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Original Article

Estimation of tree characteristics as conservation tools in the tropical rainforest ecosystem of Oluwa Forest Reserve, Ondo State, Nigeria

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ABSTRACT

This study was carried out in the Oluwa forest reserve describing some forest characteristics as forest inventory results to draw the attention of the forest managers to the declining status of the forest and also showcase the conservation potentials of the tropical rainforest of Oluwa forest reserve, Ondo State, Nigeria. Stratified random sampling was adopted to capture the different land use classes present in the forest reserve with clusters of 115 m x 115 m containing three sample plots of 35 m x 35 representing elbow, north and east plot called parent plots. In each parent plot, three nested plots (2 m x 2 m; 7 m x 7 m; and 25 m x 25 m) were constituted to capture different diameter classes of trees. The data collected were scientific names, DBH, diameter at the base (Db), diameter at the middle (Dm), diameter at the top (Dt) and total height of all live trees. The data were screened and analysed for analysis; basal area, volume, biomass and carbon. The result revealed that the mean diameter at breast height (DBH, 16.20 cm) was far lower than the recommended tree for exploitation as the minimum merchantable size (48 cm) stipulated by the logging policy of South-western Nigeria. The basal area ranged between 140.01 and 170.48 m^2 ha^{-1} and the tree volume ranged between 821.65 and 1,247.46 m^3 ha^{-1}. Also, the above ground biomass of trees ranged between 290.87 and 830.02 Mg ha^{-1}; and the carbon stock assessed spanned from 145.44 and 415.01 Mg C ha^{-1} for different land use classes considered for this study.This study has provided another opportunity for informed decisions on the need for more conservation efforts. The forest managers, policymakers and other stakeholders should prioritise strategies in forest reserve management to include forest services, rather than the only exploitation mechanism.

HIGHLIGHTS

- Study reveals declining status of Oluwa forest reserve.
- Data shows mean DBH of 16.20 cm, below exploitation size.
- Proactive measures needed to protect and conserve resources.
- Policy changes needed to prioritize conservation over exploitation.

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1. Introduction

Forest inventory is the assessment of forest resources both extent and content; tangible and intangible resources present in the forest ecosystem (Ajayi, 2021). It is very important in forest resources management since it provides the information (data) needed for planning, monitoring, evaluation, research, growth and management (Dau and Chukwu, 2018). The information on the current situation of forest, whether timber or non-timber resources, organic or inorganic component are essential for planning and management of forest estate for short- and long-term objectives of the forest manager for sustainability (Adekola and Mbalisi, 2015). Protection and conservation of forest resources has become imperatives in order to meet the increasing demand of human population who depend on these resources for sustenance (Adekunle et al., 2013). In addition, the timber as well as non-timber components are essential for biodiversity integrity. Forest ecosystems are important for diverse reasons; as a source of food, wood, income and habitat as well as environmental services it renders by protecting the planet earth (Dau and Chukwu, 2018; Ajayi, 2021). Forest ecosystems regulate stream flow, reduce temperature, prevent soil erosion, provide non-timber forest products (NTFPs) and protect wild animals and birdsetc. (Dau and Chukwu, 2018).

Unfortunately, the tropical rainforest resources are under threat because it is seen as free gift of nature all over the world (Silvia, 2019). In Nigeria, forest exploitation had remained gigantic business to governments and citizenry with its attendant forest destruction and degradation (Adekunle et al., 2013). Regardless, the tropical rainforest emerged blossoming because the trees observed growth throughout the year due to the temperature and adequate precipitation of the ecosystems (Adekunle et al., 2013). Though, it should be noted that these forest ecosystems are

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declining at a high speed. Therefore, forest managers should not judge with greening nature ofthe forest but with reliable forest resources assessment (Adekunle et al., 2013).

The Nigeria forest management live in it shadow because the guiding principles of managing the forest sustainably are not followed by the forest managers (Adekunle et al., 2013). This is evident in the challenges such as illegal activities, declining of manpower, lack of trained personnel, inadequate forest patrol, moribund forestry laws and regulations as well as conversion of forest estate to agriculture lands that pose great threat to Sustainable Forest Management (SFM) in the country (Adekola and Mbalisi, 2015).

In addition, the forest reserves can now best be described as relics and bushes due to heavy-dependent on the forest resources (Adekola and Mbalisi, 2015). Regardless, the rate of forest exploitation is increasing and higher than the regeneration potential of the tropical rainforest as well as plantation establishment (Adekola and Mbalisi, 2015).Consequently, this study was conducted in Oluwa Forest Reserve to estimate forest characteristic such as basal area, volume, biomass and carbon content to draw attention of the forest managers to the declining status of the forest and also showcase the conservation potentials of the tropical rainforest of Ondo State, Nigeria.

2. Materials and Methods

Study Area

Oluwa Forest Reserve is one of the thirteen (13) viable forest reserves in Ondo State and has the largest landmass (Adekunle et al., 2013) with an area of about 829 km^2 and it is situated in Odigbo Local Government Area of Ondo State. This forest reserve lies between Latitude 6° 40' - 7° 00'N and Longitude 4° 30' - 4° 50'E. The rainfall in the forest reserve ranges between 1700 and 2200 mm annually (Ogunjemite and Olaniyi, 2012). Annual mean temperature is put at 26 °C. In addition, the relative humidity of the forest reserve is high with 75 % and 95 % humidity. The soils of Oluwa forest reserve are predominantly ferruginous tropical and sandy-loamwhich is commonly found in intensively weathered areas of basement soil formations in the rainforest zone of south-western, Nigeria (Onyekwelu et al., 2008). These soils are well-drained, matured red with little stony or gravely textured in upper parts of the sequence (Ogunjemite and Olaniyi, 2012). The vegetation of Oluwa forest reserve is predominantly tropical rainforest with varied tree species such as Melicia excelsa, Terminaliaspp, Triplochiton scleroxylon, Ricinodendron heudelotii (Baill.), Anthonotha macrophylla, P. Beauv, Sterculiaspp, etc.

Forest classification

To capture the variability (land use diversity) of the forest reserve, its LandSat image was obtained from USGS portal and classified into seven landuse classes: Agricultural land, Disturbed forest (<50% canopy cover), Plantation, Rock outcrop, Settlement, Undisturbed forest (>50% canopy cover) and Water body (Figure 1). But only four landuse classes (agriculture, disturbed forest, plantation forest and undisturbed forest classes) were considered for this study and other land use classes were excluded for lack of tree and inaccessibility.

Sampling design

Stratified random sampling was adopted for this study using landuse classes as strata. This sampling design was used in order

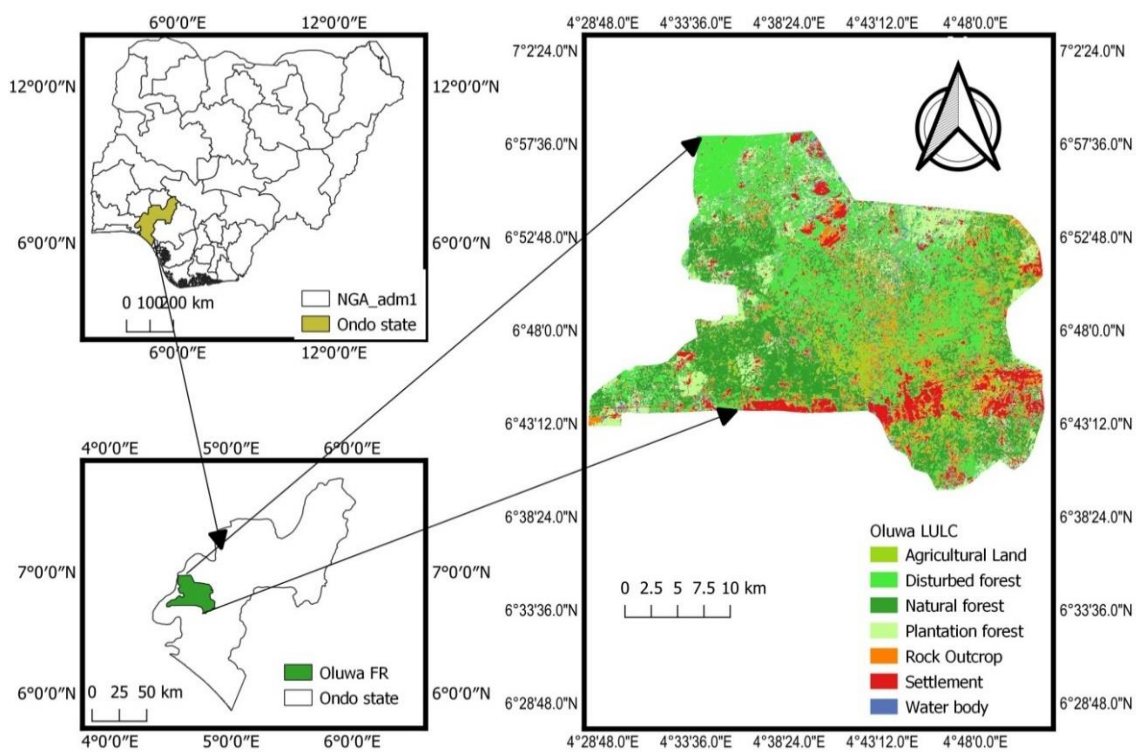

Figure 1. Land use Classified Map of Oluwa Forest Reserve with Ondo State and Nigeria

to capture the land use diversity within the forest ecosystem. Grids of 115 m x 115 m were created in ArcGIS 10.7 version and overlaid on the shapefile of the study area and these grids were called "clusters". Consequently, two sample clusters were selected randomly using random numbers to avoid bias from each land use class, making a total of eight clusters. Random sampling ensures that each point or grid in the land area has an equal chance of being sampled (Ravindranath and Ostwald, 2007).

Plot configuration

Two clusters were selected in each land use class. In each selected cluster, three plots of 35 m x 35 m (parent plot) representing elbow, north and east plot were laid systematically by first locating the cluster southwest coordinate as starting point to lay the elbow plot and from end point of the elbow plot to the north, 10 m distance was adopted before north plots were laid. Also, from end point of the elbow plot to the east, 10 m distance was adopted before east plots were laid. Both north and east plots were laid outwardly (Figure 2). In each parent plot (35 m x 35 m), three nested plots (2 m x 2 m, 7 m x 7 m and 25 m x 25 m) were laid as designed to cover different diameter classes as outlined in Table 1. Total of eight (8) clusters were selected comprising of twenty-four (24) parent plots and seventy-two (72) nested plots were laid in the forest reserve.

Table 1. Sizes of Nested Plot and Diameter Class

Nest Size	Tree DBH range
35 m x 35 m	> 40 cm
25 m x 25 m	20.1 - 40 cm
7 m x 7 m	5.1 - 20 cm
2 m x 2 m	2 - 5 cm

Data collection

The data collected were trees' scientific names, DBH, diameter at the base (Db), diameter at the middle (Dm), diameter at the top (Dt) and total height of all live trees. These measurements were obtained with the use of girth tape, vernier caliper and Spiegel relaskop. The data collected were digitalized with Microsoft Excel package prior analysis.

Data Analysis

Basal Area

The basal area of all trees encountered in the study per sample plot and subplot were estimated using Equation 1.

$$BA < -(pi * \left(\left(\frac{D}{100}\right)^2\right))/4 \tag{1}$$

where BA = Basal area (m2), D = DBH (cm) and л = 3.142. The BA per hectare was obtained by multiplying each tree value by their respective scaling factor (number of such plots in hectare) for the plot or subplot.

Estimation of Tree Volume

The volume of all trees encountered in the study per sample plot and subplot were estimated using Newton's formula Equation 2.

$$Vol < -((\mathrm{pi} * \mathrm{c(Height)})/24) * \mathrm{c}(((Db/100)\hat{}2) + (4 * (Dm/100)\hat{}2) + (Dt/100)\hat{}2) \tag{1}$$

where; Vol = volume of tree, Height = height of tree, Db = diameter at the base, Dm = diameter at the middle and Dt = diameter at the top. The Volume per hectare was obtained by multiplying each tree value by their respective scaling factor (number of such plots in hectare) for the plot or subplot.

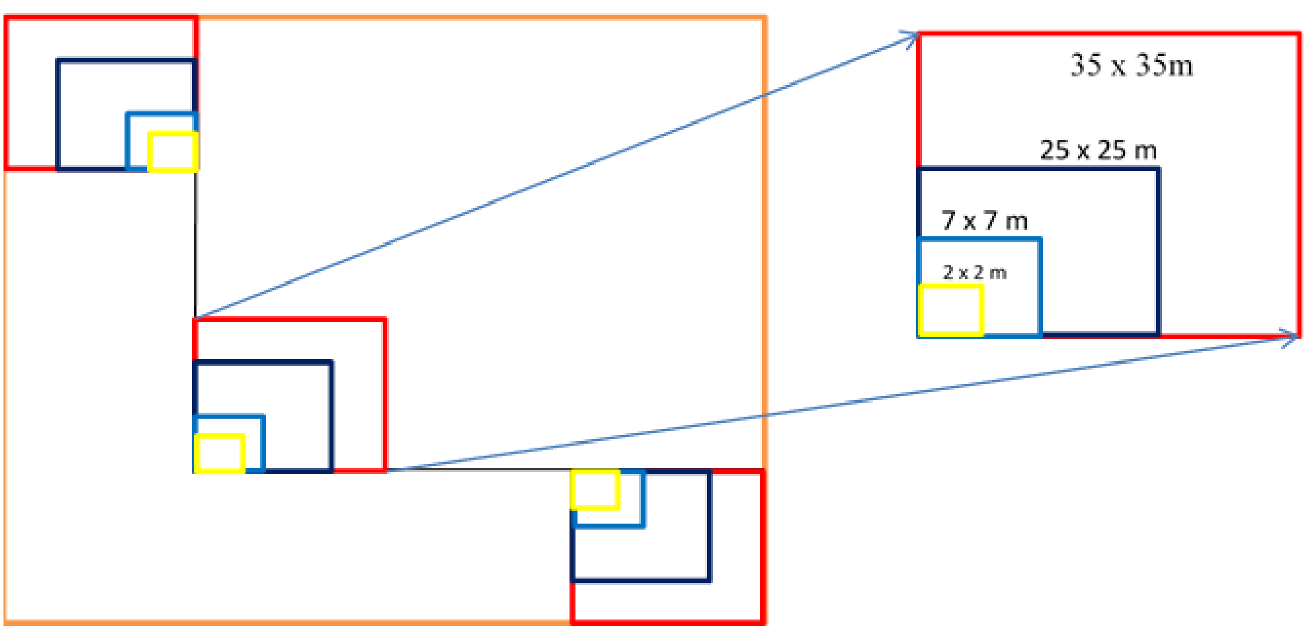

Figure 2. Cluster and plot arrangement

Estimation of Aboveground Biomass (AGB)

The stem wood biomass was estimated by multiplying volume with wood density (Oke et al., 2020). The stem biomass package in R-studio was adopted to estimate biomass of trees enumerated for this study. This biomass package, corrects tree genus and species name through its "correctTaxo" function and also, retrieve wood density through its "getWoodDensity" function. Therefore, Equation 3 was adapted as written in the package.

$$AGB < -\text{computeAGB}(\text{D} = \text{DBH}, \text{WD} = \text{Wdensity}, \text{Height} = \text{tree height}) \quad (3)$$

where; AGB = Aboveground biomass (Mg), D= DBH (cm), WD = wood density (g/cm3), Height = tree height (m). The AGB per hectare was obtained by multiplying each tree value by their respective scaling factor (number of such plot in hectare) for the plot or subplot.

Estimation of Aboveground Carbon (AGC)

The tree biomass estimated was used to determine the amount of carbon stock in each land use (stratum) and the study area because carbon content ranges between 47% and 53% of tree dry matter. Consequently, the value of 50% of biomass estimate (Losi et al., 2003) was adopted for this study, Equation 4.

$$Carb < -c(Biomass * 0.5) \quad (4)$$

where Carb = Carbon value (Mg), Biomass = value obtained in Equation 3

3. Results and Discussion

The result of this study observed a total of 324 individual trees belonging to 53 species and 21 families (Table 2). The number of individual trees obtained per species varied considerably as well as per hectare stems but the average stem per hectare was 407 stems ha-1.This result is higher than similar studies conducted within similar ecosystem e.g. Adekunle et al., (2013) who reported 387 stems ha-1, (Oke et al., 2020) who reported 152 stems ha-1 and (Ige and Adekunle, 2021) who reported 135 stems ha-1. This may be attributed to the inclusion of trees with low DBH (≥ 2 cm) in the computation of stem density in this study as opposed to the adoption of the minimum DBH of 10 cm. It has been reported that stem density is higher at lower diameter in protected forests (Onyekwelu et al., 2021), which may further explain the high tree densities in Oluwa Forest Reserve since low diameter trees were included in their estimations.

Figure 3 shows the spread of trees across the nested plots adopted for this study. It was observed that most trees encountered fall between nests 3 and 4 that is trees less than 20 cm(≤20 cm)DBH. The tree growth variable measured in the study area showed that the mean DBH value was 16.20 cm for the forest stand (Table 2) and this revealed that most of the trees encountered in this study area are below the minimum merchantable size of 48.00 cm stipulated by logging policy of South-western, Nigeria (Adekunle, 2006).This means that there is limited or little matured trees in the forest reserve. Therefore, there is a need for proactive measures to protect and conserve these essential resources for further exploitation.

The dry biomass of tree in this study was estimated to be between 0.61 and 22.28 Mg/tree, with an average of 6.87 Mg/tree (Table 2). The biomass estimates for this study were limited to AGB because most biomass estimations usually focused on the aboveground tree components which account for the greatest fraction of total biomass (Ajayi, 2021). Again, the methods for other

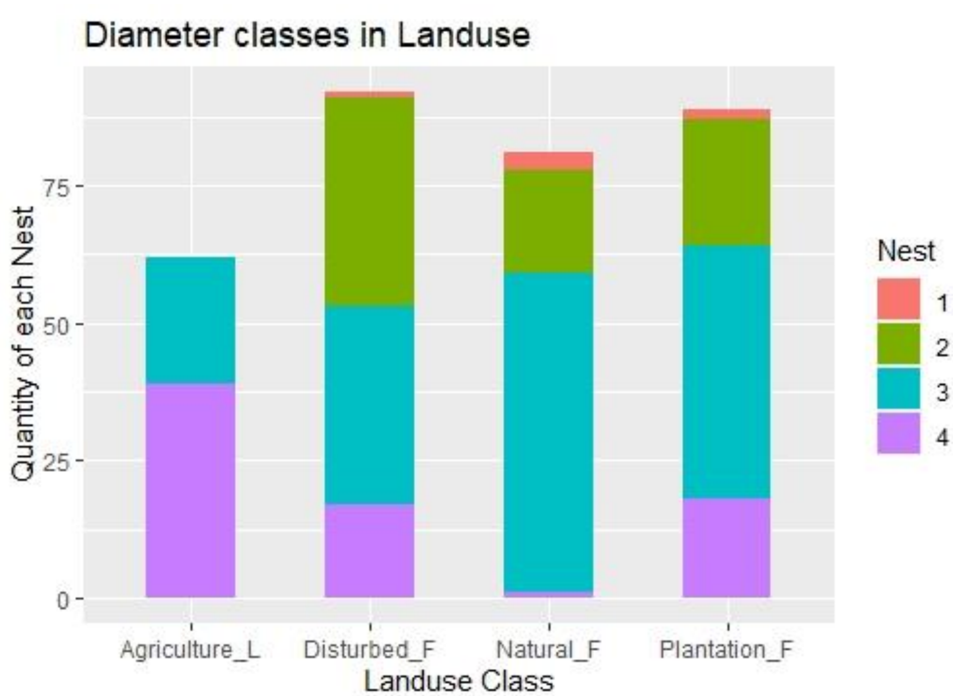

Figure 3. Trees spread across the Nests (DBH classes) adopted for this study

biomass of forest ecosystem components are not as straightforward compared to AGB (Makinde et al., 2017).

The total carbon accumulation per land use class ranged between 145.44 Mg C ha-1 for agricultural land and 415.01 Mg C

Table 2. Tree Species Mean values

SN	Family	Species	DBH (cm)	THeight (m)	BA/ha (m^2)	Vol/ha (m^3)	Biom/ha (Mg)	Carbon/ha (Mg)
1	Anacardiaceae	*Lannea welwitschii* (Hiern) Engl.	23.6	18.5	0.70	4.60	2.07	1.03
2	Apocynaceae	*Funtumia elastica* (Preuss) Stapf	16.8	14.8	1.85	12.87	6.56	3.28
3		*Holarrhena floribunda* (G. Don)	3.1	4.3	1.89	4.53	2.49	1.24
4		*Picralima nitida* (Stapf) Th. & H. Dur.	12.3	7.2	1.39	7.19	5.46	2.73
5	Bignonaceae	*Markhamia tomentosa (*Benth.)	26.1	15.0	0.86	5.43	2.55	1.28
6		*Newbouldia laevis* (P. Beauv.)	11.1	9.5	1.97	39.79	22.28	11.14
7		*Stereospermum acuminatissimum*	24.7	11.9	0.78	4.47	2.77	1.38
8	Capparidaceae	*Buchholzia coriacea* Eng	6.2	7.0	0.62	2.07	1.03	0.52
9		*Myrianthus arboreus* P. Beauv.	27.0	12.0	0.92	3.95	1.82	0.91
10	Detarioideae	*Anthonotha macrophylla* P. Beauv.	15.8	10.6	2.47	21.19	19.28	9.64
11	Ebenaceae	*Diospyros dendo* Welw. ex Hiern	9.4	8.3	2.38	13.92	11.42	5.71
12	Euphorbiaceae	*Antidesma laciniatum* Müll. Arg.	10.0	10.5	1.60	9.33	7.18	3.59
13		*Bridelia micrantha* (Hochst.) Baill	15.1	13.6	1.82	10.90	6.98	3.49
14		*Croton penduliflorus* Hutch.	7.0	16.5	0.79	8.04	3.86	1.93
15		*Discoglypremna caloneura* (Pax) Prain	28.4	15.0	1.38	12.35	4.20	2.10
16		*Macaranga barteri* Müll. Arg.	23.0	23.0	0.66	7.05	2.54	1.27
17		*Macaranga hurifolia* Beille	21.3	12.5	1.64	8.13	2.60	1.30
18		*Ricinodendron heudelotii* (Baill.)	18.8	14.9	2.22	14.99	3.90	1.95
19		*Tetrorchidium didymotemon* (Baill.)	13.4	12.7	3.08	26.61	11.71	5.85
20	Lecythidaceae	*Napoleona imperialis* P. Beauv.	2.1	5.5	0.87	2.70	1.57	0.78
21	Meliaceae	*Khaya grandifoliola* C. DC.	22.1	14.5	0.61	2.68	1.61	0.80
22		*Trichilia heudelotii* Planch. ex Oliv.	28.8	13.8	1.07	7.08	3.12	1.56
23	Moraceae	*Ficus exasperata* Vahl	10.6	12.5	2.17	18.88	10.01	5.00
24		*Ficus mucuso* Welw. ex Ficalho	12.8	13.3	2.95	39.32	19.66	9.83
25		*Ficus sur* Forssk.	13.2	9.0	2.79	12.15	6.80	3.40
26		*Milicia excelsa* (Welw.) C.C. Berg	15.2	10.5	3.70	17.44	10.29	5.14
27		*Musanga cecropioides* R.Br.	27.6	16.9	0.97	6.92	1.87	0.93
28		*Treculia africana var. mollis (Engl.)*	12.2	13.5	2.37	16.34	10.13	5.06
29		*Trilepisium madagascariense DC.*	15.6	13.5	3.90	32.30	16.15	8.07
30	Myristicaceae	*Pycnanthus angolensis (Welw.)*	28.7	10.5	1.04	4.80	2.06	1.03
31	Olacaceae	*Strombosia pustulata Oliv. var.*	11.3	14.0	2.63	22.69	20.42	10.21
32	Papilionoideae	*Baphia nitida Load.*	10.2	11.6	2.22	15.94	9.57	4.78
33		*Baphia pubescens Hook. f*	7.5	8.6	0.91	6.97	4.11	2.06
34		*Desmodium adscendens (Sw.)*	9.4	10.0	1.42	10.32	5.37	2.68
35	Rhamnaceae	*Maesopsis eminii Engl.*	5.9	7.5	0.56	1.35	0.61	0.30
36	Rubiaceae	*Dictyandra arborescens Welw.*	14.3	9.0	3.82	12.03	6.26	3.13
37		*Hunteria umbellata (K. Schum.)*	13.2	11.1	3.01	20.32	14.63	7.32
38		*Psydrax parviflora Subsp.*	37.7	13.1	1.24	7.14	4.93	2.46
39		*Rothmannia whitfieldii (Lindl.)*	8.3	8.4	1.14	5.65	4.18	2.09
40	Sapindaceae	*Blighia unijugata Bak*	2.7	3.5	1.43	2.04	1.31	0.65
41	Sterculiaceae	*Cola gigantea A. Chev. var.*	28.5	19.8	1.04	6.54	3.01	1.50
43		*Cola heterophylla (P. Beauv.)*	6.5	6.2	2.53	10.99	8.90	4.45
44		*Sterculia rhinopetala K. Schum*	27.2	18.2	2.10	14.80	13.17	6.59
45		*Sterculia tragacantha Lindl.*	20.8	14.6	1.26	8.95	4.30	2.15
42		*Theobroma cacao Linn.*	4.9	6.5	2.26	13.25	5.57	2.78
46	Ulmaceae	*Celtis mildbraedii Engl.*	22.9	15.0	2.46	19.00	10.07	5.03
47		*Celtis zenkeri Engl.*	16.1	16.0	4.30	29.50	17.41	8.70
48		*Holoptelea grandis (Hutch.) Mildbr.*	40.5	8.5	1.05	5.69	3.47	1.74
49	Ulmaceae	*Trema guineensis (Schum. & Thonn.)*	11.5	6.0	2.12	6.08	2.43	1.22
50	Verbenaceae	*Gmelina arborea Roxb.*	13.0	12.4	1.78	12.77	5.62	2.81
51		*Tectona grandis Linn. f.*	18.1	12.4	0.95	5.49	4.67	2.33
52		*Vitex rivularis Gürke*	22.7	15.5	0.65	5.55	3.72	1.86
53	Violaceae	*Rinorea brachypetala*	3.5	5.0	2.69	10.36	6.53	3.26
		Mean	**16.2**	**11.8**	**1.8**	**11.9**	**6.87**	**3.44**

Table 3. Total Forest characteristic per hectare obtained in Oluwa Forest Reserve

Landuse Classes	Basal A/ha (m^2)	Volume/ha (m^3)	AGB/ha (Mg)	AGC/ha (Mg)
Natural-forest	166.01	1,247.46	830.02	415.01
Disturbed-forest	170.48	971.66	574.24	287.12
Agriculture-land	140.01	821.65	290.87	145.435
Plantation-forest	149.34	1,056.18	568.97	284.485

ha-1 for natural forest (Table 3). The result of this study is consistent with Agboola et al., (2021) who reported that the lowland forest of South-west Nigeria still has the capacity of storing between 145.17 to 745.57 Mg C ha-1 of carbon. The total carbon stock of 1,132.05 Mg C ha-1 obtained in this study is lower than the result of Makinde et al., (2017), who reported 97,702 Mg C ha-1 in the same forest reserve. Again, this is a red flag showing a decline in the forest carbon and the need for a genuine effort to protect the forest estate.

Conclusions and Recommendations

The study provides features of the forest reserve assessed i.e. basal area, volume aboveground biomass and carbon are concrete evidence of the nature and status of the forest ecosystem. Moderate aboveground biomass and carbon were obtained as well as basal area and volume values compared to other tropical rainforest ecosystem with similar protection mechanism. The results revealed that the mean DBH was far lower than the recommended tree for exploitation and lower than minimum merchantable size of 48 cm as stipulated by logging policy of South-western Nigeria. This means that there is limited or little matured trees in the forest reserve. Therefore, there is need for proactive measures to protect and conserve these essential resources. This study offers another opportunity for informed decision(s). Importantly, the forest managers, policymakers and other stakeholders should look into this information and proffer policies that will judiciously prioritize strategies in the forest reserve management to include forest ameliorative services rather than the present exploitation mechanisms.

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