}{\mathrm{In}\ (S)}$$

**RESULTS**

The results of the study revealed that *Funtumia elastica* (Preuss) Stapf was the tree species with highest frequency of occurrence in the SNR with 48 stems. So, it could be regarded as the dominant species in the site. This was followed by *Sterculia rhinopetala* K. Schum with 32 stems. *Annonidium manii* (Oliv.) Engl. & Diels was the most abundant tree species in buffer zone and Enrichment Planting represented by 40 and 12 stems respectively. Some of the species represented by four stems in the buffer zone are *Alstonia boonei* De Wild, *Brachystegia eurycoma* Harms, *Celtis mildbreadii* Engl., *Chrysophyllum purpuchrum* Mildbr. ex Hutch. & Dalziel, *Cola hispida* Brenan & Keay, *Khaya grandifoliola* C. DC., *Milicia excelsa* (Welw.) C. Berg, *Margaritaria discoidea* (Baill.) G.L. Webster and *Ricinodendron heudelotii* (Baill.) Heckel. In enrichment planting site, *Strombosia postulata* Oliv. and *Trilepisium madagascariense* DC. are represented by 6 and 8 stems respectively. Some of the tress species with just 2 stems $ha^{-1}$ include; *Baphia nitida* Lodd., *Boscia senegalensis* (Pers.) Lam. ex Poir., *Triplochyton scleroxylon* K. Schum, *Milicia excelsa*, *Entadrophragma cylindricum* C. DC. (Table 1). Table 2 shows the Shannon wiener Index values obtained in the three protected areas. In Strict Nature Reserve, *Funtumia elastica* had the highest Shannon Wiener value of 0.31, followed by *Sterculia rhinopetala* with an index of 0.26. Some of the tree species with Shannon Wiener value of 0.02 are *Alstonia boonei*, *Brachystegia eurycoma*, *Celtis philippensis* Planch, *Daniellia ogea* (Harms) Holland, *Diospyros mespiliformis* Hochst. ex A.DC. and *Diospyros dendo* Welw., *Annonidium manii* had the highest Shannon Wiener value of 0.32 in the buffer zone followed by *Cola gigantea* A. Chev. with a value of 0.22. Some of the species with Shannon Wiener value of 0.05 include; *Cola acuminata* (P. Beauv.) Schott & Endl., *Khaya grandifoliola*, *Trichilia welwitschii* C. DC., *Garcinia kola* Heckel, *Gmelina arborea* Roxb., *Greenwayodendron* sp., *Lecaniodiscus cupanioides* Planch. ex Benth. Enrichment planting site was dominated by the species of *Annonidium manii* with a Shannon Wiener value of 0.3. Shannon Wiener values of 0.21 and 0.24 were obtained for *Strombosia pustulata* Oliv. and *Trilepisium madagascariense*.

The summary of tree growth variables & biodiversity indices is presented in table 3. The number of stems per hectare follows the order of SNR: 264 > Buffer Zone: 198 > Enrichment Planting: 72. A high volume of the trees per hectare was recorded in the SNR (461.74 $m^3$), followed by Buffer zone (424.46 $m^3$) and Enrichment Planting (138.28 $m^3$). The basal area per hectare obtained in this study ranges from 14.35$m^2$ for Enrichment Planting site to 60.62 $m^2$ recorded for SNR. The Shannon-Wiener Diversity values of 3.10, 2.97, and 3.0 were recorded for SNR, Buffer zone and Enrichment Planting respectively. The Buffer Zone and SNR both had evenness of 0.86 and 0.93 was obtained for Enrichment Planting site. In SNR, the highest IVI was recorded for *Funtumia elastica* (14.37) while the lowest IVI was recorded for *Milicia excelsa* and *Diospyros dendo* with an IVI of 0.43 each. *Annonidium manii* had the highest IVI in the buffer zone with IVI of 22.85, this was followed by *Celtis zenkeri* Engl. and *Cola gigantea* with an IVI of 10.83 and 10.24 respectively. Species with high IVI in the Enrichment planting site are *Annonidium manii* with IVI of 20.8, *Trilepisium madagascariense* with IVI of 13.71 and *Cola acuminata* with IVI of 4.40. Only *Brachystegia nigerica* Hoyle & A.P.D. Jones had IVI that is less than 2 (Table 4). Analysis of Variance (ANOVA) for biodiversity indices obtained in the study sites is presented in table 5. The results revealed a significant difference ($P < 0.05$) in the Species

**Table 1.** Tree species distribution in the three protected areas *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

| S.N. | Species | Family | Number of stems $ha^{-1}$ | | |
|---|---|---|---|---|---|
| | | | SNR | BZ | EP |
| 1 | *Alstonia boonei* De Wild | Apocynaceae | 2 | 4 | 0 |
| 2 | *Annonidium manii* (Oliv.) Engl. & Diels | Annonaceae | 10 | 40 | 12 |
| 3 | *Baphia nitida* Lodd. | Fabaceae | 0 | 0 | 2 |
| 4 | *Boscia senegalensis* (Pers.) Lam. ex Poir. | Moraceae | 0 | 0 | 2 |
| 5 | *Brachystegia eurycoma* Harms | Leguminosae | 2 | 4 | 0 |
| 6 | *Brachystegia nigerica* Hoyle & A.P.D. Jones | Leguminosae | 0 | 0 | 2 |
| 7 | *Ceiba pentandra* (L.) Gaertn. | Malvaceae | 0 | 0 | 2 |
| 8 | *Celtis mildbreadii* Engl. | Ulmaceae | 8 | 4 | 0 |
| 9 | *Celtis philippensis* Planch | Cannabaceae | 2 | 0 | 2 |
| 10 | *Celtis* sp. | Ulmaceae | 0 | 0 | 2 |
| 11 | *Celtis zenkeri* Engl. | Ulmaceae | 14 | 16 | 0 |
| 12 | *Chrysophyllum albidum* G. Don | Sapotaceae | 0 | 0 | 2 |
| 13 | *Chrysophyllum purpuchrum* Mildbr. ex Hutch. & Dalziel | Sapotaceae | 4 | 4 | 0 |
| 14 | *Cola acuminata* (P. Beauv.) Schott & Endl. | Malvaceae | 2 | 2 | 0 |
| 15 | *Cola gigantea* A. Chev | Sterculiaceae | 10 | 18 | 4 |
| 16 | *Cola hispida* Brenan & Keay | Sterculiaceae | 0 | 4 | 2 |
| 17 | *Cola nitida* Schott & Endl. | Malvaceae | 8 | 0 | 0 |
| 18 | *Cordia millenii* Baker | Boraginaceae | 4 | 0 | 0 |
| 19 | *Daniellia ogea* (Harms) Holland | Leguminosae | 2 | 0 | 0 |
| 20 | *Diospyros dendo* Welw. | Ebeneceae | 0 | 10 | 0 |
| 21 | *Diospyros mespiliformis* Hochst. ex A.DC. | Ebeneceae | 2 | 0 | 0 |
| 22 | *Diesplacia suberulcapa* Juan Rulfo | Ebeneceae | 0 | 2 | 0 |
| 23 | *Diospyros borneensis* Hiern | Ebeneceae | 0 | 0 | 2 |
| 24 | *Entandrophragma angolense* (Welw.) C. DC. | Meliaceae | 0 | 12 | 0 |
| 25 | *Entadrophragma cylindricum* C. DC. | Meliaceae | 0 | 0 | 2 |
| 26 | *Entandrophragma utile* (Dawe & Sprague) Sprague | Meliaceae | 8 | 0 | 0 |
| 27 | *Funtumia elastica* (Preuss) Stapf | Apocynaceae | 48 | 2 | 2 |
| 28 | *Garcinia kola* Heckel | Clusiaceae | 0 | 2 | 2 |
| 29 | *Gmelina arborea* Roxb. | Lamiaceae | 0 | 2 | 0 |
| 30 | *Greenwayodendron* sp. | Annonaceae | 0 | 2 | 0 |
| 31 | *Khaya grandifoliola* C. DC. | Meliaceae | 2 | 2 | 0 |
| 32 | *Lecaniodiscus cupanioides* Planch. ex Benth. | Sapindaceae | 0 | 2 | 0 |
| 33 | *Malacantha alnifolia* (Baker) Pierre | Sapotaceae | 6 | 0 | 0 |
| 34 | *Mallotus oppositifolius* (Gieseler) Mull. Arg. | Euphorbiaceae | 0 | 0 | 2 |
| 35 | *Mansonia altissima* A. Chev | Sterculiaceae | 20 | 10 | 2 |
| 36 | *Margaritaria discoidea* (Baill.) G.L. Webster | Phyllanthaceae | 0 | 4 | 0 |
| 37 | *Milicia excelsa* (Welw.) C. Berg | Moraceae | 2 | 0 | 2 |
| 38 | *Musanga cecropioides* R.Br. | Urticaceae | 4 | 0 | 0 |
| 39 | *Myrianthus arboreus* P. Beauv. | Urticaceae | 2 | 2 | 0 |
| 40 | *Picralima nitida* (Stapf) T.Durand & H.Durand | Apocynaceae | 2 | 0 | 0 |
| 41 | *Pterocarpus osun* Craib | Leguminosae | 2 | 6 | 2 |
| 42 | *Pterocarpus* sp. | Leguminosae | 2 | 2 | 0 |
| 43 | *Pterygota macrocarpa* K. Schum | Malvaceae | 12 | 0 | 0 |
| 44 | *Pycnanthus angolensis* (Welw.) Warb. | Myristicaceae | 2 | 2 | 0 |
| 45 | *Ricinodendron heudelotii* (Baill.) Heckel | Euphorbiaceae | 0 | 4 | 0 |
| 46 | *Spathodea campanulata* P. Beauv. | Bignoniaceae | 0 | 0 | 2 |
| 47 | *Sterculia oblongata* R. Br. | Sterculiaceae | 2 | 0 | 0 |
| 48 | *Sterculia rhinopetala* K. Schum | Sterculiaceae | 32 | 6 | 2 |
| 49 | *Strombosia postulata* Oliv | Olacaceae | 6 | 10 | 6 |
| 50 | *Terminalia ivorensis* A. Chev. | Combretaceae | 2 | 0 | 0 |
| 51 | *Terminalia superba* Engl. & Diels | Combretaceae | 10 | 0 | 0 |
| 52 | *Trichilia heudelotii* Planch. ex Oliv. | Meliaceae | 8 | 0 | 0 |
| 53 | *Trichilia* sp. | Meliaceae | 0 | 2 | 0 |
| 54 | *Trichilia welwitschii* C. DC. | Meliaceae | 4 | 2 | 2 |
| 55 | *Trilepisium madagascariense* DC. | Moraceae | 6 | 14 | 8 |
| 56 | *Triplochyton scleroxylon* K. Schum | Malvaceae | 8 | 6 | 2 |
| 57 | *Zanthoxylum utile* Huang. | Rutaceae | 2 | 0 | 0 |
| 58 | *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler | Rutaceae | 2 | 0 | 0 |
| | | **Total** | **264** | **198** | **72** |

**Table 2.** Shannon wiener index for the three protected areas *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

| Tree species | BZ | | SNR | | EP | |
|---|---|---|---|---|---|---|
| | **Freq. ha$^{-1}$** | **H$^1$** | **Freq. ha$^{-1}$** | **H$^1$** | **Freq. ha$^{-1}$** | **H$^1$** |
| *Alstonia boonei* De Wild | 4 | -0.08 | 2 | -0.04 | - | - |
| *Annonidium manii* (Oliv.) Engl. & Diels | 40 | -0.32 | 10 | -0.12 | 12 | -0.3 |
| *Baphia nitida* Lodd. | - | - | - | - | 2 | -0.1 |
| *Boscia senegalensis* (Pers.) Lam. ex Poir. | - | - | - | - | 2 | -0.1 |
| *Brachystegia nigerica* Hoyle & A.P.D. Jones | - | - | - | - | 2 | -0.1 |
| *Brachystegia eurycoma* Harms | 4 | -0.08 | 2 | -0.04 | - | - |
| *Ceiba pentandra* (L.) Gaertn. | - | - | - | - | 2 | -0.1 |
| *Celtis mildbreadii* Engl. | 4 | -0.08 | 8 | -0.11 | - | - |
| *Celtis philippensis* Planch | - | - | 2 | -0.04 | 2 | -0.1 |
| *Celtis zenkeri* Engl. | 16 | -0.2 | 14 | -0.16 | 2 | -0.1 |
| *Chrysophyllum albidum* G. Don | - | - | - | - | 2 | -0.1 |
| *Chrysophyllum purpuchrum* Mildbr. ex Hutch & Dalziel | 4 | -0.08 | 4 | -0.06 | - | - |
| *Cola acuminata* (P. Beauv.) Schott & Endl. | 2 | -0.05 | 2 | -0.04 | - | - |
| *Cola gigantea* A. Chev. | 18 | -0.22 | 10 | -0.12 | 4 | -0.16 |
| *Cola hispida* Brenan & Keay. | 4 | -0.08 | - | - | 2 | -0.1 |
| *Diospyros borneensis* Hiern | - | - | - | - | 2 | -0.1 |
| *Cola nitida* Schott & Endl. | - | - | 8 | -0.11 | - | - |
| *Cordia millenii* Baker | - | - | 4 | -0.06 | - | - |
| *Daniellia ogea* (Harms) Holland | - | - | 2 | -0.04 | - | - |
| *Diospyros mespiliformis* Hochst. ex A.DC. | - | - | 2 | -0.04 | - | - |
| *Diospyros dendo* Welw. | 8 | -0.13 | 2 | -0.04 | - | - |
| *Diesplacia suberulcapa* Juan Rulfo | 2 | -0.05 | - | - | - | - |
| *Entadrophragma cylindricum* C. DC. | - | - | - | - | 2 | -0.1 |
| *Entandrophragma utile* (Dawe & Sprague) Sprague | - | - | 8 | -0.11 | - | - |
| *Entandrophragma angolense* (Welw.) C. DC. | 12 | -0.17 | - | - | - | - |
| *Funtumia elastica* (Preuss) Stapf | 2 | -0.05 | 48 | -0.31 | 2 | -0.1 |
| *Garcinia kola* Heckel | 2 | -0.05 | - | - | 2 | -0.1 |
| *Gmelina arborea* Roxb. | 2 | -0.05 | - | - | - | - |
| *Greenwayodendron* sp. | 2 | -0.05 | - | - | - | - |
| *Khaya grandifoliola* C. DC. | 2 | -0.05 | 2 | -0.04 | - | - |
| *Lecaniodiscus cupanioides* Planch. ex Benth. | 2 | -0.05 | - | - | - | - |
| *Malacantha alnifolia* (Baker) Pierre | - | - | 6 | -0.09 | - | - |
| *Mallotus oppositifolius* (Gieseler) Mull. Arg. | - | - | - | - | 2 | -0.1 |
| *Mansonia altissima* A. Chev | 10 | -0.15 | 20 | -0.2 | 2 | -0.1 |
| *Margaritaria discoidea* (Baill.) G.L. Webster | 2 | -0.05 | - | - | - | - |
| *Milicia excelsa* (Welw.) C. Berg | - | - | 2 | -0.04 | 2 | -0.1 |
| *Musanga cecropioides* R.Br. | - | - | 4 | -0.06 | - | - |
| *Myrianthus arboreus* P. Beauv | 2 | -0.05 | - | - | 2 | -0.1 |
| *Picralima nitida* (Stapf) T.Durand & H.Durand | - | - | 2 | -0.04 | - | - |
| *Pterocarpus osun* Craib | 6 | -0.11 | 2 | -0.04 | 2 | -0.1 |
| *Pterocarpus* sp. | 2 | -0.05 | 2 | -0.04 | - | - |
| *Pterygota macrocarpa* K. Schum | - | - | 12 | -0.14 | - | - |
| *Pycnanthus angolensis* (Welw.) Warb. | 2 | -0.05 | 2 | -0.04 | - | - |
| *Ricinodendron heudelotii* (Baill.) Heckel | 4 | -0.08 | - | - | - | - |
| *Spathodea campanulata* P. Beauv. | - | - | - | - | 2 | -0.1 |
| *Sterculia oblongata* R. Br. | - | - | 2 | -0.04 | | - |
| *Sterculia rhinopetala* K. Schum | 6 | -0.11 | 32 | -0.26 | 2 | -0.1 |
| *Strombosia postulata* Oliv. | 10 | -0.15 | 6 | -0.09 | 6 | -0.21 |
| *Trichilia* sp. | 2 | -0.05 | - | - | - | - |
| *Terminalia ivorensis* A. Chev. | - | - | 2 | -0.04 | - | - |
| *Terminalia superba* Engl. & Diels | - | - | 10 | -0.12 | - | - |
| *Trichilia heudelotii* Planch. ex Oliv. | - | - | 8 | -0.11 | - | - |
| *Trichilia welwitschii* C. DC. | 2 | -0.05 | 4 | -0.06 | 2 | -0.1 |
| *Trilepisium madagascariense* DC. | 14 | -0.19 | 6 | -0.09 | 8 | -0.24 |
| *Triplochyton scleroxylon* K. Schum | 6 | -0.11 | 8 | -0.11 | 2 | -0.1 |
| *Zanthoxylum utile* Huang | - | - | 2 | -0.04 | - | - |
| *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler | - | - | 2 | -0.04 | - | - |
| **Total** | **198** | **-2.97** | **264** | **-3.1** | **72** | **-3** |

**Table 3.** Summary of tree growth variables & biodiversity indices from Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

| Growth Variables & Biodiversity Indices | SNR | BZ | EP |
|---|---|---|---|
| No of trees $ha^{-1}$ | 264 | 198 | 72 |
| No of species | 37 | 31 | 25 |
| Volume per hectare ($m^3$) | 461.74 | 424.46 | 138.28 |
| Basal area per hectare ($m^2$) | 60.62 | 36.48 | 14.35 |
| Mean DBH (cm) | 30.0 | 31.0 | 24.7 |
| Mean height (m) | 15.70 | 14.38 | 13.00 |
| Shannon Wiener index ($H^1$) | 3.10 | 2.97 | 3.00 |
| Pieolus Species Evenness | 0.86 | 0.86 | 0.93 |

**Table 4.** Importance value index (IVI) of tree species in the study sites *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

| Tree species | BZ | | | SNR | | | EP | | |
|---|---|---|---|---|---|---|---|---|---|
| | RD% | RDO% | IVI | RD% | RDO% | IVI | RD% | RDO% | IVI |
| *Alstonia boonei* De Wild | 2.02 | 1.38 | 1.7 | 0.76 | 0.16 | 0.46 | - | - | - |
| *Anonidium mannii* (Oliv.) Engl. & Diels | 20.2 | 25.49 | 22.85 | 3.79 | 1.41 | 2.60 | 16.67 | 24.91 | 20.8 |
| *Baphia nitida* Lodd. | - | - | - | - | - | - | 2.78 | 2.35 | 2.57 |
| *Boscia senegalensis* (Pers.) Lam. ex Poir. | - | - | - | - | - | - | 2.78 | 1.76 | 2.27 |
| *Brachystegia nigerica* Hoyle & A.P.D. Jones | - | - | - | - | - | - | 2.78 | 1.03 | 1.91 |
| *Brachystegia eurycoma* Harms | 2.02 | 1.37 | 1.70 | 0.76 | 0.16 | 0.46 | - | - | - |
| *Ceiba pentandra* (L.) Gaertn. | - | - | - | - | - | - | 2.78 | 2.06 | 2.42 |
| *Celtis mildbreadii* Engl. | 2.02 | 0.85 | 1.435 | 3.03 | 2.83 | 2.93 | - | - | - |
| *Celtis philippensis* Planch | - | - | - | 0.76 | 0.5 | 0.63 | 2.78 | 1.22 | 2 |
| *Celtis* sp. | - | - | - | - | - | - | 2.78 | 5.39 | 4.09 |
| *Celtis zenkeri* Engl. | 8.08 | 13.58 | 10.83 | 5.3 | 1.45 | 3.38 | - | - | - |
| *Chrysophyllum albidum* G. Don | - | - | - | - | - | - | 2.78 | 1.35 | 2.07 |
| *Chrysophyllum purpuchrum* Mildbr. ex Hutch. & Dalziel | 2.02 | 2.29 | 2.16 | 1.52 | 0.94 | 1.23 | - | - | - |
| *Cola acuminata* (P. Beauv.) Schott & Endl. | 1.01 | 0.34 | 0.68 | 0.76 | 0.17 | 0.47 | - | - | - |
| *Cola gigantea* A. Chev | 9.09 | 11.39 | 10.24 | 3.79 | 4.06 | 3.93 | 5.56 | 3.23 | 4.40 |
| *Cola hispida* Brenan & Keay | 2.02 | 0.47 | 1.25 | | | | 2.78 | 1.62 | 2.2 |
| *Cola nitida* Schott & Endl. | - | - | - | 3.03 | 0.7 | 1.87 | - | - | - |
| *Cordia millenii* Baker | - | - | - | 1.52 | 7.76 | 4.64 | - | - | - |
| *Daniellia ogea* (Harms) Holland | - | - | - | 0.76 | 1.24 | 1.00 | - | - | - |
| *Diospyros mespiliformis* Hochst. ex A.DC. | - | - | - | 0.76 | 0.22 | 0.49 | - | - | - |
| *Diesplacia suberulcapa* Juan Rulfo | 1.01 | 0.34 | 0.675 | - | - | - | - | - | - |
| *Diospyros borneensis* Hiern | - | - | - | - | - | - | 2.78 | 2.21 | 2.495 |
| *Diospyros dendo* Welw. | 4.04 | 2 | 3.02 | 0.76 | 0.1 | 0.43 | - | - | - |
| *Entandrophragma angolense* (Welw.) C. DC. | 6.06 | 2.91 | 4.485 | - | - | - | - | - | - |
| *Entadrophragma cylindricum* C. DC. | - | - | - | - | - | - | 2.78 | 1.39 | 2.085 |
| *Entandrophragma utile* (Dawe & Sprague) Sprague | - | - | - | 3.04 | 6.18 | 4.61 | - | - | - |
| *Funtumia elastica* (Preuss) Stapf | 1.01 | 0.18 | 0.595 | 18.18 | 10.55 | 14.37 | 2.78 | 1.86 | 2.32 |
| *Garcinia kola* Heckel | 1.01 | 0.19 | 0.6 | - | - | - | 2.78 | 3.67 | 3.225 |
| *Gmelina arborea* Roxb. | 1.01 | 1.34 | 1.175 | - | - | - | - | - | - |
| *Greenwayodendron* sp. | 1.01 | 0.69 | 0.85 | - | - | - | - | - | - |
| *Khaya grandifoliola* C. DC. | 1.01 | 1.05 | 1.03 | 0.76 | 0.18 | 0.47 | - | - | - |
| *Lecaniodiscus cupanioides* Planch. ex Benth. | 1.01 | 0.91 | 0.96 | - | - | | - | - | - |
| *Malacantha alnifolia* (Baker) Pierre | - | - | - | 2.27 | 0.32 | 1.30 | - | - | - |
| *Mallotus oppositifolius* (Gieseler) Mull. Arg. | - | - | - | - | - | - | 2.78 | 2 | 2.39 |
| *Mansonia altissima* A. Chev | 5.05 | 8.47 | 6.76 | 7.58 | 5.86 | 6.72 | 2.78 | 2.47 | 2.625 |
| *Margaritaria discoidea* (Baill.) G.L. Webster | 1.01 | 0.35 | 0.68 | - | - | - | - | - | - |
| *Milicia excelsa* (Welw.) C. Berg | - | - | - | 0.76 | 0.09 | 0.43 | 2.78 | 3.49 | 3.135 |
| *Musanga cecropioides* R.Br. | - | - | - | 1.52 | 0.95 | 1.24 | | | 0 |
| *Myrianthus arboreus* P. Beauv | 1.01 | 1.21 | 1.11 | | | | 2.78 | 1.33 | 2.055 |
| *Picralima nitida* (Stapf) T. Durand & H. Durand | - | - | - | 0.76 | 0.2 | 0.48 | - | - | - |
| *Pterocarpus osun* Craib | 3.03 | 1.46 | 2.245 | 0.76 | 0.09 | 0.43 | 2.78 | 2.53 | 2.655 |
| *Pterocarpus* sp. | 1.01 | 0.14 | 0.575 | 0.76 | 0.2 | 0.48 | - | - | - |
| *Pterygota macrocarpa* K. Schum | | | | 4.55 | 12.65 | 8.60 | - | - | - |
| *Pycnanthus angolensis* (Welw.) Warb. | 1.01 | 1.88 | 1.445 | 0.76 | 0.21 | 0.49 | - | - | - |
| *Ricinodendron heudelotii* (Baill.) Heckel | 2.02 | 0.38 | 1.2 | - | - | - | - | - | - |
| *Spathodea campanulata* P. Beauv. | - | - | - | - | - | - | 2.78 | 5.32 | 4.05 |
| *Sterculia oblongata* R. Br. | - | - | - | 0.76 | 1.28 | 1.02 | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Sterculia rhinopetala* K. Schum | 3.03 | 2.54 | 2.785 | 12.12 | 13.17 | 12.65 | 2.78 | 2.15 | 2.465 |
| *Strombosia pustulata* Oliv. | 5.05 | 5.32 | 5.185 | 2.27 | 0.79 | 1.53 | 8.33 | 5.54 | 6.935 |
| *Terminalia ivorensis* A. Chev. | - | - | - | 0.76 | 2.18 | 1.47 | - | - | - |
| *Terminalia superba* Engl. & Diels | - | - | - | 3.79 | 8.69 | 6.24 | - | - | - |
| *Trichilia heudelotii* Planch. ex Oliv. | - | - | - | 3.03 | 0.67 | 1.85 | - | - | - |
| *Trichilia* sp. | 1.01 | 0.13 | 0.57 | - | - | - | - | - | - |
| *Trichilia welwitschii* C. DC. | 1.01 | 0.19 | 0.6 | 1.52 | 0.16 | 0.84 | 2.78 | 2.21 | 2.495 |
| *Trilepisium madagascariense* DC. | 7.07 | 8.17 | 7.62 | 2.27 | 1.02 | 1.65 | 11.11 | 16.31 | 13.71 |
| *Triplochyton scleroxylon* K. Schum | 3.03 | 3.01 | 3.02 | 3.03 | 12.01 | 7.52 | 2.78 | 2.53 | 2.655 |
| *Zanthoxylum utile* Huang | - | - | - | 0.76 | 0.23 | 0.50 | - | - | - |
| *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler | - | - | - | 0.76 | 0.66 | 0.71 | - | - | - |

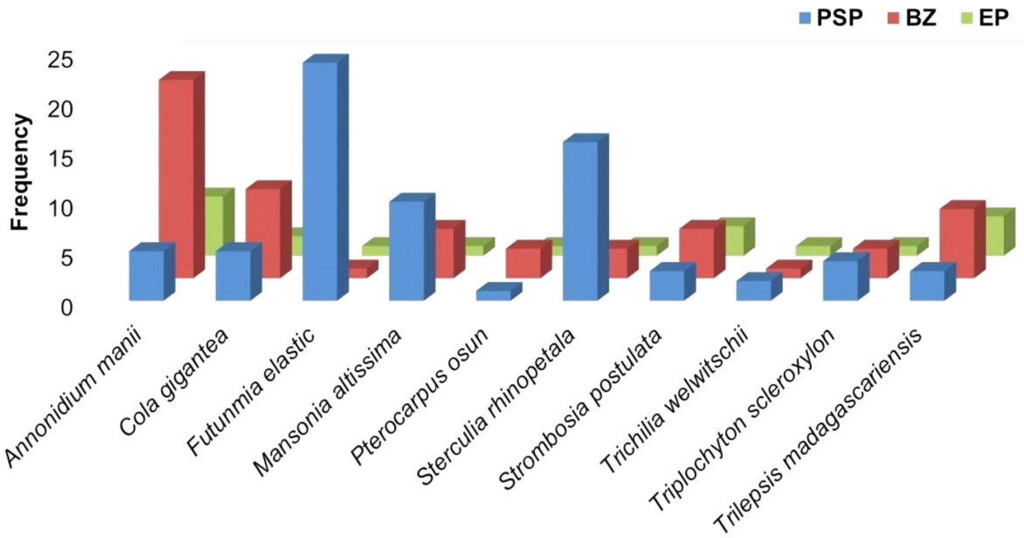


**Figure 1.** Species frequency in the study sites *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

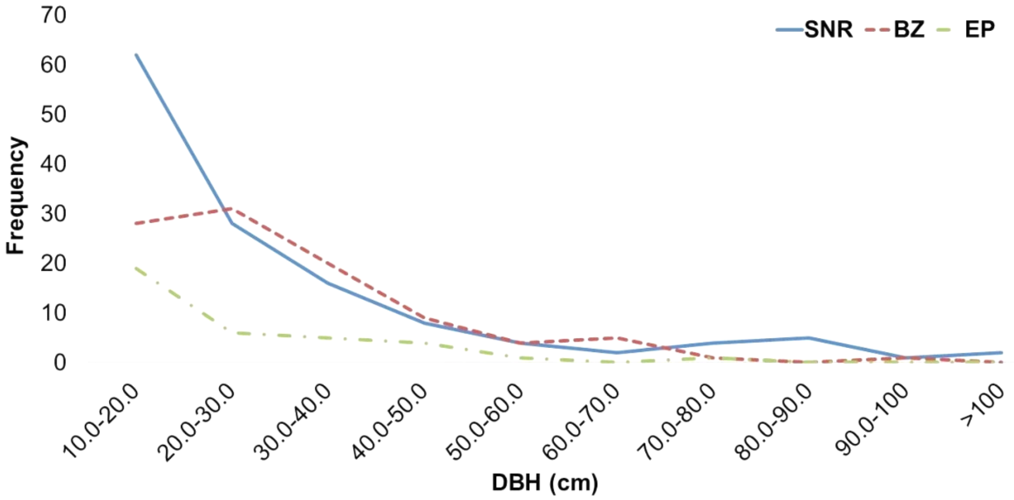


**Figure 2.** Stems distribution based on DBH class in the study sites *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

evenness and Shannon Wiener index of the three protected areas but no significant difference was observed in their Simpson Concentration. Ten tree species were common to the three protected areas, *Annonidium manii*, *Cola gigantea*, *Funtumia elastica*, *Mansonia altissima* A. Chev, *Pterocarpus osun* Craib, *Sterculia rhinopetala*, *Strombosia postulata*, *Trichilia welwitschii*, *Triplochyton scleroxylon* and *Trilepisium madagascariense*. Frequency of these common species in all the three protected areas is presented in figure 1. Stems distribution based on DBH class in the three protected areas is presented in figure 2. Majority of the trees in the SNR fell in the lowest diameter class. Twenty-eight (28) trees fell in the DBH class of 20-30 cm. Only two trees fell in the DBH class above 100 cm. Buffer zone is dominated by trees with diameter class 20-30 cm, followed by trees in the lowest diameter class (10-20 cm). Only one tree fell in the diameter class of 70-80 cm and 90-100 cm. Most of the trees (18) in Enrichment planting site fell in the lower diameter of 10-20 cm, followed by trees in the diameter class of 20-30 cm. The distribution of trees into height classes is presented in figure 3. The highest percentage of trees (61) in the SNR and buffer zone fell in the height class of 10-20m. Only one tree fell in the height class of 30-40 m in Buffer zone and Enrichment Planting site (Fig. 3).

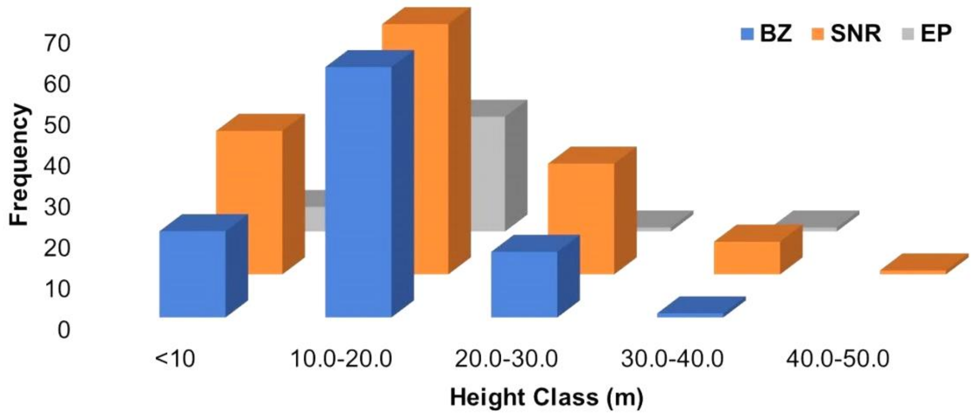


**Figure 3.** Tree height distribution based on DBH class in the study sites *i.e.* Strict Nature Reserve (SNR), Buffer zone (BZ) and the Enrichment Planting (EP).

**Table 5.** Analysis of Variance (ANOVA) for Biodiversity indices of the study sites.

| Biodiversity indices | Source | SS | Df | MS | F | Sig. |
|---|---|---|---|---|---|---|
| Species Evenness | Indices | 0.004 | 2 | 0.002 | 6.281 | 0.003* |
| | Error | 0.029 | 90 | 0.00 | | |
| | **Total** | **0.033** | **92** | **0.00** | | |
| Simpson Conc. | Indices | 8.43E-06 | 2 | 0.00 | 0.102 | $0.903^{ns}$ |
| | Error | 0.004 | 90 | 0.00 | | |
| | **Total** | **0.004** | **92** | **0.00** | | |
| Shannon Wiener index | Indices | 0.026 | 2 | 0.013 | 3.465 | 0.035* |
| | Error | 0.335 | 90 | 0.891 | | |
| | **Total** | **0.361** | **92** | **0.004** | | |

**Note:** *= Significant; ns= Insignificant.

## DISCUSSION

Forests are rich in biological diversity in terms of species, genetic material and ecological processes of all ecosystems (EU, 2008). Forest ecosystem plays vital roles in water cycles, climate change mitigation and carbon sequestration. Protected area is one of the *in-situ* methods of conservation that are needed to be protected from human anthropogenic activities (Adekunle *et al.*, 2013). The number of trees obtained per hectare in the three protected areas SNR (264), Buffer Zone (198) and Enrichment Planting (72), similar to what was obtained by (Onyekwelu *et al.*, 2007). Most tropical forest ecosystems are rich in floristic composition,this results in a variety of life forms and preservation of global biodiversity (Shi & Singh, 2002). Biodiversity indices are generated to compare forests compositions and similarities of different species. The higher the value of an ecological index, the higher the species richness (IIRS, 2002).

The Shannon Wiener index values obtained for the three protected areas (SNR 3.16, Buffer Zone 2.97 and Enrichment 3.1) fell within the range of values reported by Adekunle (2006) and Onyekwelu *et al.* (2008) who revealed that Shannon-Wiener diversity index for tropical rainforests in South-western Nigeria could range between 3.34-3.66 or 2.82-3.31. Species richness is the number of species in a given area of the forest. This was generated to put the three protected areas used in this study on the scale of comparison (Magurran, 2004). The higher the values obtained, the higher the richness of the forest, the high diversity and abundance of the forest denotes that biodiversity is highly conserved (UNEP-WCMC, 2008). The floristic composition and diversity of the protected areas used in this study can be compared to some selected forest reserves in southwest Nigeria (Adekunle *et al.*, 2004), but below what was reported by Kumar *et al.* (2006) for tropical forests of Garo Hills, India. The high species evenness recorded in the protected areas (PAs) revealed a forest with an evenly distributed number of tree species and stems.

Diameter distribution is an indication of how well the forest is regenerating (Adekunle, 2013). The diameter distribution of trees is used to represent the population structure of forests (Rao *et al.*, 1990). The results of this study revealed that as tree diameter increases, the number of trees decreases and the basal area increases as the DBH increases. The forest reserve is dominated by trees with small diameter, which is common to tropical rainforests. Similar results have been reported by previous workers in other tropical rainforests of Nigeria (Adekunle *et al.*, 2004; Adekunle & Olagoke, 2008). The reason for few numbers of trees having DBH greater than 50 cm could be as a result of forest degradation activities which might have removed large trees as well as the fact that some trees with large diameter would have been removed through logging activities that has occurred in the past. The basal area per hectare obtained in the three protected area is greater than what was recorded by Maradana & Owk (2015). The difference in the basal area obtained in each of the PAs can be attributed to species richness, age of stand and level of anthropogenic activities that have occurred in the past (Maradana & Owk, 2015).

According to Tonolli (2011), tree stem volume is important in forest management and it requires data from field survey. The values obtained for volume per hectare in the buffer zone and Strict nature reserve are less than the value recorded by Adekunle (2006) for an undisturbed site of Akure forest reserve.

The distribution of individual stems into diameter class follows an inverse J shape, which denotes development of small diameter logs into big diameter trees, a feature that is common to mature natural tropical forests (Adekunle *et al*., 2013). The height distributions follows a vertical pattern of the forest, this is an indication that the forest will continue to grow till maturity if biodivesity is strictly conserved. However, the presence of trees with large diameter has been reported to be a sign of matured tropical forest (Zheng *et al*., 2006).

The high volume $ha^{-1}$ obtained especially in the SNR and buffer zone can be attributed to conservation. The study has also shown that the forest ecosystem can be conserved through *in situ* method of conservation if proper managerial actions are put in place. The species that are present in all the three PAs are typically from the families of Sterculiaceae, Malvaceae, Meliaceae, Moraceae Apocynaceae, Olacaceae and Annonaceae. This finding corroborates the works of Adekunle (2006) and Adekunle *et al.* (2010) who found that tropical rainforest of southwest Nigeria is dominated by the families of Sterculiaceae, Meliaceae, Moraceae and Ebenaceae.

## CONCLUSION AND RECOMMENDATIONS

Deforestation and degradation are threats to biodiversity conservation. Protected area is one of the insitu methods of conservation and it plays important roles in biodiversity conservation. The floristic composition of these PAs has revealed the efficacy of protected areas in biodiversity conservation. The high biodiversity indices obtained in this study is an indication that the forest will continue to grow till maturity if biodiversity is conserved. The data obtained in this study will provide baseline information for the management of protected areas. This study recommends that conservative measures should be put in place to protect protected areas from deforestation and that more protected area should be established. Forest that have been degraded should be protected from further degradation,

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## REFERENCES

Adekunle V.A.J. & Olagoke A.O. (2008). Diversity and biovolume of tree species in natural ecosystem in bitumen-producing area of Ondo State, Nigeria: A baseline study. *Biodiversity and Conservation*, 17: 2735-2755.

Adekunle V.A.J. (2006) Conservation of tree species diversity in tropical rainforest ecosystem of southwest Nigeria. *Journal of Tropical Forest Science* 18(2): 91-101.

Adekunle V.A.J., Akindele S.O. & Fuwape J.A. (2004). Structure and yield models of tropical lowland rainforest ecosystem of southwest Nigeria. *Food, Agriculture and Environment*, (2): 395-399.

Adekunle V.A.J., Olagoke A.O. & Akindele S.O. (2013). Tree species diversity and structure of a Nigerian strict nature reserve. *International Society for Tropical Ecology*, 54(3): 275-289.

Adekunle V.A.J., Olagoke A.O. & Ogundare L.F. (2010). Rate of timber production in tropical rainforest ecosystem of Nigeria and its implications on sustainable forest management. *Journal of Forestry Research*, 21(2): 225-230.

Bajpai O., Dutta V., Chaudhary L.B. & Pandey J. (2018). Key issues and management strategies for the conservation of the Himalayan Terai forests of India. *International Journal of Conservation Science*, 9(4): 749-760.

Bajpai O., Kumar A., Mishra A.K., Sahu N., Pandey J., Behera S.K. & Chaudhary L.B. (2012). Recongregation of tree species of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. *Journal of Biodiversity and Environmental Sciences*, 2(12): 24-40.

Barua K.N., Gogoi G. & Hazarika P. (2018). Comparative study on structural composition and community association of Nambor Wildlife Sanctuary and its South-Westward extended Bornewria forest, Assam, India. *Tropical Plant Research*, 5(2): 233-242.

Dudley N. (Ed) (2008). *Guidelines for applying protected area management categories*. Gland, Switzerland, IUCN. Retrieved from: https://portals.iucn.org/library/sites/library/files/documents/PAG-021.pdf

EU (European Union) (2008). Forest biodiversity as a challenge and opportunityfor climate change, adaptation and mitigation. In: *Presidency background paper presented at the Informal Meeting of EU Environment Ministers*. pp. 12.

Gbile Z.O. (1984). *Vernacular names of Nigerian plants Yoruba*. Forestry Research Institute of Nigeria, Ibadan, Nigeria.

Husch B., Beers T.W. & Kershaw J.A.Jr. (2003). *Forest mensuration*, 4$^{th}$, 443 Hoboken, NJ: John Wiley and Sons, Inc.

IIRS (Indian Institute of Remote Sensing) (2002). *Biodiversity Characterization at Landscape Level in North East, India Using Satellite Remote Sensing and GIS*. Indian Institute of Remote Sensing, National Remote Sensing Agency, Dept. of Space, Dehradun 248001, Uttaranchal.

IUCN (1994). *Guidelines for Protected Area Management Categories*. Gland and Cambridge: IUCN.

Keay R.W.J. (1989). *Trees of Nigeria. A revised version of 'Nigeria Trees'*. Clarendron Press, Oxford, 476 p.

Kumar A., Marcot B.G. & Saxena A. (2006). Tree species diversity and distribution patterns in tropical forests of Garo Hills. *Current Science*, 91: 1370-1381.

Magurran A.E. (2004). *Measuring Biological Diversity*. Blackwell, Oxford, U.K., pp. 256.

Maradana T.N. & Owk A.K. (2015). Tree diversity, stand structure and community of tropical forests in Eastern Ghats of Andhra Pradesh, India. *Journal of Asia-Pacific Biodiversity*, 9: 328-334.

Nurudeen T.A., Aina-oduntan O.A., Awotedu B.F. & Salami K.D. (2017). Structure and Tree Species Diversity Pattern of Gambari Forest Reserve Southwestern Nigeria. *International Journal of Applied Research and Technology*, 6(6): 21-29.

Onyekwelu J., Mosandi R. & Stimm B. (2008). Tree species diversity and soil status of Primary and Degraded Tropical Rainforest Ecosystems in South-Western Nigeria. *Journal of Tropical Forest Science*, 20(3): 193-204.

Onyekwelu J.C., Mosandl R. & Stimm B. (2007). *Tree species diversity and soil status of two natural forest ecosystem in lowland humid tropical rainforest region of Nigeria*. Tropentag 2007. University of Kassel-Witzenhausen and University of Gottingen, October 9-11. Conference of international Agricultural Research Development.

Rao P., Barik S.K., Pandey H.N. & Tripathi R.S. (1990). Community Composition and tree Population Structure in a Sub-Tropical Broad-leaved Forest along distance gradient. *Vegetation* 88: 151-162.

Rennolls K. & Reynolds K.M. (2007). Indicators for biodiversity of Tropical Forest: Problems and solutions. In: Reynolds K.M., Thomson A.J., Kohl M., Shannon M.A., Ray D. & Rennolls K. (Eds.) *Monitoring and Modelling of Knowledge Management and Policy Science.* CABI, pp. 103-128.

Sarkar M. & Devi A. (2017). Analysis of medicinal and economic important plant species of Hollongapar Gibbon wildlife sanctuary, Assam, northeast India. *Tropical Plant Research*, 4(3): 486-495.

Shi H. & Singh A. (2002). An assessment of biodiversity hotspots using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing*, 30(1-2): 105-112.

Stohlgren T.J., Binkley D. & Chong G.W. (1999). Exotic plant species invade hot spots of native plant diversity. *Ecology Monograph*, 69: 25-46.

Tonolli S., Rodeghiero M., Gianelle D., Dalponte M., Bruzzone L. & Vescovo L. (2011). Mapping and modeling forest tree volume using forest inventory and airborne laser scanning. *European Journal of Forest Research*, 130: 569-577.

UNEP-WCMC (2008). *State of the World's Protected Areas: An Annual Review of Global Conservation Progress*. United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC).

Zheng Z., Feng Z., Cao M., Li Z. & Zhang J. (2006). Forest Structure and Biomass of a Tropical Seasonal Rainforest in Xishuangbanna, Southwest China. *Biotropica*, 38: 318-327.