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Pedo–Nutrient Associations and Plant Diversity In A Cross River Ecosystem

OGBEMUDIA, F.O & EZEKIEL, A.G.
Department of Botany and Ecological Studies,
Faculty of Science, University of Uyo. P.M.B.1017 Uyo, Akwa Ibom State

ABSTRACT
The pedo-nutrient association and plant diversity in a Cross River Ecosystem Akwa Ibom State was conducted using systematic sampling method. Frequency of occurrence was enumerated for each species encountered and soil properties were also studied. The results obtained revealed a total of 22 plant species belonging to 13 families, which were unevenly distributed in the three sampling stations located along the length of the river. *Raphia hookerii* was the most frequently encountered species found in the four stations studied and had a frequency of 100%. The least species were *Anthocleista vogelii, Azolla africana, Azolla pinnata, Bambusa vulgaris, Ceratophyllum dermasum, Cleistopholis patens, Elease guineensis, Ipomoea aquatic, Ipomoea cairica, Ipomoea mauritiana, Nymphea odorata Nymphea lotus and Pistia stratiotes* with *25%* frequencies each having been found in one of the four stations. The diversity status of the different plots in the swamp forest varied markedly. Highest number of taxa (13species) and the least taxa (4 species) were recorded in stations 2 and 3, respectively. The association of the nutrients in all stations showed a close differences and similarities in relationships among certain nutrients. This was reflected in the loading of nutrients as indicated. Generally, Principal Component Analysis (PCA) assorts both plant and soil nutrient parameters in a way showing that these are but a continuum in vegetation space mandating that the concept of stations or plots are but arbitrary.
Keywords: plant diversity, pedo-nutreint, Cross River Ecosystem, PCA, Association

INTRODUCTION
Wetlands, referred to as swamps or marshes, are among the most important ecosystems in the world. They are essential for performing many ecosystem services, such as food control, maintenance of biodiversity, fish production, carbon storage, aquifer discharge and flood control as well as providing habitat for many endangered species (Barbier *et al.,* 1997). Wetlands are of high agricultural and aquaculture interest, as well as environmental conservation. Its benefits and values to the society have attracted increasing global importance, but unfortunately, wetland areas are under increasing pressure stemming from developments and industrialization, including oil exploration and spillage. Benefits provided by wetlands are quite enormous, with increased importance worldwide, hence the need to protect the remaining wetlands (Millennium Ecosystem Assessment, 2005). Many wetlands have been greatly destroyed and altered as a result of anthropogenic activities resulting from oil exploration and exploitation, therefore the need to develop an approach for monitoring wetlands is necessary in order to identify, plan and implement proper management and containment responses to affected sites, at local, regional, national and international levels. Wetlands are among the most nutrient/productive ecosystems in the world (Anwana and Ogbemudia, 2015). Immense varieties of species of microbes, plants, insects, amphibians, reptiles, birds, fish, and other wildlife depend in some way on wetlands. Decomposed matter (detritus) forms the base of the aquatic and terrestrial food web (Richardson *et al.,* 1995). However, according to Johnston (1991) decomposition rates vary across wetlands, particularly as a function of climate, vegetation types, available carbon and nitrogen and pH. A pH above 5.0 is necessary for bacterial growth and survival. The nutrients and compounds released from decomposing organic matter may be exported from the wetland in soluble or particulate form, incorporated into the soil, or eventually transformed and released to the atmosphere. The concentration of heavy metals in the environment are continually changing due to man's activities.

These changes have generated a lot of interest in pollution studies particularly with respect to the nutrient status. The understanding of soil-vegetation/nutrient relationships of an ecosystem are of utmost significance in ecology because these will go a long way in determining the diversity of plants in such ecosystem. Hence this study aims at assessment of the pedo-nutrient association and plant diversity in a Cross River Ecosystem of Akwa Ibom State using principal component analysis techniques.

METHODOLOGY

Study Area

This research was conducted in Nwaniba, Uruan L.G.A. of Akwa Ibom State in Nigeria. The study area lies between latitude $E008^{O}02^{1}.795^{11}$and longitude $N05^{O}02^{I}.892^{11}$with the elevation of 59ft. Nwaniba is located in the coastal plain of south-eastern Nigeria and has an average temperature of $29.7^{o}C$ and average relative humidity of 66.4% (Umoh *et al.*, 2012). The climate is characterized by two seasons, the wet or rainy season and the dry season. The total annual rainfall varies from 4000mm along the coast to 2000mm inland. The vegetation is dense and tangled forming layers of canopies, it comprises of aquatic grasses, shrubs, epiphytes and swamp forest trees. The major occupation of the people in the area is farming, fuel-wood cutting, wine-palm tapping, wood logging, hunting, fishing and trapping of animals. Crops cultivated include cassava (*Manihot* spp.), Maize (*Zea mays*), plantain (*Musa spp*.), Oil palm (*Elaeis guineensis*), Palm-wine (*Raphia hookeri*) and Cocoyam (*Colocasia spp*.).

Vegetation, Water and Soil Sampling

The sampling was conducted in August and October 2016. The systematic random sampling method was adopted for comprehensive assessment and evaluation of the freshwater swamp forest. Three soil samples and four water samples were taken at three different stations ($N05^{O}03^{1}.448^{11}$ $E008^{O}02^{1}.967^{11}$ 57ft, $N05^{O}02^{1}.926^{11}$ $E008^{O}03^{1}.043^{11}$59ft and $N05^{O}02^{1}.682^{11}$ $E008^{O}02^{1}.834^{11}$ 61ft, respectively).

Vegetation sampling

For the assessment of the floristic composition and plant diversity, the site was divided into four parts. Each part was sampled using systematic sampling method: species of trees, shrubs, herbs, and grasses were collected, enumerated and properly identified to the species level.

Laboratory Procedures for Soil Analysis

The soil samples were air dried, crushed with mortar and passed through a 2mm sieve and stored in polythene bags for chemical and physical analysis. All soil analyses were carried out in the Soil Science Department of the University of Uyo, Uyo.

Physicochemical Analysis of Soil Samples:

Soil samples were analyzed following the standard procedures outlined by the Association of Official Analytical Chemist (A.O.A. C, 2003). Soil pH were measured using Beckman's glass electrode pH meter (Meclean, 1965). Organic Carbon by the Walkey Black wet oxidation method (Jackson, 1962), available Phosphorus by Bray P-1 method (Jackson, 1962). The total Nitrogen content was determined by Micro-Kjeldahl method (Jackobson, 1992). Soil particle size distribution was determined by the hydrometer method (Udo and Ogunwale, 1986). Exchange Acidity was determined by titration with 1N KCl (Kamprath, 1967). Total Exchangeable Bases were determined after extraction with 1M NH_4OAc (One molar ammonium acetate solution). Total Exchangeable Bases were determined by EDTA titration method while sodium and Potassium 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 was calculated by dividing total Exchangeable Bases by ECEC multiplied by 100

Determination of micronutrients

Digestion procedure (using perchloric acid). One gram (1g) of air dried soil sample (passed through 2mm sieve) was weighed out into a digestion flask and dissolved with 20ml of nitric acid and10ml of perchloric acid. The sample was digested using hot plate until the solution turned white and it was allowed to cool. 30ml of distilled water was added and filtered using Whatman filter paper.

The solution was made up to the mark (50ml) by adding distilled water. The concentrations of the respective micro-nutrients (Pb, Cr, Mn, Cd and Zn) were measured using atomic absorption spectrophotometer. The values were expressed in mg/kg.

Statistical Analysis:

Statistical package for Social Sciences (SPSS, Version 18.0) was employed for Analysis of Variance (ANOVA), Principal component analysis (PCA) was also used to determine the assortments.

Data analyses

Standardization and transformations of data to meet the requirements for normality necessary in parametric statistics were used (Aweto,1978). Plot ordination using the principal component analysis (PCA) method was used to examine and summarize trends of variation amongst nutrients variables. Ordination of species was undertaken to examine species relationships as would be shown by their groupings.

RESULT

The floristic composition of Nwaniba swamp forest as revealed in table 1 shows that there was a total of 24 plant species belonging to 15 families were unevenly distributed in the four stations sampled. The most frequent species which is common to the studied area include; *Raphia hookeri* (100%), *Nephrolepis biserrata* (75%) *and Vossia cuspidate* (75%) while the least species with 25% frequency include; *Anthocleista vogeii, Azolla africana, Azolla pinnata, Bambusa vulgaris, Ceratophyllum dermasum, Cleistopholis patens, Elaeis guineensis, Ipomoea aquatic, Ipomoea cairica, Ipomoea muuritiana, Mitragyna ciliata, Nymphaea alba, Nymphaea odorata, Pistia stratiotes, and Platycerium bifurcatum.*

Table 1: **The Floristic Composition of Nwaniba Swamp Forest**

Plant Species	Family	Habit	Frequency %
Rahia hookerii	Arecaceae	Tree/shrub	100
Rahia vinifera	Arecaceae	Tree/shrub	75
Anthocleista vogelii (planch)	Loganiaceae	Tree	25
Azolla africana Linn.	Azollaceae	Aquatic Fern/duckweed	25
Azolla pinnata Linn.	Azollaceae	Aquatic fern	25
Bambusa vulgaris Schrad.ex J.C.Wendl	Arecaceae	Tree/shrub	25
Ceratophyllum dermasum L.	Ceratophyllaceae	Aquatic plant	25
Cleistophalis patens (benth) Engl. And Diels	Annonaceae	Tree	25
Elaeise guineensis jacq	Arecaceae	Tree	25
Ipoemea aquatica	Convolvulaceae	Water spinach	25
Ipoemea cairica	Convolvulaceae	Coast morning glory	25
Ipoemea mauritiana jacq	Convolvulaceae	Giant potatoes'	25
Nymphea odorata	Nymphaeceae	American water lily	25
Nymphea lotus	Nymphaeceae	Water lilies	25
Nymphea alba	Nymphaeceae	Herbs	25
Pistia stratiotes	Araceae	Water lettuce	25
Nephrolepsis bisserata (Sw) Schott	Nephrolepidiaceae	Tropical fern	25
Mytragyna ciliata (Aubrev.Et Pellegr)	Rubiaceae	Tree	25
Platycerium bifurcatum (cav)C.chr	Polypodiaceae	Fern	25
Vossia cuspidata	Arecaceae	Grass	75
Pandanus candelabrum P.Beauv.	Pandanaceae	Tree/shrub	25
Salvinia molesta (C.Matt). Solms	Salviniaceae	Aquatic plant	25

In table 2, Particle size analysis showed that sand had an average of 95.80 in Station 2 and 3 and a least value of 93.80 in Station1. Silt followed with an average of 2.00 in Station1 and a least value of 0.00 in Station 2 and 3. Also, clay had an average of 4.20 in the 3 samples. pH had the highest value as 6.2 in Station 3 and a least value of 5.5 in Station2. EC obtained an average value of 0.0610 in Station 2 and lowest value of 0.0490 in Station 3. Org. M showed that Station 3 had a highest value of 51.87 and Station1 had a least value of 5.58. Av. P obtained an average of 9.37 in Station1 and a lowest value of 1.25 in Station 2. Ca obtained an average of 4.5 in Station3 and a least value of 2.80 in Station1. Mg had an average of 2.00 in Station3 and a least value of 1.30 in Station1. Na had a highest value of 0.06 in Station1 and 2 with a least value of 0.05 in Station 3. K result showed that Station1 had an average of 0.15 and 0.14 in Station2 and 3. EA had an average of 1.90 in Station1 and a least value of 1.76 in Station 2. ECEC obtained an average of 8.50 in Station 3 and a least value in 6.21 in Station1. B.SAT showed that Station 3 had an average of 78.71 and a least value of 69.40 in Station 1.

Table 2: Physical and Chemical Properties of Soil attributes of the Studied Area.

Parameters	Station 1	Station 2	Station 3
Sand (%)	93.80	95.80	95.80
Silt (%)	2.00	0.00	0.00
Clay (%)	4.20	420	4.20
pH	5.7	5.5	6.2
Elect. Conductivity (d/sm)	0.0590	0.0610	0.0490
Organic Matter (%)	5.58	44.53	51.87
Total Nitrogen (%)	0.14	1.11	1.29
Available Phosphate (mg/kg)	9.37	1.25	6.87
Calcium (Cmol/kg)	2.80	4.40	4.5
Magnessium (Cmol/kg)	1.30	1.90	2.00
Sodium (Cmol/kg)	0.06	0.06	0.05
Potassium (Cmol/kg)	0.15	1.40	1.40
Exchangeable acidity (Cmol/kg)	1.90	1.76	1.81
E.C.E.C (Cmol/kg)	6.21	8.26	8.50
Base Saturation (%)	69.40	78.69	78.71

Ordination of species-soil attributes extracted two principal components of which their sizes are given in Table 3. The first two components account for about 99.9% of the variations visible in the data set. The characteristic loadings of the rotated axes are shown in Table 1 indicating that each component possess key variables with high loadings. For convenience, each of these components will be designated species-soil factor component (S-SF).

S-SF$_1$: This component is the **Major-nutrients** component. This is the primary nutrient-species interphase governing most aquatic macrophytes distribution. The nutrient status gradient is determined by the high loading of 13 soil indices including Silt (0.983) organic matter (0.932) Total nitrogen (0.932), Mg (0.927), ECEC (0.912), Ca (0.894), sand (0.869), Base saturation (0.870) and Na (0.863), K (0.869), EA (0.639), pH (-0.689), Electrical Conductivity (0.774). The major-nutrient interphase retains strong loadings for species variables such as *Mitragyna ciliata* (0.888), *Vossia cuspidata* (0.863), *Pandanus candelabrum* (0.863), *Ceratophyllum dermasum* (0.863) and *Raphia vinifera* (0.863) *Salvinia molesta* (0.863) and *Nymphea odorata* (0.863).

S-SF$_2$: This is the **Complementary-nutrient** component. Within the component the following soil variables had high loadings: clay (0.999), Available phosphorus (0.952), Exchangeable acidity (0.769), pH (0.725) and Electrical Conductivity (0.633). The species sensitive to the complementary-nutrient complex are *Raphia hookerii* (0.999) and *Pistia stratiotes* (0.999). The fact that their distribution depends on this nutrient complex mandates these constant high loadings. Figure 1 represents the ordination diagram of the species-soil interactions in Cross River ecosystem. The diagram illustrates the segregation of species- soil characteristics into five abstract grouping.

Table 3: The size, percentage total variation and cumulative percentages of the correlation matrix of the first two components in the original data set of Species-soil variables of River Cross Ecosystem.

Species-soil Component	Eigen value	Percentage Variation	Cumulative percentage
I	15.787	63.137	63.137
II	9.216	36.863	100.000

Table 4: Rotated component Matrix of Ordination of soil variables of River Cross Ecosystem

Soil/plant parameters	Components	
	I	II
Sand	-.869	.495
Silt	.983	-.183
Clay	.006	.999
pH	-.689	-.725
EC	.774	.633
Org Matt	-.932	.361
TotN	-.932	.363
Av. Phosp	.306	-.952
Ca	-.894	.449
Mg	-.927	.376
Na	.863	.505
K	-.869	.495
EA	.639	-.769
ECEC	-.912	.410
B.Sat	-.870	.493
Vossia cuspdata	.863	.505
Pandanus candelabrum	.863	.505
Nymphea odorata	-.863	-.505
Raphia hookerii	-.006	.999
Raphia vinifera	.863	.505
Mitragyna ciliata	.888	-.460
Ceratophyllum dermasum	.863	.505
Salvinia molesta	.863	.505
Cytrospermum senegalensis	.863	.505
Pistia stratiotes	-.006	.999

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

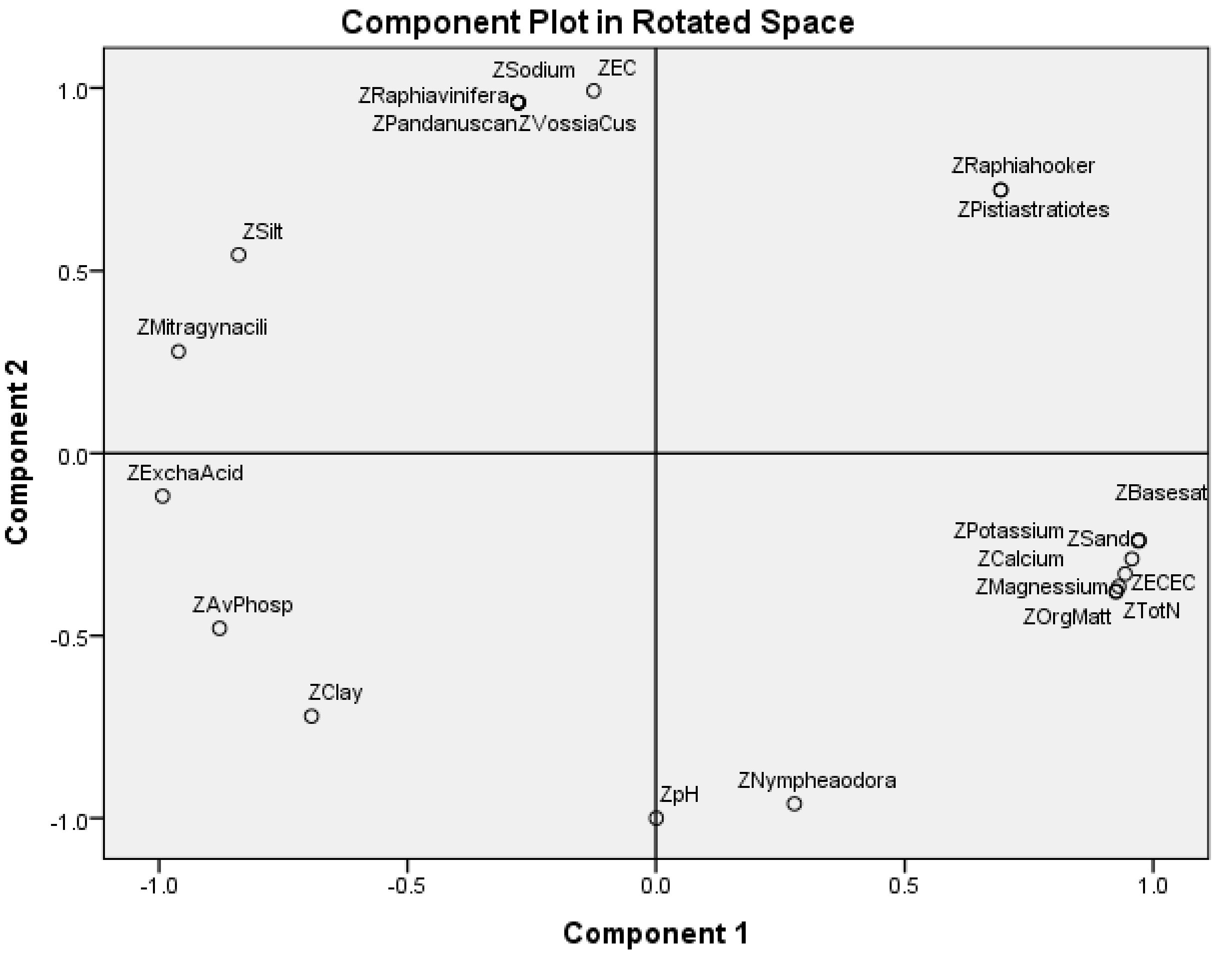

Figure 1: Ordination by Principal Component Analysis (Varimax rotation: Axes I and II) of soil variables of Cross River Ecosystem.
Definition of Variables: Av.P = Available Phosphorus, B. Sat. = Base Saturation, Ca = Calcium, Cr = Chromium, EA = Exchangeable acidity, EC= Electrical Conductivity, ECEC = Effective Cation Exchange Capacity, K = Potassium, Mn = Manganese, N = Nitrogen, Na = Sodium, Org. C = Organic Carbon, pH = Soil reaction, Pb = Lead and Zn = Zinc

DISCUSSION

The vegetation of the area investigated is as obtained in Table 1. From this study it is obvious that this ecosystem supports a good number of trees, shrubs and macrophyte species. Riparian trees include *Raphia vinifera, Mitragyna ciliata, Pandanus candelabrum, Elaies guineensis,* etc while the macrophyte species included *Azolla africana, Ceratophyllum demersum, Pistia stratiotes, Nymphea sp. etc.* Floristic assessment reveals that *Raphia hookerii* is the dominant species with 100% frequency while other species had less frequencies. This variability in the relative occurrence of this species reflect poor adaptability or stress related activities such as timber harvesting, road construction and establishment of industry in and around the swamp forest. Similar to this were the observation of Sharma and Joshi (2008) who recorded a major decline in vegetation structure of Mothronwala freshwater swamp due to human settlement, timber harvesting, agriculture and developmental activities around the periphery of the swamp. In confirming this Ubom *et al.* (2012) reported that human disturbances like selective logging or cultivation seems to have an influence on plant species diversity and density. High plant density showed low disturbance and/or minimal exploitation. This is in consonance to what Pitchairamu *et al*. (2008) opined that undisturbed vegetation stands showed high species richness while disturbed vegetation stands showed low species richness. The dominance of *Raphia hookeri* in this terrain should not be taken for granted. The dominance of this plant species indicated the suitability of the conditions and adaptation to the environment by the plant. A similar trend was recorded by Agbagwa and Ekeke (2011). The low values of density and frequency recorded for other species may be related to unfavorable soil conditions, high rate of exploitation, slow regeneration etc. The occurrence of amphibious, submerged and floating macrophytes shown is typical for fresh water systems (Ubom *et al.,* 2012). The presence of species such as *Anthocleista vogelii*, *Elaies guineensis*, *Bambusa vulgaris* and *Raphia sp*. is diagnostic of a secondary forest. It also indicates the economic value attached to this forest (Agbagwa and Ekeke, 2011). Ubom *et al.* (2012) while working on freshwater swamp forest revealed that soil properties form a constellation of factors determining vegetation distribution and structure. This is evident in this research in that principal component analysis generated two factor components on which both soil and plant variables loaded highly. Primary nutrient parameters such as calcium, phosphorus, total nitrogen loaded highly on these components. Jones and Wild (1975) posited that soil texture contributes to the presence of soil nitrogen since its availability is proportional to organic matter status of the soil which relies on the soil clay content. Shukla and Chandel (2008) had reported that the nitrogen content in surface soils range between 0.02-0.5% and that soil Nitrogen occur as part of organic molecule. This is evident in this research. The percentage of organic carbon present reflects the level of humus content of soil. This is dependent on the rate of decomposition of dead trees and leaves due to the action of soil bacteria and fungi present in the frequently moist wetland forest soil (Brady and Weil, 1999). Also, a fall in organic matter content leads to deterioration in soil physical properties and nutrient supply. Hence organic matter content improves soil structure and root penetration, moisture retention, resistance to erosion, maintenance of N and P levels and increase in exchange capacity of the soil. These then affect vegetation composition at a site. This summarizes the high loadings of most nutrient parameters in the first component. Generally, PCA assorts both plant and soil nutrient parameters in a way showing that these are but a continuum in vegetation space mandating that the concept of stations or plots are but arbitrary.

CONCLUSION AND RECOMMENDATIONS

Soil properties influence plant nutrition and distribution. Some of the nutrient factors that played vital roles in the wetland ecosystems include pH, nutrient cations and soil physical properties (sand, silt and clay). Positive interactions of the plant species with the soil nutrients and textural properties show their importance in the ecosystem. Correlation analyses between floristic attributes with pedological indices of this ecosystem reflect strong relationships at high statistically significant levels. Generally, negative correlation values signified levels of nutrient availability which were limiting to the plant performance (stressors) whereas positive relationships indicated essential nutrient levels. However, the pH has been identified as a key stressor in this ecosystem and the plant species show variability in pH tolerance as judge from their distribution. The result of this research has confirmed that there is a complex link existing between the vegetation morphology and soil properties in this wetland. The information obtained from this research could be essential in management and conservation of our fast eroding mangrove ecosystems.

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