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Soil-Woody Plant Relationship in Oban Forest Reserve, Akamkpa, Cross River State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author EII designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author OFO managed the analyses of the study. Author EAG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Relationship between soil and woody species were assessed in the forest reserve in view of highlighting plant diversity status, population density and nutrient-relations in the forest.
Study Design: Systematic sampling method was used in sampling soil and vegetation parameters.
Place and Duration of Study: The study was conducted in the Oban Division of Cross River National Park, Nigeria, between November 2015 and July 2016.
Methodology: Systematic sampling method was used in studying the vegetation and soil. A total of thirty plots were sampled in each season. Total area of vegetation sampled was 1500 m^2. Soil samples were analyzed following the standard procedures outlined by the Association of Official Analytical Chemist.
Results: The result revealed a total of 24 species from 16 families and 23 plant species from 21 families in the wet and dry seasons respectively. *Coula edulis* was the most frequent plant species (100%) while *Baphia nitida,* recorded low frequency (20%) values. *Barteria nigitiana* (120±5.26) and *Diospyros mespiliformis* (120±6.20) dominated in density. *Berlinia confusa* was the tallest species (47.33±0.67 m) while *Anthocleista vogelli* was the smallest plant species (4.73±0.96 m). *Brachystegia nigerica* and *Berlinia confusa* had the widest crown coverage of 15.27±4.61 m^2/ha and

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15.27±4.73 m^2/ha, respectively. *Brachystegia nigerica* had the largest basal area (0.42±0.07 m^2/ha). Shannon and Simpson diversity indices were high in both wet (2.684 and 0.9029) and dry (2.968 and 0.9373) seasons respectively. Correlation analysis indicated significant relationship between woody species and soil edaphic factors. Stepwise multiple regression technique showed that soil variables predicted for the variations observed in vegetation parameters in both seasons.

Conclusion: The pedological indices and nutrient status of soil play critical roles in plant species distribution and vegetation morphology in Oban Forest Reserve.

Keywords: Dominance; diversity; woody species; floristic composition; important value index.

1. INTRODUCTION

Vegetation and Soil are inter-related and exert reciprocal effects on each other. This is because soil gives support in terms of moisture, nutrients and anchorage to vegetation to grow effectively on the one hand, and on the other, vegetation provides covers for soil, suppresses soil erosion as well as helps to maintain soil nutrients through litters accumulation and subsequent decay [15]. Vegetation strongly affects soil characteristics, including soil volume, chemistry and texture, which feedback affects various vegetation characteristics including productivity, structure and floristic composition [4]. The complexity of the relationships between the vegetation and the soil makes the soil one of the major factors determining the vegetation performance [27].

Eni et al. [42] studied Soil-vegetation interrelationships in a secondary forest of South-Southern Nigeria using principal component analysis (PCA) showed that exchangeable sodium, organic matter, cation exchange capacity, exchangeable calcium, and sand content were the major soil properties sustaining the regenerative capacity and luxuriant characteristics of the secondary forest, while tree size and tree density constituted the main vegetation parameters protecting and enriching the soil for its continuous support to the vegetation.

Oban Forest Reserve harbours a significant portion of Nigeria's remaining tropical rainforest. The entire landscape is recognized internationally as biodiversity hotspot [49]. Being fully aware of forest importance for present and future generations there is therefore the need to carry out adequate assessment to save the forest and minimize the resulting environmental degradation that occur due to forest deforestation. Presently, there is limited information on current forest resource. This gap is causing sustainable management and conservation problem of forest resources in the state. This study will appraise the vegetation of the forest reserve in view of highlighting plant diversity status, population density and nutrient-relations in the forest. Meanwhile, the study will be useful for the management of the state forest resource and for the provision of necessary guidelines for its conservation.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was conducted in the Oban Division of Cross River National Park, Nigeria (Fig. 1). It is one of the seven national parks in Nigeria. It comprises of two divisions (Oban and Okwangwo). Oban Division lies within longitudes 8°20′ E and 8°55′ E and latitudes 5°00′ N and 6°00′ N; while Okwangwo Division is located on longitudes 9°02′ E and 9°27′ E and latitudes 6°04′ N and 6°28′ N [29]. The Oban Division was carved out of Oban Groups of Forest Reserve which occupies an area of about 251,345 ha and it shares boundary with Korup National Park of Cameroon in the east. The co-ordinates for the research carried out was 05°19' 33.3'' N and 008°26' 20.6'' E within the forest reserve. Most of the area is characterized by hilly terrain ranging from 100 to over 1,000 m in height. The dominant rock types are ancient metamorphic rocks of the Basement Complex which covers 50% of Nigeria. The metamorphic rocks are mainly gneisses (biotite-hornblende, granite and migmatitic gneiss and to a lesser extent amphibolite (schist) [20]. Less sandy soils are found in areas with igneous rocks and deeper soils prevail in the plains of the southern part of the park whilst on steeper slopes they are increasingly stony, shallow and erodible [20]. Nigerian Meteorological Agency (Cross River) revealed that temperatures are generally high (average around 27°C) and vary little throughout the year with the annual range of the monthly average temperature varying only between 3° and 3.5°C. The prevailing wind is southerly, but during the dry season, the north-east trade winds carry dust-laden air from the Sahara, as far as Calabar. Mean monthly relative humidity varies between 78% and 91% with an average of annual rainfall generally between 2,500 mm-3,000 mm. At times, it can be up to 4,000 mm or 85% [17]. The seasons for this study were the dry and wet season within the months of November and July respectively.

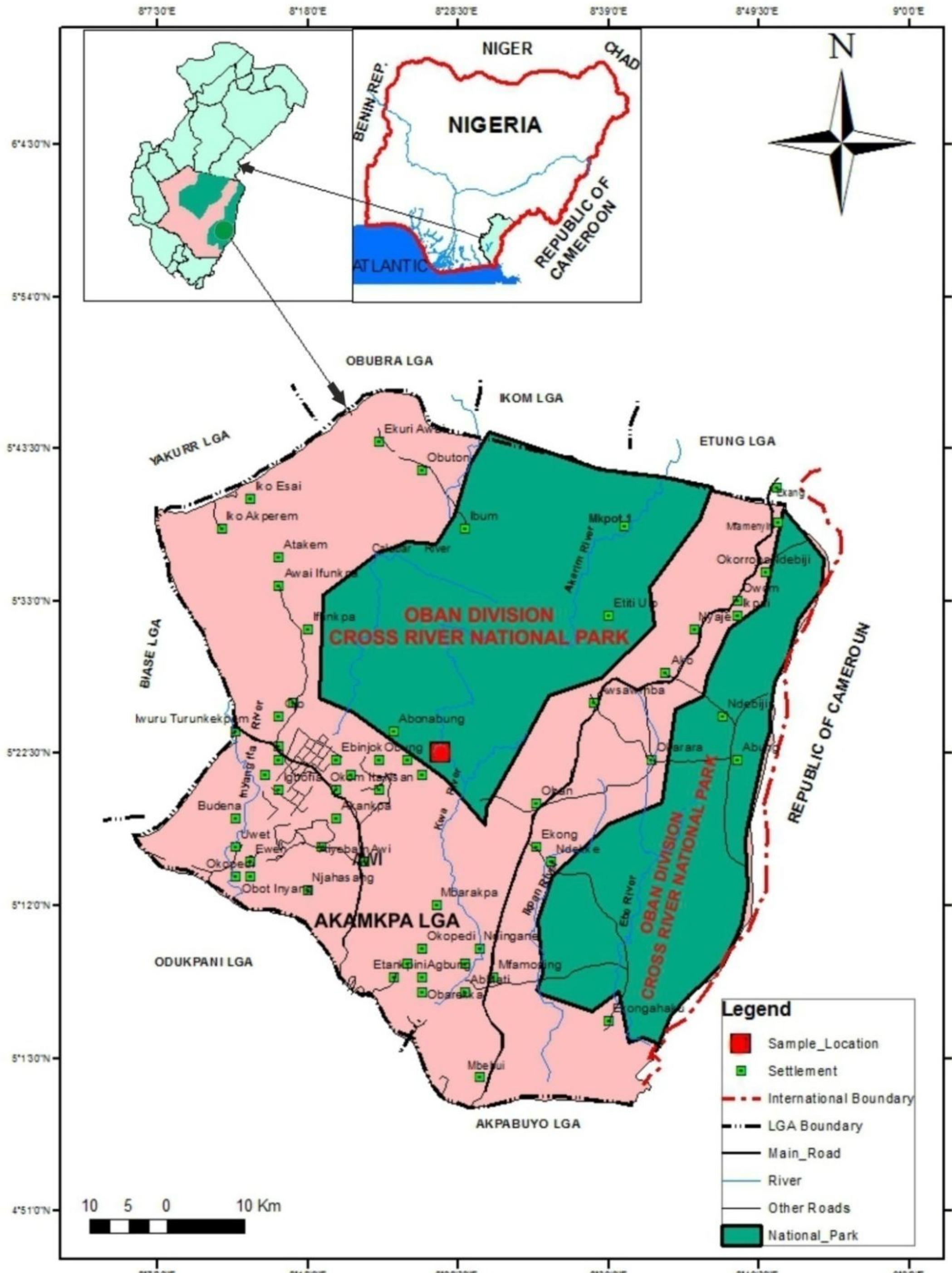

Fig. 1. Location on map of oban division cross river national park

2.2 Data Collection

Data collection was done for two seasons to ascertain the seasonal variation in parameters. Systematic sampling method was used in studying the vegetation and soil [25]. In this method, 6 belt transects (sized 50 m x 10 m) were marked within the forest. Each transect comprised 5 quadrats (plots) (sized 10 m x 10 m). A total of thirty plots were sampled in each season. Total area of vegetation sampled was 1500 m^2. In each quadrat plants were enumerated and properly identified to species level. However, voucher specimens of unknown plants were collected and deposited at the Department of Botany and Ecological studies herbarium at the University of Uyo, Uyo for proper identification. Vegetation calculated parameters were absolute frequency of plant species, height, absolute density, basal area, and crown cover. In each quadrat, soil samples were obtained at the two opposite ends of the quadrat. At each point of collection for the dry and wet season two soil samples at 0-15 cm and 15-30 cm depths were obtained and then bulked into a composite sample (0-30 cm). In all, 60 soil samples were collected and stored in labelled Ziploc bags and then taken to the laboratory for physicochemical analyses.

2.3 Phytosociological Parameter

2.3.1 Frequency

The frequency of each species occurrence was calculated thus:

$$\text{Frequency} = \frac{\text{Number of occupied quadrat for a species}}{\text{Total number of quadrats thrown}} \times 100$$

2.3.2 Density

The density of each plant species in the study area was estimated by enumerating all individual of each species present in each quadrat. The mean number of individual species was taken as a proportion of the area of the quadrat to give density m² which was multiplied by 10,000 m to give density per hectare [12]

Mean of the species =

$$\frac{\text{Number of individuals of the species}}{\text{Number of transects x Number of quadrats}}$$

$$\text{Density per m}^2 = \frac{\text{Mean of the species}}{\text{Area of quadrat}}$$

Density per hectare = Density per square metre x 10,000

2.3.3 Importance value index (IVI)

The Importance Value Index for the enumerated plant species was determined as the sum of the Relative frequency (R_f), Relative density (R_d) and Relative dominance (R_D).

2.3.3.1 Relative frequency (R_F)

This was calculated thus:

$$R_f = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

2.3.3.2 Relative density (R_D)

This was calculated thus:

$$R_f = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

2.3.3.3 Relative dominance (R_D)

This was calculated thus:

$$R_D = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

2.4 Soil Sample Digestion

Samples were ground, mixed, and divided into fine particles that could pass through a 0.5-mm sieve. Soil samples were digested by adding 2 g of soil to 15 ml of concentrated nitric acid and perchloric acid at a ratio 1:1, and allowed to stand for 135 min until the mixture became colorless. The samples were filtered and washed with 15 ml of deionized water, and made up the filtrate to 100 ml in a standard flask. Five micro nutrients (lead (Pb), Iron (Fe), Zinc (Zn), cadmium (Cd) and Manganese (Mn) were determined in the filtrate at their respective wavelengths using an atomic absorption spectrophotometer (AAS). In all determinations, the triplicate samples agreed very well. The result given is the mean of three estimations [7].

2.5 Physicochemical Analysis of Soil Samples

Soil samples were analyzed following the standard procedures outlined by the Association of Official Analytical Chemist [7]. Soil pH (potential hidrogenionic) was measured using Beckman's glass electrode pH meter [13]. Org Carbon (Org c) by the Walkey Black wet oxidation method [49], available Phosphorus (P) by Bray P-1 method [23]. The total Nitrogen (N) content was determined by Micro-Kjeldahl method [3]. Soil particle size distribution was determined by the hydrometer method [45], using mechanical shaker, and sodium hexametaphosphate as physical and chemical dispersant. Exchange Acidity was determined by titration with 1N KCl [26]. Total Exchangeable Bases were determined after extraction with 1 M NH4Oac (One molar ammonium acetate solution). Total Exchangeable Bases were determined by EDTA titration method while Na and Potassium (K) were determined by photometry method. The Effective Cation Exchange Capacity (ECEC) was calculated by the summation method (that is summing up of the Exchangeable Bases and Exchange Acidity (EA). Base Saturation (B.Sat) was calculated by dividing total Exchangeable Bases by ECEC multiplied by 100. Statistical analysis involved Analysis of variance (ANOVA), Correlation, Stepwise Multiple Regression Analysis (SMRA) and Diversity indices

3. RESULTS AND DISCUSSION

3.1 Vegetation Characteristics and Diversity Profile

A total of twenty four taxa were recorded for the dry season vegetation characteristics of the Oban Forest , while the numbers of plant families recorded were 16 (Table 1). While A total of twenty three taxa were recorded for the wet season vegetation characteristics of the Oban Forest and the number of plant families recorded were 16 (Table 2).

The total number of individuals encountered in the wet and dry season were 1690 and 1020 stem/ha, respectively. The dry season vegetation parameters show that *Coula edulis* Baill. was the most frequent plant species (100%) while *Baphia nitida* Lodd*, Berlinia confusa* Hoyle*, Brachystegia nigerica* Hoyle*, Bridelia micrantha* Baill.*, Cleistopholis patens (*Benth*), Musanga cecropioides R.Br, Khaya ivorensis A. Chev, Pentaclethra macrophylla* Benth*, Pycnanthus angolensis* (Welw.) Warb*, Staudtia stipitata* (Welw.) Warb had the least frequency (20%). *Barteria nigritiana Hook. f.* (120±5.26 st/ha) *Diospyros mespiliformis* Hochst. (120±6.20 st/ha) dominated in mean density while *Afzelia africana* Sm (20±2.40 st/ha), *Baphia nitida* Lodd (20±1.82 st/ha), *Berlinia confusa* Hoyle (20±1.98 st/ha), *Brachystegia nigerica* Hoyle(20±1.79 st/ha), *Bridelia micrantha* Bailll.(20±2.01 st/ha), *Cleistopholis patens* (Benth) (20±0.98 st/ha), *Musanga cecropioides R.Br* (20±1.54 st/ha), *Khaya ivorensis* A.Chev (20±1.53 st/ha), *Pentaclethra macrophylla* Benth(20±1.39 st/ha), had the least mean density. In terms of height, *Berlinia confusa* Hoyle was the tallest species (47.33±0.67 m) while *Anthocleista vogelli* Planch was the shortest plant species (4.73±0.96 m). *Brachystegia nigerica* and *Berlinia confusa* had the highest mean crown cover of 15.27±4.61 m^2/ha and 15.27±4.73 m^2/ha, respectively. *Brachystegia nigerica* Hoyle had the largest mean basal area (0.42±0.07 m^2/ha) (Table 1).

While the wet season vegetation parameters shown in Table 2 shows that *Diospyros mespiliformis* Hochst., *Musanga cecropioides R.*Br and *Pycnanthus angolensis* (Welw.)Warb dominated in frequency (80%) while *Baphia nitida* Lodd*, Berlinia confusa* Hoyle*, Bridelia micrantha* Baill*, Khaya ivorensis* A. Chev and *Staudtia stipitata* (Welw.)Warb had the least frequency (20%). *Anthocleista vogelli* Planch dominated in density (320±10.51) while *Afzelia Africana* Sm. (20±2.40 st/ha), *Baphia nitida* L. (20±1.87st/ha), *Bridelia micrantha B.* (20±2.01 st/ha), *Cleistopholis patens B.* (20±0.98 st/ha), *Khaya ivorensis* A.Chev (20±1.53 st/ha) and *Pentaclethra macrophylla* B. (20±1.39 st/ha) had the least density. *Berlinia confusa* H. was the tallest species (47.33±3.97 m) while *Baphia nitida* L. (7.00±1.23 m) and *Funtumia elastica* Stapf (7.01±1.72 m) were the shortest plant species. *Brachystegia nigerica* H. had the highest mean crown cover of 15.30±4.60 m^2/ha while *Funtumia elastica* had the least mean crown cover (0.20±0.08 m^2/ha). *Entandrophragma cylindricum* Harms had the largest mean basal area (0.68±0.14 m^2/ha) while *Baphia nitida* L.had the least (0.007±0.001 m^2/ha).

The diversity Profile in Table 3 shows that there were a total of 23 and 24 plant species recorded in the wet and dry seasons, respectively. Also, the total number of individuals encountered in the wet and dry season were 1690 and 1020 stem/ha, respectively. The species dominance was low in the dry season (0.06267 *D*s) but higher in the wet season (0.09709 *D*s) while Shannon-Weiner indices were 2.684 H' and 2.968 H' in the wet and dry seasons, respectively. Simpson diversity values were 0.9029 λ and 0.9373 λ in wet and dry seasons, respectively. Evenness values ranged between 0.6369 and 0.8108 in the wet and dry seasons, respectively. The Berger-Parker indices were 0.1893 and 0.1176 in the wet and dry seasons.

Table 1. Vegetation characteristics of Oban Forest during the dry season, Nigeria

Species	Author	Family	Frequency(%)	Mean Density(st/ha)	Mean Height(m)	Mean Crown Cover	Mean Basal Area (m^2/ha)
Afzelia africana	Sm.	Fabaceae	40	20±2.40	16.35±4.00	2.78±0.96	0.19±0.04
Anthocleista vogelli	Planch	Potaliaceae	40	40±3.51	4.73±0.96	2.47±0.81	0.007±0.000
Baphia nitida	Lodd	Fabaceae	20	20±1.82	5.33±0.33	0.24±0.04	0.007±0.001
Barteria nigitiana	Hook.f.	Passifloraceae	40	120±5.26	8.73±1.79	4.91±0.97	0.02±0.001
Berlinia confusa	Hoyle	Fabaceae	20	20±1.98	47.33±0.67	15.27±4.61	0.26±0.05
Brachystegia nigerica	Hoyle	Fabaceae	20	20±1.79	42.67±1.45	15.27±4.73	0.42±0.07
Bridelia micrantha	Baill.	Phyllanthaceae	20	20±2.01	10.00±0.00	4.03±0.89	0.02±0.006
Cleistophilis patens	(Benth)	Annonaceae	20	20±0.98	11.00±0.00	1.23±0.56	0.07±0.004
Coelocaryon preussii	Warb	Myristicaceae	40	40±3.10	7.48±2.30	3.24±1.10	0.16±0.06
Coula edulis	Baill.	Olacaceae	100	100±4.87	20.60±5.98	4.51±1.20	0.21±0.05
Cola rostrata	K. Schum	Sterculiaceae	40	60±2.14	8.00±0.58	0.80±0.36	0.08±0.01
Diospyros mespiliformis	Hochst.	Ebenaceae	80	120±6.20	12.36±2.03	1.48±0.64	0.03±0.02
Entandrophragma cylindricum	Harms	Miliaceae	20	40±3.21	8.43±1.43	6.11±0.83	0.36±0.04
Funtumia elastica	Stapf.	Apocynaceae	20	60±2.00	6.88±0.63	0.19±0.05	0.01±0.002
Glyphaea brevis	(Spreng)Monach.	Tiliaceae	40	20±4.10	7.36±2.38	4.66±0.20	0.10±0.01
Khaya ivorensis	A.Chev	Miliaceae	20	20±1.53	10.93±0.23	2.27±0.75	0.25±0.02
Maesobotrya barteri	(Baill) Hutch.	Euphorbiaceae	40	40±3.21	6.17±1.36	1.60±0.16	0.007±0.002
Musanga cecropioides	R.Br	Urticaceae	20	20±1.54	19.50±2.33	3.78±1.21	0.25±0.04
Pentaclethra macrophylla	Benth	Fabaceae	20	20±1.39	26.50±6.43	8.78±2.59	0.27±0.05
Piptadeniastrum africanum	(Hook.f)	Fabaceae	40	40±2.81	11.0±3.84	4.32±1.64	0.3±0.01
Poga oleosa	Pierre	Rhizophoraceae	40	20±.310	8.63±1.42	2.86±1.01	0.20±0.0
Pycnanthus angolensis	(Welw.)Warb	Myristicaceae	20	40±3.26	33.33±7.26	6.87±2.89	0.23±0.07
Spondias mombin	L.	Anacardiaceae	20	40±2.62	8.42±1.03	2.44±1.41	0.12±0.06
Staudtia stipitata	(Warb.) Warb	Myristicaceae	20	60±4.68	27.33±8.87	9.35±2.87	0.22±0.01

Table 2. Vegetation characteristics of oban forest during the wet season, Nigeria

Species	Author	Family	Frequency (%)	Mean Density (st/ha)	Mean Height (m)	Mean Crown Cover	Mean Basal Area (m^2/ha)
Afzelia africana	Sm.	Fabaceae	40	20±2.40	16.90±4.00	3.02±0.92	0.20±0.04
Anthocleista djalonensis	Planch	Potaliaceae	40	40±8.42	8.3±1.36	2.10±0.10	0.30±001
Anthocleista vogelli	Planch	Potaliaceae	60	320±10.51	6.61±1.89	2.87±0.94	0.03±0.002
Baphia nitida	Lodd	Fabaceae	20	20±1.87	7.00±1.23	0.79±0.07	0.007±0.001
Barteria nigitiana	Hook.f.	Passifloraceae	40	100±5.26	8.80±1.79	4.81±0.97	0.02±0.001
Berlinia confusa	Hoyle	Fabaceae	40	40±1.98	47.83±3.97	15.00±4.81	0.52±0.03
Brachystegia nigerica	Hoyle	Fabaceae	40	40±1.79	42.77±1.45	15.30±4.60	0.44±0.07
Bridelia micrantha	Baill.	Phyllanthaceae	20	20±2.01	11.00±0.00	4.09±0.89	0.02±0.006
Cleistopholis patens	(Benth)	Annonaceae	40	20±0.98	11.00±0.00	2.23±0.56	0.07±0.004
Coula edulis	Baill.	Olacaceae	60	200±9.45	33.00±5.17	4.91±1.45	0.26±0.07
Cola rostrata	K. Schum	Sterculiaceae	40	60±2.14	8.04±0.58	0.90±0.36	0.09±0.01
Diospyros mespiliformis	Hochst.	Ebenaceae	80	120±7.10	14.67±2.49	3.80±1.64	0.11±0.02
Entandrophragma cylindricum	Harms	Meliaceae	40	40±3.86	7.82±1.64	2.46±1.84	0.68±0.14
Funtumia elastica	Stapf	Apocynaceae	40	60±3.21	7.01±1.72	0.20±0.08	0.01±0.002
Glyphaea brevis	Monach	Tiliaceae	40	40±3.41	8.63±2.11	0.5±0.03	0.32±0.04
Holarrhena floribunda	G. Don	Apocynaceae	40	30 ±6.34	11.22±3.00	0.68±0.11	0.36±0.03
Khaya ivorensis	A.Chev	Miliaceae	20	20±1.53	10.93±0.23	2.27±0.75	0.25±0.02
Maesobotrya barteri	(Baill) Hutch.	Euphorbiaceae	40	40±3.21	6.72±1.40	1.60±0.16	0.01±0.002
Musanga cecropioides	R.Br	Urticaceae	80	100±8.67	18.60±2.43	8.89±2.71	0.28±0.07
Pentaclethra macrophylla	Benth	Fabaceae	20	20±1.39	26.50±6.43	8.78±2.59	0.27±0.05
Poga oleosa	Pierre	Rhizophoraceae	20	20±2.6	24.11±8.2	4.23±1.40	0.34±0.02
Pycnanthus angolensis	(Welw.)Warb	Myristicaceae	80	280±9.78	34.34±7.13	12.57±2.89	0.25±0.08
Staudtia stipitata	(Warb.)Warb	Myristicaceae	20	40±4.68	27.33±8.87	10.35±2.87	0.33±0.01

Table 3. Diversity profile of the oban forest reserve, Nigeria, in season dry and wet

	Dry Season	Wet Season
Taxa	24	23
Individuals	1020	1690
Dominance	0.06267	0.09709
Simpson	0.9373	0.9029
Shannon	2.968	2.684
Evenness	2.968	2.684
Berger-Parker	0.1176	0.1893

3.2 Physicochemical Characteristics of the Soil of Oban Forest Reserve

The physicochemical characteristics of the soil of Oban forest reserve in wet and dry seasons in Table 4 revealed that the general soil texture for forest was sandy-loam and it showed that sand fragment dominated other particle size classes in both wet (86.57±2.018%) and dry seasons (90.57±0.243%). Clay ranked next (wet season =7.600±0.5007; dry season =7.11±0.0948) and then silt (wet season =3.6300±0.358; dry season =2.14±0.224). Soils were weakly acidic (wet season = 5.5±0.0394; dry season =4.248) whereas conductivity ranged between 0.0632±0.0055 (wet season) and 0.0879±0.0117 (dry season).Org content ranged between 2.4390±0.0515 (wet season) and 4.3360±0.351 (dry season) while total N content reached values of 0.0590±0.0038 (wet season) and 0.1070±0.008 (dry season). Available P was 16.3880±2.765 in the wet season but 8.2020±0.7111 in the dry season. Ca was the most abundant of the exchangeable cations (wet season= 5.04 ±0.1759; dry season=4.075±0.2909), Mg followed (wet season =1.915±0.0796; dry season = 1.78 ± 0.1171), then K (wet season = 0.1020±0.0042; dry season = 0.1320 ± 0.0049). Na was the least concentrated cation (wet season = 0.0490±0.00233; dry season = 0.0490 ± 0.00233) in the forest soils. Exchange acidity ranged between 2.1630±0.0834 in the wet season and 2.1910±0.0485 in the dry season while effective cations exchange capacity values were 9.2430±0.2155 and 8.3090±0.4732 in the wet and dry seasons respectively. The B. sat values were 76.4260±1.17 and 72.9520±1.173 in the wet and dry seasons, respectively. Among the micronutrient, Fe ranged between 363.93±18.58 and 357.73±13.123 in the wet and dry seasons, respectively. Mn followed with 2.6650±0.2425 and 2.922±0.228 in the wet and dry seasons, respectively. Lead had 0.6120±0.0588 in the wet and 0.7290±0.5527 in the dry seasons. Cd had the least with 0.0223±0.0106 and 0.017±0.00978 in the wet and dry seasons, respectively.

The interrelationships between soil and vegetation parameters in the wet season reveals a significantly positive relationship between org and height (r = 0.697*). Similarly, there is also a positive correlation between Na and crown cover (r = 0.734*). Positive correlation coefficients have been obtained for two pairs of variables which are density with Pb (r=0.633*) and crown cover with Cd (r=0.697*). While the interrelationships between soil and vegetation parameters in the dry season reveals a significantly positive relationships between org and density (r = 0.670*) and between sand and density (r = 0.635*). Silt had inverse relationships with plant parameters: density (r = -0.661*) but positively with crown cover (r = 0.643*), basal area (r = 0.690*). Strong positive correlation existed between exchange acidity and crown cover (r = 0.708*) and between Cd and crown cover (r = 0.700*). On the other hand, basal area correlated positively with these three parameters: exchange acidity (r = 0.777*), Cd (r = 0.678*) and Fe (r = 0.734*).

Predictive multiple regression equation for the wet season showed the influence of Av.P and Mn for *Coula edulis*,Org C for *Diospyrous mespiliformis*, while B.sat had influnce on *Funtumia elastica*, it also showed the presence of Sand, Silt, K and Fe having effect of *Berlinia confusa*. Zn was present for *Staudtia stipitata* while Av.P, K, Pb and EC showed some predictions for *Musanga cecropioides*. In the dry season Cd and Mg had predictive nutrient response for *Coula edulis* while Mn also showed nutrient response for *Diospyrous mespiliformis*. *Anthocleista vogelli* showed response to pH gradient while *Berlina confusa* showed predictive response to pH, N, EA, ECEC and B. sat. Finally *Pycnanthus angolensis* showed response to Na in the dry season.

Table 4. Physico-chemical parameters (0-30) mean (± S.E.) of oban forest soil in both seasons in Nigeria

Parameters	Wet Season	Dry Season
Sand (%)	86.57±2.018	90.57±0.243
Silt (%)	3.6300±0.358	2.14±0.224
Clay (%)	7.6000±0.5007	7.11±0.0948
pH	5.5000±0.0394	4.248±0.144
Electrical conductivity (ds/m)	0.0632±0.0055	0.0879±0.0117
Organic carbon (%)	2.4390±0.0515	4.3360±0.351
Total Nitrogen (%)	0.0590±0.0038	0.1070±0.008
Available Phosphorus (mg/kg)	16.3880±2.765	8.2020±0.7111
Calcium (Cmol/kg)	5.0400±0.1759	4.0750±0.2909
Magnesium (Cmol/kg)	1.9150±0.0796	1.7800±0.1171
Sodium (Cmol/kg)	0.0490±0.00233	0.0590±0.0038
Potassium (Cmol/kg)	0.1020±0.0042	0.1320±0.0049
Exchange acidity (Cmol/kg)	2.1910±0.0485	2.1630±0.0834
E.C.E.C. (Cmol/kg)	9.2430±0.2155	8.3090±0.4732
Base saturation (%)	76.4260±1.17	72.9520±1.173
Iron (mg/kg)	363.93±18.58	357.73±13.123
Zinc (mg/kg)	41.999±4.009	29.356±3.287
Manganese (mg/kg)	2.6650±0.2425	2.922±0.228
Lead (mg/kg)	0.6120±0.0588	0.7290±0.5527
Cadmium (mg/kg)	0.0223±0.0106	0.017±0.00978

Table 5. Soil-vegetation correlates (0-30) of oban forest reserve during the wet season, in Nigeria

Soil parameters	Density	Cc	B.A.	Height
Sand	.139	-.617	-.399	-.481
Silt	-.248	.051	-.096	-.055
Clay	.100	.136	.055	.239
pH	.068	.028	.000	.250
EC	-.546	.404	.131	.523
OrgC	.513	-.373	-.102	.697*
TotN	.202	-.274	-.131	-.511
Av.P	.414	-.174	-.206	-.229
Ca	.165	.418	.483	.303
Mg	-.038	.474	.535	.337
Na	.023	.734*	-.574	-.547
K	-.004	-.351	-.271	-.550
EA	-.073	-.318	-.253	-.244
ECEC	.115	.313	.441	.212
Bsat	.112	.343	.357	.246
Fe	.003	-.060	-.077	-.169
Zn	.584	.171	.367	-.127
Mn	.021	-.212	-.057	-.046
Pb	.633*	-.413	-.209	-.505
Cd	-.023	.697*	.533	.511

Note: P= .05, CC = Crown cover, B.A = Basal area, EC = Electric conductivity, Org C = Organic carbon, TotN = Total N, Av.P= Available P, E.A=Exchange acidity, ECEC =Effective cation exchange capacity, B.sat = Base saturation*

Forest in the tropical regions has been subjected to frequent disturbances as a result of several factors such as periodic fires, grazing, cultivation and timber exploitation. These disturbances bring about certain species being restricted to particular areas within the ecosystem or forest. The results obtained in this study showed marked variations in abundance and distribution of species. It indicates that species respond and adapt differently to environmental (soil) factors. The high frequency and density of *Coula edulis, Calamus deeratus, Barteria nigritiana* and *Diospyros mespiliformis* could be attributed to the fact that they have inherent ability to adapt to prevailing conditions and micro-site variations in the forest. It could also reflect their ecological amplitudes and dominance [1]. It could denote that these species have a high regeneration potential [29]. On the other hand, the occurrence of diverse species such as *Baphia nitida, Berlinia confusa, Brachystegia nigerica, Bridelia macrantha, Cleistophilis patens, Funtumia elastica, Musanga cecropioides, Khaya ivorensis, Pentaclethra macrophylla, Pycnanthus angolensis and Staudtia stipitata* with low density values is well noticed. This reflects their inability to adapt to the prevailing environmental conditions in the forest. Also, this observation portends slow rate of regeneration for these species which cannot compensate for mortality and exploitation rate within the reserve [22].

Again, the close range of frequency and density values of some species however portrays a fierce competition levels between taxa within the forest. This had been alluded to by earlier researchers [43]. The distinct variation in height of woody species within and between plots in the forest is an indication of their diverse growth forms [32] or could be attributed to differences in age or maturity stages. For instance, short and intermediate height values recorded for *Berlinia confusa* in the forest reflect their seedling or sapling stages of development. Also, the variation in height is a diagnostic evidence of stratification within the ecosystem. These assertions fall in tandem with Ubom et al. [43].

The total number of individual tree species per hectare (Wet season = 1690 and Dry season = 1020) obtained in this study depeats the high regeneration rate of species and this far exceeds the values reported for other closed canopy and secondary forest types by Adekunle et al. [2] and Sidiyasa [36] in Wain River, East Kalimantan. The higher values obtained in this study confirms the inkling of Bisong and Mfon [8] that Cross River National Park remains the richest of the tropical rainforest left in Nigeria. This may also be an indication of conservation success in the park.

Table 6. Soil- vegetation correlates (0-30 cm) of oban forest reserve during the dry season, in Nigeria

Soil parameters	Density	CC	B.A	Height
Sand	.635*	.262	.527	.020
Silt	-.661*	.643*	.690*	-.499
Clay	-.191	.144	-.068	.006
pH	-.124	-.347	.073	-.604
EC	.583	.333	.400	-.190
OrgC	.670*	.211	.357	.019
TotN	.630	.191	.351	.012
Av.P	-.411	-.036	-.359	.022
Ca	.169	-.008	.260	-.366
Mg	-.067	-.121	.070	-.416
Na	.018	-.225	-.191	-.253
K	.540	.322	.607	-.146
EA	.348	.708*	.777*	.344
ECEC	.207	.131	.355	-.291
Bsat	.007	-.320	-.046	-.587
Fe	.001	.573	.734*	.110
Zn	.039	-.340	-.459	-.560
Mn	-.072	-.476	-.629	-.141
Pb	-.459	-.380	-.399	-.448
Cd	.556	.700*	.678*	.113

Note: P=.05, CC = Crown cover, B.A = Basal area, EC = Electric conductivity, Org C = Organic carbon, TotN = Total N, Av.P= Available P, E.A=Exchange acidity, ECEC =Effective cation exchange capacity, B.sat = Base saturation*

Table 7. Predictive multiple regression equations for species response to nutrient gradient

Variable	Equation
Coula edulis (Wet)	Y = - 0.440 + 1.575 log Av.P - 2.211 log Mn.
Diospyrous mespiliformis (Wet)	Y = 13.942 – 14.325 log Org.C.
Funtumia elastica(Wet)	Y = -46.269 +10.742 log B.sat
Berlinia confusa (Wet)	Y = 20.062 – 4.010 log Sand -0.142 log Silt + 0.381 log K -0.176 log Fe.
Staudtia stipitata (Wet)	Y = 8.360 -2.168 log Zn
Musanga cecropioides(Wet)	Y = 0.974 -1.025 log EC -0.943 log Av.P +2.301 log Pb +0.899 log K.
Coula edulis (Dry)	Y = - 1.523 + 49.251 log Cd + 3.253 log Mg.
Diospyrous mespiliformis (Dry)	Y = 4.290 – 2.807 log Mn.
Anthocleista vogelli (Dry)	Y = -37.423+27.209 log pH.
Berlinia confusa (Dry)	Y = -45.564+3.673 log pH -0.531 log Tot N +7.056 log EA -4.529 log ECEC +10.090 log B.sat.
Pycnanthus angolensis, (Dry)	Y = -9.650 – 3.582 log Na.

The Shannon-Weiner index measures the relative abundance of species. The value of Shannon-Weiner Index (H') is 2.68 and 2.96 recorded for wet and dry seasons, respectively. These values are higher than 2.20 and 2.65 which were reported for wet and dry seasons respectively in the tropical forests of Kodayar, Western Ghats of Southern India [41]. However, these values are low compared to the value (H' =4.8) recorded in tropical forests of Barro Colorado Island in Panama [25]. Generally, quantitative comparison of species diversities obtained in this study with previous similar studies yield numeric aberrations. This variation is clearly understood and so may be attributed to gaps in sampling procedures, size of sampling area, plot size, age of vegetation, environmental conditions, level of disturbances and other site factors [31]. There is an inverse relationship observed in comparing diversity and dominance values in the forest. This corroborates the opinions of Clarke and Warwick [14] and Ogbemudia et al. [29] who reported that when comparing natural ecosystems, higher Shannon-Weiner diversity correspond with low dominance in same sites/community. Positive significant correlations between plant parameters (e.g girth and height) relate that these parameters vary together. This agrees with the findings of other researchers such as Mbong [28] and Sundaranpandian and Swamy [41].

Generally, the soil nutrient status of the forest reserve compares with that recorded for a closed canopy forest [2]. The availability of nutrients is one of the most important abiotic factors which determine the plant species composition in ecosystems [43]. This supports the luxuriant and rich flora of the forest reserve. N is a limiting nutrient for plant growth in many natural and semi-natural ecosystems. According to Shulka and Chandel [35], N content in surface mineral soils ranges between 0.02 – 0.5 percent and that soil N occurs as part of organic molecule. This is evident in this research work as N content falls within this range 0.05 and 0.01 in the wet and dry season respectively. Naturally, major nutrients (N, P, K) are usually lacking or low in the soil because plant use large amounts for their survival and growth [6]. Again, the percentage of org present reflects the level of humus content of soil and is dependent on the rate of decomposition of dead trees and leaves due to the action of soil micro flora present in the forest soil [10].

The low pH value of these soils portends acidity. This is not unlinked with litter decomposition. This assertion emanates from Stevenson [40] who confirmed that litter decomposition releases humic and fulvic acids thus reducing the soil reaction. Verma and Verma [48] have shown the negative influence of reduced soil reaction on nutrient availability, plants establishment and distribution. This explains the negative relationship traced for floristic (crown cover and basal area of the plant species) and exchangeable acidity (Tables 5 and 6). Floristic variables (density, basal area and crown cover of plants) correlated negatively with silt. This interprets that silty substrates did not favour the establishment and flourishing of woody species. Mbong [28] reported that this is not unrelated with the poor nutrient status and water logging potentials associated with this particle size class.

The correlation relationships between soil variables emphasize that soil factors contribute significantly to the variations observed in terms of structure and species composition within the forest. Significant and positive correlation between total nitrogen and organic carbon directly relates to litter deposition and decomposition. The positive relationship reveals that both parameters vary together. This indicates that these elements have positive effects or that the species are sensitive to these soil nutrients. Similar observations were made by Isichei [21]. The positive correlation observed between base cation pairs implies that the distribution patterns of these cations are similar and that these increases together. Similarly, there exist positive relationships between base cations, ECEC and exchange acidity. This confirms the notion by Essumang [16] that positive correlation indices between pairs of soil variables portray the likelihood that both have a similar source of enrichment. This example confirms that both the cations and soil exchange acidity share same sources of deposition. This pattern of relationship is clearly linked with organic matter decomposition and nutrient release [40]. The correlation between soil physical properties (sand and silt) with total nitrogen authenticates Jones and Wild [23] that soil texture also shows profound influence on nitrogen availability in some terrestrial ecosystems. This means that a higher value of sand in the forest is associated with high values of total nitrogen. Conversely, there is a negative significant relationship between total nitrogen and silt. This relates that a high value of silt in the plots is associated with nitrogen deficiency in the plots. Similar observations were made by Mbong [28] and Ogbemudia et al. [29].

Harold and Robert [19] reported that woody species in forest ecosystem differ greatly in the relative and absolute amounts of nutrient elements absorbed from the soil. Iron correlated positively with basal area this confirms the observation by Follett and Westfall [17] which states that iron plays an important role in plant respiratory and photosynthetic reactions. Another relation between electrical conductivity with manganese was noted and this falls in line with the work of Verma and Verma [48] who reported that the function of manganese in plant include acceleration of germination and maturity, increasing the availability of calcium and phosphorus and supporting the movement of iron, therefore the trace availability of this element in the forest soil could be related to plant metabolism. Cadmium and lead correlated negatively with sand this authenticate the work of Scokat et al. [34] who reported that Cd interacted with soil components and showed a higher accumulation capacity for loamy soil than for sandy soil. Conversely lead was noted to show positive relationship with silt, this can explain the reason while lead was among the predictor for *Musanga cecropioides* in Table 7.

The species response to nutrient gradient in Table 7 showed that Org.C. and B.Sat was an important factor in the wet season which could explain the variation observed in the crown cover of *Diospyros mespiliformis* and *Funtumia elastica*, while Zn was retained as an influence in the prediction of *Staudtia stipitata* during the wet season. This could be the case because Zn plays a functional role in DNA transcription and important for internode elongation [48]. Conversly K was predicted for *Berlinia confusa*. Silva and Uchida [37] reported that K is essential for photosynthesis and activates enzymes to metabolize carbohydrate for the manufacture of amino acid and protein and facilitates cell divison and growth by helping to move starch and sugar between plant pairs and this could explain the reason for the height of this plant species. Mg was retained in the dry season equation predicting for *Coula edulis*. Sollins [39] confirmed that Mg is a constituent of the chlorophyll molecule which is the driving force for photosynthesis and also essential in the metabolism of carbohydrate. This could explain the dominance and height noted for this species. Furthermore soil Na yielded predictor for *Pycnanthus angolensis*. This nutrient is reported by Silva and Uchida [37], to be involved in the regeneration of Phosphenolpyruvate in CAM and C4 plant and also replaces K function, this currently accounts for the variation visible in the height and crown cover of this plant. The pH was retained for *Anthocliesta vogelli* in the dry season and this explains the low values obtained for height, crown cover and basal area obtained for this plant species and this could be attributed to the fact that soil pH influences the availability of plant nutrient, mineralization of soil organic matter and consequently adsorption inhabiting growth [9]. Also, in the dry season equation base cation pairs and total nitrogen predicted for

Berlinia confusa and the relative amount of the base cations in this plant could be attributed to the fact that there is a restriction of N and base cation at the soil surface via decomposition [5].

Generally, woody species revealed different response to nutrient gradient with variations in seasonality. The results also suggest that patterns of diversity may differ not only among plant groups but also among diversity indices and that such patterns are primarily caused by habitat heterogeneity. These summarizes that these extracted soil and vegetation variables are indeed significantly important in explaining soil-vegetation interrelationships in the highly regenerative forest.

4. CONCLUSION

This research concludes that, different species growing together under similar environmental conditions vary in their response and adaptability to nutrient limits. Also, soil properties exert profound effects on plant growth, nutrition and distribution. Correlations of vegetation attributes with nutrients showed strong relationships at statistically significant levels. Negative relationships showed levels of nutrient availability that were limiting to plant performance while positive relationships suggested essential nutrient levels. Conclusively, the result of this work showed that there is a complex relationship existing between the vegetation characteristics of Oban forest and its soil properties and that seasonality affects nutrient status of the forest.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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