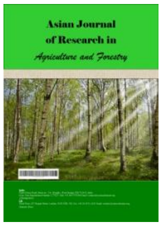

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Diversity and Volume Assessment of Tree Species in the Tropical Forest at Obanla, Akure, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author OTO carried out the data collection in the field. Author ASA performed the statistical analysis and wrote the first draft of the manuscript. Authors OGO and FEA coordinated the research work, reviews the entire work, corrected the final manuscript and carried out literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study focused on the assessment of tree species diversity and abundance at The Federal University of Technology, Akure Tropical Forest Obanla. The research was carried out from May, 2019 to September, 2019. Complete enumeration sampling was adopted for the data collection and all trees with diameter at breast height (Dbh) above 0.1 m were identified and measured. Other tree growth variables, such as diameter at the base (db), diameter at the middle (dm), diameter at the top (dt) and the total height were all measured for volume estimation. *Ricinodendron heudelotii Hd* the highest number of stems (13), so it was the dominant tree species.The result shows that mean tree volume ranges from a minimum of 0.26 m^3 for Olalaceae family, to a maximum of 77.70 m^3 for Euphorbiaceae family. *Ceiba pentandra* of Malvaceae family had the highest mean volume (14.62 m^2) while the lowest was recorded for both *Khaya senegalensis* and *Newbouldia laevis* with a volume of 0.13 m^2. The family of Euphorbiaceae was regarded as the dominant family in the natural forest with 26 tree species which is the highest in this study and with the highest volume (77.70 m^2). Shannon Wiener diversity index and species equitability index according to Pielou's of 3.24

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and 0.92 were respectively obtained for the study area. This study revealed the efficacy of an undisturbed natural forest in *in situ* conservation. Active regeneration can be carried out for proper stocking of the forest so has to make it a potential biodiversity hotspot.

Keywords: Species diversity indices; tree growth variables; Euphorbiaceae; Olalaceae.

1. INTRODUCTION

Tropical rainforests are the support of life, because of its richness in plant species composition (>250 plant species/hectare) and fauna diversity (>50% of animal species in the world) [1]. They are mostly dominated by a wide variety of broad-leaved trees which form dense canopy and make it one of the most complex ecosystems [2]. Tropical rainforest are vital ecosystems that provides services, such as raw materials, reservoirs for biodiversity, habitat to diverse animal species, soil protection, sources of timber, medicinal plants, carbon sequestration, watershed protection and also form the livelihood for many different human settlements, including 60 million indigenous people [3-6]. Beside this, it is seen to contain up to 82% of the terrestrial plant biomass, which is interlinked with atmospheric CO_2 levels, through the carbon cycle.

Tree species diversity as one of the important components of the tropical forest, is fundamental to rainforest biodiversity. Moreover, the favorable environmental conditions and the canopy structure of the tropical rainforest are special features which promote species diversity and about 70–90% of living flora and fauna depend on trees for survival in the rainforest ecosystem [7]. It has been stated that 25–50% of the world's tropical rainforest has been lost and degraded due to economic exploitation and land-use change, such as deforestation (palm oil plantations, agriculture expansion, cattle ranches, mining, and development of housing societies) [8-9], while the rest of the rainforest areas is under a major shift in the dynamic structure and productivity [1]. However, for effective management of tropical forest in a sustainable way there is need to estimate the growing stock of the forest. Information on the estimation of the growing stock guides forest managers in timber valuation as well as in allocation of forest areas for harvest. For timber production, an estimate of growing stock is often expressed in terms of timber volume, which can be estimated from easily measurable tree dimension [10]. Beside this, the assessment of stem volume is becoming of great global interest especially in the context of Kyto protocol rules where each nations has to maintain CO_2 emission under a certain threshold, which must be calculated by talking into account both sources and sink of CO_2, including the CO_2 absorbed and stored by trees [11-12].Thus, having a detailed knowledge of forest stem volume of a tropical forest is therefore indispensable in term of management, timber allocation and its power to sequester carbon.This research therefore aims to estimate the tree volume for sustainable forest management and to investigate the present status of tree species diversity and abundance of natural rainforest ecosystems in south-western Nigeria, despite the global changes affecting tropical forest.

2. METHODOLOGY

2.1 Study Area

This research work was carried out at Obanla Natural Forest, Federal University of Technology Akure (FUTA), Ondo state. The forest was left behind during land clearing for the establishment of the Federal University of Technology, Akure, Ondo State, Nigeria in 1981. It was formerly part of Akure Forest Reserve located between four towns namely Akure, Idanre, Ondo and Ilesa. As a result, the forest was very rich in tree and animal species diversity [13]. It is located along Akure-Ilesa road in the north western part of FUTA on Longitude 05°08’03”E and Latitude 07°18’ 28”N. The forest is about 9.34 ha in size [13].

2.2 Method of Data Collection

A complete enumeration technique with a non-destructive approach was used for data collection. All living woody plants in the forest were enumerated.

2.3 Tree Enumeration

All trees were identified by taxonomists and Dbh ≥0.1 m were enumerated for the tree species diversity and abundance. Tree growth variables measured are the diameters at the base, diameter at the middle, diameter at the top and the total height.

2.4 Data Analyses

2.4.1 Basal area computation

Basal area of each tree was calculated using the formula below:

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

Where BA = Basal Area (m^2), D = Dbh (m) and π=3.412

2.4.2 Tree volume computation

The tree total volume was calculated for each tree using the Newton's formula [14]

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

WhereV= Total Volume of tree (m^3), h= height (m), D_b = Diameter at the base (m),

D_m = Diameter at the middle (m), D_t = Diameter at the top (m)

2.4.3 Computation of diversity indices

(i) Species relative density was computed using the equation of Brashears [15]

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

Where: RD (%) = Species Relative Density; n_i = number of individuals of species i; N = total number of all tree species in the entire community.

(ii)Species Relative Dominance (RDo (%)) was computed using the equation:

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

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

(iii) The Shannon's Diversity index:

Shannon–Wiener diversity index equation given by Price [16] was employed to calculate the tree species diversity.

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

Where H' = Shannon diversity index, S = the total number of species in the community, pi = proportion S (species in the family) made up of the Ith species and In = natural logarithm.

(iv)To determine the Species evenness (E) in each community Pielou's Species Evenness index equation was adopted as stated by Kent and Coker[17]:

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

Where pi = proportion S (species in the family) made up of the ith species, S = the total number of species in the community and In = natural logarithm

(v)The Family Importance Value Index (FIV) was obtained using:

$$\frac{RD + RDo}{2} \quad (7)$$

Where: RD (%) = Species Relative Density and RDo (%) = Species Relative Dominance

3. RESULTS

Table 1 shows the Descriptive statistics of the tree growth variables in the study area. Values of 0.01 and 1.50 were obtained for the minimum and maximum basal area. Dbh has the minimum value of 11.00 cm and maximum of 138 cm. The values recorded for the lowest and highest height were 8.00 m and of 47.30 m respectively. The study area has the highest volume of 18.85 m^3 and minimum of 0. 07 m^3.Amean height of 21.64 m with a mean Dbh of 46.79 cm was recorded for the study area. The skewness ranges from 1.07 for the Dbh to 2.35 for the basal area.

The number of stems and tree species encountered in the study area is presented in Table 2. *Ricinodendron heudelotii* (Baill) Pierre ex Pax had the highest number of stems (13). This was followed by the species of *Uapaca heudelotii Baill* with eleven (11) stems. *Albizia ferruginea* (Guill. & Perr.) Smith, *Ceiba pentandra* (Linn.) Gaertn, *Celtis mildbraedii* Engl., *Chrysophyllum albidum* G. Don, Cleistopholis patens (Benth.) Engl. & Diels, *Croton penduliflorus* Hutch, *Khaya senegalensis* (Desr.) A. Juss, *Margaritaria discoidea* (Baill.) G.L, *Newbouldia laevis* (P. Beauv.) Seemann. ex Bureau etc. were all represented by one stem.

Table 1.Descriptive statistics of the tree growth variables

	Dbh(cm)	Total Height	Basal Area (m^2)	Vol. (m^3)
Mean	46.79	21.64	0.23	3.00
Standard Error	2.53	0.77	0.03	0.34
Standard Deviation	26.77	8.11	0.27	3.58
Sample Variance	716.76	65.71	0.07	12.83
Kurtosis	1.01	0.45	6.51	5.45
Skewness	1.07	0.76	2.35	2.16
Range	127.00	39.30	1.49	19.78
Minimum	11.00	8.00	0.01	0.07
Maximum	138.00	47.30	1.50	19.85

Table 2. No of stems and tree species in the study area

Species	no of stem
Albizia adianthifolia (Schum.) W. F. Wight	5
Albizia ferruginea (Guill. &Perr.) Smith	1
Albizia zygia (DC.) J. F. Macbr.	9
Alstonia boonei De Wild	5
Amphimas pterocarpoides Harms	5
Anthocleista liebrecht siana De Wild. & Th. Dur.	4
Blighia sapida Konig	2
Ceiba pentandra (Linn.) Gaertn	1
Celtis mildbraedii Engl.	1
Chrysophyllum albidum G. Don	1
Cleistopholis patens (Benth.) Engl. & Diels	1
Cola gigantea A. Chev.	2
Croton penduliflorus Hutch.	1
Erythrina senegalensis DC.	3
Ficus exasperate Vahl	5
Funtumia elastica (Preuss) Stapf	4
Khaya grandifoliola C. DC.	3
Khaya senegalensis (Desr.) A. Juss	1
Margaritaria discoidea (Baill.) G.L	1
Mitragyna ciliate Aubrév. & Pellegr.	2
Newbouldia laevis (P. Beauv.) Seemann. ex Bureau	1
Petersianthus macrocarpus (P. Beauv.) Liben	1
Pseudospondias microcarpa (A. Rich.) Engl	3
Pterocarpus mildbraedii Harms	4
Pycnanthus angolensis (Welw.) Warb	5
Ricinodendron heudelotii (Baill.) Pierre ex Pax	13
Solanum giganteum Jacq.	1
Sterculia rhinopetala K. Schum	3
Sterculia tragacantha Lindl.	2
Stereospermum acuminatissimum K. Schum	1
Strombosiapustulata Oliv	1
Terminalia ivorensis A. Chev.	2
Terminalia superba Engl. & Diels	5
Trichilia heudelotii Planch. ex Oliv	2
Uapaca heudelotii Baill	11
Grand Total	112

Table 3. Summary of tree growth variables in the study area

S/N	Family	Species	Mean Dbh(cm)	Mean Ht(m)	MeanVol.(m^3)
1	Anacardiaceae	*Pseudospondias microcarpa* (A. Rich.) Engl	63.33	26.2	3.9
2	Annonaceae	*Cleistopholis patens* (Benth.) Engl. & Diels	84	26.4	6.13
3	Apocynaceae	*Alstonia boonei* De Wild	42.2	16.16	2.02
		Funtumia elastica (Preuss) Stapf	28.25	15.9	0.55
4	Bignoniaceae	*Newbouldia laevis* (P. Beauv.) Seemann. ex Bureau	16.5	10.52	0.13
		Stereospermum acuminatissimum K. Schum	80	24.3	7.49
5	Caesalpinioideae	*Amphimas pterocarpoides* Harms	58.5	29.76	5.71
6	Combretaceae	*Terminalia ivorensis* A. Chev.	71	28.4	5.81
		Terminalia superba Engl. & Diels	54.6	26.48	3.8
7	Euphorbiaceae	*Croton penduliflorus* Hutch.	54	12.9	1.49
		Margaritaria discoidea (Baill.) G.L	53	14.9	1.2
		Ricinodendron heudelotii (Baill.) Pierre ex Pax	57.23	25.55	4.19
		Uapaca heudelotii Baill	41.91	22.39	1.87
8	Lecythidaceae	*Petersianthus macrocarpus* (P. Beauv.) Liben	76	38.6	10.21
9	Loganiaceae	*Anthocleista liebrechtsiana* De Wild. & Th. Dur.	33.25	21.18	0.91
10	Malvaceae	*Ceiba pentandra* (Linn.) Gaertn	120	37.6	14.62
11	Meliaceae	*Khaya grandifoliola* C. DC.	78.33	30.2	10.1
		Khaya senegalensis (Desr.) A. Juss	14	15.1	0.13
		Trichilia heudelotii Planch. ex Oliv	30.5	26.3	1.48
12	Fabaceae	*Albizia adianthifolia* (Schum.) W. F. Wight	60	23.02	3.5
		Albizia ferruginea (Guill. &Perr.) Smith	34	15.3	0.98
		Albizia zygia (DC.) J. F. Macbr.	41.33	19.47	2.15
13	Moraceae	*Ficus exasperata*Vahl	41.9	18.42	2.42
14	Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb	32.6	16.46	1.2
15	Olacaceae	*Strombosia pustulata*Oliv	19	13.2	0.26
16	Papilionoideae	*Erythrina senegalensis* DC.	25.5	9.2	0.28
		Pterocarpus mildbraedii Harms	41	16.35	2.48
17	Rubiaceae	*Mitragyna ciliata*Aubrév. & Pellegr.	36	22.75	1.26
18	Sapindaceae	*Blighia sapida* Konig	26.5	18.4	0.79
19	Sapotaceae	*Chrysophyllumalbidum* G. Don	23	19.5	1.42
20	Solanaceae	*Solanum giganteum* Jacq.	40	16.4	1.65
21	Sterculiaceae	*Cola gigantea* A. Chev.	80.5	22.5	7.53
		Sterculia rhinopetala K. Schum	41.67	23.43	2.71
		*Sterculia tragacantha*Lindl.	22.5	15.5	0.51
22	Ulmaceae	*Celtismildbraedii* Engl.	31	25.3	1.04
		Total	1653.1	744.04	111.92

Dbh=Diameter at breast height, Ht =height, Vol.=Volume

A total of 112 stems were distributed among thirty-five tree species belonging to 22 families. Table 3 shows that *Malvaceae* family had the highest Dbh of 120.00 cm, with a height of 37.60 m, volume of 3.64 m^3 and mean basal area of 1.13 m. The lowest mean Dbh which is 19.00 cm was recorded in the family of *Olacaceae,* with a mean height of 13.20 m, mean volume of 0.26m^3 and mean basal area of 0.03 m.

Table 4 shows that the Shannon Wiener's index and Pielou's Species evenness index of 3.24 and 0.92 were obtained respectively in the study area. The family of Euphorbiaceae had the highest volumes (77.70 m^3). This was followed by the family of *Fabaceae* with a volume of 37.81 m^3, while the lowest was recorded for the family of Olacaceae with a volume of 0.26 m^3 as seen in Table 5. Table 6 shows that the highest number of treespecies was observed in the family of Euphorbiaceae, so it could be regarded as the dominant family in the study area. It has highest family importance value (26.68%) with a total of 26 tree species, while the lowest was observed in the family Annonaceae, Lecythidaceae, Malvaceae, Olacaceae, Sapotaceae, Solanaceae and Ulmaceae with one species-each.

Table 4. Tree species diversity indices in the study area

Diversity Indices	Values
No of Trees	112
No of Species	34
No of Families	22
Shannon Weiner	3.24
Pielou'sSpp evenness index	0.92

4. DISCUSSION

Tropical ecosystem has been adjudged to be the richest single ecosystem of the world, due to its species richness and diversity [18]. Species in the ecosystem are useful for climate regulation, creation of microclimate, enrichment of soil fertility andserves as timber resources. The tree species encountered in the study area are of the typical rainforest ecosystem. A total of thirty-five (35) species was distributed among twenty-two (22) families encountered in the study area. The family of Euphobiaceae was represented by 26 tree species which is the highest in the

Table 5.Total volumes for each of the families encountered in the study area

Family	No of stems	Volume (m^3)
Anacardiaceae	3	11.69
Annonaceae	1	6.13
Apocynaceae	9	12.29
Bignoniaceae	2	7.62
Caesalpinioideae	5	28.53
Combretaceae	7	30.61
Euphorbiaceae	26	77.70
Lecythidaceae	1	10.21
Loganiaceae	4	3.64
Malvaceae	1	14.62
Meliaceae	6	33.39
Fabaceae	15	37.81
Moraceae	5	12.08
Myristicaceae	5	6.00
Olacaceae	1	0.26
Papilionoideae	7	10.75
Rubiaceae	2	2.52
Sapindaceae	2	1.57
Sapotaceae	1	1.42
Solanaceae	1	1.65
Sterculiaceae	7	24.20
Ulmaceae	1	1.04
Grand Total	**112**	**335.73**

Table 6. Family importance index of tree species in the study area

Family	No of Spp.	RD (%)	RDo (%)	FIV (%)
Anacardiaceae	3	2.68	3.73	3.20
Annonaceae	1	0.89	2.17	1.53
Apocynaceae	9	8.04	4.55	6.29
Bignoniaceae	2	1.79	2.05	1.92
Caesalpinioideae	5	4.46	6.63	5.55
Combretaceae	7	6.25	8.33	7.29
Euphorbiaceae	26	23.21	24.15	23.68
Lecythidaceae	1	0.89	1.78	1.34
Loganiaceae	4	3.57	1.41	2.49
Malvaceae	1	0.89	4.43	2.66
Meliaceae	6	5.36	8.40	6.88
Fabaceae	15	13.39	12.71	13.05
Moraceae	5	4.46	4.46	4.46
Myristicaceae	5	4.46	1.98	3.22
Olacaceae	1	0.89	0.11	0.50
Papilionoideae	7	6.25	3.35	4.80
Rubiaceae	2	1.79	0.84	1.31
Sapindaceae	2	1.79	0.51	1.14
Sapotaceae	1	0.89	0.16	0.52
Solanaceae	1	0.89	0.49	0.69
Sterculiaceae	7	6.25	7.45	6.85
Ulmaceae	1	0.89	0.30	0.59

RD=Relative Density, RDo=Relative Dominance, FIV=Family Importance Index value

study area, which could be regarded as the dominant family. The fact that Euphobiaceae is the dominant family in the forest is in conformity with the study of Were et al. sarunmi et al. and Adekunle [19-21] who all reported that Nigerian lowland rainforest ecosystem is dominated by members of the Sterculiaceae, Moraceae, Ulmaceae and Euphorbiaceae. This also is in support of the work of Onyekwelu [22] which observed that members of *Euphorbiaceae, Sterculiaceae, Meliaceae, Mimosoideae and Apocynaceae* families are dominant in three rainforest ecosystems in south western Nigeria. The tree species distribution according to this family corresponds with what was reported by Isichei [23]. Several authors have adopted the use of Shannon Weiner diversity index to investigate ecosystem diversity, as it considers both species richness and evenness in the forest community [24]. Biodiversity indices are produced to bring the diversity and abundance of species in different habitats to similar scale for comparison and the higher the value, the greater the species richness [25]. According to Hawthorne et al. [26], Shannon index is an indicator of the high species diversity and reflects the dominance of a few tree species in the forest. The Shannon Weiner diversity index (H^1) of 3.24 shows that the forest is biologically diverse. The value is close to the range of values (3.34-3.66) reported for some tropical rainforest sites in Southern Nigeria [21]. However, the Shannon index of this study is lower, but close to the value of 3.34 obtained by Adekunle [27] in a strict nature reserve ofAkure Forest Reserve.The high species evenness obtained in this study revealed that the trees species in this forest are evenly distributed, this can be attributed to the fact that exploitation has not taken place in the forest. According to Tonolli et.al. [12] stem volume at stand level is very important for proper management of the forest. However, volume estimation is very costly and time consuming as field survey needed to be carried out.The volume obtained in this study is greater than what was recorded by Adekunle [21] in a logged forest of a similar ecosystem butless than the volume obtained by Tonolli [12] for a multilayer forest area of the Italian Alps.The basal area obtained in this study is below theaverage basal area of $15m^2$ reported by Alder and Abayomi [28] for a well-stocked tropical rainforest in Nigeria, which implies that the forest used in this study is not very stock. However, the study area couldstill serve as a reference for similarecosystem

5. CONCLUSION

Deforestation and degradation are threats that affects forest productivity. This research revealed that present status of Obanla Natural Forest at The Federal University of Technology, Akure in term of its volume and species composition and the efficacy of an undisturbed natural forest in biodiversity conservation The Floristic composition of this forest shows that the forest will grow until it becomes a mature forest. Active regeneration should be carried out for proper stocking of the forest so has to improve tree volume. Proper management of the study area should be enhanced so that the forest biodiversity is conserved. Periodic assessment of tree species diversity of the study area should also be carried out.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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