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Predictive Models for Floristic Components using Soil Variables in Seasonal Lacustrine Wetlands

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Abstract: The overlap between vegetation and environmental factors in wetlands has always been a key area in plant ecology. Studying vegetation components in wetland without allusion to the environmental factors governing their distribution is inconclusive. To this end, mathematical models were applied to predict floristic components using soil variables in seasonal lacustrine wetlands. A quadrat size of 5m × 5m was used to systematically sample the vegetation for density, frequency, height, basal area and crown cover. In each quadrat, soil samples were obtained at different rooting depths (0 -15 cm and 15 – 30 cm). Results obtained showed variations in the floristic composition in the wetlands seasonally. Rural wetland had seventeen (17) plant species during the dry season and fourteen (14) plant species during the wet season while urban wetland had eleven (11) plant species in the dry season and thirteen plant species (13) in the wet season. Variations in density, height, frequency, basal area and crown cover occurred in the wetlands. The physicochemical properties of the soil in these wetlands varied seasonally. A prediction model using stepwise multiple regression analysis revealed the vegetation and species responses to the environment on the basis of soil variables and also showed their relationship with each other. It also showed the various predictors (soil properties) of the vegetation components such as density (exchangeable acidity, sand, pH, Na, Zn, Cd, Ca and total nitrogen), height (base saturation, Ni and sand), crown cover (exchangeable acidity, clay and electrical conductivity) and basal area (exchangeable acidity). In summary, it is established that using mathematical models, environmental variables (soils) can serve as good predictors of vegetation components in wetlands by elucidating the soil-vegetation interrelationships.
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1. Introduction

The assessment or analysis of species-environment relationship and the quantification of this relationship has epitomized the fundamental of predictive modeling in ecological studies. These models are mostly based on how several environmental variables or factors regulate the occurrence and distribution of species and communities. Plant distribution is an all-inclusive product of the prolonged interaction of geomorphological features, pedological and hydrological conditions. Floristic variables such as density, frequency, height, basal area and crown cover are distinct components in vegetation ecology and they embody information by displaying significant feedbacks or responses to several environmental factors (Cui and Shi, 2010). Consequently, on the basis of quantitative research and broad theoretical investigation on the relationship between vegetation and environmental factors, scholars have developed series of predictive mathematical models on both regional and global scales. These models are valuable for the environmental interpretation of vegetation distributional patterns (Wen *et al*., 2009). One of such models proven effective in plant ecology for prediction is multiple regression.

Multiple regression analysis (MRA) is a multivariate analytical technique useful in establishing relationships between sets of vegetation and environmental variables. This involves the specification and identification of the type of dependence of a single variable upon a set of controlling predictor variables (Mather, 1976). This method analyses the collective and separate contributions of two or more independent variables to the variation of dependent variables. It helps to explain the variance of a dependent variable and also predict, explain and indicate the nature and magnitude of the relations between dependent and independent variables (Mather, 1976). Three approaches of multiple regression exist depending on the method of selection of predictor variables namely; forward, backward and stepwise multiple regression (SMR). For this study, stepwise multiple regression is utilized.

The choice of SMR is strengthened by the fact that this model identifies from many available factors a small subset of factors that explains or relate significantly to the outcome.

Several studies on wetlands in ecology have focused mainly on species richness in response to disturbance, hydrological and seasonal regimes. Very few scientific literatures exist with regards to the use of mathematical models in specifically predicting vegetation components using soil variables in wetland ecosystems. Against this backdrop, an investigative framework using stepwise multiple regression is therefore desired which will unravel series of explanatory variables (soil) accounting for variations evidenced in the response variables (vegetation) in wetlands.

2. Material and Methods

2.1 Study Areas

The study was carried out in two lacustrine wetlands in Akwa Ibom State, Nigeria. They include Mbak Akpan Ekpenyong pond, a rural lacustrine wetland in Mbak Etoi and Udoudoma pond, an urban lacustrine wetland in Aka Offot, all in Uyo Local Government Area of Akwa Ibom State, Nigeria. The rural wetland is situated at longitudes 7° 59' 9" E and latitudes 5° 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. Udoudoma pond is located at longitudes 7° 55' 19" E and latitudes 5° 0' 35" N with altitude 22.13 m above sea level. The topography is sloppy with infrastructural developments and residential estates dominating the area. Akwa lbom State lies entirely on the coastal plain of South-eastern Nigeria, characterized by two seasons, namely, rainy season and the dry season. The rainy season begins about March to April and lasts until mid-November. The dry season begins in mid-November and ends in March. Akwa lbom State receives relatively higher rainfall totals than other parts of Southern Nigeria (AKSG, 2008). The total annual rainfall varies from 4000 mm along the coast to 2000 mm inland (AKSG, 2008). The average humidity is about 75% to 95%, with the highest and lowest values in July and January respectively. Temperature values are relatively high in Akwa lbom State throughout the year, with the mean annual temperatures varying between about 26°C to 36°C. Akwa Ibom State is characterized by luxuriant tropical rainforests dominated by secondary forests of predominantly wild oil palms, woody shrubs and various grass under growths (AKSG, 2008).

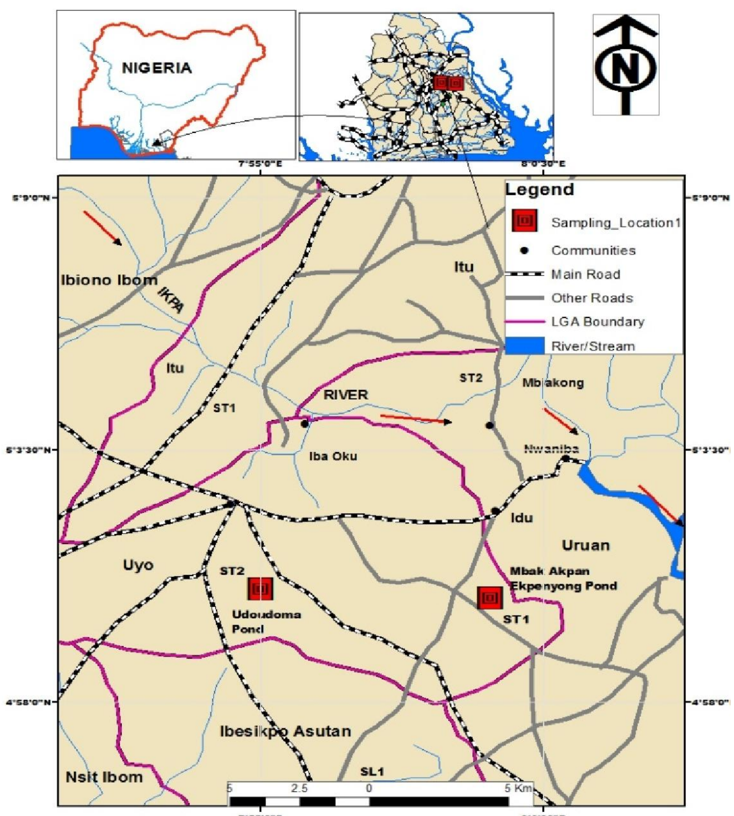

Figure 1. Map of the study areas

2.2 Vegetation and Soil Sampling

A total of four (4) plots in each wetland site were used for this study. In each plot, 5 belt transects were laid and in each transect, vegetation and soil each were systematically sampled at regular intervals using a quadrat of 5 m x 5 m. In each quadrat, vegetation components (plants) were identified to species level and their frequency and density were obtained by enumeration. Unknown plant species specimens were collected for identification and confirmation from voucher specimens in Botany and Ecological studies Departmental Herbarium, University of Uyo, Uyo. In each quadrat, frequency and density of species, basal area as cross sectional area of individuals, crown cover as crown horizontal area were determined. Height of woody species using Haga altimeter was also measured. Using a soil auger in each of the quadrats, soil samples were obtained at two depths; 0 – 15 cm and 15 – 30 cm. Two soil samples were collected in each quadrat, stored in labelled Ziploc bags and taken to the laboratory for physicochemical analyses.

2.2.1 Determination of Vegetation Parameters

2.2.1.1 Density

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

2.2.1.2 Frequency

The frequency of each species occurrence was calculated thus:

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

2.2.1.3 Height

The heights of woody species were measured using a Haga altimeter (43913 model). The reading was taken 15 m away from the base of the woody plant from where the crown was sighted through the eye piece of the altimeter and the upper reading taken. The base of the woody plant was similarly sited and the lower altimeter readings taken. The height of each species was calculated using the relation:

Height (m) = Algebraic sum of the reading of the top and bottom of each plant × horizontal distance from observer to each species divided by scale factor used on the altimeter.

2.2.1.4 Basal Area

This was calculated using the relation:

$$\text{Basal Area} = \frac{C^2}{4\pi}$$

Where $4\pi = 4 \times 3.142 = 12.568$

C = girth size of the species at breast height

2.2.1.5 Crown Cover

The crown cover of woody plant species was determined by the crown cover diameter method (Muller- Dombios and Ellenberg, 1974).

2.3. Physicochemical Analysis of Soil Samples

Approved standard methods were adopted in analyzing soil samples. 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, 1962). 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.

2.4 Statistical Analysis

Statistical Package for Social Sciences (SPSS, Version 20.0) was employed for descriptive statistics (mean and standard error). Stepwise multiple regression technique was used to determine which of the soil parameters accounted significantly for variations in the vegetation attributes. This model followed the general equation as shown below:

$$Y = a + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + b_nX_n \pm S.E$$

Where Y = (response variable)

a = intercept

b = partial regression coefficient

X = explanatory variable (predictor)

S.E = Standard error of estimates

3. Results

3.1 Vegetation Characteristics of the Wetlands

The vegetation characteristics of the wetlands were analyzed seasonally. The dry season vegetation characteristics of the rural lacustrine wetland revealed that seventeen (17) species of plants were identified (Table 1). The vegetation characteristics showed that *Elaeis guineensis* was the most dominant (3200 ± 0.20 stems/ha). *Elaeis guineensis* also dominated in terms of height (10.83 ± 1.11 m). *Pentaclethra macrophylla* had the lowest density (160 ± 0.11 stems/ha). *Longocarpus griffoneonus* was the shortest species with the height of 2.00 ± 0.02 m. *Raphia hookeri* had the highest crown cover (7.15 ± 1.20 m^2/ha) and this was closely followed by *Elaeis guineensis* (5.65 ± 1.74 m^2/ha). *Pentaclethra macrophylla* had the least crown cover (1.57 ± 0.01 m^2/ha). *Elaeis guineensis and Raphia hookeri* had the highest basal area of 0.14 ± 0.02 m^2/ha and 0.14 ± 0.01 m^2/ha, respectively. The seventeen plant species found in this wetland represented twelve (12) families and sixteen genera. However, some of the plant species here were ephemerals with negligible girths and coverage.

The dry season vegetation characteristics of the urban lacustrine wetland showed that eleven (11) plant species were identified belonging to ten (10) families and ten (10) genera (Table 1). This wetland was dominated by *Persicaria senegalensis* with density of 1200 ± 0.13 stems/ha. This was followed by *Azolla africana* (400 ± 0.00 stems/ha). *Commelina communis*, *Gliricidia sepium, Ludwigia erecta and Lagenaria breviflora* had the least density of 80 ± 0.40, 80 ± 0.11, 80 ± 0.10 and 80 ± 0.41 stems/ha, respectively. *Persicaria senegalensis* occurred most in this wetland with a frequency of 100%.

The wet season vegetation characteristics of rural lacustrine wetland showed that fourteen (14) plant species were found belonging to twelve (12) families and fourteen (14) genera (Table 2). The vegetation characteristics showed that *Elaeis guineensis* dominated in density (5067±3.80 stems/ha), height (10.43±0.87m), frequency (60%), Basal area (0.21±0.02 m^2/ha) and Crown Cover (5.04 ± 1.14m^2/ha). *Dioscorea bulbifera*, *Mallotus oppositifolius*, *Pentaclethra macrophylla*, *Podococcus barteri* and *Synsepalum dulcificum* had the least density of 1600±2.21, 1600 ± 0.21, 1600 ± 0.30, 1600 ± 0.20 and 1600 ± 0.20 stems/ha, respectively. *Albizia zygia*, *Alchornea cordifolia*, *Andropogon gayanus*, *Barteria nigritiana*, *Dioscorea bulbifera*, *Mallotus oppositifolius*, *Pentaclethra macrophylla* and *Podococcus barteria* had the least frequency of 20%, respectively. *Chromolaena odorata* was the shortest plant species (3.00 ± 0.10m), *Alchornea cordifolia* and *Barteria nigritiana* had the least basal area (0.06 ± 0.01 m^2/ha and 0.06 ± 0.02 m^2/ha). *Barteria nigritiana* and *Synsepalum dulcificum* had the least crown cover of 1.77 ± 0.005 m^2/ha and 1.77 ± 0.02 m^2/ha, respectively.

The wet season vegetation characteristics of urban lacustrine wetland revealed that thirteen (13) plant species were found (Table 2). *Persicaria senegalensis* dominated in frequency (100%) and density (1800 ± 30.70 stems/ha). *Elaeis guineensis* dominated in height (9.20 ± 1.21 m), basal area (3.20 ± 0.62 m^2/ha) and crown cover (9.71±1.91). *Gliricidia sepium* had the least density of 80 ± 0.11 stems/ha.

3.2 Physical and Chemical Properties of Soil in the Wetlands

Table 3 shows the dry season physical and chemical parameters of the soil in the wetlands. The results showed that the pH of the soil in both the rural and urban wetlands were slightly acidic with mean values of 6.02 ± 0.21 and 6.57 ± 0.67 respectively. Organic carbon, available phosphorus (Av.P), sodium (Na), total nitrogen and exchangeable acidity (EA) were high in the rural wetland while calcium (Ca), magnesium (Mg), electrical conductivity (EC) Effective Cation Exchange Capacity (ECEC) and base saturation (B.S) were high in the urban wetland. Heavy metal analysis in these wetlands revealed that the urban wetland had the highest contents of iron (Fe) (713.22 ± 59.39), lead (Pb) (5.95 ± 0.42), zinc (Zn) (88.54 ± 8.03 mg/kg) and cadmium (Cd) (1.53 ± 0.65 mg/kg) while nickel (Ni) was high in the rural wetland. The percentages of sand and silt contents were high in the rural wetland (69.40 ± 4.56 and 13.40 ± 0.40) while the urban wetland recorded high clay content value of 22.73 ± 2.22. The soil textures of these wetlands were sandy loam.

The wet season physical and chemical parameters of soils in the study wetlands is presented in Table 4. The result showed that the pH of the soil in the wetlands were moderately acidic. Organic carbon, available phosphorus, exchangeable acidity (EA), iron (Fe), cadmium (Cd) and clay content were high in the urban wetland. Calcium (Ca), magnesium (Mg), base saturation (B.S), ECEC, Lead (Pb), nickel (Ni), zinc (Zn), sand and silt contents were high in the rural wetland. Texturally, the soils were sandy loam.

Table 1. Dry Season Vegetation Characteristics of the Wetlands

Plant species	Habit	Family	Density (stems/ha)	Frequency (%)	Height (m)	Basal area (m^2/ha)	Crown cover (m^2/ha)
Rural Wetland							
Alchornea cordifolia Muell. Arg.	Shrub	Euphorbiaceae	640±0.00	20	3.50±0.50	-	-
Barteria nigritiana Hook f.	Tree	Passifloraceae	960±0.00	40	3.00±0.00	0.13±0.02	2.22±0.65
Cnestis ferruginea DC	Shrub	Connaraceae	240±2.13	20	-	-	-
Commelina lagosensis C. B. Clarke	Herbaceous	Commelinaceae	320±0.50	20	-	-	-
Crassocephalum crepidioides	Herbaceous	Asteraceae	240±1.23	20	-	-	-
(Benth) S. Moore	Herbaceous	Aracaceae	2400±5.32	20	-	-	-
Culcasia scandens P. Beauv.	Herbaceous	Araceae	1040±1.23	20	-	-	-
Cyrtosperma senaglense (Schott)	Herbaceous	Melastomaceae	1600±1.32	20	9.00±4.04	-	-
Engl.	Tree	Aracaceae	3200±0.20	60	10.83±1.11	0.14±0.02	5.65±1.74
Dissotis rotundifolia (Sm) Triana	Shrub	Fabaceae	240±0.20	20	2.00±0.02	-	-
Elaeis guineensis Jacq.	Shrub	Lomariopsidaceae	320±0.81	20	-	-	-
Longocarpus griffoneonus (Schum.	Herbaceous	Commelinaceae	480±0.02	20	3.00±0.00	-	-
& Thonn) Benth	Tree	Fabaceae	160±0.11	20	3.00 ±0.25	0.12±0.01	1.57±0.01
Nephrolepis cordifolia (L.) K. Presl	Tree	Aracaceae	400±0.69	20	5.00±0.37	0.14±0.01	7.15±1.20
Palisota hirsuta (Thumb.) K.	Grass	Malvaceae	400±1.32	20	-	-	-
Schum	Tree	Sapotaceae	240±0.10	20	3.33±0.33	0.04±0.02	-

Pentaclethra macrophylla Benth.	Herb	Malvaceae	320±2.10	20	-	-	
Raphia hookeri Mann & Wendland							-
Sida acuta Burm. F.							
Synsepalum dulcificum (Schum & Thonn) Daniell.							
Urena lobata L.							

Urban Wetland

Plant Species	Habit	Family	Density (stems/ha)	Frequency (%)	Height (m)	Basal area (m^2/ha)	Crown cover (m^2/ha)
Azolla africana L.	Free floating	Salviniaceae	400±0.00	40	-	-	-
Commelina benghalensis L.	Herb	Commelinaceae	160±0.12	20	-	-	-
Commelina communis L.	Herbaceous	Commelinaceae	80±0.40	20	-	-	-
Elaeis guineensis Jacq.	Tree	Aracaceae	240±0.30	20	9.20±1.40	3.20±0.50	9.82±2.31
Gliricidia sepium (Jacq.) Wall	Tree	Euphorbiaceae	80±0.11	20	4.30±0.40	0.90±0.00	0.90±0.03
Kyllinga brevifolia Rottb	Sedge	Cyperaceae	240±0.30	20	-	-	-
Lagenaria breviflora (Benth) Roberty. [Adenopus breviflorus Benth.]	Creeper	Curcubitaceae	80±0.41	20	-	-	-
Ludwigia erecta L.	Herbaceous	Onagraceae	80±0.10	20	-	-	-
Nymphaea lotus L.	Floating macrophyte	Nymphaeceae	240±0.24	40	-	-	-
Panicum maximum Jacq.	Herbaceous	Poaceae	320±0.14	20	-	-	-
Persicaria senegalensis Mill.	Herbaceous	Polygonaceae	1200±0.13	100	-	-	-

Table 2. Wet Season Vegetation Characteristics of the Wetlands

Plant species	Habit	Family	Density (stems/ha)	Frequency (%)	Height (m)	Basal area (m^2/ha)	Crown cover (m^2/ha)
Rural Wetland							
Albizia zygia (DC.) J.F. Macbr							
Alchornea cordifolia Muell. Arg							
Andropogon gayanus Kunth							
Barteria nigritiana Hook f.	Tree	Fabaceae	3200±0.20	20	4.50±0.00	0.16±0.01	3.14±0.20
Chromolaena odorata (L.) King	Shrub	Euphorbiaceae	2400±0.31	20	9.11±0.06	0.06±0.01	-
& Robinson	Herbaceous	Poaceae	2400±0.23	20	6.32±0.02	-	-
Costus afer Ker – Gawl	Tree	Passifloracaceae	3200±0.21	20	3.11±0.01	0.06±0.02	1.77±0.005
Dioscorea bulbifera L.	Herbaceous	Asteraceae	4400±2.80	20	3.00±0.10	-	-
Elaeis guineensis Jacq.	Herbaceous	Costaceae	2667±0.91	40	3.83±0.52	-	-
Mallotus oppositifolius (Geisel.)	Climber	Dioscoreaceae	1600±0.25	20	7.61±0.005	-	-
Muell. Arg.	Tree	Araceae	5067±3.80	60	10.43±0.87	0.21±0.02	5.04±1.14
Nephrolepis cordifolia (L.) K.	Shrub	Euphorbiaceae	1600±2.21	20	3.21±0.01	-	-
Presl.	Epiphytic	Lomariopsidaceae	4000±3.10	40	3.95±0.15	-	-
Palisota hirsuta (Thunb.)K.	Herbaceous	Commelinaceae	2400±1.12	40	3.55±0.15	-	3.14±0.005
Schum	Tree	Fabaceae	1600±0.21	20	3.11±0.003	0.12±0.05	-
Pentaclethra macrophylla Benth.	Herbaceous	Arecaceae	1600±0.30	20	3.11±0.003	-	1.77±0.02
Podococcus barteri G. Mann &	Tree	Sapotaceae	1600±0.20	40	5.05±0.25	0.09±0.00	
H. Wendl.							
Synsepalum dulcificum (Schum & Thonn.) Daniell.							

Urban wetland

Plant Species	Habit	Family	Density (stems/ha)	Frequency (%)	Height (m)	Basal area (m^2/ha)	Crown cover (m^2/ha)
Azolla africana L.	Free floating	Salviniaceae	450±2.30	40	-	-	-
Commelina benghalensis L.	Herb	Commelinaceae	169±0.42	20	-	-	-
Commelina communis L.	Herbaceous	Commelinaceae	85±0.60	20	-	-	-
Cyperus rotundus L.	Sedge	Cyperaceae	850±20.14	80	-	-	-
Elaeis guineensis Jacq.	Tree	Aracaceae	240±0.47	20	9.20±1.21	3.20±0.62	9.71±1.91
Gliricidia sepium (Jacq.) Wall	Tree	Euphorbiaceae	80±0.65	20	4.30±0.40	0.90±0.00	0.87±0.04
Kyllinga brevifolia Rottb	Sedge	Cyperaceae	280±3.12	20	-	-	-
Lagenaria breviflora (Benth) Roberty. [Adenopus breviflorus Benth.]	Creeper	Curcubitaceae	85±0.71	20	-	-	-
Ludwigia erecta L.	Herbaceous	Onagraceae	92±0.30	20	-	-	-
Nymphaea lotus L.	Floating macrophyte	Nymphaeceae	290±0.69	40	-	-	-
Panicum maximum Jacq.	Herbaceous	Poaceae	368±1.65	20	-	-	-
Persicaria senegalensis Mill.	Herbaceous	Polygonaceae	1800±30.70	100	-	-	-
Urena lobata L.	Herbaceous	Malvaceae	700±25.10	80	-	-	-

Table 3. Dry Season Physical and Chemical Properties of Soils in the wetlands

Parameters	Rural wetland	Urban wetland
pH	6.02 ± 0.21	6.57 ± 0.67
E.C (ds/m)	0.042 ± 0.12	0.055 ± 0.17
Organic carbon (%)	4.80 ± 0.57	4.23 ± 0.32
Av.P (mg/kg)	37.98 ± 8.50	33.86 ± 3.86
Total N (%)	0.12 ± 0.16	0.11 ± 0.11
Ca (cmol/kg)	3.44 ± 0.16	5.07 ± 0.52
Mg (cmol/kg)	1.46 ± 0.05	2.13 ± 0.29
Na (cmol/kg)	0.36 ± 0.29	0.07 ± 0.006
K (cmol/kg)	0.14 ± 0.004	0.13 ± 0.009
EA (cmol/kg)	3.00 ± 0.12	2.42 ± 0.19
ECEC (cmol/kg)	8.11 ± 0.22	9.81 ± 0.92
B.S (%)	62.96 ± 1.44	73.98 ± 1.94
Fe (mg/kg)	663.65 ± 69.81	713.22 ± 59.39
Ni (mg/kg)	9.45 ± 1.56	8.41 ± 1.57
Pb (mg/kg)	4.73 ± 0.20	5.95 ± 0.42
Zn (mg/kg)	80.23 ± 3.57	88.54 ± 8.03
Cd (mg/kg)	1.06 ± 0.16	1.53 ± 0.65
Sand %	69.40 ± 4.56	64.17 ± 2.77
Silt %	13.40 ± 0.40	12.76 ± 1.01
Clay %	18.00 ± 2.04	22.73 ± 2.22
Soil texture	Sandy loam	Sandy loam

± Standard Error

Table 4. Wet Season Physical and Chemical Properties of Soils in the wetlands

Parameters	Rural wetland	Urban wetland
pH	5.32±0.15	5.82±0.10
E.C (ds/m)	0.069±0.0039	0.039±0.0038
Organic carbon (%)	4.62±0.16	5.91±0.12
Av.P (mg/kg)	47.47±1.71	53.95±4.38
Total N (%)	0.12±0.16	0.15±0.0014
Ca (cmol/kg)	8.00±0.52	6.40±0.83
Mg (cmol/kg)	2.60±0.13	2.30±0.22
Na (cmol/kg)	0.07±0.004	0.08±0.005
K (cmol/kg)	0.15±0.004	0.13±0.005
EA (cmol/kg)	2.33±0.06	2.35±0.09
ECEC (cmol/kg)	13.15±0.06	11.15±0.97
B.S (%)	82.2±0.77	78.4 ±2.11
Fe (mg/kg)	310.72±5.87	346.14±64.74
Ni (mg/kg)	18.25±0.75	12.50±2.50
Pb (mg/kg)	14.55±1.15	11.15±3.55
Zn (mg/kg)	56.25±0.75	53.50±13.50
Cd (mg/kg)	3.67±0.21	5.05±0.15
Sand %	72.40±1.47	70.60±1.74
Silt %	15.00±0.80	10.12±0.32
Clay %	13.00±1.17	19.40±2.28
Soil texture	Sandy loam	Sandy loam

± Standard Error

3.3 Predictive Models of Floristic Components by Soil Variables

Table 5 shows the predictive multiple equations for floristic determinants in lacustrine wetlands.

In the dry season of the rural wetland, exchangeable acidity predicted density. Height was predicted by base saturation, nickel and sand. Exchangeable acidity predicted the crown cover and basal area. In the rural wetland during the wet season, only two vegetation attributes were predicted. The sand fragments predicted the height while clay and electrical conductivity predicted the crown cover.

In the dry season of the urban wetland, only one vegetation parameter (density) was predicted by cadmium, sand, zinc, pH and sodium (Na). Height, crown cover and basal area failed to yield any predictor variable. In the wet season of the urban wetland, only density was predicted and the predictor variables were exchangeable acidity, sodium, calcium and total nitrogen.

3.3.1 Vegetation Density

In the rural wetland during the dry season, the regression of density on twenty (20) soil variables yielded a prediction model equation as follows:

Density, Y = 4.36 + log 4.079 Ea

From the above density prediction equation, it can be drawn that exchangeable acidity (Ea) is directly related to density in the rural wetland during the dry season.

The regression of density on twenty (20) soil variables in the urban wetland during the dry season yielded a prediction model as follows:

Density, Y = -3.707 – log 1.23 Sand + log3.02 pH - log4.12 Na + log2.51 Zn + log 2.15Cd

From the equation above, it can be deduced that sand fragments and sodium (Na) were inversely related to density while pH, zinc (Zn) and cadmium (Cd) were directly related to density of plant species.

The regression of density on twenty (20) soil variables in the urban wetland during the wet season yielded a prediction model equation as follows:

Density, Y = 3.865 – log 3.432 Ea + log4.171 Na - log 1.57Ca + log 2.54 Total Nitrogen

The above equation in density prediction implies that exchangeable acidity (Ea) and calcium (Ca) had an inverse relationship with density while sodium (Na) and total nitrogen related positively with density of species in the urban wetland during wet season.

3.3.2 Vegetation Height

The regression of height with twenty (20) soil variables in the rural wetland during the dry season yielded an equation of this form:

Height, Y = 2.122 – log0.274 B.Sat. + log 0.11 Ni + log 1.28 Sand

The equation from the height prediction model showed that base saturation had an inverse relationship with plants' height while nickel (Ni) and sand fragments related directly with height of plants in the rural wetland during the dry season.

In the rural wetland during the wet season, the regression of height with twenty soil variables yielded an equation of this form:

Height, Y= 2.09 – log 0.169 Sand

From the above equation, sand fragments related inversely with height of plant species in wet season of the rural wetland.

3.3.3 Vegetation Crown Cover

The Crown cover of plant species in the rural wetland during the dry season yielded the equation below when regressed with twenty (20) variables:

Crown cover, Y = - 1.446 + log 1.04 Ea

The equation above shows that only exchangeable acidity (Ea) associated with the vegetation attribute of crown cover during the dry season in the rural wetland.

During the wet season in the rural wetland, the crown cover of plant species yielded an equation when regressed with twenty (20) soil variables as follows:

Crown cover, Y = 0.726 + log 1.28 Clay – log 2.254 EC

From the equation, crown coverages of plants related directly with clay and inversely with electrical conductivity (EC) in the rural wetland during the wet season.

3.3.4 Vegetation Basal Area

The basal area of plants yielded the equation below when regressed with twenty (20) soil variables in the rural wetland during the dry season.

Basal area, Y = 0.216 + log 0.198 Ea

From the equation, exchangeable acidity had a positive relationship with basal area implying that both parameters increased together in the rural wetland.

Table 5: Predictive model equations for floristic components in the wetlands

Wetland type	Variables	Equation
Rural (dry season)	Density, Y	= - 4.36 + log 4.079 Ea
Urban (dry season)	Density, Y	= - 3.707 – log 1.23 sand + log 3.02 pH - log4.12 Na + log2.51 Zn + log2.15 Cd
Urban (wet season)	Density, Y	= 3.865 – log 3.432 Ea + log4.171 Na - log1.57 Ca + log2.54 Total Nitrogen
Rural (dry season)	Height, Y	= 2.122 – log 0.274 B.sat. + log0.11 Ni + log 1.28 Sand
Rural (wet season)	Height, Y	= 2.09 – log 0.169 Sand
Rural (dry season)	Crown cover, Y	= - 1.446 + log 1.04 Ea
Rural (wet season)	Crown cover, Y	= 0.726 + log 1.28 Clay – log 2.254 EC
Rural (dry season)	Basal area, Y	= 0.216 + log 0.198 Ea

4. Discussions

The compendium of flora in the wetlands revealed a rich flora of obligate and facultative species. While species like *Elaeis guineensis* and *Persicaria senegalense* dominated in density and frequency values seasonally owing to their inherent abilities to comfortably adapt and withstand varying hydric and anoxic conditions, others with low values for these parameters may highlight their sensitivities to this environment. Also, the dominance of these species in both seasons may further point to their insensitivity and wide ecological amplitudes. The variations observed seasonally in vegetation components such as height, basal area and crown cover is suggestive of the various biomass production levels in the wetlands.

The pH of the wetland being moderately acidic may have originated from litter decomposition which releases fulvic and humic acids during the process (Stevenson, 1991; Ita *et al*., 2017). Generally, the soil nutrient levels (total nitrogen, organic carbon, Ca, Mg, Na and K) were observed to be low seasonally in both wetlands. This may be an indication that the wetland soils had low sink for nutrients. The low ability of this soil to retain important soil nutrients may be a function of its porosity as evidenced in the particle size classes where a high sand substrate was observed over clay and silt. This aligns with the views of Ita *et al*. (2017). The high heavy metal values recorded in this wetland is characteristic of several anthropogenic upheavals such as municipal waste disposal from point and non-point sources which was clearly evidenced around this ecosystem.

The stepwise multiple regression technique applied enabled predictive equations to be derived as illustrative models, based on the responses of vegetation and species along environmental gradients. It identified those independent variables having strong relationships with the vegetation variables. The most valuable contribution of these is not in predicting presence of species as such, but in illustrating the environmental variables that are important in floristic dynamics of the species (Ubom, 1992). Results showed overlapping occurrence of species within the wetlands. Some environmental variables were important in the distribution of species within the wetland.

The most frequently retained environmental variable, exchangeable acidity (Ea), played a major role in determining the density, crown cover and basal area of species in the area. It was involved in four (4) out of eight (8) predictive equations obtained. The relative importance of this parameter is well noted, and is not unrelated with litter deposition and decomposition. Going by Stevenson (1991), the acidic condition in these soils is due to high rate of litter decomposition which released humic and fulvic acids to the soil and as this litter decomposes, it also adds other nutrients to the soil which favoured the growth of plants. This explains the increase in these floristic variables as a function of exchangeable acidity.

Another soil factor that was retained in 3 out of 8 equations was sand. It was involved in equations involving height and density. This retention is not clearly understood but tangles with the views of Akpan, (2006) in a related research where he authenticated that sand particles could be useful in loosening mud soils thus allowing permeability of water and root penetration due to its large structural pores.

Sodium was also retained in equation involving density. This suggests that sodium played an important role in plant species distribution. This confirms the notion that it aids metabolism and synthesis of chlorophyll during photosynthesis thereby enhancing growth (Pedler *et al*., 2000).

Zinc, an important element that was retained in density related equations, functions primarily as enzymes activator (Pedler *et al*., 2000), aids in protein synthesis and chlorophyll formation (Akhtar *et al*., 2009; Rahman *et al*., 2008). Hardy (2007) and Mousavi *et al*. (2007) stated that zinc availability increases the growth and yield potentials of plants species.

Cadmium was also involved in accurate prediction of density of species in the urban wetland. The retention of this biological nuisance in the species density equation of the urban pond is not clearly understood but might be interpreted to mean that the numeric abundance or distribution of species is dependent on pollution tolerance. This implies that only plant species that were tolerant to heavy metals and other contaminants' infiltration had high density.

pH being named a density predictor in the urban wetland underscores its overall influence on plant growth and distribution. Soil pH is an important factor required for growth of plant species. According to Ita (2017), different plant species respond differently to varying soil pH. Soil pH affects nutrient availability, nutrient toxicity and microbial activities. This corroborates with the findings of Gould and Walker (1999) that plant species richness tend to decline in acidic and alkaline soils. According to Larcher (1980), the essential nutrients, such as Ca, Mg, K, P and molybdenum become depleted or unavailable in acidic soils (pH < 6) and this leads to nutrient deficiency. In a similar vein, Marschner (1986) reported that sodic soils (pH > 8) tend to be deficient in Fe, Zn, Cu, Mn and K.

Nitrogen was also retained in one of the density equations in the urban wetland. This is consistent with the reports of Pandey and Sinha (2007) that nitrogen is an essential constituent of different proteins, nucleic acid and many other essential molecules like chlorophyll in plants, hence, its relevance in plant growth, nutrition and development. This therefore confirms its effects on plant distribution in the area.

Another important environmental variable that influenced the vegetation structure of the wetland was calcium. It showed its influence on the density of species in the urban wetland during the wet season. This is possible because calcium is a principal constituent of plant as calcium pectate in the middle lamella of the cell wall and is irreplaceable by any other element. It provides a base for the neutralization of organic acids and is concerned with the growing root apices (Verma and Verma, 2007). These could be related to its relevance and identification as a key soil factor in fulvic and humic acidified wetland.

Clay and electrical conductivity predicted crown cover in the rural wetland during the wet season. This explains the importance of clayey soil texture in the adsorption and retention of soluble salts and other important nutrients such as nitrogen, phosphorus, magnesium and organic carbon. The nutrients retained by clay fractions will nourish the plant coverages and promote the growth of plants species in general (Roselle *et al*., 2011).

Silt was retained in equations involving height of plant species. Due to the moderate compaction of silt particles, water permeability and nutrient retention, silt particles favour plant species as root penetration for available nutrients and development of plants is made possible (Bationo and Buerkwert, 2001).

Nickel was a predictor in equations involving height in the dry season of the rural wetland. Generally, nickel is not an important element for plants' growth and development, but it is an essential micronutrient required for the growth of higher plants (Brown *et al*., 1987). Though required in minute quantity, it is one of the components of some plant enzymes, most notably urease, which metabolizes urea nitrogen into useable ammonia in plants (Brown *et al*., 1987). Without nickel, toxic levels of urea can accumulate within the tissues forming necrotic lesions on the leaf tip. Ammonia being a source of nitrogen helps in promoting maximum growth and photosynthetic rates and by extension helps in increasing plant height (Sinclair, 1990). Koul (1997) in his study also posited that nitrogen application resulted in greater values of plant height, leaf area, number of leaves and stem diameter of fodder maize.

Base saturation also was involved in equations involving height in the dry season of the rural wetland. Base saturation is the fraction or percentage of the exchangeable cations/bases in the cation forming complex. This cation complex acts as a nutrient reserve where plants utilize these soil nutrients for their growth and productivity in height, coverage and density (Verma and Verma, 2007).

4. Conclusion

This study adopted a mathematical model (stepwise multiple regression) to predict floristic components using soil variables in seasonal lacustrine wetlands. Plant composition assay carried out showed a rich flora diversity seasonally in the rural wetland than in the urban wetland. Using stepwise multiple regression as a prediction model, exchangeable acidity, sand, pH, Na, Zn, Cd, Ca and total nitrogen predicted density, base saturation, Ni and sand predicted height, exchangeable acidity, clay and electrical conductivity predicted crown cover while only exchangeable acidity predicted basal area. Conclusively, this study shows that the use of mathematical models in prediction of floristic components is very essential in plant community studies most especially in understanding the dynamic responses and feedback mechanisms of vegetation in response to varying environmental conditions. It also reveals that the soil and vegetation components of the wetlands are interdependent and exert reciprocal influence on each other.

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