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Forest inventory for sustainable forest management in cross river state, Nigeria

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Abstract
Basic ecological data is mandatory if a forest is to be regulated sustainably. This knowledge is mainly secured via forest inventories. Consequently, our study inventoried the stand structure and soil physicochemical properties in 22 forests across the northern, central, and southern zones of Cross River State using the systematic sampling method. Stand structure was assessed using a Rangefinder and measuring tape at dbh≥10 cm and above. An aggregate of 646, 407, and 474 stands were inventoried in the northern, central, and southern zones of Cross River State, respectively. An aggregate of 1527 stands were inventoried in the study area. Using class intervals per zone, stand diameter, and height were used to evaluate the proportion of mature to younger trees. Soil properties were evaluated from ten soil samples collected randomly in each of the surveyed plots in the twenty-two forest areas. We took soil samples with a soil drill at a root depth of 15-50 cm during the rainy season (April - October). Twenty-three soil properties were studied (textural class, soil pH, Organic Carbon, Organic matter, Total Nitrogen, Available Phosphorus, Calcium, Magnesium, Sodium, Potassium, seven trace elements, Electrical conductivity, Exchangeable acidity, Cation exchange capacity, and Base saturation). Results of the stand structure showed that stand diameter class size of 100cm and above had the highest number of stands (19.39%) while the 90-100cm diameter class had the lowest (3.14%). The 10-20m height class had the highest number of stands (56.12%) while the 30m and above class had the lowest (20.37%) in the study area. Soil physicochemical properties revealed the varied presence of the twenty-three soil properties studied across forests. Our findings will provide conservationists, ecologists, and forest managers z with ecological data necessary for sustainable forest management in Cross River State, Nigeria.
Keywords: Forests ecosystem information, Structural framework, edaphic factors

Introduction
A forest is a sizable or wide-ranging area influenced by trees and is the preponderant terrestrial ecosystem of Earth, distributed across the universe. Forests contribute to 75% of the gross primary production of Earth's ecosphere, accommodating 80% of the Earth's plant biomass, and offering habitat to the world's terrestrial biodiversity. Forests perform a key function in supporting foundational ecological processes in supplying livelihoods and aiding economic growth. Concerning tree composition and species diversity, tropical rainforests are Earth's conspicuously complex ecosystems. The diversity of trees is central to whole rainforest biodiversity, as trees supply resources and habitat structure for practically all other rainforest species. In addition, trees play a critical function in the effort to reduce poverty and alleviate and acclimatize to climate change. They contribute exceedingly to economic and social growth via conventional trade, environmental services, and spiritual and aesthetic values, pivotal for the welfare of the populace and providing a wide scale of products, services, and purposes. The forest, as a biological community composed of interacting organisms and their physical environment, generally exhibits assortments of soils with different characteristics. Soil is basic to ecosystem sustainability and production as it provides a great deal of the key conditions for plant growth like water, nutrients, anchorage, oxygen for roots, and average temperature. Soil provides an essential role in nature, contributing nutrients for plants to grow and habitat for loads of micro/macro-organisms. Active soil aids vegetation to grow or thrive, discharges oxygen, retains water, decreases catastrophic storm overflow, disintegrates waste residues, coheres and disintegrates pollutants, and acts as the first process in the broad food chain. Awareness of the conditions of a forest, at

temporal and spatial scales, is foundational for planning and management of forest habitats in a logical way for momentary and protracted goals; with sustainability ratiocination.
Forest inventory is the methodical or organized cumulating of data and forest statistics for evaluation. Precise, advanced awareness concerning the composition, distribution as well and condition of our forests is pivotal for advancing and monitoring blueprints and counsel to shore their sustainable management. To congregate these statistics and keep them current for managing forests, it is imperative to conduct a periodical inventory of forests. A forest inventory doesn't just document the trees' growth parameters even incorporates the state of the forest like geology, site and soil conditions, tree health as well as other tree components. Forest inventory encapsulates a high-priority tool in forest management; it supplies the statistics for planning, monitoring, evaluation, research, growth, and yield. It is an endeavor to delineate quantity, quality, and stocking densities (diameter distributions) of forest trees and diverse features of soil whereupon trees are thriving as regards the methodical and sustainable managing of the forest ecosystem. Inventory is riveted on forest management. Beyond forest inventory, forest managing wouldn't be sustainable as there wouldn't be adequate statistics for designing organization, and execution. Sustainable forest management has turned out to be a concern for decades amid issues of the duality of excessive utilization of the resource, as well as potential climate change impacts. Sustainable forestry comprises several management schemes to support and intensify the continuing healthiness and wholeness of forest ecosystems and forest-reliance populace, whilst supplying ecological, economic, social, and cultural opportunism for the well-being of current and next generations. Utmost assets and gains from forests could be attained if the subsisting forests are effectively managed. Distinct from the paramount difficulties of sustainable forest managing is the dearth of requisite statistics on the copious facets of forestry, on where to build forethought for sustainable development. As a consequence, sustainability in forest management can solely be executed if forest managers possess the requisite in addition to upgraded data encircling the forest stocks, soil properties, and other site conditions. Such statistics is principally procured via forest inventories. Forest inventories are a fundamental tool for orienting sustainable management and are built upon ecological postulates and the conservation of the forest. From the foregoing, since no literature abounds on extensive forest inventories of stand structure and soil physicochemical properties in Cross River State, Nigeria, our study bridges this gap and provides basic forest statistics of stand structure and soil physicochemical properties in twenty-two forests across Northern, Central, and Southern Cross River State, Nigeria. Knowledge of the stand structure and physicochemical properties of forest soils will make available to conservationists, ecologists, and forest managers the foundational ecological data necessary for sustainable forest management in Cross River State, Nigeria.

Materials and methods

Study area

The study was carried out in twenty-two communities, selected based on their forested areas located in the northern, central, and southern zones of Cross River State, Nigeria (Figure 1). The survey to provide field data was conducted between April 2019 and October 2020. The coordinates of sampling locations in the study area are presented in (Table 1). The northern zone is part of the Tropical Dry Forest/Guinean Savannah agro-ecological zone of Nigeria and lies between latitude 6.6659716 and 6.654837˚N and longitude 8.7945557 and 8.797694˚E. The topography ranges from less than 80 to 140 m above sea level (excluding the Obudu plateau (1,700 m) altitude with threesome soil types, i.e.; clay, silt, and sand (NIMET, 2015). The area has a yearly rainfall of 1,250-1,300 mm, an average yearly temperature of 30˚C, as well as a dry period of 3 to 5 months (NIMET, 2015). The central zone falls within the tropical high forest agroecological zone of Nigeria and lies between Latitude 6.268036 and 6.2467˚N and Longitude 9.029084 and 9.9245˚E. The terrain or forest landform in this zone is exceptionally compounded with several linked mountain arrangements, outlying summits, and crops, with elevation stretching at intervals 200 m - 1300 m altitude and fast-moving streams (Nsor , 2004). Soils range from clay loam to loam and are generally red with high iron oxide content (Agbor, 2003). Yearly rainfall spans between 3, 000 mm - 3, 800 mm (Agbor, 2003), mean yearly temperature of 22.2˚C - 27.4˚C and with mean annual relative humidity of 78% (Agbor, 2003). The southern zone belongs to the tropical high forest belt agroecological zone of Nigeria and lies at Latitude 5.389646/5.3190˚N and Longitude 8.544654/8.3499˚E. The vegetation is mostly lowland rainforest with rough terrain and altitude surges through the river basins to above 1, 000 mm in steep areas (Jimoh *et al.,* 2012). Lesser sandy soils are located in igneous areas, while the plains are dominated by deeper soils, while on hilly or elevated slopes they become progressively pebble, facile, and corroded (Ogunjobi *et al.,* 2010). The zone has rains of not less than nine months (March – November) and receives more than 3,800 mm of rain per year (Ogunjobi *et al.,* 2010). The temperature range is 25°C - 27°C, sometimes a bit more than 30°C. Relative humidity ranges from 75 - 95%, but gradually decreases due to the dry season (Bisong & Mfon, 2006). The flora of the zone is a combination of mangroves, tropical forests, and savannahs. Tropical forests are also divided into lowland tropical forests and freshwater marshes.

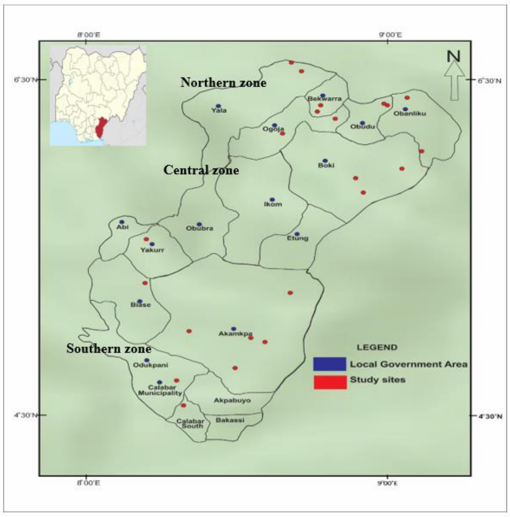

Figure 1. Cross River State map indicating study sites

Table 1. Coordinates of study sampling locations, Cross River State, Nigeria

S/N	Sampling locations	Latitude (˚N)	Longitude (˚E)
	NORTHERN ZONE		
	OGOJA	6.6659716/6.654837	8.7945557/8.797694
1.	Winniba-Ekajuk	6.4858898/6.870621	8.7166204/8.947166
2.	Aragban	6.5704818/6.657341	8.9457893/8.973452
	YALA	6.7791710/6.53995	8.6709595/101.28128
3.	Gabu	6.8879176/6.8593	8.7557602/8.7552
4.	Aliforkpa	6.8425784/6.953885	8.7986755/8.807544
	BEKWARRA	6.7378324/6.6485802	8.9249325/8.8821030
5.	Ukpah	6.6485802/6.7374701	8.8821030/8.973120
6.	Afrike	6.6097031/6.718020	8.8694000/8.962134
	OBUDU	6.6843853/6.6499442	9.1667175/9.1711807
7.	Bebuabong	6.6499442/6.6571054	9.1711807/9.195665
8.	Alege	6.6571054/6.660432	9.1566753/9.245652
	OBANLIKU	6.5391026/6.628104	9.1653442/9.356413
9.	Sankwala	6.5964023/6.6126019	9.2518616/9.3323708
10.	Becheve	6.383763/6.5964023	9.318852/9.2518616
	CENTRAL ZONE		
	BOKI	6.268036/6.2467	9.029084/9.9245
11.	Buanchor	6.6127724/6.3303	9.0889549/9.0071
12.	Okwangwo	6.2833333/6.31667	9.23333333/9.21667
13.	Mbe	6.25/6.2212	9.03333/9.0678
	YAKURR	5.817609/5.7973	8.77906/8.1776
14.	Agoi Ibami	5.7238/5.7269	8.176/8.1748
	BIASE	5.57751/5.5483	8.12291/8.0902
15.	Abini	5.548807/5.6919	8.105057/8.0656
	SOUTHERN ZONE		
	AKAMKPA	5.389646/5.3190	8.544654/8.3499
16.	Nsan	5.580532/5.3501	8.748117/8.3936
17.	Oban	5.3192/5.2231	8.5795/8.5529
18.	Aningeje	5.1426/5.310979	8.5101/8.349917
19.	Ekuri	5.8847222/5.398732	8.1208333/8.106204
20.	Ekong-Anaku	5.290683/5.3161395	8.638418/8.769783
	CALABAR MUNICIPALITY	4.9796/5.1066	8.33736/8.3636
21.	Adiabo	5.069783/5.0384	8.253782/8.2760
	CALABAR SOUTH	4.863733/4.8627	8.3245628.3307
22.	Idim Ita	4.84026/4.9321	8.26988/8.3335

Source: Field data (April 2019 – October 2020)

Forest inventory of stand structure

Our study employed the systematic sampling method to survey the stand structure of forest tree species. In each forest, we set up three 500m × 500m plots outlined in a spoke pattern (Herrick *et al.*, 2005). All plots were surveyed and the tree species present were identified and recorded. This was augmented by the use of line transects in areas of challenging or intractable topography. Our assessment comprised listing and taking account of all free stationed trees of 10 cm and above diameter at breast height (dbh) in each plot. Forest tree species were identified using the works of Hutchinson and Dalziel (1972) and authenticated by a plant taxonomist. The dbh at a value of ≥ 10 cm and above was considered at 1.4-1.5m from the forest floor. Stand height was measured using a Nikon Forestry Pro Rangefinder (USA), while dbh was measured using a Diameter tape and documented following the method of Avery and Burkhart (2002). An aggregate of 646, 407 and 474 stands were sampled in the northern, central and southern zones of Cross River State, respectively. A total number of 1527 stands were assessed in the study area. Class intervals, stand height and diameter were used to evaluate the ratio of mature to younger trees. The stem diameter of the trees was distributed into ten class intervals; 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm and 100 cm and above while that of height was classified into three intervals; 10-20 m, 20-30 m and 30 m and above. Distribution of the diameter class sizes and height of tree species in each study zone/Cross River State was calculated as; Number of trees in class interval × 100/Total number of trees in population/1 and analysed using OriginPro software ver. 2021.

Forest inventory of soil physicochemical properties

Soil parameters were evaluated from ten soil samples collected randomly in each of the surveyed plots in the twenty-two forest areas (north, central and south) of Cross River State. We took soil samples with a soil drill (auger) at a root depth of 15 - 50 cm during the rainy season (April - October), packed in polyethylene bags and studied at the soil science laboratory, Department of Soil Science, University Calabar, Calabar, Cross State River, Nigeria for soil physicochemical components. Twenty-three soil components were studied. Soil texture was ascertained by Bouyoucous hydrometer method (Bouyoucous, 1951). Soil pH was calculated in a 1:1 soil-water scale utilizing a digitized pH meter (EDT-BA350). Organic matter was determined by the wet oxidation of dichromate as proposed by Nelson & Sommer (1996). Total N (Nitrogen) by the micro-Kjeldahl method (Jackson, 1965). Available Phosphorus by Bray P-1 method (Bray & Kurtz, 1945). Soil trace elements such as zinc (Zn), lead (Pb), manganese (Mn), iron (Fe) etc. were analyzed using WD-XRF method (Beckhoff *et al.,* 2007). Conductivity was calculated in the extract obtained from soil 1:2.5: water suspension using conductive bridges. Exchangeable cations (Ca2+, Mg2+, K^+ and Na^+) were isolated using 1N ammonium acetate (NH4OAc) absorbed at pH 7.0 (Thomas, 1996). Exchangeable potassium (K) and Sodium (Na) via a flame photometer (Jenway PFP7). Ca and Mg were explored using an Atomic Absorption Spectrophotometer. Exchange acidity was determined with I N KCl and calibrated by titrating with 0.05 N NaOH utilizing a phenolphthalein indicator (McClean, 1982). ECEC was gotten by summing of exchangeable cations and percent Base saturation calculated as Exchangeable Bases x 100/ECEC × 1

RESULTS

Stand structure

Results of the stand diameter class sizes recorded in the various zones; (North, Central and South) of the study area are presented in Figures 2, 4 and 6 with a summary of the stand diameter class sizes recorded in the study area in Figure 8. The results of the stand height classes measured in the different zones (North, Central and South) are presented in Figures 3, 5 and 7 with a summary of the stand height measured in the study area presented in Figure 9.

In the Northern Zone (Gabu, Aliforkpa, Winniba-Ekajuk, Aragban, Ukpah, Okpeche-Afrike 1, Alege/Utugwang, Bebuabong/Ohong, Becheve and Sankwala) of Cross River State, out of the 646 stands measured in the zone, 147 stands were in the 30-40 cm diameter class and accounted for 22.76% of the overall trees measured. One hundred and ten (110) stands were in the 40-50 cm diameter class which accounted for 17.02% of the overall tree population. The 20-30 cm diameter class had 106 stands (16.41%), 100 cm and above cm diameter class had 103 stands (15.95%), 10-20 cm had 47 stands (7.28%), 60-70 cm had 45 stands (6.97%) and 50-60 cm had 41 stands (6.34% of the total stand population measured). In the uppermost diameter class 70-80 cm had 22 stands (3.40%). 80-90 cm had 14 stands (2.17%) while 90-100 cm had only 11 stands (1.70% of the total stand population in the zone) (Figure 2).

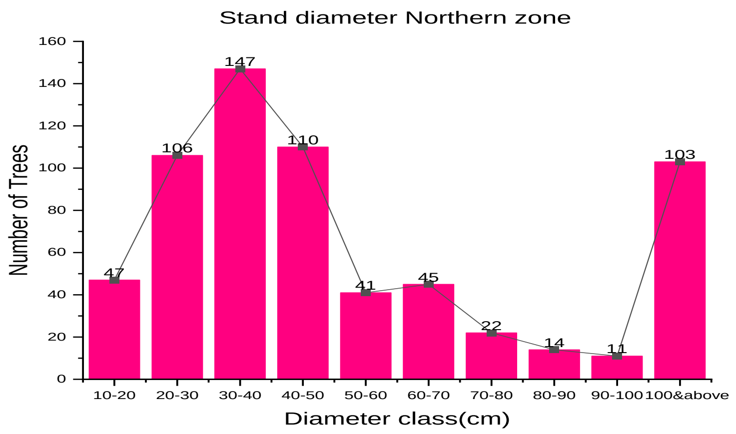

Fig. 2: Stand diameter in the Northern zone of Cross River State

Figure 3 shows the stand height classes measured in the Northern Zone (Gabu, Aliforkpa, Winniba-Ekajuk, Aragban, Ukpah, Okpeche-Afrike 1, Alege/ Utugwang, Bebuabong/Ohong, Becheve and Sankwala) of Cross River State. Of the 646 stands measured in the study zone, 426 were in the height class of 10-20 m making up 65.95% of the total stands measured. This was followed by the height class of 20-30 m with 123 stands accounting for 19.04% of the total number of stands in the zone. The height class of 30 m and above had the least stands of 97 making up 15.01% of the total stand population in the zone.

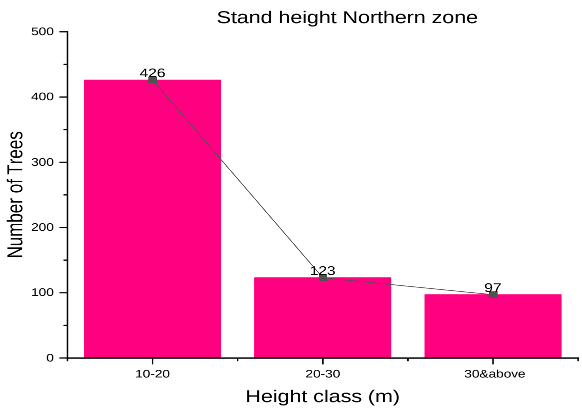

Fig. 3: Stand height in the Northern zone of Cross River State

Figure 4 shows the distribution of the stand diameter class sizes measured in the Central zone
(CRNP-Okwangwo, Mbe, Afi and Agoi) of Cross River State. Of the 407 stands measured in the study zone, 103 stands were in the diameter class of 100 cm and above accounting for 25.30% of the overall trees measured. This was followed by the diameter class of 20-30 cm with 60 stands accounting for 14.74% of the overall stand population. The diameter class of 60-70 cm had 45 stands (11.05%), 40 -5 0 cm had 44 stands (10.81%), 30-40 cm had 39 stands (9.59%), 70-80 cm had 30 stands (7.38%), 50-60 and 80-90 cm had 28 stands each accounting for 6.88% of the total stand population measured. The diameter class of 90-100 cm had 20 stands (4.91%) while the diameter class of 10-20 cm had the least stands making up 2.46% of the total stand population in the zone.

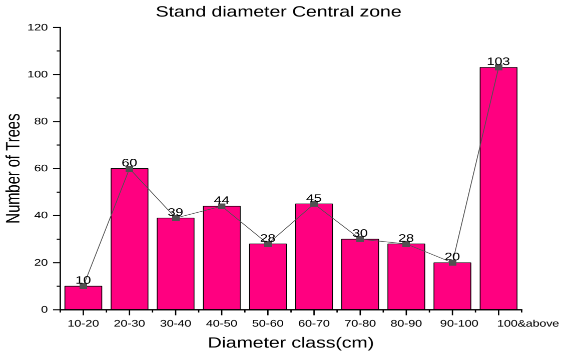

Fig. 4: Stand diameter in the Central zone of Cross River State

Figure 5 shows the stand height classes measured in the Central zone (CRNP – Okwangwo, Mbe, Afi and Agoi) of Cross River State. Of the 407 stands measured, 179 were in the height class of 10-20 m making up 43.99% of the total stands measured. This was followed by the height class of 30 m and above with 117 stands accounting for 28.74% of the total number of stands in the zone. The height class of 20-30 m had the least stands of 111 making up 27.27% of the total stand population in the zone.

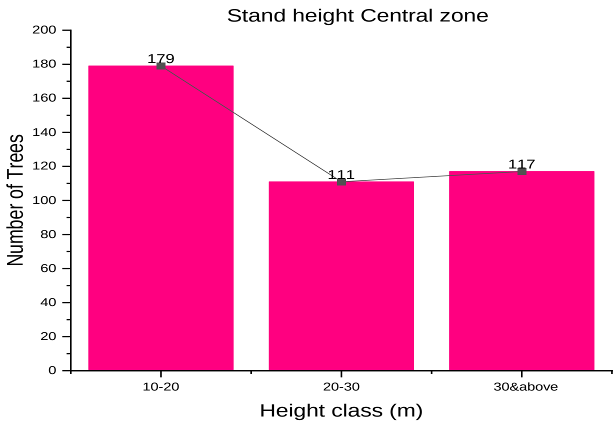

Fig. 5: Stand height in the Central zone of Cross River State

Figure 6 shows the distribution of the stand diameter class sizes measured in the Southern zone (CRNP-Oban, Oban, Kwa Falls, Ekuri, Ekong-Anaku, Adiabo and Idim Ita) of Cross River State. Of the 474 stands measured in the study zone, 90 stands were in the diameter class of 100 cm and above accounting for 18.99% of the overall stands measured. This was followed by the diameter class of 40-50 cm with 64 stands accounting for 13.50% of the overall stand population. The diameter class of 30-40 cm had 62 stands (13.08%), 20-30 cm had 56 stands (11.81%), 60-70 cm had 45 stands (9.50%), 50-60 cm had 42 stands (8.86%), 70-80 cm had 38 stands (8.01%) and 10-20 cm had 31 stands accounting for 6.54% of the total stand population measured. The diameter class of 80-90 cm had 29 stands (6.12%) while the diameter class of 90-100 cm had the least stands of 17 making up 3.59% of the total stand population in the zone.

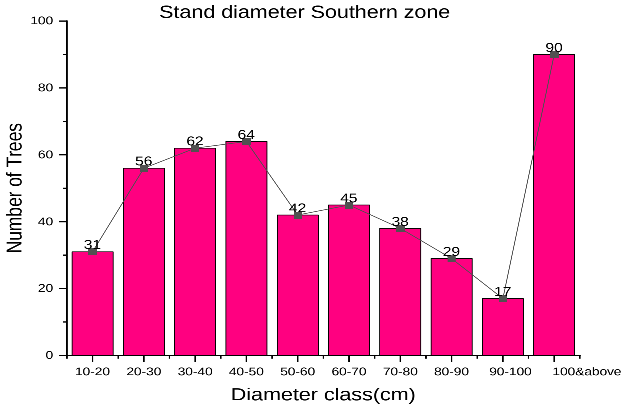

Fig. 6: Stand diameter in the Southern zone of Cross River State

Figure 7 shows the stand height classes measured in the Southern zone (CRNP-Oban, Oban, Kwa Falls, Ekuri, Ekong-Anaku, Adiabo and Idim Ita) of Cross River State. Of the 474 stands measured, 252 were in the height class of 10-20 m making up 53.16% of the total stands measured. This was followed by the height class of 20-30 m with 125 stands accounting for 26.37% of the total number of stands in the zone. The height class of 30 m and above had the least stands of 97 making up 20.47% of the total stand population in the zone.

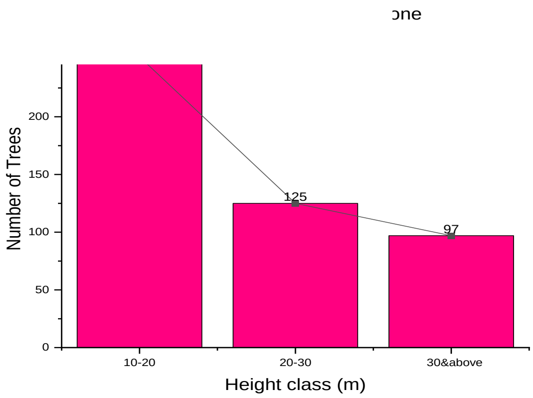

Figure 7. Stand height in the Southern zone of Cross River State

Figure 8 shows a summary of the distribution of the stand diameter class sizes measured in
Cross River State (Gabu, Aliforkpa, Winniba-Ekajuk, Aragban, Ukpah, Okpeche-Afrike 1, Alege/Utugwang, Bebuabong/Ohong, Becheve, Sankwala, CRNP-Okwangwo, Mbe, Afi, Agoi, CRNP-Oban, Oban, Kwa Falls, Ekuri, Ekong-Anaku, Adiabo and Idim Ita). Of the 1527 stands measured, 296 stands were in the diameter class of 100 cm and above accounting for 19.39% of the total stands measured. This was followed by the diameter class of 30 - 40 cm with 248 stands accounting for 16.24% of the overall stand population. The diameter class of 20-30 cm had 222 stands (14.54%), 40-50 cm had 218 stands (14.27%), 60-70 cm had 135 stands (8.84%), 50-60 cm had 111 stands (7.28%) and 70-80 cm had 90 stands accounting for 5.90% of the total stand population measured. The diameter class of 10-20 cm had 88 stands (5.76%), 80-90 cm had 71 stands (4.64%) while the stem diameter class of 90-100 cm had the least stands of 48 making up 3.14% of the total stand population. Northern Cross River zone had stands with the highest number in the lower stand diameter class sizes (10-20 cm) while the central and southern zones had the highest number of stands in the higher stand diameter class sizes. Results of the stand diameter class sizes measured in Cross River State showed that there were more stands in the higher stand diameter classes compared to those in the lower stand diameter classes.

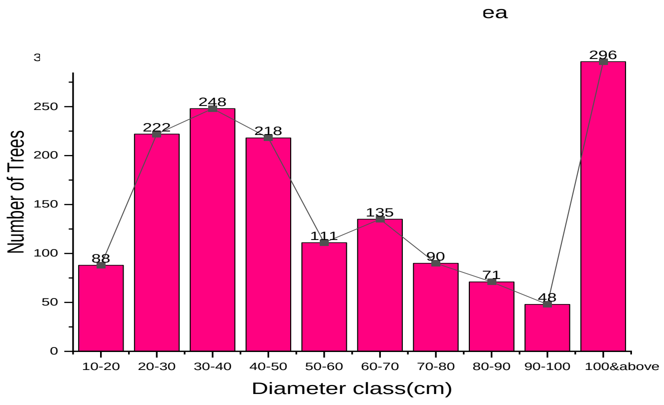

Figure 8. Summary of stand diameter in Cross River State

Figure 9 shows a summary of the stand height classes measured in Cross River State (Gabu, Aliforkpa, Winniba-Ekajuk, Aragban, Ukpah, Okpeche-Afrike 1, Alege/Utugwang, Bebuabong/Ohong, Becheve, Sankwala, CRNP-Okwangwo, Mbe, Afi, Agoi, CRNP-Oban, Oban, Kwa Falls, Ekuri, Ekong-Anaku, Adiabo and Idim Ita). Of the 1527 stands measured for height in Cross River State, 857 were in the height class of 10-20 m making up 56.12% of the total stands measured. This was followed by the height class of 20-30 m with 359 stands accounting for 23.51% of the total number of stands in the study area. The height class of 30 m and above had the least stands of 311 making up 20.37% of the total stand population in Cross River State. Results of height classes showed that there were more stands in the lower height class of 10-20 m in the Northern, Central and Southern geographical zones of Cross River State than in the higher height classes of 20-30 m and 30 m and above.

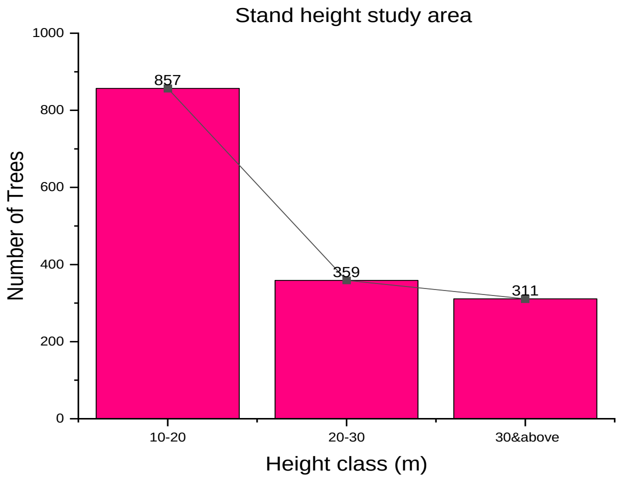

Figure 9. Summary of stand height in Cross River State

Soil physicochemical properties

The results of physicochemical properties of forest soils obtained at a depth of 15-50 cm from the twenty-two sampling locations comprising the northern, central and southern zones of Cross River State are presented in Table 2. In the northern zone, the soil properties

Table 2. Physicochemical properties of forest soils in the Northern, Central and Southern zones of Cross River State

S/N	Study locations	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	TC	pH	OC (%)	OM (%)	TN (%)	AVP mg/kg	Ca cmol/kg	Mg	Na	K	H	B	Mn	Zn	Pb	Fe	Si	EC cmol/kg	EA	CEC	BS (%)
1.	GCF (North)	15-50	20.0	39.0	25.0	CL	5.90	4.07	0.33	0.56	9.20	0.06	12.0	0.39	0.09	9.20	0.82	13.64	10.47	12.97	19.43	2.61	1.36	0.46	17.30	61.09
2.	AlCF (North)	15-50	38.0	13.0	22.0	SCL	4.7	6.2	4.29	0.42	3.73	0.06	6.6	0.2	0.04	12.0	0.74	10.98	12.3	11.42	17.22	1.89	1.44	0.53	11.2	91.07
3.	WECF (North)	15-50	25.0	33.1	27.8	CL	4.6	4.8	8.06	0.18	7.46	0.1	7.01	0.08	0.1	39.2	1.6	11.19	10.24	12.45	19.72	1.09	1.2	0.48	7.0	20.2
4.	ArCF (North)	15-50	50.05	35.0	25.6	L	5.2	4.0	4.29	0.04	9.33	0.09	0.23	0.59	0.06	14.8	0.64	13.49	13.2	10.98	18.41	1.2	1.01	0.07	8.8	39.14
5.	UCF (North)	15-50	41.01	19.0	36.0	SCL	5.3	4.5	1.06	0.84	5.6	0.52	5.0	0.43	0.32	0.08	0.99	9.76	11.5	11.62	15.91	2.4	1.57	0.6	5.0	90.18
6.	OACF (North)	15-50	31.0	33.0	29.0	CL	5.1	3.4	0.79	0.7	4.66	0.28	3.6	0.26	3.6	0.8	0.85	10.28	9.72	9.45	12.39	2.1	1.86	0.8	13.2	88.47
7.	AUC (North)	15-50	37.0	29.0	26.0	L	4.5	5.3	1.12	0.42	5.6	0.04	2.6	0.34	0.04	0.46	0.97	9.54	10.22	8.26	10.95	1.91	1.2	0.4	2.6	74.94
8.	BOC (North)	15-50	39.0	25.0	22.0	SCL	4.4	5.5	0.73	0.84	7.46	0.08	1.62	0.25	0.07	0.4	0.62	12.91	12.46	12.47	16.26	2.84	1.6	1.2	5.25	48.82
9.	BFR (North)	15-50	37.9	29.0	26.0	L	4.9	5.5	0.73	0.08	11.19	0.25	3.2	0.28	0.05	0.8	0.95	16.34	15.78	13.32	19.66	2.9	2.25	0.79	10.8	63.02
10.	SCF (North)	15-50	30.0	35.0	32.0	CL	5.5	3.5	0.65	0.56	7.26	0.17	2.8	0.24	0.17	1.0	0.77	14.21	14.83	12.68	18.77	2.64	2.18	0.88	10.4	82.17
11.	CRNPOk (Central)	15-50	96.82	19.5	26.8	SCL	4.64	1.76	3.95	0.32	6.51	3.7	1.59	4.97	3.81	0.74	0.80	18.62	15.1	14.1	23.2	1.91	2.92	0.52	7.61	90.91
12.	MMCF (Central)	15-50	53.0	19.2	30.4	CL	5.9	4.82	2.88	0.09	1.68	4.0	1.42	0.05	0.14	0.98	0.77	20.0	13.47	9.44	20.52	2.12	1.68	1.03	5.8	82.24
13.	AMWS (Central)	15-50	50.52	15.8	44.0	SCL	5.3	4.55	3.76	0.1	7.34	4.8	1.7	0.06	0.13	0.86	0.51	15.2	15.86	13.21	16.84	1.65	2.49	0.81	9.84	79.65
14.	AFR Agoi Ibami/	15-50	70.12	20.4	22.0	SL	4.8	5.6	2.71	0.14	6.04	1.95	0.47	3.68	2.98	0.31	0.96	14.54	12.32	10.63	18.73	2.2	2.26	0.74	8.73	23.8
15	AFR Abini (Central)	15-50	57.3	30.1	27.82	SL	4.9	1.96	3.44	0.26	3.25	0.76	0.33	1.62	0.12	0.55	0.74	12.31	14.45	11.48	17.37	1.79	2.88	0.66	8.94	25.53
16.	CRNPOb (South)	15-50	68.3	28.7	4.0	SL	7.91	1.27	2.19	0.1	8.37	8.0	0.5	0.09	0.14	0.68	1.42	10.67	10.88	15.6	20.2	2.24	1.67	1.89	8.6	82.0
17.	OFR (South)	15-50	65.2	25.8	11.0	SL	8.0	0.67	1.18	0.07	4.39	7.9	0.9	0.08	0.11	0.96	0.63	9.21	10.16	17.7	19.4	1.86	2.42	2.07	8.8	89.0
18.	KF (South)	15-50	64.4	26.9	11.14	SL	8.0	0.88	1.54	0.02	13.45	7.5	0.53	0.1	0.13	0.77	0.86	8.65	17.63	15.45	15.94	2.32	1.99	1.08	8.03	81.0
19.	EkCF (South)	15-50	73.5	24.3	4.16	SL	8.0	0.91	0.67	0.08	2.39	8.42	6.68	0.07	0.12	0.45	0.97	12.7	14.81	12.1	13.61	1.99	2.02	2.01	9.31	74.0
20.	EACF (South)	15-50	59.4	22.6	18.0	CL	7.99	0.39	0.49	0.08	3.87	6.72	1.8	0.19	0.11	0.81	0.55	18.32	15.55	11.43	14.72	2.08	2.04	2.61	7.4	85.01
21.	AC (South)	15-50	46.5	14.7	42.0	CL	7.88	0.27	2.26	0.07	2.04	10.7	0.6	0.18	0.38	0.34	0.68	7.89	11.88	18.91	11.22	2.04	1.97	1.93	11.7	79.0
22.	IIC (South)	15-50	45.8	13.9	49.7	SL	7.97	0.75	1.39	0.06	2.38	5.8	0.95	0.06	0.14	0.92	0.49	10.23	13.24	16.24	16.58	2.1	1.44	1.06	7.38	87.0

Note: TC (Textural class), OC (Organic carbon), OM (Organic matter), TN (Total nitrogen), AVP (Available phosphorus), EC (Electrical conductivity), EA (Exchangeable acidity), CEC (Cation exchange capacity), BS (Base saturation), CL (Clay loam), SCL (Sandy clay loam), L (Loam), SL (Sandy loam), GCF - Gabu Community Forest, AlCF - Aliforkpa Community Forest, WECF - Winniba-Ekajuk Community Forest, ArCF - Aragban Community Forest, OACF -Okpeche-Afrike 1 Community Forest, UCF - Ukpah Community Forest, AUC - Alege/Utugwang Community, BOC - Bebuabong/Ohong Community, BFR - Becheve Forest Reserve, SCF - Sankwala Community Forest, CRNPOk - Cross River National Park, Okwangwo Division MMCF - Mbe Mountain Community Forest, AMWS - Afi Mountain Wildlife Sanctuary, AFR - Agoi Forest Reserve (Agoi Ibami/Abini sections), CRNPOb - Cross River National Park, Oban Division, OFR - Oban Forest Reserve, KF - Kwa Falls, Aningeje, EkCF - Ekuri Community Forest, EACF - Ekong – Anaku Community Forest, AC - Adiabo Community, IIC - Idim Ita Community showed that across the zone at a depth of 15-50 cm sand fractions ranged between 20.0 (Gabu community forest) and 50.05% (Aragban community forest). The silt fractions of the soil ranged between 13.0 (Aliforkpa community forest) and 39.01% (Gabu community forest) while the clay fraction ranged between 22.0 (Bebuabong/Ohong community) and 39.0% (Ukpah community forest). For soil chemical properties, the pH of the soil ranged from 4.4 (Bebuabong/Ohong community) to 5.9 (Gabu community forest). The soil pH values indicate that the soils in the northern zone are mostly acidic soils. The soil organic carbon content ranged between 3.4 (Okpeche-Afrike community forest) and 6.2% (Aliforkpa community forest), organic material ranged between 0.33 (Gabu community forest) to 8.06% (Winniba-Ekajuk community forest), Total Nitrogen ranged between 0.04 (Aragban community forest) to 0.84% (Ukpah community forest and Bebuabong/Ohong community), available phosphorus content ranged between 3.73 (Aliforkpa community forest) and 11.19mg/kg (Becheve forest Reserve). Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Hydrogen ion (H^+), Boron (B), Manganese (Mn), Zinc (Zn), Lead (Pb), Iron (Fe), Silicon (Si), Exchangeable cation (EC), Exchangeable acidity (EA), Cation exchangeable capacity (CEC) and Base saturation (BS) ranged between 0.06 (Gabu community forest) and 0.52mg/kg (Ukpah community forest), 0.23 (Aragban community forest) and 7.01mg/kg (Winniba-Ekajuk community forest), 0.08 (Winniba-Ekajuk community forest) and 0.59mg/kg (Aragban community forest), 0.04 (Aliforkpa community forest) and 3.6cmol/kg (Okpeche-Afrike community forest), 0.4 (Aliforkpa community forest) and 39.2cmol/kg (Winniba-Ekajuk community forest), 0.62 (Bebuabong/Ohong community) and 1.6cmol/kg (Winniba-Ekajuk community forest), 9.54 (Alege/Utugwang community) and 16.34cmol/kg (Becheve forest reserve), 9.72 (Okpeche-Afrike community forest) and 15.78cmol/kg (Becheve forest reserve), 8.26 (Alege/Utugwang community) and 13.32cmol/kg (Becheve forest reserve), 10.95 (Alege/Uugwang community) and 19.66cmol/kg (Becheve forest reserve), 1.09 (Winniba-Ekajuk community forest) and 2.84cmol/kg (Becheve forest reserve), 1.01 (Aragban community forest) to 2.25cmol/kg (Becheve forest reserve), 0.07 (Aragban community forest) and 1.2cmol/kg (Bebuabong/Ohong community), 2.6 (Alege/Utugwang community) and 17.30cmol/kg (Gabu community forest), 20.2 (Winniba-Ekajuk community forest) and 90.18% (Ukpah community forest), respectively.

In the central zone, at a depth of 15-50 cm sand fraction ranged between 57.3 (Agoi forest reserve (Abini) to 96.82% (Cross River National Park, Okwangwo), silt fraction between 15.8 (Afi mountain wildlife sanctuary) and 30.1% (Agoi forest reserve (Abini) while clay fraction ranged between 22.0 (Agoi forest reserve (Agoi-Ibami) and 44.0% (Afi mountain wildlife sanctuary). For soil chemical properties, soil pH ranged from 4.64 (Cross River National Park, Okwangwo) to 5.9 (Mbe mountain community forest). Based on the soil pH, the soils of the central zone are also mostly acidic soils. Organic carbon ranged between 1.76 (Cross River National Park, Okwangwo) and 5.6% (Agoi forest reserve (Agoi-Ibami), Organic matter ranged between 1.68 (Mbe mountain community forest) and 5.6% (Agoi forest reserve (Agoi-Ibami), Total Nitrogen ranged between 0.09 (Afi mountain wildlife sanctuary) to 0.32% (Cross River National Park, Okwangwo), Available phosphorus between 1.68 (Mbe mountain community forest) to 7.34% (Afi mountain wildlife sanctuary). Other soil parameters such as Ca, Mg, Na, K, H, B, Mn, Zn, Pb, Fe, Si, EC, EA, CEC and BS ranged between 0.76 (Agoi forest reserve (Abini) and 4.8mg/kg (Afi mountain wildlife sanctuary), 0.33 Agoi forest reserve (Abini) and 1.75cmol/kg (Afi mountain wildlife sanctuary), 0.05 (Afi mountain wildlife sanctuary) and 4.97cmol/kg (Cross River National Park, Okwangwo), 0.13 (Afi mountain wildlife sanctuary) and 3.81cmol/kg (Cross River National Park, Okwangwo), 0.31(Agoi forest reserve (Agoi-Ibami) to 0.98cmol/kg (Mbe mountain community forest), 0.51(Afi mountain wildlife sanctuary) and 0.96cmol/kg (Agoi forest reserve (Agoi-Ibami), 14.54 (Agoi forest reserve (Agoi-Ibami) to 20.0cmol/kg (Mbe mountain community forest), 12.32 (Agoi forest reserve) and 15.86cmol/kg (Afi mountain wildlife sanctuary), 9.44 (Mbe mountain community forest) and 14.1cmol/kg (Cross River National Park, Okwangwo), 16.84 (Afi mountain wildlife sanctuary) and 23.2cmol/kg (Cross River National Park, Okwangwo), 1.65 (Afi mountain wildlife sanctuary) and 2.12cmol/kg (Mbe mountain community forest), 1.68 (Mbe mountain community forest) and 2.92cmol/kg (Cross River National Park, Okwangwo), 5.8 (Mbe mountain community forest) and 9.84cmol/kg (Afi mountain wildlife sanctuary) and 23.8 (Agoi forest reserve (Agoi-Ibami), 90.91% (Cross River National Park, Okwangwo), respectively.

In the southern zone, at a depth of 15-50 cm sand fraction ranged from 45.8 (Idim Ita community) to 73.5% (Ekuri community forest), Silt ranged from 13.9 (Idim Ita community) to 28.7% (Cross River National Park, Oban) while clay fraction ranged from 4.0 (Cross River National Park, Oban) to 49.7% (Idim Ita community). For soil chemical properties, soil pH value ranged from 7.91(Cross River National Park, Oban) to 8.0 (Oban forest reserve, Kwa Falls and Ekuri community forest). The soils in the south are therefore mostly alkaline soils. Organic carbon ranged from 0.27(Adiabo community) to 1.27% (Cross River National Park, Oban), organic matter ranged from 0.49 (Ekong Anaku community forest) to 2.26% (Adiabo community), Total Nitrogen ranged from 0.02 (Kwa Falls) to 0.1% (Cross River National Park, Oban), Available phosphorus ranged from 2.04 (Adibo community) to 13.45% (Kwa Falls). Other soil parameters such as Ca, Mg, Na, K, H, B, Mn, Zn, Pb, Fe, Si, EC, EA, CEC and BS ranged from 5.8 (Idim Ita community) to 10.7mg/kg (Adiabo community), 0.5 (Cross river National Park, Oban) to 6.68mg/kg (Ekuri community forest), 0.06 (Idim Ita community) to 0.19mg/kg (Ekong Anaku community forest), 0.11 (Oban forest reserve and Ekong Anaku community forest) to 0.38mg/kg (Adiabo community). 0.34 (Adiabo community) to 0.96cmol/kg (Oban forest reserve), 0.49 (Idim Ita community) to 1.42cmol/kg (Cross River National Park, Oban), 7.89 (Adiabo community) to 18.32cmol/kg (Ekong Anaku community forest), 10.16 (Oban forest reserve) to 17.63cmol/kg (Kwa Falls), 11.43 (Ekong anaku community forest) to 18.91cmol/kg (Adiabo community), 13.61 (Ekuri community forest) to 19.4cmol/kg (Oban forest reserve). 1.86 (Oban forest reserve) to 2.32cmol/kg (Kwa Falls), 1.44 (Idim Ita community) to 2.04cmol/kg (Ekong Anaku community forest), 1.06 (Idinm Ita community) to 2.61cmol/kg (Ekong Anaku community forest), 7.38 (Idim Ita community) to 11.7cmol/kg (Adiabo community) and 74 (Ekuri community forest) to 89.0% (Oban forest reserve), respectively.

Discussion

Stand structure

Results of stand structure in the northern zone showed that there were greater numbers of stands in the lower diameter classes (Figure 2). For height, there were a higher number of stands in the lower height class (Figure 3). The rationale for the high number of stands in the lower diameter classes in the zone may be due to anthropogenic factors such as logging which may have removed older trees for timber and other uses. A similar finding was reported by Ogunjemite (2015) and Naidu and Kumar (2016) in Ologbo forest, Edo State, Nigeria and a tropical forest in Eastern Ghats, India, respectively. Also, the high number of stands in the lower diameter classes may imply that the forests in the zone has regressed to aggradation and equitably unstable phase of the forests life process consequently is oftentimes distinguished by greater abundance of trees with smaller diameter. Related findings were recorded by researchers in other forests of Nigeria (Adekunle *et al.,* 2004; Adekunle & Olagoke, 2008) and distant tropical regions (Boulbi *et al.,* 2004; Bobo *et al.*, 2006). The ratio (15.95 and 15.01%) recorded for stands in the diameter class of 100 cm and above and height class of 30 m and above respectively, in the study zone was mostly recorded for tree species in the Becheve Forest Reserve. The indicated is to be envisioned considering the locality is under preservation by law, with lowest human interference and conjointly greater yearly precipitation rate and regular semi temperate climate of the locality could have leaded to high tree growth rates. This finding corroborates that of Aigbe and Omokhua (2015) in Oban Forest Reserve, Nigeria. The high number of stands in the height class of 10-20 m (65.95%) in the zone corresponds with the high number of trees in the lower diameter classes. This confirms that established large stands may have been thus far lessened by indiscriminate removal for certain utilizations previously (Hadi *et al.,* 2009). Results of stand structure in the central zone of the study area showed that there were a greater number of stands for higher diameter classes with 25.30% of stands falling between 100 cm and above (Figure 4). There was lesser number of stands in the lower diameter classes. For height, the number of stands in the lower height classes was greater. However, those of the upper height class had a good representation (Figure 5) in comparison to the northern zone (Figure 4). The greater number of stands in the higher diameter classes and height is expected as the zone is mostly made up of strictly conserved areas protected by law with zero tolerance for illegal logging. The greater number of stands in the higher diameter and height classes in the zone is also an indication of matured forests. Stephenson and Mantgem (2005) reported that full-grown forests are biota with a known potential to sustain both structure and floral diversity which is fixed over the years via the continuous and productive activity or change of mortality, reclamation and growth of plants. This full-grown stage is consisted of mature stands in diverse layers and a closed canopy (Saiter *et al.,* 2011). Results of stand structure in the southern zone of the study area showed that there were a greater number of stands of higher diameter classes. There was lesser number of stands in the lower diameter classes. For height, there were a higher number of stands in the lower height classes. The greater number of stands of the higher diameter stands in the zone is as expected since the zone is well protected from excessive timber operations. Similar findings were reported by Aigbe *et al.,* (2014) and Aigbe and Omokhua (2015) in Afi River Forest and Oban Forest Reserve, Nigeria, respectively. Also, high yearly rainfall and favorable tropical climate of the study zone might contribute to high tree growth rates. This observation is similar to the findings of Adekunle *et al.,* (2004) for a tropical rainforest in southwest Nigeria and Kumar *et al.,*

(2002) for other tropical forests of the globe. The diameter class sizes of stands recorded in the Northern, Central and Southern zones of Cross River State showed that majority of the stands were in the diameter class of 100 cm and above (19.39%). This finding is similar to that of Wending *et al.*, (2003) who observed trees with diameter class greater than 100 cm and above in a tropical forest in Tanzania. This result however, does not agree with that of Oduwaiye *et al.*, (2002) who reported greater number of stands in the lowest diameter class of less than 10 cm and 25-30 cm at the Okomu forest permanent sampled plots in Benin, Nigeria. Also, Oduwaiye and Ajibode (2005) gave an account of the greater number of stands for diameter class of 11-30 cm preceded by those in the middle of 0-10 cm at Onigambari Forest Reserve, Ibadan. Aigbe *et al.*, (2014) recorded the greater number of stands with lesser diameter in Afi Forest Reserve in Cross River State, Nigeria. Similar accounts have also been given by preceding researchers in other tropical rainforests of Nigeria (Adekunle *et al.*, 2004; Adekunle & Olagoke, 2008). The finding of this study also disagrees with that of Adekunle *et al.*, (2004) for some tropical rainforests in Southwest Nigeria and Kumar *et al.*, (2002) for other global tropical forest. The greater number of stands in the diameter class of 100 cm and above is to be anticipated since Cross River State has high number of protected areas or reserves and is under protection by decree, with less human disturbance and also the high yearly rainfall rate of the study area could have led to greater stand growth rates. In general, effective protection and managing schemes had notable impact on stand diversity and abundance, and thus, on forest growth and yield (Banda *et al.*, 2006; Munishi *et al.*, 2011). The height classes of stands recorded in the Northern, Central and Southern zones of Cross River State (Figure 9) shows trees with minimum and maximum height classes of 10-20 m (56.12%) and 30 m and above (20.37%), respectively. The rationale for the very poor no presence of stands in the higher height classes in the study area could be ascribed to forest degradation activities in communal forests which probably destroyed large individuals and the actuality that some massive trees of economic value may have been eliminated through selective logging activities (Hadi *et al.*, 2009). Aigbe *et al.*, (2014) reported the least and highest heights of stands at 2.7 m and 55.0 m, respectively and 12.0 m to 62.2 m, respectively in Afi Mountain Wildlife Sanctuary of Nigeria. However, Aigbe and Omokhua (2015) and Adekunle *et al.*, (2013) reported the minimum and maximum height of tree species of 20 m and 44 m and 20 m and above in Oban Forest Reserve, Cross River State, Nigeria and a Strict Nature Reserve in Southwest Nigeria, respectively, which is in agreement with the findings of this study. The 56.12% of the stands inhabiting the middle stratification (height class of 10-20 m) is peculiar to full-grown primary forests. Full-grown forests are biotas with a known capacity to support both structure and flora diversity which is fixed over time via the changing balance of death, recovery and thriving of flora (Stephenson & Van Mantgem, 2005). This full-grown stage is made up of matured stands in different strata with a closed canopy (Saiter *et al.*, 2011). In due course, as the matured stands perish or are broken, smashing the smaller stands nearby, gaps are formed and before long, these gaps are fill up with herbs, climbers and tree lets, for-which can emerge from uncovered roots and stumps or a bank of seeds and seedlings (Saiter *et al.*, 2011). The smaller diameter stands might as well grow into matured stands and substitute the aged ones over time if the current conservation endeavor is sustained in Cross River State. Stands in the study area were represented in all the diameter and height classes. This in general suggests that stands are thriving and restoration in the forests is in progress. Natural restoration is reliant on the availableness of the oldest trees in the forest, fruiting sequence and favorable conditions (Sanwo *et al.*, 2015). The existence of growth of the forest is designated by the upwards development of stands in differing or diverse diameter classes (Akinyemi *et al.*, 2012).

Soil physicochemical properties

The inventory on twenty three physicochemical properties of forests soils revealed varied presence of soil properties across forests in the northern, central and southern zones of the study area. In the northern zone, soil physical properties; sand, silt and clay ranged from 20.0 to 50.5%, 13.0 to 39.01% and 22.5 to 36.0% at a depth of 15-50 cm, analogous trends in the particle size sequence have been reported by Muoghalu and Awokunle (1994) in the Nigerian rainforest region and Chima (2007) in Omo biosphere reserve, Nigeria. Albeit there are contrasts amongst the forests, the variant in sand, silt and clay content across forests is moderate. The soil pH in the zone ranged from 4.4 to 5.9. The soils of the zone therefore are acidic in nature (Cyprian *et al.*, 2014). This lower value is expected as most soil in the tropics has their ranging from acidic to slightly neutral (Alloway & Aryes, 1997). Comparable tendencies has been observed in the study by Oyedele *et al.*, (2008). This might also be ascribed to the absorbing impact of soil organic matter in opposition to pH interchange in as well as the discharge of key cations in the course of organic matter putrefaction. Soil pH characterizes decisive variable that speedily impact sorption and desorption, dissolution, complex formation and redox (oxidation/reduction) reactions in soils. As detected by Mclean and Bledsoe (1992) the climax absorption of cationic metals transpire at pH >7 while anionic metals transpire at pH <7.

The lower pH value recorded in soils in the zone could be as a result of rainfall over the years (Grace *et al.,* 2013) which might have induced the extreme leaching of soluble bases translating into low pH examined in the soils. Related pattern have been observed by certain researchers (Onweremadu & Uhuegbu, 2007; Yasin *et al.,* 2010). The soils in the zone were observed to have high levels of trace elements such as manganese, zinc, iron and lead concentrations. Trace elements are very vital for growth of plants, enzyme production, hormone regulation, and protein synthesis. These elements are needed in very small quantities. Notwithstanding, when the concentration of such trace elements amplify it catalyze negative impacts on soil physical, chemical and biological properties (Venkatesan & Senthurpandian, 2006). The concentrations of these trace elements in soils might be correlated with biological and geochemical cycles. They are induced by human activities, like transport, waste disposal, industrialization, social, and agricultural activities have an influence on environmental pollution and the universal ecosystem (Wong *et al.,* 2002). These outcomes pilot a negative influence on human health and biodiversity. Despite the fact that trace elements are inherently bestowed in soil, contamination arises from local sources; mainly industry waste incineration, combustion of fossil fuels, irrigation with polluted waters, syntactic fertilizer, contaminated manure, and pesticide containing heavy metals (Fytianos *et al.,* 2001). The soils in the zone also showed reasonable levels of magnesium. Magnesium is the foremost nucleus of the chlorophyll molecule in plant tissue. Consequently, Magnesium is deficient; the paucity of chlorophyll culminates in poor and undersized growth. Magnesium additionally aids to trigger specified enzyme systems in plants (Daniel & Carl, 2016). In the central zone, soil physical properties; sand, silt and clay ranged from 57 to 96.82%, 15.8 to 30.1% and 22.0 to 44.1%. This high variant of sand particles in the zone is in all likelihood connected to local pedogenic components like modification in slope gradients specifically between undulant and steeply gradient slopes (Fasina, 2004). Soil pH in the zone ranged from 4.64 to 5.9. Soil was therefore acidic in the zone. This can be attributed to the leaching of the cations down the soil depth by rainfall (Wong *et al.,* 2005). The soils in the zone were also observed to be rich in manganese, zinc, lead and iron. Higher manganese, zinc, lead, and iron contents in the soil are an indicator of the increased decomposition of organic matter eventuating beneath regenerating canopy. Related findings have been recorded in the studies of Ola-Adams (1992) and Chima, (2007). In the southern zone, the proportion of sand, silt and clay ranged from 45.8 to 73.5%, 13.9 to 28.7% and 4.0 to 49.7%. The variation in physical properties in the zone could be ascribed to vegetation alteration which might have brought about the variants in particle size distribution (Chima, 2007). Soil pH in this zone was mainly alkaline ranging from 0.79 to 8.0. This perhaps maybe due to elevation/decline in rainfall, temperature, ensuing increase/decrease in CO_2 concentration, surge/descend in microbial activity and organic matter accumulation /decomposition in soils (Sivansan *et al.,* 1993). Calcium and magnesium decreased in the soil samples. This may be ascribed to the methodical restoration of nitrogen, phosphorus and basic cations at the soil surface through decomposition (Agoume & Birang, 2009; Dabin, 1984). Sodium content decreased, the agglomeration of this cation is presumably to increase pH (Muoghalu & Awokunle, 1994; Chima, 2007; Agoume & Birang 2009). Potassium content was naturally high. This could be connected to the leaching of the cations downwards the soil bed by rainfall (Wong *et al.*, 2005). It was detected that soil content of bulk of the exchangeable bases decreased downwards the profile. This is ostensible since the cations are condensed in the organic matter rich surface soil that is variegated with slight moisture at distinct phase of decomposition thus constantly releases the cations. This is similar to the finding of Oyedele *et al.,* (2008); cation exchange capacity (CEC) decreased consistently in the zone. The decline in CEC could be connected to a fall in organic matter content. The decreased CEC content points out that the adsorption capacity of these soils might be humus dependent. However the result of the CEC of this study is higher when compared with studies of Chima (2007) in Omo biosphere, Nigeria, Menzies and Gillman (1997) and Agoume and Birang (2009) in the humid forest zone of southern Cameroon. Also, related interrelations of soil organic matter and CEC have been reported by Muoghalu and Awokunle, (1994) in Nigerian rainforest region and Chima, (2007) in Omo Biosphere Reserve, Nigeria.

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