Stand Structure, Density And Yield Of Tree Community In Ukpon River Forest Reserve, Cross River State, Nigeria

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Abstract: The stand structure, density and yield of trees in Ukpon River Forest Reserve, a tropical rainforest reserve in Cross River State, Nigeria, was surveyed. The study aimed at obtaining quantitative information on stem-diameter, basal area-diameter and standing volume-diameter distributions as well as stand density and yield of trees in the reserve and recommending suitable management practices for the reserve. Adopting systematic cluster sampling technique, 16 sample plots of 50m x 50m were enumerated. A total of 1,534 trees, belonging to 79 species were encountered. The average number of trees, basal area and volume of wood per hectare were estimated at 385 trees, 29.78m^2 and 174.98m^3 respectively, and the inversed-J shaped stem-diameter distribution, typical of all natural forest, was obtained. Fully stocked with wood, coupled with a high percentage of smaller trees and a large merchantable volume of wood per hectare, the area was considered viable for sustainable production of wood on long rotation basis, with the adoption of an initial conservative annual allowable cut of 1.5m^3/ha/yr.

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1. Introduction

Trees are very important components of any forest community in view of their economic values, ecological functions, genetic resources and influence on the physiognomy of the forest. Trees and forest exist to serve man, even as they and their products play critical roles in human environment, situation, needs and lifeline (Adeyoju, 2001). Trees provide wood as industrial raw materials for building, construction, furniture and energy production, non-wood products such as leaves, fruits, nuts, oil, barks, roots, gum and other exudates for food, medicine and industrial purposes. They maintain and protect the environment against degradation, and provide genetic materials for the improvement of cultivated tree crops.

The demand for wood as industrial raw material, building and construction material and sources of energy is increasing daily due to population growth and the attendant economic development. In Nigeria, natural forests, particularly rainforests, are the major reservoir of wood resources for meeting the growing demand for wood. Unfortunately, our natural forest, which are of greater attraction to timber contractors due to their wide variety of species and tree sizes not obtainable in plantations (Akinsanmi and Akindele, 2002), are fast disappearing and mankind is losing their invaluable, indispensable and innumerable goods and services. However, trees are renewable resources. Although most of the economically valuable indigenous timber species cannot be raised successfully in the plantation due to some silvicultural and ecological limitations, they can grow and yield their benefits continually in their natural environment under sound forest management system. According to Olajide and Akinyemi (2007), the continuous existence of many indigenous timber tree species depends on the sustainable management of the remaining areas of our rainforest.

Sustainability of available timber resources and their benefits requires adequate planning which in turn requires knowledge of the extent of growing stock in the forest (Akindele, *et al.,* 2001). Okojie *et al*. (1988) asserted that the quantitative information required usually include the abundance of each species, stem diameter or girth distribution, volume and yield tables. Therefore the objective of this study was to obtain quantitative information on stem-diameter, basal area-diameter and standing volume-diameter distributions of trees and the total number of trees, basal area and standing volume of wood per hectare in Ukpon River Forest Reserve in Cross River State, Nigeria, and recommend suitable management practices for the reserve.

2. Materials and Methods

The study was carried out in Ukpon River Forest Reserve, which is a secondary natural rainforest in Cross River State, Nigeria. The area is located between latitudes 5 41' and 5 57'N, and longitudes 8 13' and 8 31'E. The Forest Reserve covers an area of about 31,380 hectares (Dunn *et al*., 1994), out of which about 21,777 hectares were still forested. The vegetation of the area is the West African lowland evergreen tropical rainforest, sometimes called the lowland rainforest or tropical moist forest biome. Just like any other tropical rainforest, the Forest Reserve has a complex structure, which is stratified both vertically and horizontally. The area has an annual rainfall ranging from 2,500mm to 4,000mm per annum and minimum and maximum annual temperature means of 24 C and 30 C respectively, while the relative humidity ranges from 70% to 80%. The soil type is clay-loam, mixed with gravels in most parts. Topographically, the area has many hills and valleys and is drained by many rivulets, which empty into the main Ukpon River.

The area was first reconnoitred through a careful study of the reserve map and proper ground-truthing. The thickly forested area of the reserve (area not yet converted to farmland) was selected for the study. The systematic cluster sampling technique was adopted for data collection. This method involved laying 2 clusters in the forest. Each cluster consisted of 1,000 metres (1km) long base-line with 200m x 200m tract at each end (FORMECU, 1997; Abayomi, 2001; Akindele *et al*., 2001). The two tracts in each cluster were therefore separated by a distance of 600 metres. Every tract consisted of four 50m x 50m sample plots, located at the four corners of the tract for the enumeration of adult trees. The two baselines were separated by a distance of 1,000 metres (1km). The total area sampled was four hectares.

Tree species in all the sample plots were identified, measured, marked and enumerated. However, only individual trees whose diameters at breast height (dbh) were 10cm and above were enumerated and measured for dbh. The diameters of trees standing on slopes were measured from the upper side of the slope, while the diameters of trees with high buttresses were taken at 30cm above the point where the buttresses converged with the stem.

The stem diameters of the trees were classified into ten size-classes (diameter classes), as follows: 10cm-19cm (diameter class 1), 20cm-29cm (diameter class 2), 30cm-39cm (diameter class 3), 40cm-49cm (diameter class 4) 50cm-59cm (diameter class 5), 60cm-69cm (diameter class 6), 70cm-79cm (diameter class 7), 80cm-89cm (diameter class 8) 90cm-99cm (diameter class 9) 100cm and above (diameter class 10).

The stem-diameter distribution of the trees was obtained and used to determine the population structure of the trees in the reserve. First, all the trees encountered were assigned to their appropriate diameter classes, species by species, using their respective diameter measurements. The sum total of trees in each diameter class was then obtained by adding together the number of trees of all species represented in each diameter class, using equation 1.

where;

N = Total number of trees in the jth diameter class.

n_j = The number of individuals of the various tree species represented in jth diameter class.

The average number of trees per hectare in each diameter class was estimated by dividing the total number of trees in the respective diameter classes by 4 (the number of hectares sampled) as presented in equation 2.

N_{hj} = …………………. (2)

where;

N_{hj} = Average number of trees per hectare in the jth diameter class.

N = Total number of trees in the jth diameter class.

The basal area of each tree was calculated with the basal area function as stated by Avery and Burkhart (2002). The function is:

BA = …………………. (3)

Where;

BA = Basal Area (m^2)

= Constant (3.142)

D = Diameter at breast height (cm).

The volume of each tree was estimated using the volume equation developed for the estimation of volumes of standing trees in tropical rainforest in Nigeria by FORMECU (1999).

The formula is given as:

$InV = -8.525 + 2.209\ InD$ ……………. (4)

where;

In = Natural logarithm

V = Tree Volume (m^3)

D = Diameter at breast height (cm)

The basal areas and volumes of all the individual trees encountered were properly sorted into their respective diameter classes using the diameter measurements of the trees. The basal areas and volumes of trees in each diameter class were then summed together and divided by 4 (the number of hectares enumerated), using equations 5 and 6 respectively, to obtain the average basal area and volume of trees per hectare for each diameter class.

……………………(5)

where;

BA_{hj} = Average basal area of trees per hectare in the jth diameter class.

BA_j = Basal area of trees in the jth diameter class.

……………………………….
(6)

where;

V_{hj} = Average volume of trees per hectare in the jth diameter class.

V_j = Volume of trees in the jth diameter class.

Measures of stand density and yield for the study area were obtained using equations 7, 8 and 9.

where;

N_h = Total average number of trees per hectare.

N_{hj} = The average number of trees per hectare in diameter classes 1 to 10.

where;

BA_h = Total average basal area of trees per hectare.

BA_{hj} = The average basal area of trees per hectare in diameter classes 1 to 10.

where;

V_h = Total average volume of trees per hectare.

V_{hj} = The average volume of trees per hectare in diameter classes 1 to 10.

3. Results

A total of 1,534 individuals of 79 tree species were encountered. This gave an average of about 385 trees per hectare. The number of individuals of each species, their stem-diameter distributions, the total number of trees in each diameter class and their averages per hectare are presented in appendix 1. The stem-diameter distribution of the trees enumerated per hectare had an inversed J-shaped population structure with a large number of small-size trees (Figure 1). Diameter class 1 had the highest number (199) of trees per hectare. The frequency followed a downward trend as the diameter size increases. However, diameter class 10 had more individuals per hectare than diameter classes 7, 8 and 9, probably due to its wider range.

The 1,534 trees enumerated gave a total basal area of about 119.10m^3 and a total volume of about 699.86m^3. The basal area and standing volume per hectare of the Forest Reserve were estimated at 29.78m^2 and 174.98m^3 respectively. The basal area-diameter distribution (Table 1) showed that diameter class 10 had the highest basal area of about 8.47m^2 per hectare, followed by diameter-classes 2 and 3, with basal areas of about 4.22m^2 and 3.84m^2 per hectare, respectively. The standing volume-diameter distribution followed the same trend (Table 1). Diameter-class 10 had the highest standing volume of about 59.54m^3 per hectare, followed by diameter-classes 2 and 3 with standing volumes of about 20.74m^3 and 20.21m^3 per hectare, respectively.

Table 1: The basal area and standing volume per hectare according to diameter-classes in Ukpon River Forest Reserve, Cross River State, Nigeria.

Size class	Basal area/ha	Volume/ha
1	3.17m^2	14.18m^3
2	4.22m^2	20.74m^3
3	3.84m^2	20.21m^3
4	2.62m^2	14.61m^3
5	1.69m^2	9.82m^3
6	2.01m^2	12.08m^3
7	1.77m^2	10.97m^3
8	0.81m^2	5.12m^3
9	1.18m^2	7.71m^3
10	8.47m^2	59.54m^3
Total	**29.78m^2**	**174.98m^3**

The percentages of tree population, basal area and volume of wood in the respective diameter classes are presented in Table 2. Diameter class 1 had the highest percentage of tree population (51.69%/ha), followed by diameter size classes 2 and 3, with 24.94%/ ha and 11.43%/ha, respectively. Size classes 8 and 9 recorded the least percentage of tree population (0.52%/ha, each). On the other hand, diameter size class 10 recorded highest percentages of basal area (28.44%/ha) and standing volume (34.03%/ha), followed by size class 2, with 14.17%/ha for basal area and 11.85%/ha for standing volume. Size class 3 came third, having 12.89%/ha for basal area and 11.55%/ha for standing volume, while size class 8 recorded the least percentages of 2.72%/ha for basal area and 2.93%/ha for standing volume.

Table 2: Percentage of tree population, basal area and volume of wood per hectare in each diameter class

Size class	% of tree population/ha	% of basal area/ha	% of volume/ha
1	51.69	10.64	8.10
2	24.94	14.17	11.85
3	11.43	12.89	11.55
4	4.42	8.80	8.35
5	1.82	5.67	5.61
6	1.82	6.75	6.90
7	1.04	5.94	6.27
8	0.52	2.72	2.93
9	0.52	3.96	4.41
10	1.82	28.44	34.03
Total	**100.02**	**99.98**	**100.00**

4. Discussion

The classification of tree dbh into diameter classes is used to show the number, basal area and standing volume of trees in each diameter class. The stem-diameter, basal area-diameter and volume-diameter distributions of trees in a forest are very important information for decision making in sustainable forest management. In the case of natural forest, were sustainability can be ensured through selective felling of only matured trees, the distributions help to show whether or not sustained yield harvest would be possible. The stem-diameter distribution pattern obtained in this study (Figure 1), is typical of an uneven aged stand (Avery and Burkhart, 2002; Husch *et al.,* 2003), and corroborates the results obtained by Abayomi (2001) and Adekunle, *et al.* (2002) in separate studies of natural tropical forest ecosystems in Nigeria.

With the very large number of smaller trees recorded in this study, the tree population structure would facilitate sustained yield harvest through regular recruitment from lower diameter-classes into higher diameter-classes. Ogbonnaya (2002) asserted that a juvenile size class population of about 35% is ideal for sustained yield harvest. In this study, trees in the lower diameter-classes (1 – 3 size classes) constituted about 88% (Table2) of the total tree population, which is quite adequate to ensure sustained yield harvest.

Alder and Abayomi (1994) recommended a basal area of about 23m^2 per hectare for a fully stocked forest for timber. Going by this recommendation, the present study area with a basal area of about 29.78m^2 per hectare (Table 1) was considered fully stocked for timber harvesting. When comparing the stem-diameter distribution with basal area-diameter and standing volume-diameter distributions (Table 2), it was observed that about 88% of the total number of trees per hectare fell within the unexploitable diameter-classes (1 -3 size classes). On the other hand about 62% of the total basal area and 69% of the total standing volume per hectare (Table 2) were contributed by only few trees (12% of the population) in the exploitable diameter-classes (4 – 10 size classes). It thus implied that only 12% of the total number of trees per hectare were exploitable and could yield a merchantable volume of about 119.85m^3 (Tables 1 and 2). Since Annual Allowable Cut (AAC) is always taken from within the merchantable volume, a large merchantable volume of about 119.85m^3 per hectare could permit long felling cycle (rotation).

However, under sustainable forest management, it is not advisable to remove the total available merchantable volume per hectare because of the rather slow rates of volume and diameter increments in the natural tropical high forest (Abayomi, 2001). The Mean Annual Increments (MAI) of both tree volume and diameter are very essential for the estimation of Annual Allowable Cuts (AAC) and choice of appropriate rotation cycle. The volume and diameter increments of merchantable trees in the lowland rainforest of Nigeria and Cross River State have been estimated at about 2.0m^3/ha/yr and 0.823cm per year by Alder and Abayomi (1994) and Dunn *et al.* (1994), respectively. These give about 12 years time of passage across a 10cm diameter class. The time of passage is the time (in years) it takes a tree to grow to a certain size and is conveniently estimated for passage across a size class, from class entry point to departure point (Dunn *et al*., 1994; Abayomi, 2001). Thus, a tree recruited into diameter class 3 today may not be recruited into diameter class 6 until the next 36 years (12 x 3 size classes), depending on genetic, environmental, biotic and edaphic factors. Since 2.0m^3/ha/yr is the volume increment for only merchantable trees (Alder and Abayomi, 1994), it can pass for annual allowable cut (AAC) (Dunn *et al*., 1994). From the merchantable volume estimated for the forest and the estimated mean annual increments of 2.0m^3/ha/yr and 0.823cm/yr, a 40 year rotation, as proposed by Sutter (1979) in Nigeria, is appropriate for the area. With a rotation of 40 years and MAI of 2.0m^3/ha/yr, the volume of wood expected to be removed from the forest in any given year, including the felling and extraction damages, equals 80m^3 per hectare. This volume can conveniently be extracted without going below diameter class 7 as minimum (Table 1). However, for lack of adequate information on the growth rate of commercially harvested species and how different disturbances affect forest growth and regeneration, one must adopt a conservative strategy in setting the annual allowable cut to ensure that the future productivity of the forest is not compromised. Adopting a conservative approach means setting the allowable cut at the initial moment below the expected 80m^3 per hectare. This could be adjusted appropriately in due course when adequate necessary information is made available.

5. Conclusion and Recommendations

With a population of 385 trees per hectare and majority of the trees in lower diameter classes, sustained yield harvesting of wood from the reserve is possible. Also the basal area of about 29.78m^2 per hectare indicated that the area is fully stocked for sustainable production of wood. The large merchantable volume of wood of about 119.84m^3 per hectare would allow the cutting of a large volume of wood per unit area during harvesting, which in turn would support long felling cycle (rotation).

However, the following recommendations are made to ensure sustainable management of the resources in Ukpon River Forest Reserve:

i. The reserve should be managed for sustained yield production of wood on long-term basis. The 40 year rotation proposed by Sutter (1979) should be adopted and a comprehensive forest management plan for the reserve should be prepared and meticulously implemented. Areas of the reserve with flat and gentle sloping terrains should be compartmentalized and allocated to forest concessionaires on long-term basis for sustained yield production of wood.

ii. The volume of wood to be removed from the reserve should be regulated by calculating and implementing an annual allowable cut (AAC) for the reserve. The annual allowable cut should be set conservatively at $1.5m^3$/ha/yr until reliable data on growth and yield for the area are available. Felling and extraction damages should be estimated and incorporated in the annual allowable cut. The harvesting of allowable cut should start from the higher diameter classes.

iii. Stock survey should be conducted before any area is harvested. This will provide the necessary information for planning of harvest operations to ensure greater efficiency, reduced wastage and reduced environmental damage.

iv. Reduced impact logging system should be used during timber harvesting to minimize damage to the residual stand.

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APPENDIX I

Tree Species and their stem-diameter distributions in Ukpon River Forest Reserve, Cross River State, Nigeria.

Species	**Number of trees in each size class**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Strombosia spp. Blume	158	55	21	3							237
Treculia obovoidea N. E. Br.	88	64	12	1							165
Calpocalyx winkleri Harm	44	30	12								86
Diospyros spp. Linn.	57	15	2								74
Carapa procera DC.	53	16	3	1							73
Klainedoxa gabonensis Engl.	26	8	12	4	2	6	3	3		3	67
Uapaca spp. Baill.	19	18	12	3		1					53
Xylopia spp. Linn.	28	16	5	1							50
Cola spp. Schott & Endl.	32	10		1							43
Staudtia stipitata Warb.	17	9	9	4	2		1			1	43
Berlinia spp. Hook. f. & Benth.	19	14	3			2					38
Coelocaryon preussii Warb.	11	8	5	4	3						31
Irvingia spp. Hook. f.	11	11	3	1			1				27
Trilepisium madagascariense DC.	10	7	4	4	1						26
Chrysophyllum spp. Linn.	7	8	6	3							24
Pycnanthus angolensis (Nelw.) Warb.	9	1	2		3		3	2		4	24
Symphonia globulifera Linn, f.	4	5	5	6	1	2				1	24
Afzelia spp. Smith.	8	7	6	2							23
Pterocarpus spp. Jacq.	7	2	5	4		1	1			3	23
Eribroma oblonga (Mast.) Peire ex A. Chev	10	4	6	1							21
Hylodendron gabunense Taub.	5	7	5		1	2				1	21
Blighia sapida Konig	8	7	3	1		1					20
Mammea Africana Sabine	5	4		6	1	1				1	18
Allanblackia floribunda Oliv.	8		4	4							16
Lannea welwitschii (Hiem) Engl.	8	1	4	1	1						15
Psydrax spp. Gaertn.	8	2	3		1	1					15
Dacryodes spp. Vahl	9	3	1			1					14
Allophylus africanus P. Beauv.	11	2									13
Celtis spp. Linn.	9	3	1								13
Vitex spp. Linn.	5	5	1	1			1				13
Monodora tenuifolia Benth.	7	2	2								11

Parkia bicolor A. Chev.	6	2		1				1		1	11
Albizia spp. Durazz	4	3	1	2							10
Brachystegia nigerica Hoyle & A. P. D. Jones	4		1			1	1		1	2	10
Parinari spp. Aubl.	7	1	1		1						10
Pausinystalia johimbe (K. Schum.) Pierre ex Beille	5	2	1	2							10
Uvariodendron spp. (Engl. & Diels) R. E. Fries	8	1	1								10
Araliopsis soyauxii Engl.	1	2	1	2	1	2					9
Musanga cecropioides R. Br. Ex Tedlie	5	3	1								9
Panda oleosa Pierre	3	2	3		1						9
Trichilia spp. P. Browne	7	2									9
Hannoa klaineana Pierr & Engl.	6	2									8
Piptadeniastrum africanum Brean			1	1	2		2		1		7
Sterculia spp. Linn.	5	1	1								7
Amphimas pterocarpoides Harms	1	2			2	1					6
Baillonella toxisperma Pierre	2			1		1			1	1	6
Brachystegia eurycoma Harms	2									4	6
Coula edulis Bail.	3	2	1								6
Macaranga barteri Muell. Arg.	6										6
Ricinodendron heudelotii (Baill.) Heckel	1					1		1	1	2	6
Daniellia ogea (Harms Rolfe ex Holl.	2		2							1	5
Cylicodiscus gabunensis Harms	1	3									4
Distemonanthus benthamianus Baill.	2				1				1		4
Guarea cedrata (A. Chev.) Pellegr.		2			1		1				4
Zanthoxylum zanthoxyloides (Lam.) Zepernick & Timler		3		1							4
Cleistopholis patens (Benth.) Engl. & Diels	1		1	1							3
Enantia chlorantha Oliv.	1	1			1						3
Pentaclethra macrophylla Benth.					2		1				3
Tabernaemontana pachysiphon Stapf	2	1									3
Antiaris Africana Engl.	2										2
Erythrophleum suaveolens (Guill. & Perr.) Brenan						2					2
Ficus spp. Linn.	1	1									2
Margaritaria discoidea (Baill.) Webster	1		1								2
Pterygota marcrocarpa K. Schum.	2										2
Alstonia boonei De Wild.							1				1
Alstonia congensis Engl.							1				1
Anonidium mannii (Oliv.) Engl. & Diels	1										1
Aubrevillea kerstingii (Harms) Peuegr.				1							1

Bombax buonopozense P. Beauv.			1								1
Bridelia spp. Willd.		1									1
Ceiba pentandra (Linn.) Gaertn.		1									1
Dialium guineense Willd.	1										1
Garcina spp. Linn.			1								1
Holoptelea grandis (Hutch.) Milbr.	1										1
Khaya spp. A. Juss.									1		1
Nauclea diderrichii (De Wild. & Th. Dur.) Merrill										1	1
Nesogordonia papaverifera (A. Chev.) R. Capuron					1						1
Petersianthus macrocarpus (P. Beauv.) Liben				1							1
Terminalia superba Engl. & Diels	1										1
Total	**796**	**382**	**176**	**69**	**29**	**26**	**17**	**7**	**6**	**26**	**1534**
Average per hectare	**199**	**96**	**44**	**17**	**7**	**7**	**4**	**2**	**2**	**7**	**384**

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