Influence of Pedological Regimes on Plants Distribution in a Lacustrine Wetland in Uyo, Akwa Ibom State, Nigeria.

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Abstract: Studies on the influence of pedological regimes on plant distribution in a lacustrine wetland in Uyo, Akwa Ibom State, Nigeria revealed variations in density and frequency of plant species as a function of the soil parameters. A quadrat size of 5m x 5m through systematic sampling was used to sample the vegetation spaced at regular intervals. The vegetation parameters determined were density and frequency. Soil samples were collected at different depths (0 – 15 cm and 15 – 30 cm) and analyzed using standardized methods. Results obtained revealed a total of fourteen (14) plant species belonging to twelve families (12). *Elaeis guineensis* dominated in terms of density (5067±3.80 stems/ha) and frequency (80%). Species such as *Dioscorea bulbifera* (1600±0.25 stems/ha) *Mallotus oppositifolius* (1600±2.21stems/ha), *Pentaclethra macrophylla* (1600 ± 0.21 stems/ha), *Podococcus barteria* (1600 ± 0.30 stems/ha) and *Synsepalum dulcificum* (1600 ± 0.20 stems/ha) had low density values, respectively. Species such as *Albizia zygia*, *Alchornea cordifolia*, *Andropogon gayanus*, *Barteria nigritiana*, *Dioscorea bulbifera*, *Mallotus oppositifolius*, *Pentaclethra macrophylla* and *Podococcus barteria* had low frequency values of 20% each. The results revealed that lacustrine wetlands are conservatories for diverse plants species whose composition, growth and distribution are dependent upon the soil nutrient and substrate conditions. In the light of this, there is need to assess the anthropogenic activities that can alter soil properties and enforce proper conservation strategies in the management of this and other wetland ecosystems.

[Ita, Richard Ekeng, Ogbemudia, Felix Okpako and Udo, Nsikak Sebastian. **Influence of Pedological Regimes on Plants Distribution in a Lacustrine Wetland in Uyo, Akwa Ibom State, Nigeria.** *Researcher* 2017;9(8):16-21]. ISSN 1553-9865 (print); ISSN 2163-8950 (online). http://www.sciencepub.net/researcher. 4. doi:10.7537/marsrsj090817.04.

Keywords: Influence, Pedological regimes, plant distribution, lacustrine, wetland, density, frequency

1. Introduction

Wetlands are areas of marsh, fen, peatlands, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth at which at low tide does not exceed six meters (Ramsar Convention, 2011). They serve as important sites for biological conservation because they support a rich biodiversity and are characterized by high level of productivity (Mitsch and Gosselink, 2000). Wetlands are diverse in types all over the world ranging from marine, riverine, estuarine, palustrine and lacustrine wetlands but for the purpose of this study, the focal point is on lacustrine wetland.

Lacustrine wetlands (lakes) are ponded waters situated in topographic depressions or dammed river channels. They consist of persistent emergent vegetation, either sparse or lacking but include any areas with abundant submerged or floating-leaved aquatic vegetation (Mitsch and Gosselink, 2000). Some are known to dry out and to support species adapted to these large changes while others stay wet for long periods and provide a refuge for many species during dry times. They are an integral part of the global hydrobiological regime and are greatly influenced by both physiographic and climatic conditions. Such wetlands, artificial or natural, constitute an important component of aquatic ecosystem as they support human civilization, living animals and plant resources. They are often characterized by high levels of biodiversity and biological production (Roy and Nandi, 2008). These wetlands exhibit enormous diversity based on the origin, geographical location, hydrobiological regimes and substrate factors (Roy and Nandi, 2008).

Wetlands are characterized by the occurrence of plants of various life forms ranging from herbs, shrubs and trees. Some of these plants float freely on the water surface or remain suspended in the water column. Most are rooted in or attached to the substratum with their shoots being either wholly submerged or emergent above the water surface. Among the aquatic biota, plants are important components especially in nutrient rich wetland ecosystem (Seabloom, 2003), contributing immensely towards primary production and influencing various hydro-chemical processes. Their importance in wetlands cannot be overlooked as they serve as a complex habitats which offer support, protection and food to aquatic fauna (Tessier *et al*., 2004), erosion control, oxygen enrichment of water through photosynthesis, nutrient cycling, filtering and sedimentation and absorption of pollutants (Halls, 1997).

Soils in wetlands are characterized by a high degree of spatial variability due to a combination of physical, chemical and biological processes that operate with different intensities at different scales. These processes in wetland ecosystems include for example; surface run-off, erosion, over bank flooding, sediment deposition, ground water inputs, fire, animal burrowing, litter production and root activity (Bruland and Richardson, 2005). The distribution of plant species in lacustrine wetlands vary along different environmental gradients and soil conditions. For instance, flood-sensitive plants are usually distributed at higher-elevation sites because of their low tolerance to flooding, whereas flood-tolerant species usually occur at lower elevations (Luo *et al.*, 2008). Also, studies have shown that pedological attributes such as textural class, pH and nutrients among others, play significant roles in regulating vegetation patterns (Ubom, *et al.*, 2012; Kwon *et al.*, 2007).

Little or no attention in literature has been directed towards the status of plant distribution in relation to pedological properties in lakes and this has resulted in the paucity of information in this regards. This study reports the plant composition in a tropical lacustrine wetland relates their distribution to soil properties.

2. Materials and Methods

2.1. Study Area

The study was carried out in a lacustrine wetland in Uyo, Local Government Area of Akwa Ibom State, Nigeria. The wetland is situated at longitudes 7º 59’ 9” E and latitudes 5º 0’ 7” N with altitude 53.65 m above sea level. The topography is undulating with sparsely distributed homesteads and the surrounding lands are cultivated. Akwa Ibom State has a distinct rainy season stretching between April and October and a dry season occurring between November and early March. The average humidity is about 80%, and up to 95% occurring at the peak of the rainy season (AKSG, 2008).

2.2. Vegetation and Soil Sampling

Systematic (vegetation and soil) sampling method (Cochran, 1963) was used to sample the vegetation using a quadrat of 5 m x 5 m. In all, a total of 20 quadrats were marked. In each quadrat, vegetation components (plants) were identified to species level and their frequency and density were enumerated. Unknown plant species specimens were collected for identification and confirmation from voucher specimens in the Botany and Ecological studies Departmental Herbarium, University of Uyo, Uyo. Soil samples were obtained at two depths; 0 – 15 cm and 15 – 30 cm using a soil auger in each of the quadrats. A total of 20 soil samples were collected. The soil samples were air-dried and preserved in labelled Ziploc bags for laboratory analysis.

2.2.1. Determination of Vegetation Parameters

Density of plant species was determined using the method of Cochran (1963).

Frequency of plants was calculated thus:

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

2.3. Physicochemical Analysis of Soil Samples

Soil samples were analyzed using standardized methods. Soil Particle sizes, organic carbon, total nitrogen and available phosphorus were determined using the Hydrometer method, Walkey Black wet oxidation method, Micro-Kjeldahl method and Bray No 1 method (Jackson, 1992). Electrical conductivity, exchangeable acidity and pH were determined using a conductivity meter (Jenway Pcm 128723 model), titration with 1N KCL (Kramprath, 1967) and Beckman’s glass electrode pH meter (Mcclean, 1961), respectively. 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. Heavy metals were analyzed using Unicam 939 Atomic Absorption Spectrometer (AAS).

2.4. Statistical Analysis

Mean and standard error were computed from triplicates of physico-chemical parameters of soil. The relationships between soil variables and vegetation within the study area were established by bivariate correlation method using Statistical Package for Social Sciences (SPSS) version 20.0.

3. Results

The distribution of the plant species in the wetland is shown in Table 1. A total of fourteen (14) plant species belonging to twelve (12) families and fourteen (14) genera were recorded. The vegetation characteristics showed that *Elaeis guineensis* dominated in density (5067±3.80 stems/ha) while species such as *Dioscorea bulbifera*, *Mallotus oppositifolius*, *Pentaclethra macrophylla*, *Podococcus barteria and Synsepalum dulcificum* had the least density of 1600±0.25, 1600 ± 2.21, 1600 ± 0.21, 1600 ± 0.30 and 1600 ± 0.20 stems/ha, respectively. High frequency was also recorded by *Elaeis guineensis* (60%) while plant species such as *Albizia zygia*, *Alchornea cordifolia*, *Andropogon gayanus*, *Barteria nigritiana*, *Dioscorea bulbifera*, *Mallotus oppositifolius*, *Pentaclethra macrophylla* and

Podococcus barteria had the least frequency of 20%, respectively.

Table 1: Mean (±) S.E of Plants' Distribution in Lacustrine Wetland

Plant Species	Family	Habit	Density (stems/ha)	Frequency (%)
Albizia zygia	Fabaceae	Tree	3200±0.20	20
Alchornea cordifolia	Euphorbiaceae	Shrub	2400±0.31	20
Andropogon gayanus	Poaceae	Herbaceous	2400±0.23	20
Barteria nigritiana	Passifloracaceae	Tree	3200±0.21	20
Chromolaena odorata	Asteraceae	Herbaceous	4400±2.80	20
Costus afer	Costaceae	Herbaceous	2667±0.91	60
Dioscorea bulbifera	Dioscoreaceae	Climber	1600±0.25	20
Elaeis guineensis	Araceae	Tree	5067±3.80	80
Mallotus oppositifolius	Euphorbiaceae	Shrub	1600±2.21	20
Nephrolepis cordifolia	Lomariopsidaceae	Epiphytic	4000±3.10	40
Palisota hirsuta	Commelinaceae	Herbaceous	2400±1.12	40
Pentaclethra macrophylla	Fabaceae	Tree	1600±0.21	20
Podococcus barteri	Arecaceae	Herbaceous	1600±0.30	20
Synsepalum dulcificum	Sapotaceae	Tree	1600±0.20	40

S.E = Standard error

The physicochemical properties of soil in the wetland is shown in Table 2.

Table 2: Mean (± S.E) physicochemical properties of soil

Parameters	Unit	Values
pH		5.82±0.10
EC	(ds/m)	0.039±0.0038
Organic carbon	(%)	5.91±0.12
Av.P	(mg/kg)	53.95±4.38
Total N	(%)	0.15±0.0014
Ca	(cmol/kg)	6.40±0.83
Mg	(cmol/kg)	2.30±0.22
Na	(cmol/kg)	0.08±0.005
K	(cmol/kg)	0.13±0.005
EA	(cmol/kg)	2.35±0.09
ECEC	(cmol/kg)	11.15±0.97
B.S	(%)	78.4 ±2.11
Fe	(mg/kg)	346.14±64.74
Ni	(mg/kg)	12.50±2.50
Pb	(mg/kg)	11.15±3.55
Zn	(mg/kg)	53.50±13.50
Cd	(mg/kg)	5.05±0.15
Sand	%	70.60±1.74
Silt	%	10.00±0.32
Clay	%	19.40±2.28

S.E = Standard Error, EC= Electrical conductivity, Org.C = organic carbon, T.N = total nitrogen, Av.P= Available phosphorus, Ea = exchangeable acidity, ECEC = Effective Cation Exchange Capacity, B.S = Base Saturation.

3.1. Influence of Soil Parameters on Distribution of Plant Species

The influence of soil parameters on the distribution of plant species were established using multiple correlation analyses (Tables 3 and 4).

Table 3: Correlation Matrix of Soil Variables in the Study Wetland

	Ph	EC	Org.C	T.N	Av.P	Ca	Mg	Na	K	Ea	ECEC	B.S	Fe	Ni	Zn	Pb	Cd	Sand	Silt	Clay
pH	1																			
EC	-0.25	1																		
Org.C	0.27	-0.44	1																	
T.N	-0.84	-0.36	0.97**	1																
Av.P	-0.37	0.47	-0.14	-0.19	1															
Ca	0.52	0.29	-0.28	0.00	0.88*	1														
Mg	-0.34	0.04	0.66	0.63	0.64	0.70	1													
Na	-0.49	0.16	0.49	0.33	0.59	0.31	0.72	1												
K	-0.44	-0.42	-0.11	-0.32	-0.29	-0.60	-0.45	0.16	1											
Ea	0.46	0.23	0.89*	-0.85	0.32	0.37	-0.39	-0.49	-0.06	1										
ECEC	0.01	0.27	0.03	0.05	0.47	0.99**	0.89*	0.36	-0.58	0.31	1									
B.S	-0.25	0.15	0.52	0.52	0.73	0.82	0.56	0.64	-0.56	-0.24	0.85	1								
Fe	-0.44	-0.49	0.13	-0.50	-0.51	-0.78	-0.42	-0.15	0.69	-0.35	0.75	-0.57	1							
Ni	-0.42	0.37	-0.09	-0.29	0.52	0.62	0.18	0.77	0.49	-0.08	0.09	0.14	0.37	1						
Zn	0.49	-0.77	-0.11	-0.17	-0.11	0.08	-0.16	-0.38	0.29	0.43	0.08	-0.16	0.16	-0.37	1					
Pb	0.13	-0.84	0.06	-0.09	-0.79	-0.04	-0.07	-0.06	0.58	0.19	-0.21	-0.13	0.46	-0.05	0.92*	1				
Cd	-0.65	0.33	0.24	0.09	0.14	-0.28	0.16	0.75	0.43	-0.55	-0.24	0.53	0.49	0.83	-0.67	-0.32	1			
Sand	0.61	0.48	-0.84	-0.67	-0.10	0.00	-0.63	-0.76	-0.32	0.73	-0.07	0.42	-0.43	-0.36	-0.04	-0.35	-0.49	1		
Silt	0.46	-0.79	0.59	0.61	-0.18	0.19	0.38	-0.13	-0.19	-0.21	0.22	0.58	-0.11	-0.63	0.65	0.57	-0.59	-0.41	1	
Clay	-0.81	0.26	0.05	-0.14	0.79	0.46	0.53	0.54	0.27	-0.01	0.49	0.38	0.09	0.74	-0.16	0.11	0.60	-0.49	-0.30	1

**Correlation is significant at 0.01 level (2-tailed)

*Correlation is significant at 0.05 level (2-tailed)

EC = Electrical Conductivity, Org. C = Organic carbon, T.N = Total Nitrogen, Av.P = Available Phosphorus, Ea = Exchangeable acidity, ECEC = Effective Cation Exchange Capacity, B.S = Base Saturation

3.1.1. Soil-Soil Correlates

Table 3 shows the correlation matrix for soil variables in lacustrine wetland. There was a positive relationship between nitrogen and organic carbon (r = 0.97, p = 0.01). Exchangeable acidity also showed a positive correlation with organic carbon (r = 0.89, p = 0.05). Calcium gave a positive correlation with available phosphorus (r = 0.88, p = 0.05), while Effective Cation Exchange Capacity correlated positively with magnesium (r = 0.89, p = 0.05) and calcium (r = 0.99, p = 0.01). Lead correlated positively with zinc (r = 0.92, p = 0.05).

3.1.2. Soil-Vegetation Correlates

The soil-vegetation correlates as shown in Table 4 show that density had a significant positive relationship with organic carbon (r = 0.97, p = 0.01), calcium, magnesium (r = 0.88, p = 0.05), exchangeable acidity (r = 0.89, p = 0.05), iron (r = 0.97, p = 0.01) and a negative relationship with sand (r = -0.90, p = 0.05). Frequency correlated positively with organic carbon (r = 0.92, p = 0.05) available phosphorus (r = 0.87, p = 0.05) and iron (r = 0.99, p = 0.01).

Table 4: Soil-vegetation Correlates

Soil properties	Density (Stems/ha)	Frequency (%)
pH	-0.43	0.40
EC	-0.40	-0.56
Organic carbon	0.97**	0.92*
Av.P	0.51	0.87*
Total N	0.48	0.62
Calcium	0.90*	0.11
Magnesium	0.88*	0.66
Sodium	0.73	0.52
Potassium	0.08	0.30
Exchangeable acidity	0.89*	-0.61
Effective Cation Exchange Capacity	0.55	0.18
Base saturation	0.74	0.52
Iron	0.97**	0.99**
Nickel	0.31	0.45
Zinc	0.27	0.19
Lead	0.48	0.68
Cadmium	0.17	0.35
Sand	-0.90*	-0.73
Silt	0.52	0.51
Clay	0.64	0.50

**Correlation is significant at 0.01 level (2-tailed).
*Correlation is significant at 0.05 level (2-tailed)

4. Discussion

The vegetation characteristics portray a rich diversity of plant species. This is not unlinked to the suitability of the soil conditions which favoured the establishment of these plant species. A wide range of variability in terms of density and frequency was also observed in the wetlands. These variations may be attributed to the different levels of biomass production in various plots across the wetland. The dominance of *Elaeis guineensis* is this pond is not unswerving to the fact this plant species have a wide range of ecological tolerant to varying pedological (soil) and hydrological regimes. The dominance of this species may also vindicate the economic importance attached to the pond. The low species density associated with species such as *Dioscorea bulbifera, Mallotus oppositifolius, Pentaclethra macrophylla, Podococcus barteri* and *Synsepalum dulcificum* may invariably point to their inability to adapt fully to hydric conditions. Excessive anthropogenic perturbations, inability to compete for environmental resources (light and nutrients), slow regeneration and selective exploitation of species may further account for the low diversity of these species. This corroborates with the findings of Wassie and Teketey (2006). Lacustrine wetland supports a good number of tree and shrubby species and this contradicts the reports earlier made by Cowardin *et al.* (1979) that lacustrine wetlands lack trees, shrubs and persistent emergent vegetation.

The moderate acidity of the soil pH might have arose on the basis of litter decomposition in the wetland. This had been confirmed earlier by Stevenson (1991). Texturally, the soil was sandy loam resulting in their poor structural stability, nutrients and water retention capacities. This may justify the low levels of vital soil nutrients such as total nitrogen, organic carbon and potassium recorded in this study. This agrees with the findings of Jones (1973) that low soil nutrients is attributed to low litter, low clay and moisture contents. The low levels of basic cations such as Ca, Mg and Na recorded in the study may substantiate that the soil had a low sink for these nutrients. Similar instance had been reported by Ubom (2006). Also the high sand content in this wetland might further account for low retention of cations in the soils. The high values recorded for heavy metals such as Fe, Zn, Ni, Pb and Cd may underscore the various intensity of anthropogenic perturbations going on around the wetland.

The synergistic relationship between nitrogen and organic carbon (Table 3) may not be unrelated to litter decomposition. This view is not indifferent from that of Brady and Weil (1996) who had inferred that organic carbon through litter decomposition is a major source of nutrients such as nitrogen, calcium, magnesium in the soil. Furthermore, as these nutrients are released into the soil, the luxuriant growth of plant species is also favoured. This further confirms the positive relationship of density with organic carbon (Table 4). The positive association between exchangeable acidity and organic carbon is in line with the view of Stevenson (1991) that fulvic and humic acids are released into soil during litter decomposition. This further implies that the acidity of this wetland is related to litter decomposition. Calcium and available phosphorus related positively with each other and this may invariably point to same source of nutrient enrichment in the wetland. The positive association between ECEC with Ca and Mg may portray that these cations are the principal components of the cation exchange complex, retained greatly in the soil and were devoid of leaching. The positive affiliation between Pb and Zn may suggest that the source of Zn in this wetland was rich in Pb (pollutant) and this trend is not unconnected to anthropogenic incursions.

The significant correlation matrices between soil and vegetation parameters confirm the influence of soil properties on plants' distribution (Table 4). Density of plant species correlated positively with Ca and Mg. The may suggest that the retention of these cations (secondary macronutrients) in increasing amount played a contributive role in the growth of plants in terms of density. This view corroborates with the findings of Hepler (2005) who reported that Ca is important to every plant for their growth and development and is involved in activating the enzymes, inducing water movement and salt balance in plant cells, and also activating K to control the process of opening and closing of stomata. It is also required for cell growth, division, elongation, and various essential biological functions (Hirschi, 2004). Calcium boosts the nutrient uptake, improves the plant tissue's resistance, makes cell wall stronger, and contributes to normal root system development (Hirschi, 2004). Magnesium on the other hand is a central atom of chlorophyll and therefore plays a major role in plant photosynthesis, and thus its deficiency degrades the chlorophyll content and leaves become yellowish in color, a condition termed as chlorosis. However, an adequate supply of Mg makes the plant healthy (Hermans *et al*., 2010). The significant positive relationship observed between density and exchangeable acidity is not clearly understood in this study but can be interpreted in terms of tolerance to acidic substrate. This may imply that species with high tolerance to acidic conditions had high density while those with inability to adapt or tolerate acidic conditions had low density. Iron related positively with density and frequency of plant species. This direct relationship is not unprecedented but rather studies have shown that iron plays critical role in metabolic processes in plants such as DNA synthesis, chlorophyll synthesis, respiration, and photosynthesis (Rout and Sahoo, 2015). Also, iron aids in the activation of many metabolic pathways and is a prosthetic group constituent of many enzymes. Deficiency of iron in plants results in poor yields, chlorosis, stunted root growth and reduced nutritional quality (Rout and Sahoo, 2015). An inverse relationship evidenced between density of plants and sand may underscore the influence of textural class on species composition. This entails that as the sand content increases, the density of plant species decreased. Sandy substrate is porous with low water and nutrient retention abilities and these attributes are detrimental to the growth and distribution of plants in this wetland. Similar assertion was made by Smith *et al*. (1997). The positive association of frequency with organic carbon and available phosphorus may invariably points to the fact that the increasing occurrences of plants in the wetland plots are dependent on these nutrient availability.

5. Conclusion

The study shows that lacustrine wetlands are conservatories for diverse plant species whose distribution varied in terms of density and frequency. These variations in the vegetation parameters are functions of the pedological parameters which exert great influence on plants' growth and distribution. The soil-soil and soil-vegetation correlates showed relationships between these variables at statistically significant levels. Negative relationships showed levels of nutrients that were low to plants' performance while positive relationships suggested essential nutrient levels required for their growth. Conclusively, this study shows that plants' distribution are dependent on varying levels of nutrient availability in the soil and as such efforts should be geared towards avoiding anthropogenic perturbations of various forms which can result in the alteration of the important soil parameters and nutrient loss in the wetlands. The information obtained in this study will be useful for the monitoring, protection, conservation and management of lacustrine systems and other lentic ecosystems since it supports rich and diverse plant species.

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8/25/2017