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Research article

Phytoecological studies of some protected and degraded forest areas of lowland humid forest, Ondo state, Nigeria: a comparative approach

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Abstract: This study compared the phytoecological characteristics of some protected areas [Strict nature reserve (SNR), Oluwa natural forest (ONF) and permanent sample plot 29 aimed at biodiversity conservation and a degraded forest not under reservation] in the lowland humid forest, Ondo state, Nigeria. Data were collected using Systematic Line Transect method with two parallel transects of 200 m apart for plot location. Four sample plots (25 m × 25 m) were laid alternately on each transect in each of the forests. In each plot, trees with DBH ≥ 10 cm were measured (diameters at the base, middle, top and total height), identified and classified into families and frequency of occurrence to ascertain the present status of the protected areas in term of tree diversity, abundance and yield. A total of 411 stems.ha^{-1} from 78 species and 30 families was recorded in the study sites. *Celtis zenkeri, Cola gigantea* and *Funtumia elastica* were common to all the forests. The DBH distribution curve of the species followed inverse J-shaped pattern with 49.4% of trees falling within the lowest diameter class (10–20 cm) while only 7.14% falls in the highest diameter class (>80 cm). SNR and ONF have emergent trees whose heights were above 30 m (18.7% and 7.02% of the total number of trees in the Sterculaceae and Meliaceae families, respectively) whereas 14.90 m was the highest height recorded in the free forest. On biovolume yield, ONF has the highest volume per hectare (141.06 m^3) while the least (14.56 m^3) was from the forest not under reservation. The Shannon-Weiner index, Pielou's Evenness index and Margalef's index for all the forest reserves are 5.11, 0.69 and 12.79 respectively with the highest for ONF. These indices indicated that the protected areas are mature and foster in-situ conservation of tree species especially the keystone species.
Keywords: Biodiversity - Protected areas - Conservation - Deforestation - Forest structure.

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INTRODUCTION

Biodiversity has been defined as the variety and variability of life forms on earth. The "biological diversity" typically measures variation at the genetic, the species, and the ecosystem level, though not evenly distributed on earth but richest in the tropics (UNEP 2011). Flora and fauna diversity and the activities vary from one ecological zone to the other in the tropic. This could be attributed to the differences in climate and weather condition of the ecosystems. The tropical rainforest, which is located in the southwest and southeast geopolitical zones of Nigeria, is highly complex and is known for its astonishing wealth of plant species because of the usual favorable climate (Adekunle *et al.* 2007). Forest biodiversity provides wide variety of goods and services that support the existence of humans on earth. These services include the provision of services which involve the production of renewable resources such as food, wood, fertile land, wildlife, and fresh water, regulating services. These are those that are responsible for environmental changes (*e.g.* climate regulation and mitigate, biodiversity conservation, combating desertification encroachment, pest/disease control) and cultural services

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representing human values and beliefs (*e.g.* landscape aesthetics, cultural heritage, outdoor recreation and spiritual significance) (Behera *et al.* 2012, Cardinale *et al.* 2012, Daniel *et al.* 2012). According to Phillips *et al*. (2003) and Royal Society (2003), biodiversity assessment was recognized by international policy process such as the convention on biological diversity, as inevitable tool to guide conversation. The importance of Biodiversity can be related to the phytosociology of a community (Bajpai *et al.* 2015).

As stated by Dengler (2017), Phytosociology is an aspect of science which study vegetation in terms of plant assemblages, classification and characterization of the vegetation types based on the floristic composition in the plant community. Phytosociological studies are essential to characterize and classify plant community (trees) in term of their structure and composition for protecting the natural plant environment and proper management of the forest resources. Understanding and appreciating the need for biodiversity conservation in Nigeria is of great worth (Aju & Ezeibekwe 2010) as this could help in reducing the continuous external threat imposed on protected areas and the restoration of loss that has taken place in the ecosystems. More than half of Nigeria's primary forest has been lost to deforestation through: urbanization, over exploitation of timber, subsistence agriculture, and increase in the demand for fuel wood in the last decade (FAO 2006). Other factors against biological diversity conservation in the tropics include explosive growth in human population, poverty, and failure to implement the methods or approaches aimed at sustainable agriculture and forestry practices (Ekpo *et al.* 2011).

Protected Areas (PAs) are potentially beneficial for carbon sink and environmental conservation. Adekunle *et al.* (2014), defined Protected Areas as geographical space, recognised, dedicated and managed by means of legal or other effective strategies to achieve the continuing conservation of nature with associated ecosystem services and cultural values. Protected areas were categorised into: the Strict Nature Reserves (strict protection), National Parks (Ecosystem Conservation and Protection), Natural Monuments (conservation of natural features), Habitat/Species Management Area, Protected landscape/seascape (Landscape/Seascape conservation and recreation) and Managed Resource Protected Area (Sustainable use of natural resources) (IUCN 2008). Every PA, irrespective of the management strategy should have the following objectives: conservation of the composition, structure, function and evolutionary potential of biodiversity; contributions to regional conservation strategies; maintenance of diversity of landscape or habitat and of associated species and ecosystems; long-term maintenance of the specified conservation targets; maintain the values for which it was assigned in perpetuity; be operating under the guidance of a management plan and possess a clear and equitable governance system (IUCN 2008, Adekunle *et al.* 2014). Also, it should be able to conserve significant landscape features, geomorphology and geology; provide regulatory ecosystem services, including buffering against the impacts of climate change and recreational benefits; provide for cultural, spiritual, educational opportunities and scientific research purposes and deliver benefits to resident and local communities." These losses are unfavourable to the continued existence of animals, plants, human beings, and the general environment because biodiversity conservation is recognized as a global life support system (Isichei 1995).

Tree canopy of the tropical rainforest ecosystem is made up of the upper layer (at about 30–40 m), the second layer (between 23–30 m) and the lower layer which is made up of saplings of a number of species (Bourgeron 1983). However, the high species diversity and the notable number of goods and services obtainable from the rainforest ecosystem are partly responsible for the pressure to which it has been subjected for centuries; and is presently on the increase (Onyekwelu *et al*. 2005) thereby increasing deforestation and forest degradation. These, have been reported as the principal causes of forest cover change (Sedano *et al*. 2016) which is responsible for the high percentage of the global carbon emission today (Van der werf *et al.* 2009). Deforestation has been defined as the unchanging or long-term conversion of forest land use to other non-forest uses thereby, causing the sudden and rapid change in land cover; consequently resulting in forest degradation, contributing to the build-up of the carbon dioxide content in the atmosphere (GOFC-GOLD 2009, van der werf *et al.* 2009). Other direct drivers of deforestation include agricultural activities, infrastructure development and settlements (Halperin & Turner 2013). Forest degradation has caused lots of havoc among which are; colossal reduction or total loss of forest land due to several human activities (Chadman 2008, Mackey *et al*. 2008, Simula 2009, FAO 2011) and reduction in forested landscape carbon stocks in relation to its natural carbon carrying capacity (Mackey *et al.* 2008). This research therefore established the current status of selected protected areas in the tropical rainforest ecosystem of southwest Nigeria that could enhance sustainable forest management ecosystem restoration, thereby increasing the biodiversity efforts of all forest stakeholders.

MATERIALS AND METHODS

Study areas

This study was carried out at three PAs and an adjoining free forest area to one of the selected PAs (Fig. 1). The PAs are a Natural Strict Reserve within Akure Forest Reserve, Oluwa Forest Reserve and a Permanent Sample Plot (PSP 29). The free forest area is adjacent to the PSP 29.

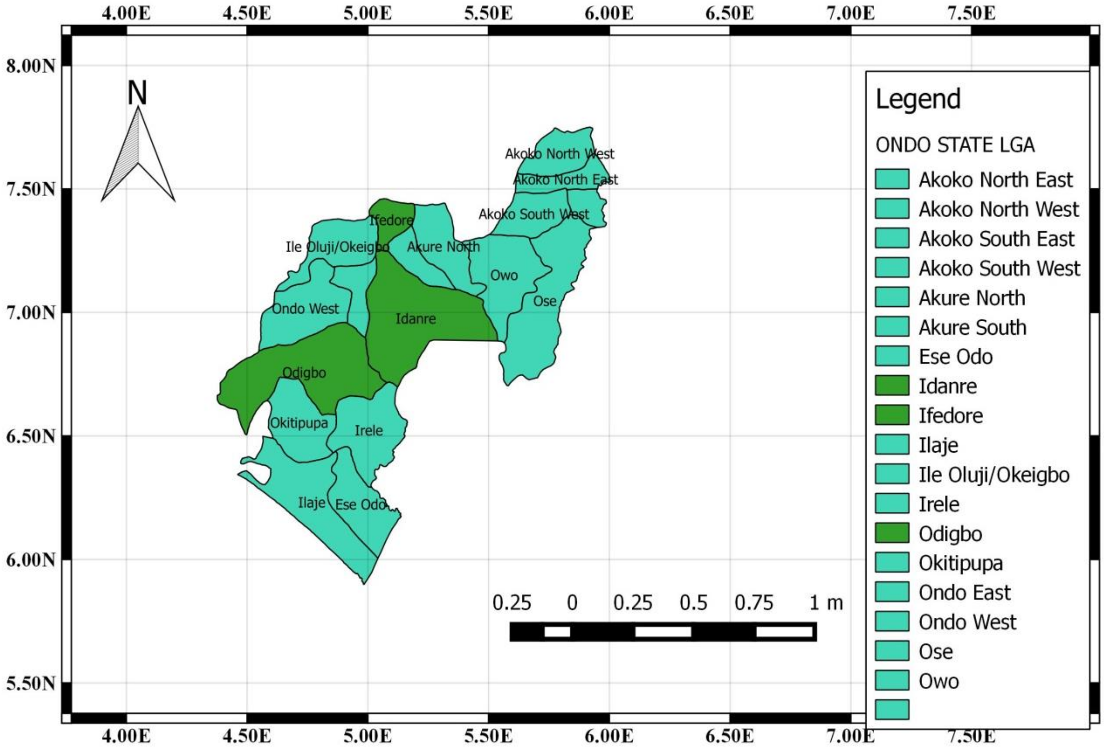

Figure 1. Map of Ondo state showing the location of the forest reserves.

Location, climate and vegetation

Akure Forest Reserve (Aponmu) is one of the Strict Nature Forest Reserves in Nigeria located in the tropical rainforest in Ondo State. It covers an area of about 32 hectares (Adeduntan & Olusola 2013) and lies between latitude 06.59718° N and longitude 004.49199º E. In this protected area, the mean annual rainfall is about 1700 m and the temperature ranges from 20.6–33.5 ºC. Oluwa natural forest is within Oluwa Forest Reserve. This forest lies between latitude 06.59718º N and longitude 004.49199º E and covers an area of 87, 816 ha (Adeduntan 2009). The average rain fall of this reserve is 1700 mm, Relative Humidity of 80%, an annual temperature of 26ºC with an average elevation of 100 m (Adekunle & Dafiwhare 2011). Akure/ Owena Permanent Sample plot (PSP 29) is situated along Akure-Ondo road and about 1km away from Cocoa Research Institute of Nigeria (CRIN) Owena substation. It covers an area of 65.93 km and falls within the high forest Zone of Nigeria between longitude 005.02911º E and latitude 07.20109º N (Pelemo *et al.* 2011). In this reserve, the relative humidity during the raining season ranges between 85 and 100% but less than 60% during the dry season (Fasinmirin & Oguntuase 2008). It has a mean annual rainfall between (1300–1600 mm) and average temperature of 27ºC. This area was demarcated and being managed by the Federal Research Institute of Nigeria (FRIN).The Raining season in these locations starts from March and ends November with dry season starting from December and ends in February. The soil in these PAs is typical of the soil found in the rainforest region of the south western part of Nigeria. The soil texture is sandy-loamy but gradually becomes heavier in depth. The ferrric luvisol soils are formed as a result of continuous weathering of the crystalline rock which feature mostly in the typical upland soils in many parts of South-Western Nigeria (FAO 1988).

Data collection

I. Plot demarcation: The systematic line transects was employed in laying of plots for data collection, two parallel transects of 200 m apart were laid in each of the study sites after a 50 meter distance has been taken from the edge of each forest. Thereafter, four sample plots of equal size (25 m × 25 m) were laid alternately on each transect.

II. Measurement of tree growth variables: All trees with Diameter at Breast Height (DBH) ≥ 10 cm encountered in each sample plot were tagged identified and measured (Okali & Ola-Adams, 1987, Chavan & Rasal 2010). The diameters at the base, middle and top and the total height of all the trees (DBH ≥ 10 cm) in each plot were measured.

III. Tree species identification: The scientific names of all the tree species encountered on each field plot were recorded. Local names were used for tree species whose scientific names were not known immediately on the field and their parts (such as leaves, barks and fruits) were collected and taken to the herbarium for identification. Such species were temporarily referred to as unknown but were subsequently assigned their scientific name immediately after identification. All the species were classified into families and their frequency of occurrence were obtained to ascertain tree species diversity and abundance. The trees were also grouped into diameter distribution classes based on the DBH measurement taken on the field.

Data analysis

I. Basal Area computation: The total basal area for each of the sample plot was obtained by summing up all the Basal Area of the individual trees in the plots while the basal area per hectare was obtained by multiplying the mean Basal Area per plot with 16 (the number of 25 m X 25 m plots in one hectare).

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

Where, BA = Basal area (m^2), D = Diameter at breast height (cm) and π = 3.142 or 22/7

II. Volume Estimation: The volume of individual trees was estimated using the Newton formula (Husch *et al.* 2003). Volume per hectare was obtained by multiplying the mean volume per plot with the number of 25 m × 25 m plots in a hectare (16).

$$V = \frac{\pi h}{24}\left(D_b^{\ 2} + 4D_m^{\ 2} + D_t^{\ 2}\right) \quad \text{......................................(2)}$$

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

III. Biodiversity Indices and Tree Species Classification:

a) Species relative density was computed following Brashears *et al.* (2004)

$$RD = \frac{n_i}{N} \times 100 \quad \text{.....................................(3)}$$

Where, RD (%) = species relative density; n_i = number of individuals of species i; N = total number of all tree species in the entire community

b) Species relative dominance (RDo (%)) was computed using Aidar *et al.* (2001) equation:

$$RD_O = \frac{\sum Ba_i \times 100}{\sum Ba_n} \quad \text{..(4)}$$

Where: Ba_i = basal area of individual tree belonging to species i and Ba_n = stand basal area.

c) The maximum diversity index was determined using the Shannon–Wiener diversity index (Kent & Coker 1992, Guo *et al*. 2003). This was because it takes into account the richness and abundance of each species in different ecosystems (Price 1997).

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \quad \text{..(5)}$$

Where, H' = Shannon diversity index, S = the total number of species in the community, p_i = proportion S (species in the family) made up of the i^{th} species and Ln = natural logarithm.

d) To determine the Species evenness (E), in each community, Shannon's equitability equation was adopted (Kent & Coker 1992):

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)} \quad \text{.....................................(6)}$$

e) Importance Value Index (IVI): The Importance Value Index for each species were obtained by summing up the RD and RDo divided by 2 (RD x RDo/2) (Brashears *et al*. 2004). This was used to express the share of each species in the tree community.

f) Family Importance Value (FIV): This is the sum of the relative dominance (RDm), relative density (RD) and relative frequency (RF).

RDm = (Total Basal area for a family ÷ Total Basal area of all families) X 100

RD = (Number of individual 'a' of family ÷ Total number of all individual) X 100

RF = (Frequency 'a' of family ÷ Sum frequencies all of s families) X 100

Therefore, the FIV is calculated as: RDm+ RD+ RF …………(7)

Number 1 of Hill diversity index

$$N_1=\exp(-\Sigma p_i(\ln p_i)) \quad (8)$$

$$p_i = n_i / N \quad (9)$$

Where: p_i: is the proportional abundance of i^{th} species, n_i: number of individuals of i^{th} species, N: total number of individuals.

Number 2 of Hill diversity index

N_2: Reciprocal of Simpson's dominance Index;

$$N_2= 1/\Sigma p_i^2 \quad (10)$$

g) Shannon max diversity index was also determined using

$$H_{max}= \ln S \quad (11)$$

Where, S = the total number of species in the community

h) Sorensen's species similarity index was used to compare species diversity among the selected sites:

$$SI= \frac{2C}{a+b+c+d} \times 100 \quad (12)$$

Where, C is the total number of species in four communities (*i.e.* aggregate of all species encountered in the entire study area); while a, b, c, & d are the number of species at communities 1, 2, 3 & 4 respectively.

RESULTS

Tree species diversity and abundance

This study revealed that Oluwa Forest Reserve has the highest number of species ha^{-1} (170 stems.ha^{-1}) distributed into 23 and 54 families and species respectively. *Monodora myristica (Gaertn.) Dunal*, of Annonaceae family has the highest number of stem per hectare (19 spp.ha^{-1}) with a relative density of 11.18. This is followed by *Buchholzia coriacea* Engl.of Capparaceae family with 13 spp.ha^{-1} and relative density of 7.65 and *Diospryos dendo* Welw. ex Hiern (11 stems.ha^{-1}) with relative density of 6.47. In Permanent Sample Plot 29, *Celtis zenkeri* Engl. of Ulmaceae family has the highest number of stems (15 stems.ha^{-1}) and next in abundance is *Sterculia rhinopetala* K. Schum, of the family Sterculiaceae, and *Funtumia elastica* (Preuss) Stapf of Apocynaceae family (14 spp.ha^{-1} and 12 spp.ha^{-1} respectively) in the Strict Nature Reserve of Akure forest reserve. The tree species (*Celtis zenkeri* Engl., *Cola gigantean* A.Chev. and *Funtumia elastica* (Preuss) Stapf) are common to all the four forest sites assessed.

The tree species diversity is represented in table 1. The Strict Nature Reserve has a total of 88 stems.ha^{-1}, distributed among 25 species and 15 different families. *Sterculia rhinopetala* K. Schum, has the highest number of stems (14 stems.ha^{-1}). This is followed closely by *Funtumia elastica* (Preuss) Stapf (12 stems.ha^{-1}). A total of 99 stems.ha^{-1} which spans through 27 different species from 14 families were obtained at the PSP 29. In this location, *Celtis zenkeri* Engl. has the highest occurrence (15 stems.ha^{-1}) and Relative density of 15.15. The free forest area adjoining PSP 29 has a total of 54 stems.ha^{-1}. The most abundant species in the free area is *Celtis zenkeri* Engl. (11 stems.ha^{-1}) with relative density of 20.37. The total number of families and species that were encountered in the site is 12 and 23 respectively. From these results, about 39% of all the species were represented by single individual per ha.

The Families Importance Value for the selected forests is presented in table 2. The results revealed that 30 different trees families were encountered in the four forest types. Sterculiaceae family has the highest Family Importance Value (FIV) of 39.10%. This was followed by Ulmaceae (24.93 %) while *Ochnaceae* family has the least Family Importance Value of 0.49%. The highest volume per hectare was also recorded for Papilionoideae family (3.14 m^3), followed by Myristicaceae family (2.92 m^3) and the least by Guttiferae family (0.10 m^3). The highest RD and RDo were recorded for Sterculiaceae (19.46%) and Bignoniaceae (0.13%).

Table 1. Tree Species abundance per ha, diversity indices and tree growth variables of the selected forest reserves.

Sites	S.N.	Family	Species	nha^{-1}	MDBH (cm)	Ht (m)	BA (m^2)	VOL (m^3)	PiLnPi	RD	RDO (%)	IVI
SNR	1	*Annonaceae*	*Monodora myristica* (Gaertn.) Dunal	3	22.03	22.43	0.05	0.34	-0.12	3.41	1.35	2.30
	2	*Apocynaceae*	*Alstonia boonei* De Wild.	1	16.40	15.00	0.02	0.20	-0.05	1.14	0.61	0.34
	3	*Apocynaceae*	*Funtumia elastica* (Preuss) Stapf	12	22.38	20.90	0.07	0.43	-0.27	13.64	1.93	13.15
	4	*Burseraceae*	*Canarium schweinfurthii* Engl.	5	59.24	33.62	0.31	2.71	-0.16	5.68	8.90	25.29
	5	*Ebenaceae*	*Diospyros mespiliformis* Hochst.	1	22.00	15.30	0.04	0.29	-0.05	1.14	1.09	0.62
	6	*Euphorbiaceae*	*Macaranga hurifolia* Beille	1	17.60	29.00	0.02	0.22	-0.05	1.14	0.70	0.40
	7	*Lecythidaceae*	*Petersianthus macrocarpum* (P. Beauv)	3	55.87	31.53	0.25	1.93	-0.12	3.41	7.26	12.37
	8	*Meliaceae*	*Cedrela odorata* Linn.	3	91.33	41.40	0.68	4.92	-0.12	3.41	19.39	33.05
	9	*Meliaceae*	*Trichilia heudelottii* Planch. ex. Oliv.	5	27.66	33.16	0.06	0.90	-0.16	5.68	1.86	5.28
	10	*Meliaceae*	*Trichilia prieuriana* A. Juss	3	25.60	32.37	0.07	0.64	-0.12	3.41	1.95	3.32
	11	*Moraceae*	*Trilepisium madagascariense* Dc. Fl. Cam.	5	25.24	24.48	0.06	0.50	-0.16	5.68	1.84	5.22
	12	*Olacaceae*	*Strobosia pustulata* Oliv.	3	14.10	17.97	0.02	0.10	-0.12	3.41	0.46	0.78
	13	*Rutaceae*	*Fagara leprieurii* Engl.	1	28.00	23.70	0.06	0.35	-0.05	1.14	1.77	1.00
	14	*Rutaceae*	*Fagara macrophylla* (Oliv.) Engl	1	35.80	26.10	0.10	0.66	-0.05	1.14	2.89	1.64
	15	*Sapotaceae*	*Chrysopyllum albidum* G Don.	1	33.00	35.30	0.09	1.07	-0.05	1.14	2.46	1.40
	16	*Sapotaceae*	*Chrysopyllum perpulchrum* Mildbr. ex Hutch. & Dalziel	2	27.90	29.25	0.06	0.72	-0.09	2.27	1.81	2.06
	17	*Sterculiaceae*	*Cola gigantean* A.Chev.	4	41.10	32.63	0.22	2.62	-0.14	4.55	6.24	14.17
	18	*Sterculiaceae*	*Mansonia altissima* A. Chev.	10	36.57	30.00	0.13	1.02	-0.25	11.36	3.60	20.47
	19	*Sterculiaceae*	*Pterygota macrocarpa* K Schum.	4	31.38	32.15	0.10	1.12	-0.14	4.55	2.99	6.79
	20	*Sterculiaceae*	*Sterculia rhinopetala* K. Schum.	14	30.21	27.53	0.09	0.84	-0.29	15.91	2.65	21.07
	21	*Sterculiaceae*	*Triplochiton scleroxylon* K. Schum.	2	98.50	37.00	0.77	5.59	-0.09	2.27	22.13	25.15
	22	*Surmardaceae*	*Pierradendron africanum* Hook . f	1	43.10	58.00	0.15	2.06	-0.05	1.14	4.19	2.38
	23	*Ulmaceae*	*Celtis zenkeri* Engl.	1	15.40	14.00	0.02	0.14	-0.05	1.14	0.53	0.30
	24	*Verbaneaceae*	*Gmelina arborea* Roxb.	2	23.20	36.20	0.05	0.66	-0.09	2.27	1.41	1.60
			Total	**88**			**3.48**	**30.02**	**-2.82**			
PSP 29	1	*Annonaceae*	*Anogeissus leiocarpa* (DC) Guill&Perr.	1	14.00	18.50	0.02	0.14	-0.05	1.01	0.54	0.27
	2	*Annonaceae*	*Cleistopholis patens* (Benth.) Engl. & Diels	1	8.50	9.50	0.01	0.03	-0.05	1.01	0.20	0.10
	3	*Apocynaceae*	*Alstonia boonei* De Wild.	3	23.10	14.10	0.04	0.31	-0.11	3.03	1.57	2.38

	4	*Apocynaceae*	*Funtumia elastica* (Preuss) Stapf	9	18.02	12.46	0.03	0.18	-0.22	9.09	1.04	4.75
	5	*Apocynaceae*	*Tabernaemontana pachysiphon* Stapf	1	96.00	26.50	0.72	7.44	-0.05	1.01	25.33	12.79
	6	*Boraginaceae*	*Cordia millenii* Bak	2	57.75	17.65	0.39	1.74	-0.08	2.02	13.51	13.64
	7	*Bombacaceae*	*Bombax buonopozense* P Beauv	2	23.10	14.85	0.06	0.30	-0.08	2.02	1.97	1.99
	8	*Caesalpinioideae*	*Afzelia Africana* Sm.	2	24.40	17.15	0.05	0.46	-0.08	2.02	1.72	1.74
	9	*Caesalpinioideae*	*Anthonotha macrophylla* P. Beauv.	8	13.80	10.66	0.02	0.11	-0.20	8.08	0.53	2.14
	10	*Caesalpinioideae*	*Brachystegia nigerica* Hoyle &A.P.D. Jones	2	75.63	27.00	0.48	4.92	-0.08	2.02	16.86	17.03
	11	*Combretaceae*	*Terminalia ivorensis* Chev.	5	48.56	18.96	0.27	2.23	-0.15	5.05	9.30	23.48
	12	*Ebenaceae*	*Diospryos dendo* Welw. ex Hiern	2	19.95	10.10	0.04	0.20	-0.08	2.02	1.45	1.47
	13	*Moraceae*	*Myrianthus arboreus* P. Beauv	4	23.48	12.88	0.06	0.45	-0.13	4.04	2.13	4.31
	14	*Moraceae*	*Trilepisium madagascariense* DC.	2	18.35	11.55	0.03	0.18	-0.08	2.02	1.04	1.05
	15	*Moreceae*	*Antiaris toxicaria* Lesch. subsp.	1	15.90	8.00	0.02	0.07	-0.05	1.01	0.69	0.35
	16	*Olacaceae*	*Strobosia pustulata* Oliv.	3	17.53	11.00	0.03	0.11	-0.11	3.03	0.88	1.33
	17	*Papilionaceae*	*Pterocarpus osun* Craib	1	52.00	27.20	0.21	2.28	-0.05	1.01	7.43	3.75
	18	*Sapindataeae*	*Lecaniodiscus cupanioides* Planch.	1	15.70	14.00	0.02	0.17	-0.05	1.01	0.68	0.34
	19	*Sapotaceae*	*Malacantha alnifolia* (Baker) Pierre.	1	13.65	15.50	0.01	0.13	-0.05	1.01	0.51	0.26
	20	*Sterculiaceae*	*Cola acuminata* (P.Beauv.) Schott & Endl.	2	14.45	12.90	0.02	0.09	-0.08	2.02	0.57	0.58
	21	*Sterculiaceae*	*Cola gigantean* A.Chev.	7	14.00	11.46	0.02	0.09	-0.19	7.07	0.59	2.08
	22	*Sterculiaceae*	*Mansonia altisima* A. Chev.	5	19.16	11.74	0.03	0.20	-0.15	5.05	1.14	2.87
	23	*Sterculiaceae*	*Pterygota macrocarpa* K Schum.	2	40.40	17.95	0.20	2.08	-0.08	2.02	6.89	6.96
	24	*Sterculiaceae*	*Sterculia tragacantha* K Schum.	6	16.08	14.58	0.02	0.17	-0.17	6.06	0.86	2.60
	25	*Ulmaceae*	*Celtis philippensis* Bl. var. *wightii* (Planch.) Soepadmo	9	18.49	13.82	0.03	0.16	-0.22	9.09	1.07	4.84
	26	*Ulmaceae*	*Celtis zenkeri* Engl	15	15.51	11.33	0.02	0.14	-0.29	15.15	0.73	5.53
	27	*Ulmaceae*	*Holoptelea grandis* Hutch .Mildbr	2	15.50	16.50	0.02	0.17	-0.08	2.02	0.76	0.77
			Total	**99**			**2.86**	**24.56**	**-2.96**			
FREE FOREST AREA	1	*Apocynaceae*	*Funtumia elastica* (Preuss) Stapf	1	16.50	13.35	0.02	0.17	-0.07	1.85	1.81	1.68
	2	*Apocynaceae*	*Rauvolfia vomitoria* Afzel.	1	10.50	11.25	0.01	0.04	-0.07	1.85	0.73	0.68
	3	*Boraginaceae*	*Cordia millenii* Bak.	3	20.83	9.77	0.03	0.16	-0.16	5.56	2.91	8.10
	4	*Bignoniaceae*	*Newbouldia laevis* (P. beauv)	2	13.45	12.58	0.02	0.06	-0.12	3.70	1.28	2.37
	5	*Caesalpiniaceae*	*Brachystegia eurycoma* Harms	1	18.80	13.30	0.03	0.16	-0.07	1.85	2.35	2.18
	6	*Euphorbiaceae*	*Antidesma* sp.	1	15.50	12.25	0.02	0.13	-0.07	1.85	1.60	1.48

	7	*Euphorbiaceae*	*Bridelia micrantha* (Hochst.) Baill.	5	20.26	10.99	0.04	0.18	-0.22	9.26	3.04	14.10
	8	*Euphorbiaceae*	*Macaranga barteri* Müll.-Arg.	1	9.40	13.40	0.01	0.04	-0.07	1.85	0.59	0.54
	9	*Meliaceae*	*Trichilia heldelotii* Planch. ex. Oliv.	2	16.75	11.38	0.02	0.13	-0.12	3.70	1.90	3.52
	10	*Mimoceae*	*Albizia adianthifolia* (Schumach.) Wightii	1	12.00	13.45	0.01	0.09	-0.07	1.85	0.96	0.89
	11	*Mimosaceae*	*Albizia zygia* (DC.) J. F. Macbr.	4	14.00	12.49	0.02	0.09	-0.19	7.41	1.35	5.00
	12	*Moraceae*	*Ficus exasperate* Vahl	1	12.70	12.55	0.01	0.08	-0.07	1.85	1.07	0.99
	13	*Moreaceae*	*Milicia excels* (Welw.) C. Berg	2	54.00	10.08	0.31	0.81	-0.12	3.70	26.68	49.40
	14	*Rutaceae*	*Zanthoxylum leprieurii* Guill. & Perr	1	13.40	11.60	0.01	0.08	-0.07	1.85	1.20	1.11
	15	*Sapindaceae*	*Blighia sapida* K Konig	1	38.50	14.90	0.12	0.50	-0.07	1.85	9.87	9.14
	16	*Sterculiaceae*	*Cola gigantean* A.Chev.	1	10.00	11.50	0.01	0.07	-0.07	1.85	0.67	0.62
	17	*Sterculiaceae*	*Sterculia rhinopetela* K. Schum.	1	28.90	14.20	0.07	0.29	-0.07	1.85	5.56	5.15
	18	*Sterculiaceae*	*Sterculia tragacantha* K Schum.	1	11.50	6.78	0.01	0.05	-0.07	1.85	0.88	0.82
	19	*Sterculiaceae*	*Theobroma cacao* L.	1	12.00	5.90	0.01	0.04	-0.07	1.85	0.96	0.89
	20	*Sterculiaceae*	*Triplochiton scleroxylon* K Schum.	5	35.78	11.87	0.12	0.63	-0.22	9.26	10.55	48.84
	21	*Ulmaceae*	*Celtis philippensis* Bl. var. *wightii*	5	14.30	10.00	0.02	0.08	-0.22	9.26	1.37	6.36
	22	*Ulmaceae*	*Celtis zenkeri* Engl	11	24.61	11.59	0.09	0.38	-0.32	20.37	7.55	76.93
	23	*Verbenaceae*	*Gmelina arborea* Roxb	2	47.25	13.75	0.18	0.69	-0.12	3.70	15.09	27.95
			Total	**54**			**1.18**	**4.95**	**-2.79**			
OLUWA	1	*Anacardiaceae*	*Lannea welwitschii* (Hiern) Engl.	2	19.00	13.05	0.03	0.31	-0.05	1.18	0.81	0.47
	2	*Annonaceae*	*Cleistopholis patens* (Benth.) Engl. & Diels	1	17.20	11.50	0.02	0.25	-0.03	0.59	0.64	0.19
	3	*Annonaceae*	*Enantia chlorantha* Oliv.	1	22.50	9.50	0.04	0.27	-0.03	0.59	1.10	0.32
	4	*Annonaceae*	*Monodora myristica* (Gaertn.) Dunal	19	21.50	15.10	0.05	0.61	-0.24	11.18	1.25	6.98
	5	*Apocynaceae*	*Alstonia boonei* De Wild.	2	35.05	15.65	0.12	1.62	-0.05	1.18	3.19	1.88
	6	*Apocynaceae*	*Funtumia elastica* (Preuss) Stapf	4	24.10	17.35	0.05	0.46	-0.09	2.35	1.49	1.76
	7	*Apocynaceae*	*Hunteria umbellate* K. Schum	4	13.68	12.54	0.02	0.18	-0.09	2.35	0.43	0.50
	8	*Apocynaceae*	*Picralima nitida* (Stapf) T. Durand & H. Durand	10	19.62	9.99	0.03	0.22	-0.17	5.88	0.88	2.59
	9	*Apocynaceae*	*Rauvolfia vomitoria* Afzel.	1	16.40	11.40	0.02	0.20	-0.03	0.59	0.58	0.17
	10	*Boraginaceae*	*Cordia millenii* Bak.	1	44.30	16.00	0.15	1.35	-0.03	0.59	4.26	1.25
	11	*Bignoniaceae*	*Newbouldia laevis* (P. beauv)	1	19.70	10.00	0.03	0.17	-0.03	0.59	0.84	0.25
	12	*Burseraceae.*	*Canarium schweinfurthii* Engl.	2	73.30	26.10	0.42	4.51	-0.05	1.18	11.66	6.86
	13	*Caesalpinioideae*	*Anthonatha macrophylla* P. Beauv.	3	12.03	10.90	0.01	0.09	-0.07	1.76	0.32	0.28

14	*Capparaceae*	*Buchholzia coriacea* Engl.	13	29.28	16.90	0.12	2.60	-0.20	7.65	3.23	12.34
15	*Clusiaceae*	*Allanblackia floribunda* Oliv.	1	12.70	12.90	0.01	0.14	-0.03	0.59	0.35	0.10
16	*Clusiaceae*	*Garcinia afzeli* Engl.	2	19.75	10.25	0.03	0.22	-0.05	1.18	0.87	0.51
17	*Ebenaceae*	*Diospyros barteri* Hiern.	6	18.72	17.78	0.03	0.38	-0.12	3.53	0.84	1.48
18	*Ebenaceae*	*Diospyros dendo* Welw. ex Hiern	11	18.65	10.30	0.04	0.33	-0.18	6.47	1.17	3.78
19	*Ebenaceae*	*Diospyros mespiliformis* Hochst. ex A.DC.	6	21.10	11.24	0.04	0.44	-0.12	3.53	1.14	2.01
20	*Euphorbiaceae*	*Antidesma* sp.	2	11.40	10.95	0.01	0.08	-0.05	1.18	0.28	0.17
21	*Euphorbiaceae*	*Bridelia grandis* Pierre ex. Hutch	1	50.00	34.40	0.20	4.51	-0.03	0.59	5.43	1.60
22	*Euphorbiaceae*	*Croton* sp.	2	15.65	15.65	0.02	0.35	-0.05	1.18	0.54	0.32
23	*Euphorbiaceae*	*Ricinodendron heudelotii* (Ball.) Pierre	3	46.20	21.98	0.28	3.88	-0.07	1.76	7.66	6.76
24	*Lecythidaceae*	*Napoleonaea vogelii* Hook. & Planch.	1	22.70	8.90	0.04	0.14	-0.03	0.59	1.12	0.33
25	*Meliaceae*	*Trichilia emetica* Vahl	1	13.50	14.22	0.01	0.74	-0.03	0.59	0.40	0.12
26	*Meliaceae*	*Trichilia heudelottii* Planch. ex. Oliv.	9	23.94	13.09	0.06	0.71	-0.16	5.29	1.59	4.21
27	*Meliaceae*	*Trichilia prieuriana* A. Juss	3	19.17	19.73	0.03	0.36	-0.07	1.76	0.86	0.76
28	*Mimosoideae*	*Albizia zygia* (DC.) J. F. Macbr.	1	14.70	15.90	0.02	0.27	-0.03	0.59	0.47	0.14
29	*Mimosoideae*	*Pentaclethra macrophylla* Benth.	1	11.11	9.60	0.01	0.05	-0.03	0.59	0.27	0.08
30	*Moraceae*	*Antiaris toxicaria* Lesch. subsp. *welwitschii* (Engl.) C.C Berg	2	44.30	20.00	0.16	1.06	-0.05	1.18	4.30	2.53
31	*Moraceae*	*Ficus exasperate* Vahl	2	23.50	17.45	0.05	0.46	-0.05	1.18	1.29	0.76
32	*Moraceae*	*Ficus sur* Thunb.	1	17.50	17.90	0.02	0.32	-0.03	0.59	0.66	0.20
33	*Moraceae*	*Milicia excels* (Welw.) C. Berg	1	10.70	18.80	0.01	0.08	-0.03	0.59	0.25	0.07
34	*Moraceae*	*Myrianthus arboreus* P. Beauv.	5	20.16	12.13	0.04	0.53	-0.10	2.94	1.17	1.72
35	*Moraceae*	*Trilepisium madagascariense* Dc. Fl. Cam.	1	37.30	8.00	0.11	0.39	-0.03	0.59	3.02	0.89
36	*Myristicaceae*	*Pycnanthus angolensis* (Welw.) Warb.	1	58.20	26.90	0.27	5.42	-0.03	0.59	7.35	2.16
37	*Myristicaceae*	*Staudtia stipitata* Warb.	1	24.60	14.40	0.05	0.42	-0.03	0.59	1.31	0.39
38	*Ochnaceae*	*Barteria fistulosa* Mast.	1	16.70	24.50	0.02	0.30	-0.03	0.59	0.61	0.18
39	*Olacaceae*	*Strobosia pustulata* Oliv.	2	36.95	16.30	0.16	2.17	-0.05	1.18	4.31	2.54
40	*Papilionoideae*	*Amphimas pterocarpoides* Harms	1	23.90	21.10	0.04	0.68	-0.03	0.59	1.24	0.36
41	*Papilionoideae*	*Baphia pubescens* Hook. f.	1	27.80	12.30	0.06	0.42	-0.03	0.59	1.68	0.49
42	*Papilionoideae*	*Dalbergia* sp.	1	35.80	32.00	0.10	1.78	-0.03	0.59	2.78	0.82
43	*Papilionoideae*	*Pterygota macrocarpa* K Schum.	2	16.75	29.70	0.02	0.72	-0.05	1.18	0.66	0.39
44	*Rubiaceae*	*Massularia acuminate*	1	12.20	7.20	0.01	0.04	-0.03	0.59	0.32	0.10

45	*Rubiaceae*	*Pausinystalia talbotii* Wernham.	2	29.35	15.65	0.07	0.80	-0.05	1.18	1.92	1.13
46	*Sapindaceae*	*Lecaniodis cuscupanioides* Planch.	1	26.40	23.50	0.05	1.17	-0.03	0.59	1.51	0.44
47	*Sapotaceae*	*Chrysophyllum albidum* G Don.	1	47.50	23.70	0.18	2.20	-0.03	0.59	4.90	1.44
48	*Sapotaceae*	*Malacantha alnifolia* (Baker) Pierre.	3	14.53	12.03	0.02	0.19	-0.07	1.76	0.47	0.41
49	*Sterculiaceae*	*Sterculiar hinopetala* K. Schum.	6	23.58	14.27	0.05	0.49	-0.12	3.53	1.34	2.37
50	*Sterculiaceae*	*Cola gigantea* A.Chev.	1	17.90	13.00	0.03	0.23	-0.03	0.59	0.70	0.20
51	*Sterculiaceae*	*Cola heterophylla* (P.Beauv.) Schott & Endl	5	18.84	15.05	0.03	0.43	-0.10	2.94	0.93	1.37
52	*Sterculiaceae*	*Cola nigerica* Brenan & Keay	2	13.80	8.65	0.01	0.06	-0.05	1.18	0.41	0.24
53	*Sterculiaceae*	*Sterculia tragacantha* K Schum.	4	12.50	12.80	0.01	0.09	-0.09	2.35	0.34	0.40
54	*Ulmaceae*	*Celtis zenkeri* Engl	8	29.25	17.78	0.10	1.05	-0.14	4.71	2.87	6.75
		Total	**170**	**-**	**-**	**3.62**	**46.95**	**-3.55**	**-**	**-**	**-**

Note: nha^{-1}- number of stem per hectare, MDBH - Mean Diametre at breast height (cm), M Ht -Mean height (m), BA - Basal area per hectare (m^2), VOL - Volume per hectare (m^3), RD - Spp. Relative density, RD_O - Spp. Relative dominance.

Table 2. Families' importance index for the study areas.

S.N.	Families	BA/ha	VOL/ha	RF	RD (%)	RDO (%)	FIV%
1	Anacardiaceae	0.03	0.31	0.49	0.49	0.01	0.98
2	Annonaceae	0.10	1.01	6.33	6.33	0.03	12.71
3	Apocynaceae	0.21	1.68	11.92	11.92	0.05	23.95
4	Bignoniaceae	0.50	2.62	2.19	2.19	0.13	4.52
5	Bombacaceae	0.06	0.30	0.49	0.49	0.01	0.99
6	Burseraceae	0.31	2.71	1.22	1.22	0.08	2.52
7	Caesalpinioideae	0.14	1.22	3.89	3.89	0.03	7.84
8	Capparaceae	0.12	2.60	3.16	3.16	0.03	6.37
9	Clusiaceae	0.03	0.24	0.49	0.49	0.01	0.98
10	Combretaceae	0.27	2.23	1.22	1.22	0.07	2.51
11	Ebenaceae	0.12	0.86	6.33	6.33	0.03	12.71
12	Euphorbiaceae	0.19	2.50	3.89	3.89	0.05	7.85
13	Guttiferae	0.02	0.10	0.24	0.24	0.01	0.49
14	Lecythidaceae	0.29	2.07	0.97	0.97	0.07	2.02
15	Malvaceae	0.03	0.18	0.73	0.73	0.01	1.47
16	Meliaceae	0.30	2.68	6.33	6.33	0.08	12.76
17	Mimosoideae	0.03	0.25	1.70	1.70	0.01	3.42
18	Moraceae	0.39	1.92	6.57	6.57	0.10	13.27
19	Myristicaceae	0.16	2.92	0.49	0.49	0.04	1.01
20	Ochnaceae	0.02	0.30	0.24	0.24	0.01	0.49
21	Olacaceae	0.20	2.38	1.95	1.95	0.05	3.95
22	Papilionoideae	0.26	3.14	1.46	1.46	0.07	2.99
23	Rubiaceae	0.05	0.55	0.73	0.73	0.01	1.48
24	Rutaceae	0.10	0.59	0.73	0.73	0.02	1.49
25	Sapindaceae	0.19	1.84	0.73	0.73	0.05	1.51
26	Sapotaceae	0.13	1.45	1.95	1.95	0.03	3.94
27	Sterculiaceae	0.32	2.55	19.46	19.46	0.08	39.10
28	Surmardaceae	0.15	2.06	0.24	0.24	0.04	0.52
29	Ulmaceae	0.21	1.62	12.41	12.41	0.05	24.93
30	Verbenaceae	0.23	1.34	0.97	0.97	0.06	2.01
	Total	**5.13**	**46.23**				

Biodiversity Indices

The summary of the abundance, level of diversity and evenness of all the tree species encountered with the various biodiversity indices is presented in table 3. These indices were used to compare tree species diversity of the selected forest communities. Oluwa Forest Reserve has the highest Shannon-Weiner index (3.55), indicating that it has the highest species richness when compared with the other locations. The Pielou's evenness (equitability index) and Margalef's index value of 0.69 and 10.12 respectively were also obtained for this forest reserve and 34.74 and 11.11 were obtained respectively for number 1 and number 2 of Hill's diversity indices. The free forest area adjoining PSP 29 has the lowest Shannon-wiener diversity index (2.79), Margalef's index value of 5.51 but, the highest Pielou's evenness index value of 0.70.

Table 3. Summary of the tree species diversity indices in the selected areas.

Variables	Locations				
	SNR	PSP (29)	Free Are	Oluwa FR	All locations
No of trees/ ha	88	99	54	170	411
No of Families (NF)	15	14	12	23	30
No of Species (NS)	24	27	23	53	78
Shannon- Wieners (H^1)	2.82	2.96	2.79	3.55	5.11
Pielou's spp evenness index (E)	0.63	0.64	0.70	0.69	0.69
Simpson's concentration (λ)	0.07	0.07	0.18	0.09	0.03
N1 of hill diversity (N1)	16.81	19.29	16.23	34.74	35.40
N2 of hill diversity (N2)	14.28	14.28	5.55	11.11	33.33
Margalef's index of Spp. richness (M)	5.13	5.65	5.51	10.12	12.79

Tree growth variables in the selected forest reserves

The summary of the tree growth variables according to the location is shown in table 4. Oluwa forest

Table 4. Tree growth variables for the selected area.

Variables	SNR	PSP 29	Free Are	Oluwa FR	All locations
Basal area per ha (m^2)	12.31	6.73	3.40	10.54	48.48
Volume per ha (m^3)	104.76	53.44	14.56	141.06	123.10
Mean DBH (cm)	35.15	27.15	20.48	24.57	25.06
Dominant DBH (cm)	98.50	96.00	54.00	73.30	98.50
Dominant height (m)	58.00	27.20	14.90	34.40	58.00
Mean height (m)	28.1	14.92	12.09	15.87	17.09

reserve has the highest tree volume per hectare of 141.06 m^3 while the free Forest has the lowest tree volume per hectare (14.56 m^3). The highest dominant DBH is 98.50 cm in the SNR, followed by PSP 29 (96.00 cm) while the lowest dominant DBH of 54 cm was obtained in the free forest area. The highest mean DBH value of 35.15 cm was also recorded in the SNR. The basal area/ha ranged between 3.40 m^2 and 12.31 m^2, with the least obtained at the disturbed free area and the highest at the SNR. Similarly, the dominant height and Mean height followed the same trend. The dominant height value ranged between 14.90 m and 58.00 m while the value for mean height ranged from 12.09 to 28.1 respectively.

Diameter and height Distribution

Table 5. Species diversity, abundance, basal area and volume distribution of the study area into diameter classes.

Location	DBH Class (cm)	NS	NF	Ni	Ba.h^{-1} (m^2)	Vol.h^{-1} (m^3)
SNR	0–20	17	11	34	0.61	5.47
	21–40	15	10	27	1.81	17.68
	41–60	7	5	13	2.45	21.06
	61–80	5	4	7	2.47	21.79
	81–100	5	4	5	2.92	24.84
	>100	2	2	2	1.95	13.92
	Total	**24**	**15**	**88**	**12.21**	**104.76**
Oluwa Forest Reserve	0–20	38	21	94	1.53	14.43
	21–40	29	17	60	3.80	43.80
	41–60	9	9	10	1.92	28.38
	61–80	3	3	3	1.01	11.09
	81–100	2	2	2	1.29	15.27
	>100	1	1	1	0.99	28.09
	Total	**50**	**23**	**170**	**10.54**	**141.06**
PSP 29	0–20	24	13	67	1.00	6.05
	21–40	13	8	22	1.28	8.21
	41–60	3	3	3	0.57	5.23
	61–80	3	3	3	1.01	8.71
	81–100	4	4	4	2.87	25.24
	Total	**27**	**14**	**99**	**6.73**	**53.44**
Free Forest Area	0–20	19	10	40	0.69	3.93
	21–40	7	6	7	0.45	1.96
	41–60	4	3	5	1.03	5.00
	61–80	2	2	2	1.23	3.67
	Total	**23**	**12**	**54**	**3.40**	**14.56**

Note: NF - Number of Family, NS - Number of species, Ni - Number of individual species.

The diameter distribution of the study areas is presented in tables 5. This shows that 49.4% of trees falls within the lowest diameter class (10–20 cm) while only 7.14% falls in the highest diameter class (>80cm). The highest Volume per hectare (141.06 m^3) was recorded in Oluwa forest while the lowest (14.56 m^3) was from the free Forest. The same trend was noted in the distribution of the individual species and families into diameter classes. Figure 2 was used to describe the tree species population structure based on DBH (cm) classes with frequency and volume per hectare (m^3). As one of the peculiar features of a mature natural forest ecosystem, the DBH distribution curve followed inverse J-shaped pattern (Fig. 3). Table 6 revealed that 49.4% of the tree species was in the height class of between 11–20 m in Oluwa Forest reserve. Only the SNR and Oluwa forest reserve have trees with height above 30 m (18.7% and 7.02% respectively). These are trees that can be regarded as emergent. Significant differences (P- value < 0.05) exist in all the tree growth variables of the study sites when compared with one-way ANOVA (Table 7). Table 8 revealed the results of the mean separation of tree growth variables of the forests with Duncan Multiple Range Test (DMRT). The Mean values in the same row followed by the same letter(s) are not significantly different at 0.05 level of significance.

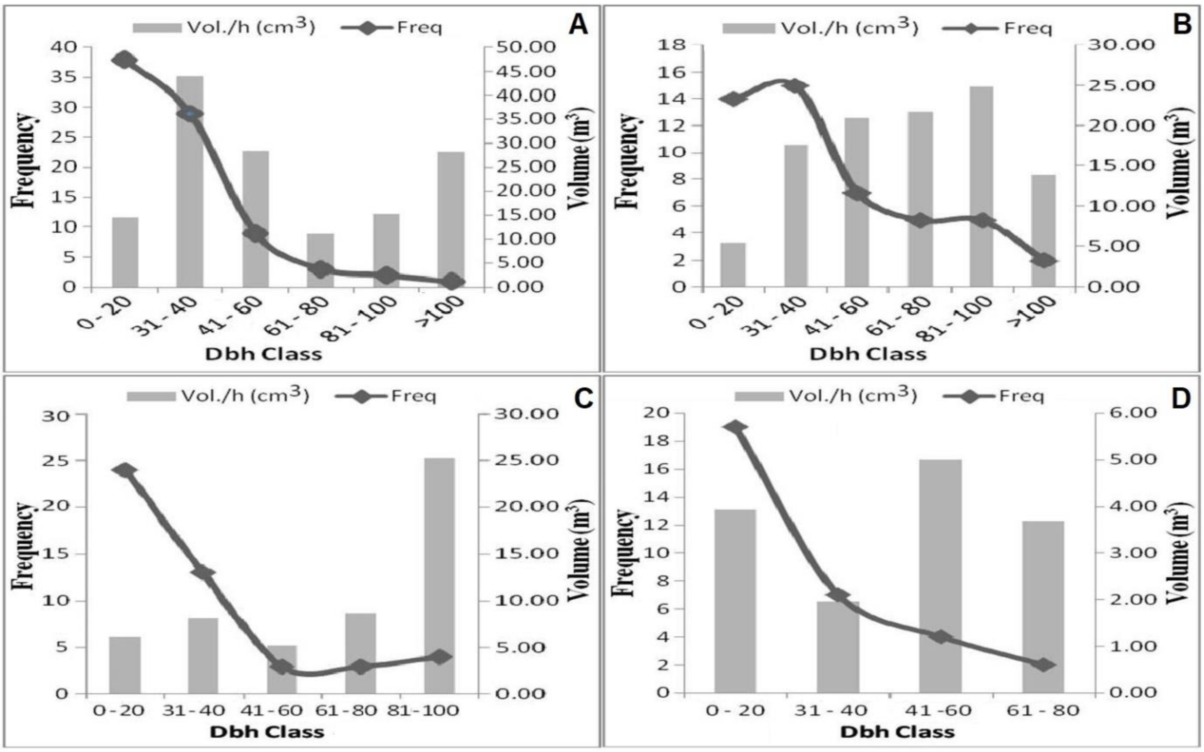

Figure 2. Tree species population structure of the study areas based on DBH (cm) classes with frequency and volume (m^3) (**A,** Oluwa Forest Reserve; **B,** SNR Aponmu; **C,** PSP 29; **D,** Free Forest).

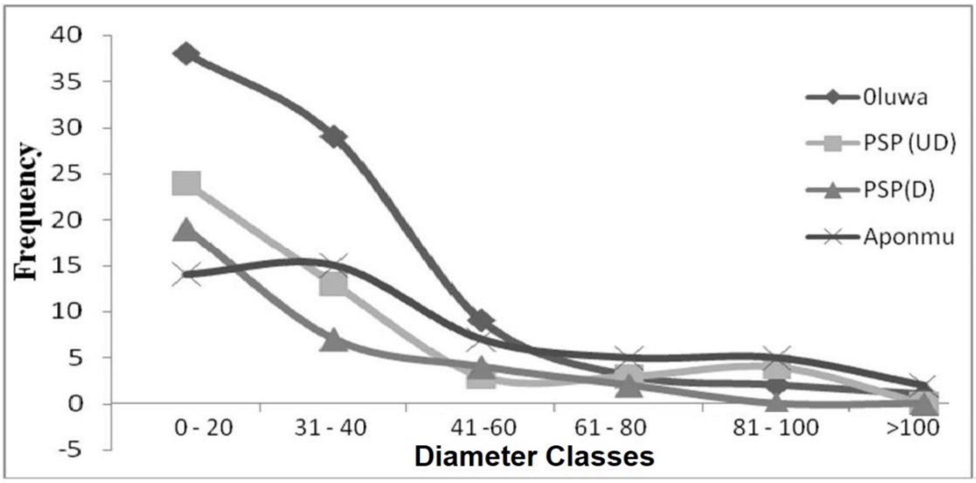

Figure 3. Diameter distribution curve for the selected Protected Areas and the free area.

Table 6. Species diversity, basal area and volume distribution of the study area into Height classes.

	Height (m)	NS	NF	Ni	Ba.h^{-1} (cm^2)	Vol.h^{-1} (cm^3)
SNR	<10	1	1	1	0.03	0.06
	11–20	14	10	24	1.08	7.21
	21–30	13	9	28	1.9	14.65
	31–40	12	6	20	4.62	38.54
	41–50	12	6	15	4.59	44.3
	Total			**88**	**12.22**	**104.76**
Oluwa	<10	23	19	47	1.17	5.34
	11–20	39	20	92	4.01	41.27
	21–30	16	15	21	3.37	45.83
	31–40	7	7	8	0.96	19.2
	41–50	2	1	2	1.02	29.41
	Total			**170**	**10.53**	**141.05**

PSP 29	<10	18	10	32	0.4	1.87
	11–20	18	12	52	2.16	12.36
	21–30	12	8	15	4.18	39.22
	Total			**99**	**6.74**	**53.45**
Free Forest area	<10	8	5	13	1.51	4.63
	11–20	22	11	41	1.9	9.95
	Total			**54**	**3.41**	**14.58**

Table 7. ANOVA table for comparing differences in tree growth variables among the study sites.

	Source of variation	**SS**	**Df**	**MS**	**F**	**Sig**
Vol.	Location	2418.06	3	806.02	5.70	0.01
	Error	1695.62	12	141.30		
	Total	**4113.69**	**15**			
BA	Location	11.99	3	4.00	3.76	0.04
	Error	12.76	12	1.06		
	Total	**24.75**	**15**			
DBH	Location	1090061.90	3	363353.97	9.14	0.00
	Error	476814.23	12	39734.52		
	Total	**1566876.14**	**15**			
Ht	Location	679483.31	3	226494.44	22.75	0.00
	Error	119471.91	12	9955.99		
	Total	**798955.22**	**15**			
Nha	Location	1782.69	3	594.23	17.45	0.00
	Error	408.75	12	34.06		
	Total	**2191.44**	**15**			

Table 8. Comparison of growth variables in the forests with Duncan multiple range test (DMRT).

Properties	**SNR**	**Oluwa**	**Free Forest**	**PSP 29**
Volume	26.19 ± 11.62ab	35.96 ± 20.02a	3.64 ± 0.83c	13.36 ± 5.34bc
Basal Area	3.06 ± 1.31a	2.68 +±1.34a	0.85 ± 0.17b	1.68 ± 0.81ab
DBH	759.97 ± 227.62ab	1012.22 ± 295.55a	303.37 ± 51.98c	553.67 ± 130.64bc
Height	625.56 ± 145.23a	649.13 ± 121.70a	155.25 ± 51.95c	336.90 ± 34.93b
N/ha	22.0 ± 3.91b	42.50 ± 8.38a	13.50 ± 4.79c	24.75 ± 5.25bc

DISCUSSION

There are two different conservation methods of natural resources in Nigeria; the in-situ and ex situ. Different types of PAs aimed at conserving the natural resources in their natural habitat, such as those used in this study, are examples of an in-situ conservation method. The tropical rainforest ecosystem of southwest Nigeria is noted for its high diversity in terms of species, genetic materials and ecological processes in comparison to other ecosystems (Adekunle *et al*. 2013). This assertion is supported by the results of this present study where 78 species in 30 families were encountered selected PAs. When these different forest communities were compared, the undisturbed PAs (PSP 29; SNR, and Oluwa Forest Reserve) were more diverse than the free forest area that has witnessed human activities. The low number of stems.ha^{-1} recorded in the free area, compared to the PAs, is an indication of an ecosystem that has been disturbed and greatly degraded. The number of species encountered in the sample survey plots can be used as a substitute for the exact species richness in the study area. Though, varying degree of degradation through illegal logging, forest conversion to Agricultural uses among others has resulted to unsustainable management of the lowland humid forest. The tropical forests are very vulnerabile to deforestation and degradation (FAO 2001, FAO 2006, Onyekwelu *et al*. 2005, Lafrankie *et al*. 2006). As a result, there is reduction in tree species richness, abundance and evenness of the ecosystem (Lafrankie *et al*. 2006) which is not creditable to biodiversity conservation. The tree species distribution into families agrees with the work of Adekunle *et al.* (2010) who indicated that the tropical rainforest ecosystem of southwest Nigeria is dominated by some specific families such as the Sterculiaceae, Meliaceae, Moraceae and Ebeneceae. Isichei (1995) also reported that Nigerian rainforest ecosystem is dominated by members of Sterculiaceae, Moraceae, Ulmaceae and Meliaceae families. The dominant families represented in this study sites differ from the families (Euphorbiaceae, Mimosoideae, Rubiaceae and Guttiferae) reported by Ifo *et al.* (2016) in their study of a similar ecosystem.

This study revealed a decrease in species richness and diversity from the undisturbed forests to the disturbed forest. The number of trees per hectare (170, 99, 88 and 54 for Oluwa forest, PSP 29, SNR, and the free forest area, respectively) are similar to the number of tree per hectare recorded for the tropical natural forest by Parthasarathy (2001) but was far below the values obtained for Kalapahad (579 ha^{-1}) and Macarthy Valley (732 ha^{-1}) in the giant evergreen forest of Andaman and Nicobar Islands as reported by Rajkumar & Parthasarathy (2008). The highest number of tree species (50 species from 23 families) was recorded in Oluwa Forest (undisturbed), indicating richness in species while the lowest number of species (23 species from 12 families) was recorded in the free forest site (disturbed site). This reveals a lower level of species richness (Table 5). Simillar trend as this was reported by Borah *et al.* (2014). This is due to more frequent and heavy extraction of forest resources such as collection of fuel wood and NTFPs by the Local people. The number of family (30), number of Species (78) and Species Evenness (0.69) in this study corresponds to the results of Adekunle & Olagoke (2008) as well as Onyekwelu *et al.* (2007) but lesser when compared to the studies of Lu *et al.* (2010), Rajkumar & Parthasarathy (2008). These researchers reported a total of 95 species and 105 species in Xishuangbana, Chain tropical rainforest and India evergreen forest of Andaman Giant respectively. Various researchers have considered the use of Shannon wiener diversity index for the determination of forest community diversity in the tropics (Onyekwelu *et al.* 2007, Adekunle & Olagoke 2008, Borah *et al*. 2014, Boboye & Jimoh 2016). Shannon Diversity Index values for this study ranged between 2.79 and 3.55. These values fall within the range (between 0.70 and 3.57) reported for tropical forests (Bhuyan *et al.* 2003, Bajpai *et al.* 2012, Borah *et al.* 2014, Sarkar & Devi 2014, Bajpai et al. 2015, Vinayaka & Krishnamurthy 2016). However, the overall Shannon-Weiner diversity index for the whole study areas (5.11) is higher than what was obtained by Onyekwelu *et al.* (2007) and Kent & Coker (1992). The Pielou's species evenness of the entire study areas (0.69) is higher than 0.66 and 0.55 reported by Onyekwelu *et al.* (2005) and Adekunle (2006) respectively but less than the 0.82 that was recorded by Adekunle *et al.* (2013) when he examined the efficacy of Strict Nature Reserves (SNR) as a means of biodiversity conservation. This finding indicated that forest exploitation could lead to a drastic reduction in species diversity but might increase stand density in terms of number of tree stems per hectare.

As one of the peculiar features of a mature natural forest ecosystem, the DBH distribution curve of tree species followed inverse J-shaped pattern (Figs. 2 & 3). The same was reflected in the study of Adekunle *et al*. 2013. Highest proportion of the trees were within the lowest diameter class (10–20 cm) and the least percentage in the highest diameter class (>80cm). In comparison, Huang *et al.* (2003) and Lu *et al.* (2010) reported a lesser percentage (4.5% and 3.5%) for trees that falls within the highest diameter class in forests of similar ecosystem as the study area.

Similarly, the same trend was noticed in the distribution of the individual species and families into diameter classes. Oluwa forest recorded the highest $Vol.ha^{-1}$ (141.06 m^3) and the lowest value (14.56 m^3) was from the free forest area adjoining Permanent Sample Plot 29, representing a degraded forest. Only the SNR and Oluwa forest reserve have trees with height above 30m (18.7% and 7.02% respectively). These are trees that can be regarded as emergent. Going by the recommended value of 25 $m^2.ha^{-1}$ for mean basal area of a well-stocked forest (Alder & Abayomi 1994), the mean basal areas obtained in some of the forest reserves in the study areas shows that the forest reserves are not yet well stocked. The variation in the basal area of the forests (ranged from 3.40 to 12.31 $m^2.ha^{-1}$) is significantly lower to the recommended basal area.

CONCLUSION AND RECOMMENDATION

The results of this study revealed the present phytosociological properties of selected PAs in the humid forest ecosystem in terms of tree species diversity, evenness, and stand bio-volume. The study also demonstrated the importance of in-situ conservation method and the detrimental effect of forest degradations to tree species diversity and abundance. The biodiversity indices were high and the forest structure shows a continuous growth feature until they reach maturity and a stable state. Therefore, logging, hunting, farming and human settlement should stop in the free forest areas and be delineated as PAs while the existing in-situ conserved areas should be strictly monitored against any form of anthropogenic activities.

For greater production, conservation and sustainability of the protected areas, the government and non-governmental organizations should provide farmers with incentives as motivation tool to enhance the forest and its resources. More attention should therefore be paid to species with narrow range and those threatened with extinction in the ecosystem through the conservation of their genetic material such as seed ex-situ conservation.

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