State of a Lowland Tropical Forest in South-West Nigeria

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Abstract

Forests play a significant role in human existence and survival. Timely and reliable information on the status of a forest is essential for assessing the extent of regeneration and degradation. However, when such information is lacking effective forest management practices becomes impossible. Therefore, this study assessed the tree species diversity, richness and structure of Oluwa forest reserve with the view of ascertaining it present state which is crucial for management and conservation purposes. To achieved these, a systematic line transect was used in the laying of eight (8) temporary sample plots (TSPs) of size 50m x 50m. Trees with Dbh≥10cm in the selected plots were enumerated, identified and measured. The results indicate that 535 individual trees were enumerated cutting across 26 families and 58 species. The reserve has the Margalef's index of species richness, Shannon-Weiner diversity Index (H') and Pielou's Species Evenness Index (E_H) of 9.07, 3.43 and 0.84 respectively. The forest has a mean Dbh (cm), mean height (m), total basal area/ha (m^2) and total volume/ha (m^3) of 24.7, 16.9, 36.63 and 602.09 respectively. Majority of trees were found in the smaller diameter and height classes; giving rise to reverse J-shaped structure. The structure of Oluwa forest reserve has been altered significantly while the species diversity and richness seems to indicate a sign of improvement compared to previous studies. With proper management, the remaining fragmented forests could regenerate and replenish to save some of the original species composition of the reserve.

Keywords: Lowland tropical forest, tree species diversity, forest structure, forest conservation

1. Introduction

Forest worldwide provides a wide range of economic, environmental and cultural benefits and services to people (Maini, 1992). The tropical forest is regarded as one of the most endowed ecosystems in the world (Thomas and Baltzer, 2002; Harrison, 2005) and home to more than half of the total number of species worldwide (Thomas and Baltzer, 2002). Majority of the global biodiversity hotspots identified worldwide are reported to be in the tropical forests (Mittermeier et al., 2004). Nigeria has eight tropical ecological zones which are broadly categorized into three namely; the tropical rainforest ecosystem, the mangrove in the southern part and the savannah in the northern part (Adekunle et al., 2013). Oluwa forest reserve lies in the lowland tropical rain forest of South-west Nigeria.

The lowland rain forests of south-west Nigeria play significant role in the biological and socioeconomic aspect of the Nation (Ogunsesan et al., 2011). The communities residing within and around the forest reserve derive their source of livelihood from it, either from the timber products or non-timber forest products (NTFPs) for food, medicinal and other domestic purposes. The continuous increase of the country's population has resulted to increased exploitation of forest resources.

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Despite of the importance of these forests, 18.56% of the natural forest in Nigeria has been lost between 2000 and 2010 and regarded as one out of five countries in the world with the highest annual rate of deforestation for the period (Global forest resource assessment (FRA) 2010). This also includes the fragmentation and degradation of many forest reserves. As a result, many important tropical forest tree species have also gone into extinction while many are vulnerable, rare or endangered as reported by Adekunle et al., (2004).

Adekunle (2006) and Ogunjemite (2015) reported a decline in species richness and diversity in 2 tropical forest reserves (Omo and Shasha) and Ologbo Forest Concession respectively in Nigeria. Similarly, Naidu and Kumar (2016) found out, that the biodiversity of the tropical forests in Eastern Ghats of Andhra Pradesh, India are under threat because of anthropogenic and upcoming mining activities. However, a Study conducted a decade ago in Oluwa forest reserve by Onyekwelu et al., (2008) indicates a semblance of recovery from decades of destruction. This may be attributed to better protective strategies adopted by the Forestry Department or the resilience nature of the reserve. Several studies had also been carried out with respect to species diversity in different part of the world (Wittmann et al., 2008; Jayakumar et al., 2011; Adekunle et al., 2013; Hu et al., 2015; Rao et al., 2015) which shows the state of those forest.

Indiscriminate logging activities in both protected and unprotected forest is derived by the monetary gains accrued from it (Adekunle et al., 2010) and is one of the major causes of declined in species diversity and richness in the forest. Other factors responsible for the decline in forest reserve according to Adekunle et al., (2010) includes; dearth of manpower and capacity of staff of Forestry Department, obsolete laws and stoppage of payment of annual royalty.

Although as discussed above, several studies had been conducted in different part of the world and Oluwa forest reserve in particular, there is still dearth of information with respect to number and distribution of species worldwide (Pimm et al., 2014). Furthermore, there is the need to determine the status of a forest over time, so that the extent of regeneration and depletion can be assessed. Globally, there is growing interest in assessing species diversity, composition and richness of degraded forest fragments (Myers et al., 2000).

Recent and reliable information on the status of a forest reserve is very important. Information on species composition, structure, richness, diversity helps us in understanding the dynamics in forest ecosystems and the management system that can be applied (Akinyemi and Oke, 2014). This study is therefore aimed at assessing the status of Oluwa forest reserve. This will provide information on the rate of depletion and possible regeneration in the forest. This information is crucial for monitoring and sustaining the phytodiversity of the forest. It will also help in understanding the threats been faced by the forest and appropriate conservation strategies that could be applied.

2. Materials and Methods

2.1 Study area

This study was carried out in Oluwa Forest Reserve located in the moist tropical rainforest zone of Nigeria. It occupies an area of about 629 km^2 with much of it lying approximately between 300 and 600 m above sea level (Ogunjemite et al., 2006). The natural forest covers about 8 km^2 (approximately 800 ha) of the Forest Reserve. The Reserve is situated in Odigbo Local Government Area of Ondo State, Nigeria and lies between Latitude 6.83°-6.91°N and Longitude 4.52°-4.59°E (Figure 1). Annual rainfall ranges from 1700 to 2200 mm. Annual mean temperature in Oluwa is 26° C. The relative humidity is high and uniform, ranging from 75% (afternoon) to 95% (morning). Soils are predominantly ferruginous tropical. The natural vegetation of the area is tropical rainforest characterised by emergent with multiple canopies and lianas.

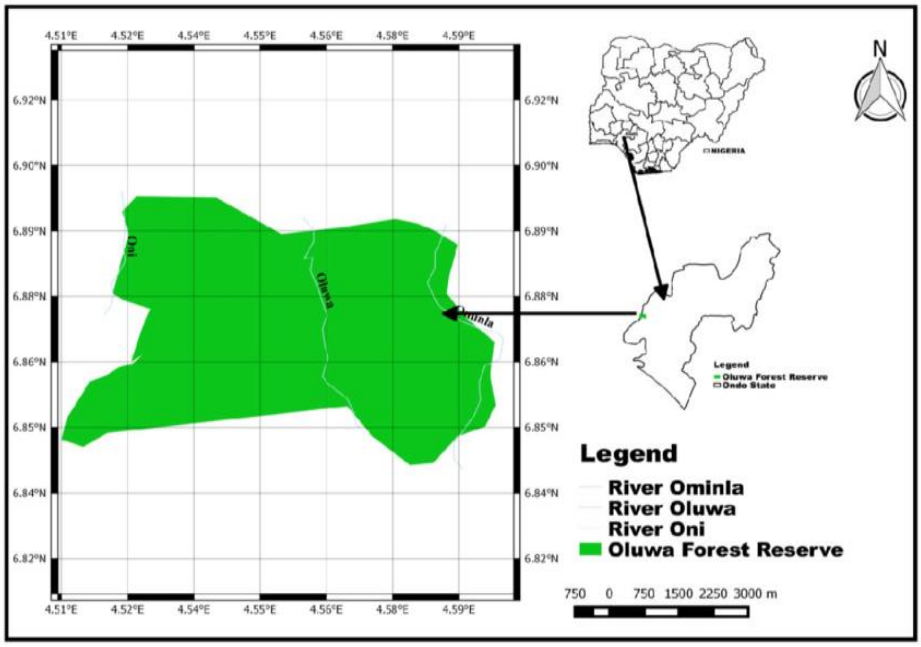

Figure 1: Map of Oluwa Forest Reserve, Ondo State, Nigeria (Source: Ogana et al., 2015).

2.1 Sampling procedure, data collection and processing

In this study, systematic sampling technique was used in the laying of the temporary sample plots in the 8 km^2 natural forest. Two transects of 500 m in length with a distance of 200 m between the two parallel transects were laid. Sample plots of 50x50 m in size were established in alternate position along each transect at 100 m interval; summing up to 4 plots per 500 m transect and a total of 8 plots in the study area. Living trees with Diameter at breast height (Dbh)≥10.0 cm in the quadrats were enumerated, identified by their botanical name using Trees of Nigeria (Keay, 1989) and a taxonomist. The Dbh measurement was done using a diameter tape. The data collected were grouped into species and families, and the following stand variables were computed from the inventory data: mean diameter, minimum diameter, maximum diameter, number of trees per hectare and basal area.

Analysis

The important quantitative analysis such as density, frequency, abundance of tree species and Relative dominance were determined according to Curtis and McIntosh (1950).

Density

$$Density\ (D) = \frac{Total\ number\ of\ individuals\ of\ the\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ studied} \quad (1)$$

Frequency (%)

$$Frequency\ (\%) = \frac{Total\ number\ of\ quadrats\ in\ which\ the\ species\ occurred}{Total\ number\ of\ quadrats\ studied} \times 100 \quad (2)$$

Abundance

$$Abundance = \frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ in\ which\ the\ species\ occured} \quad (3)$$

Relative density

The relative density was calculated according to Brashears et al., (2004) equation

$$RD = \left(\frac{n_i}{N}\right) \times 100 \quad (4)$$

Where;

RD = relative density
n_i = number of individual of the species
N = number of individual of all species

Relative dominance

It was calculated according Curtes and McIntosh (1950) given as;

$$RDom. = \left(\sum G_i \Big/ \sum G_n\right) \times 100 \quad (5)$$

Where;

RDom.= Relative dominance of the species
G_i = total basal area for a particular species
G_n = total basal area of all the species

Diversity indices

Paleontological Statistics (PAST) version 3.19 Software for ecological analysis was used in assessing the diversity indices (Margalef's index of species richness, pielou's species evenness index (E_H), Shannon-Weiner index (H') and simpson index of dominance (D))

Tree Diameter and height characterisation

Three-parameter Log-Logistic (3P) distribution was used to describe the diameter and height structure of the natural forest using the method of maximum likelihood. The probability density function (PDF) and cumulative distribution function (CDF) of the Log-Logistic distribution are given by:

$$f(x) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}\left(1+\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right)^{-2} \quad (6)$$

$$F(x) = \left(1+\left(\frac{\beta}{x-\gamma}\right)^{\alpha}\right)^{-1} \quad (7)$$

Where;

$f(x)$=probability density function
$F(x)$=cumulative distribution function
x=diameter/height
α=shape parameter
β=scale parameter
γ=location parameter

3. Results

3.1 Family distribution

A total of five hundred and thirty-five (535) trees were enumerated cutting across twenty-six (26) families and fifty-eight (58) tree species (Table 1). The family Sterculiaceae recorded the highest number of species (10) representing 17.24% and occurrence (112) representing 20.93%. The family Apocynaceae recorded seventy-four (74) number of occurrence representing 13.83%, Ulmaceae has 59 representing 11.03%, Euphorbiaceae has 50 representing 9.35%, Meliaceae recorded seven (7) numbers of species representing 12.07% and 42 number of occurrence representing 7.85% while Moraceae recorded five (5) numbers of species representing 8.62% and twenty-six (26) number of occurrence representing 4.86%. The family Verbenaceae, Mimosoideae, Loganiaceae and Chrysobalanaceae recorded the least number of species and stand with each recording 1 respectively; representing 1.72% and 0.02% respectively (Table 1).

Table 1: Family distribution of tree species in Oluwa Forest Reserve.

Family	**No. of Species**	**No. of Observation**
Anacardiaceae	2	4
Annonaceae	1	11
Apocynaceae	2	74
Bombacaceae	2	4
Boraginaceae	1	13
Burseraceae	1	2
Caesalpinaceae	5	30
Chenopodiaceae	1	5
Chrysobalanaceae	1	1
Combretaceae	1	11
Ebaneceae	1	25
Euphorbiaceae	3	50
Guttiferae	1	4
Irvingiaceae	2	5
Loganiaceae	1	1
Meliaceae	7	42
Mimosoideae	1	1
Moraceae	5	26
Myristicaceae	2	15
Olacaceae	2	6
Rubiaceae	2	7
Rutaceae	1	3
Sapotaceae	1	23
Sterculiaceae	10	112
Ulmaceae	1	59
Verbenaceae	1	1
Total 26	58	535

3.2 Species distribution and stand variables

Celtis zenkeri had the highest number of occurrence, recording fifty-nine (59) number of tree per hectare representing 11.02% followed by *Picralima nitida* which recorded fifty-five (55) representing 10.28% (Table 2). 37 stems of *Ricinodendron heudelotii,* 31 stem of *Buchholzia coriacea,* 25 stems of *Diospyros crassiflora* and *Lovoa trichilioides* and 23 stem of *Malacantha alnifolia* representing 6.92%, 5.79%, 4.67% and 4.30%, respectively were also recorded. *Albizia ferruginea, Anthocleista djalonensis, Carapa procera, Cola millenii, Distemonanthus benthamianus, Ficus letea, Hannoa klaineana, Mansonia altissima, Maranthes robusta, Mitragyna stipulosa, Olax subscorpioidea, Spondias mombin, Vitex grandifolia* recorded 1 representing 0.19% of stand making them the tree species with the least number of occurrence in the reserve (Table 2).

The species *Celtis zenkeri, Picralima nitida, Ricinodendron heudelotii, Buchholzia coriacea, Lovoa trichilioides* and *Diospyros crassiflora* are among the species with the highest important value index (IVI) of 53.81, 49.51, 43.96, 27.86, 23.18 and 22.24, respectively while the species with the least important value index are *Distemonanthus benthamianus, Hannoa klaineana, Mansonia altissima, Maranthes robusta, Mitragyna stipulosa, Olax subscorpioidea, Spondias mombin, Vitex grandifolia* recording 0.88 each (Table 2). In terms of relative density, *Celtis zenkeri, Picralina nitida, Ricinodendron heudelotii, Buchholzia coriacea, Diospyros crassiflora* and *Berlinia grandiflora* are some of the species with the highest value of 101.7, 94.8, 63.8, 53.4, 43.1 and 34.5, respectively while *Anthocleista djalonensis, Ficus letea, Mansonia altissima, Maranthes robusta* and *Vitex grandifolia* were some of the species which recorded the least value of 1.7 each (Table 2).

Diversity indices

The forest reserve has a species richness of 9.07, species evenness of 0.84, Shannon-Weiner diversity Index (H') of 3.43, Pielou's species evenness index (E_H) of 0.84 and simpson index of dominance (D) of 0.95 (Table 3). The mean Dbh of the trees in the forest was 24.7cm, dominant Dbh was 118.5 cm, mean height was 16.9, dominant height was 63.7 m, total basal area was 36.63 m^2/ha and a total volume of 602.09 m^3/ha (Table 3).

Table 2: Tree species distribution and stand variables of Oluwa Forest Reserve.

Species	N/ha	mDbh	mHt	G/ha	Vol/ha	Density	Frequency (%)	Abundance	RD%	RDom%.	IVI
Afzelia bipindensis	3	48.1	26.0	0.57	7.06	0.38	25.0	2	5.2	1.54	3.36
Albizia ferruginea	1	22.2	13.8	0.04	0.34	0.13	12.5	1	1.7	0.11	0.91
Anthocleista djalonensis	1	12.8	7.4	0.01	0.05	0.13	12.5	1	1.7	0.04	0.88
Anthostema aubreyanum	3	17.2	16.2	0.07	0.63	0.38	12.5	3	5.2	0.19	2.68
Antiaris welwitschii	3	42.3	28.0	0.60	13.91	0.38	37.5	1	5.2	1.64	3.41
Berlinia grandiflora	20	19.5	17.4	0.70	8.47	2.50	50.0	5	34.5	1.91	18.19
Bombax buonopozense	2	26.2	16.8	0.11	1.79	0.25	25.0	1	3.4	0.30	1.87
Brachystegia eurycoma	3	62.9	31.6	1.36	39.95	0.38	37.5	1	5.2	3.71	4.44
Buchholzia coriacea	31	17.5	12.1	0.83	7.74	3.88	87.5	4	53.4	2.28	27.86
Canarium schweinfurthii	2	24.8	18.2	0.11	1.38	0.25	12.5	2	3.4	0.29	1.87
Carapa procera	1	15.9	11.1	0.02	0.14	0.13	12.5	1	1.7	0.05	0.89
Cassia sieberiana	3	15.6	7.3	0.06	0.29	0.38	37.5	1	5.2	0.16	2.67
Cedrela odorata	2	25.8	14.2	0.11	0.93	0.25	25.0	1	3.4	0.29	1.87
Ceiba pentandra	2	23.8	17.1	0.09	0.97	0.25	25.0	1	3.4	0.25	1.85
Celtis zenkeri	59	20.2	15.1	2.16	24.68	7.38	100.0	7	101.7	5.89	53.81
Chenopodium ambrosioides	5	19.2	13.4	0.15	1.51	0.63	50.0	1	8.6	0.41	4.52
Cleistopholis patens	11	37.6	17.6	1.56	20.83	1.38	50.0	3	19.0	4.27	11.62
Cola acuminata	2	25.8	12.9	0.12	0.82	0.25	25.0	1	3.4	0.33	1.89
Cola millenii	1	23.7	15.8	0.04	0.38	0.13	12.5	1	1.7	0.12	0.92
Cordia millenii	13	27.4	19.9	1.03	21.42	1.63	100.0	2	22.4	2.81	12.61
Diospyros crassiflora	25	15.3	11.2	0.51	4.92	3.13	100.0	3	43.1	1.38	22.24
Distemonanthus benthamianus	1	18.1	18.5	0.03	0.35	0.13	12.5	1	1.7	0.07	0.90
Entandrophragma angolense	6	21.1	18.0	0.24	3.97	0.75	37.5	2	10.3	0.66	5.50
Entandrophragma cylindricum	3	19.2	15.3	0.09	0.91	0.38	25.0	2	5.2	0.25	2.71
Ficus letea	1	11.5	7.3	0.01	0.04	0.13	12.5	1	1.7	0.03	0.88
Ficus mucuso	17	23.2	17.6	0.81	9.46	2.13	75.0	3	29.3	2.22	15.77
Funtumia elastica	19	20.7	14.2	0.75	8.52	2.38	87.5	3	32.8	2.04	17.40
Garcinia kola	4	18.2	14.8	0.11	1.07	0.50	37.5	1	6.9	0.29	3.59
Guarea cedrata	2	12.0	10.6	0.02	0.10	0.25	12.5	2	3.4	0.06	1.75
Hannoa klaineana	1	27.0	22.6	0.06	1.07	0.13	12.5	1	1.7	0.16	0.94
Irvingia gabonensis	4	26.3	23.6	0.23	3.16	0.50	25.0	2	6.9	0.63	3.76
Khaya ivorensis	3	51.7	35.1	0.79	20.45	0.38	37.5	1	5.2	2.17	3.67

Lannea welwitschii	3	23.3	19.4	0.17	4.00	0.38	25.0	2	5.2	0.47	2.82
Lovoa trichilioides	25	22.3	15.9	1.19	16.95	3.13	100.0	3	43.1	3.26	23.18
Malacantha alnifolia	23	20.6	16.4	0.88	12.59	2.88	75.0	4	39.7	2.42	21.04
Mansonia altissima	1	13.2	11.9	0.01	0.12	0.13	12.5	1	1.7	0.04	0.88
Maranthes robusta	1	12.8	7.9	0.01	0.04	0.13	12.5	1	1.7	0.04	0.88
Milicia excelsa	3	17.5	14.0	0.08	0.70	0.38	37.5	1	5.2	0.21	2.69
Mitragyna stipulosa	1	33.2	23.4	0.09	1.35	0.13	12.5	1	1.7	0.24	0.98
Musanga cecropioides	2	42.4	31.5	0.40	7.47	0.25	12.5	2	3.4	1.10	2.27
Nesogordonia papaverifera	5	14.7	10.7	0.09	0.52	0.63	50.0	1	8.6	0.24	4.43
Olax subscorpioidea	1	39.0	20.5	0.12	1.62	0.13	12.5	1	1.7	0.33	1.03
Pausinystalia johimbe	6	31.3	16.9	0.51	6.35	0.75	50.0	2	10.3	1.38	5.86
Picralima nitida	55	17.6	12.8	1.53	16.00	6.88	100.0	7	94.8	4.19	49.51
Pterygota bequaertii	18	31.1	20.3	2.45	61.63	2.25	62.5	4	31.0	6.70	18.87
Pterygota macrocarpa	9	35.5	18.3	1.50	19.22	1.13	75.0	2	15.5	4.10	9.81
Pycnanthus angolensis	9	37.6	27.6	1.27	30.45	1.13	62.5	2	15.5	3.46	9.49
Ricinodendron heudelotii	37	51.5	24.8	8.84	148.64	4.63	87.5	5	63.8	24.14	43.96
Spondias mombin	1	41.0	25.6	0.13	2.42	0.13	12.5	1	1.7	0.36	1.04
Staudtia stipitata	6	17.7	12.9	0.16	1.27	0.75	50.0	2	10.3	0.44	5.39
Sterculia rhinopetala	14	26.3	20.3	0.87	13.65	1.75	75.0	2	24.1	2.37	13.26
Sterculia tragacantha	15	19.2	17.0	0.51	5.57	1.88	100.0	2	25.9	1.38	13.62
Strombosia pustulata	5	20.4	17.5	0.18	2.55	0.63	37.5	2	8.6	0.50	4.56
Terminalia superba	11	18.0	16.0	0.30	4.07	1.38	87.5	2	19.0	0.82	9.89
Triplochiton scleroxylon	16	28.7	22.3	1.22	26.59	2.00	100.0	2	27.6	3.32	15.45
Uapaca heudelotii	10	23.9	15.8	0.63	10.51	1.25	25.0	5	17.2	1.71	9.48
Vitex grandifolia	1	14.3	10.7	0.02	0.09	0.13	12.5	1	1.7	0.04	0.88
Zanthoxylum leprieurii	3	17.7	11.2	0.09	0.41	0.38	25.0	7	5.2	0.24	2.70

N/ha = number of tree per ha; mDbh = mean diameter at breast height; mHt = mean total height; G/ha = basal area per ha; Vol/ha = volume per ha; RD = relative density in percentage; RDom = relative dominance in percentage; IVI = important value index.

Table 3: Diversity indices and growth variables of Oluwa Forest Reserve.

Biodiversity Indices		Tree Growth Variables	
Indices	Values	Variables	Values
Margalef's Index of Species Richness	9.07	Mean Dbh (cm)	24.7
Pielou's Species Evenness Index (E_H)	0.84	Dominant Dbh (cm)	118.5
Shannon-Weiner Index (H')	3.43	Mean Height (m)	16.9
Simpson Index of Dominance (D)	0.99	Dominant Height (m)	63.7
		Total Basal Area/ha (m^2)	36.63
		Total Volume/ha (m^3)	602.09

Forest structure

The graphical distributions of the observed number of tree (N/ha) and the fitted log-logistic distribution by diameter (Dbh) and height classes were clear indication of the typical nature of a natural forest. Majority of trees were found in the smaller diameter and height classes; giving rise to reverse J-shaped structure (Figure 2 and 3). The log-logistic distribution described the structure of the forest perfectly well.

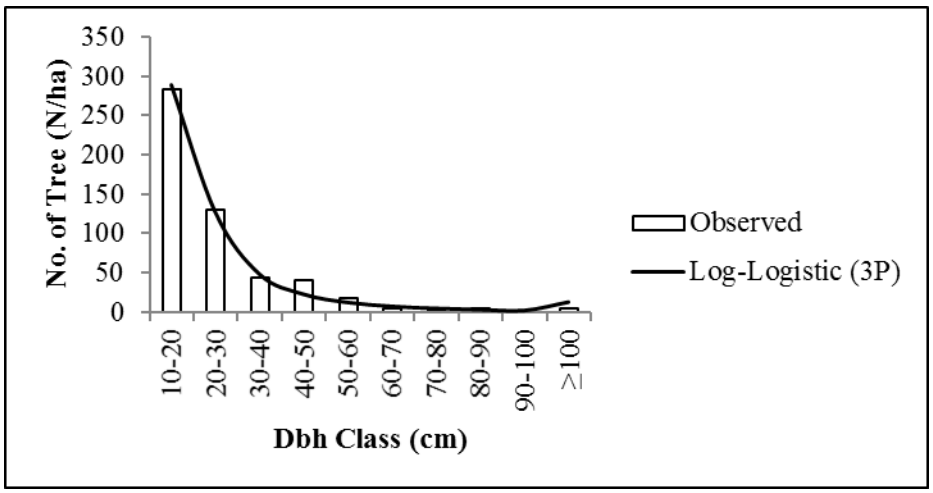

Figure 2: Diameter (Dbh) distributions of the natural forest in Oluwa Forest Reserve.

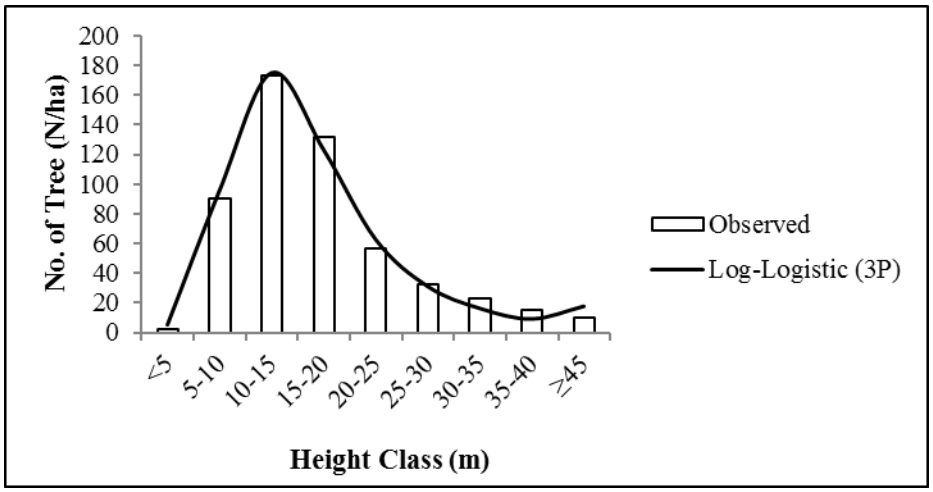

Figure 3: The height distributions of the natural forest in Oluwa Forest Reserve.

4. Discussion

4.1 Family distribution

The forest reserve is dominated by species in the family Sterculiaceae, Apocynaceae, Ulmaceae, Euphorbiaceae, Meliaceae and Moraceae. Prominent species in these families includes; *Buchholzia coriacea, Funtumia elastica,Mansonia altissima, Triplochiton scleroxylon,Cola acuminata, Celtis zenkeri, Ricinodendron heudelotii, Khaya ivorensis, Entandrophragma species, Milicia excelsa, Ficus* and *Antiaris* species. Our findings correspond with that of Onyekwelu et al., (2008) who reported a similar trend in family and species distribution in Oluwa forest reserve, although the number of families and species reported by him (24 and 45 respectively) is less than what we encountered (26 and 58 respectively). The difference could be attributed to the difference in the size of plot used and space (time) over which the studies were carried out. Sample size is one of the factors that determine the actual diversity status of an ecosystem (Jayakumar et al., 2011). The larger the size of the plot, the likelihood of identifying many number of species (Kindt and Coe, 2005). 50×50 m plots were used against 20×20 m used by Onyekwelu et al., (2008) which could be one of the reasons why more family and species were identified in this study against that reported by Onyekwelu et al., (2008). With proper management the difference in space or time (about 10 Years) between when the two studies were conducted could possibly result in increasing species population due to regeneration process in the forest. Adekunle et al., (2013) also reported 95, 31 and 387 number of species, family and individual trees, respectively in a strict nature reserve in Akure, Ondo state, Nigeria. Also, Aigbe and Omokhua (2015) reported 72, 30 and 808 number of species, family and individual trees, respectively in a tropical rain forest in Nigeria (Oban Forest Reserve) while 165 tree species and 50 families was reported by Rao et al., (2015) in tropical forest in India. Apart from the difference in plot size and space, variation in environmental conditions is another possible reason for the observed differences between different results from different tropical forest.

4.2 Species distribution and stand variables

Important timber species commonly found in the tropical low land forest of the southwest such as *Khaya ivorensis, Mansonia altisima, Milicia excelsa* are at verge of extinction in the forest reserve. This is because only 3, 1, 3 stems, respectively of these species were encountered in the study area signaling a great threat to the survival of these important tree species. Illegal timber harvesting within the forest reserve is the major reason for this observed trend. For example, Adekunle et al., (2010) reported the exploitation of 111,777 tropical rainforest hardwood species in Ondo State forest reserve between 2003 and 2010. However, the relatively fair presence of species such *Diospyros crassiflora* (4.67%) a rare and banned species of the tropical lowland forest of Nigeria is an indication that the reserve is still an important conservation site. *Celtis zenkeri* is the dominant tree species in the forest reserve since it has the highest important value index and relative density while *Anthocleista djalonensis, Ficus letea, Mansonia altissima, Maranthes robusta* and *Vitex grandifolia* are the less dominants species in the forest reserve. This implies that despite the rampant illegal logging activities taken place in the reserve, *Celtis zenkeri* has withstand the pressure. This could be because of the large number of the species or fast regeneration process. However, species such as *Mansonia altisima* etc. with the least important value index and relative density may likely disappear from the forest in no distant future if adequate conservation efforts are not put in place. This finding agrees with Adekunle et al., (2013) who reported *Celtis zenkeri* to be the abundant tree species in tropical rainforest of Akure strict forest reserve, Ondo State.

4.3 Diversity indices

The forest reserve can be said to be averagely rich, though the richness is far below that reported by Adekunle et al., (2010) in Akure forest reserve, this is not surprising considering the level of protection in Akure forest reserve which is a Strict Nature Reserve (SNR) in comparison with Oluwa forest reserve. However, the value is a bit below that reported by Aigbe and Omokhua (2015) and Oban forest reserve respectively, this shows the level of exploitation in Oluwa forest reserve in comparison to the two other reserves. In terms of relative abundance or diversity signified by the shannon-Weiner diversity Index, the

reserve can be regarded to be fairly abundant or diverse, more diverse than tropical rainforest part of Ologbo Forest Concession (Ogunjemite, 2015). However, it is less diverse than Akure and Oban forest reserve (Aigbe and Omokhua 2015; Adekunle et al., 2013). Surprisingly, the total basal area in the forest reserve is more than that reported in Akure forest, Oban forest reserve and rainforest part of Ologbo Forest Concession (Adekunle et al., 2013; Aigbe and Omokhua 2015; Ogunjemite, 2015). Since total basal area is an indication of productivity, it means Oluwa forest reserve is more productive than the three forest reserve. There are larger trees in Oluwa forest reserve and these contribute more to basal area per hectare than smaller trees. The difference in sample size, plot size, environmental conditions, and other site factors could be responsible for the observation (Aigbe and Omokhua, 2015).

4.4 Forest structure

The tree storey layer in the forest is skewed toward lower stratum, a complete deviation from the characteristically complex vertical structure of forest canopies of low land tropical rainforest. Only a few species are found in the middle and upper layer while noting exist in the emergent layer. This implies to the level of exploitation that has took place or is currently taking place. This is not surprising because logger's species of interest usually falls within the upper and middle stratum of the forest. A similar observation was made by Adekunle et al., (2004) and Ogunjemite (2015) in Omo and Ala forest reserve and the tropical rainforest part of Ologbo Forest Concession, respectively. Majority of the trees in the forest also fell below the maturity level (≤40cm) just like what Adekunle et al., (2013) observed in Akure forest reserve. The small height and diameter size of the trees in the forest is an indication of abundance of young trees occasioned by excessive exploitation of mature tree species, gaps are created making light, water available for regeneration. Although the forest structure has been altered to a large extent, with adequate conservation effort, the relatively young trees can mature in the near future.

5. Conclusion

Conclusively, it is evident from the results that Oluwa forest reserve structure and composition has been altered considerably over time as a result of anthropogenic activities. Notwithstanding, the forest still contains some important tropical forest species such as *Diospyros crassiflora, Milicia excelsa, Khaya ivorensis, Mansonia altisima, Triplochiton scleroxylon, Entandrophragma* species and structure reminiscence of an ideal tropical rainforest. There seems to be improvement in species richness and diversity if previous study more especially that of Onyekwelu et al. (2008) is to be compared with. This goes to show the resilence nature of the forest and indicate the ability of the remaining fragmented forest to regenerate and replenish to save some of the original species composition of the reserve given the right atention.

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