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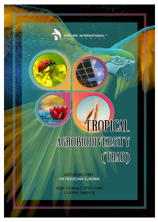

RESEARCH ARTICLE

SPECIES CHARACTERIZATION IN RELATION TO EDAPHIC FACTORS IN A MANGROVE SWAMP FOREST: AN ORDINATION APPROACH

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ABSTRACT

Species characterization in relation to edaphic factors was carried out in a mangrove swamp forest using ordination approach (PCA). Vegetation and soil were sampled systematically with a ten 50 x 10 m quadrat. In each quadrat, soil samples were obtained at the depths of 0 – 30 m while plants were identified to species level and their frequency, density, height, basal area and crown cover were determined. The floristic catalogue revealed a total of 10 species belonging to 8 families. *Rhizophora mangle* had the highest density value (120.41±16.04 st/ha) while *Nypa fruticans*, *Rhizophora mangle* and *Paspalum vaginatum* respectively had the highest frequency value (100%) *Rhizophora mangle* was the tallest species (11.50±1.37 m) as well as the species with the widest coverage (10.68±1.08 m^2/ha). *Elaeis guineensis* had the largest (1.79±0.05 m^2/ha) basal area (0.13±0.04 m^2/ha). The use of PCA delineated three principal component axes (VS_1, VS_2 and VS_3). The first, second and third axes were grouped as vegetation adaptation to salinity gradient, niche preference gradient and residual niche preference gradient, respectively. Positive associations showed nutrient levels that enhanced growth while negative relationships showed levels of nutrients that were limiting to plant performance. Conclusively, this study showed that the vegetation and soil factors in this mangrove swamp are highly interrelated, as shown by the magnitudes of correlations between them, hence, highlights that the interactions that govern mangrove abundance may produce different zonation patterns depending on the underlying environmental conditions.

KEYWORDS

Mangrove, Species distribution, Edaphic factors, Ordination, Principal Component Analysis

1. INTRODUCTION

Mangroves which occur at the border of sea and land in most sub-tropical and tropical areas, are undoubtedly one of the most important ecosystems found in coastal regions. They provide many economic and ecological benefits to man such as food provision, source of forestry (timber, firewood and charcoal) and fishery products (crabs, prawns, mollusks and fishes), sinks or reservoirs for nutrients, recycling of nutrients, mitigation in global warming (removal of CO_2 from the atmosphere), flood control and prevention of coastal erosion. Despite being a complex ecosystem, it still support diverse plants species which are adaptive and tolerance to the prevailing environmental factors such as temperature, salinity, hydroperiods, tidal flushing, hypoxic and anoxic conditions (Lugo and Snedaker, 1974; Boto and Willington, 1984; Ukpong, 1991; Sherman et al., 1998). This does not disavow the likelihood that these factors which are subsidiary are vital at their specific site scale (Matthijs et al., 1999). In line with this, these environmental variables are interrelated with the species abundance in the mangrove (Araujo et al., 2010).

The soils of mangroves consist of marine alluvium which are carried in the form of sediment and deposited by rivers and seas. These soils are aggregations of sand, silt and clay particles in different percentages and mud (mixture of silt and clay which are organic-matter rich). The soils are usually lighter or darker in color. Topsoil's that are lighter in color are usually porous with high rate of aeration and water percolation while dark colored topsoil's have poor aeration and drainage. A group researchers accentuated that the characteristics of mangrove soils is governed or determined by the blend of physical, chemical, and biological factors (frequency and duration of inundation, freshwater input, seasonality of precipitation and temperature, storms, and bioturbation), which may vary considerably from one site to another (Ferreira et al., 2007). In as much as plant species in mangroves are dependent on the soil for nutrients, most of them exhibit different requirements for soil conditions and this subsequently brings about some variants in their growth forms, proliferations, composition, functional and structural physiognomies either locally, regionally or globally (Vilarrúbia, 2000; Sherman et al., 2003). For instance, mangrove species have differential selectivity and uptake of nutrients (Bernini et al., 2006). These variations in nutrient requirements by individual species bring about the variants in floristic attributes like density, frequency, diameter at breast height (DBH), basal area, height and crown cover (Pool, 1977).

From the foregoing, the relevance of edaphic factors in the growth of vegetation in mangroves cannot be overlooked, as they are interrelated with the plant species and exert a reciprocal effect on each other. The occurrence of mangroves in mixed stands and the consequential overlap in soil properties between stands, have revealed that a multivariate technique or procedure for assessing vegetation-soil relationships in swamps is crucial to enhance a better understanding of the ecology of mangroves. Since the growth of the vegetation is knotted to the typology and evolution of the soil, it is therefore pertinent to investigate the

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complex relationship of soil with vegetation using an ordination approach (Principal Component Analysis). The use of PCA in this study stems from the fact that the vegetation is multivariate rather than a collection of independently varying attributes (Ukpong and Essien, 1999). PCA uses mathematical matrices to find the most efficient axis to draw through a hyperspace, that is, the axis that will squash down the variables that are distributed in the hyper space. It helps to reduce multiple variables in a community to a few dimensions which reflect the most important patterns in the data set. The first axis takes care of the greater part of the variance while the subsequent axis take care of the remaining variance. This implies that PCA finds out many axes that will explain every bits of the variance.

Despite the fact that mangrove species are governed by several multifaceted environmental factors, very few studies have assessed mangrove distribution patterns using pedological approaches. Emphases on mangrove species affinities to nutrients have not been given much attention recently. Such information help to improve the understanding of species' performance, abundance and distribution with regards to selectivity and uptake of nutrients despite growing in the same environment. It will portray how these mangals compete for soil nutrients under uniform conditions and also provide a baseline information which is crucial for achieving a better grasp of the overall functioning of species in this ecosystem. Hence, the lacuna in this regard further obliged this study.

2. Materials and Methods

2.1 Study Location

This study was carried out in a mangrove swamp at Okorombokho in Eastern Obolo Local Government Area of Akwa Ibom State (Figure 1). Eastern Obolo Local Government is located in the Niger Delta fringe between Imo and Qua Iboe Rivers estuaries and lies between latitudes 4° 28` and 4° 53` N and longitudes 7° 50` and 7° 55` E with an altitude of about 650 m above sea level. The climate of the area is that of a humid tropic. The temperatures of the area are typically high, ranging from 26 °C to 28 °C. The area is characterized by a heavy rainfall with average annual rainfall lying between 2,000 – 4,000 mm. Two seasons are discernable in the area; dry and rainy seasons. Rainy season spans from April to November with heavy cloud covers and high relative humidity. The dry season spans from November to March.

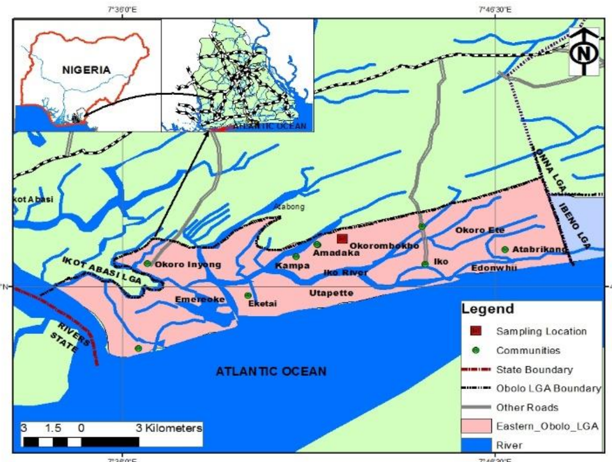

Figure 1: Area of study

2.2 Vegetation and Soil Sampling

Four vegetation plots were used for this study. In each plot, four (4) belt transects were laid and in each transect, vegetation and soil were sampled systematically (Cochran, 1963) in ten (10) 50 m × 10 m quadrats spaced at regular intervals of 20 m. In each quadrat, vegetation attributes like frequency, density, basal area as cross-sectional area of individuals, crown cover as horizontal area and height were determined for individual species. Using a soil auger in each of the quadrats, soil samples were obtained at two different depths (0 – 15 cm and 15 – 30 cm). Two soil samples were collected in each quadrat and bulked into one composite sample, stored in labelled Ziploc bags and taken to the laboratory for physicochemical analyses.

2.3 Quantitative Determination of Vegetation Parameters

2.3.1 Density

The density of each plant species was estimated by enumerating all plants present in each plot. The number of individuals of a species was taken as a proportion of the number of transects to give a mean of species. The mean was then taken as a proportion of the area of the quadrat to give density in m^2 which was multiplied by 10,000 m^2 to give density per hectare (Cochran, 1963).

2.3.2 Frequency

The frequency of each species occurrence was calculated thus:

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

2.3.3 Height

The heights of the woody plant species were measured using a Haga altimeter. For each of the woody plant height, the Haga altimeter was thus used: 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.

2.3.4 Basal Area

This was calculated thus:

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

Where 4π = 4 × 3.142 = 12.568

C = girth size of the species at breast height

2.3.5 Girth Size

The girth of the species was measured at breast height with a girthing tape. This was measured in centimeters; 1.3m above ground level depending on the branching nature of the species.

2.3.6 Crown Cover

The crown cover of woody plant species was determined by the crown cover diameter method (Muller-Dombios and Ellenberg, 1974). This involves measuring crown diameter projection on the ground of all woody plants. A tape was laid on the ground from one end of the ground perimeter to the other. This resulted in one diameter reading. A second diameter reading was taken in a similar way, but perpendicular to the first one. These gave two diameter readings which were used in calculating crown horizontal area for each woody species as follows:

$$\text{Crown cover } (m^2/ha) = \left(\frac{d_1 + d_2}{2}\right)^2 \frac{\pi}{4}$$

2.4 Physicochemical Analysis of Soil

The pH, electrical conductivity and exchange acidity were determined using Beckman's glass electrode pH meter, conductivity meter (Jenway Pcm 128723 model) and titration with 1N KCL (McClean, 1961; Kamprath, 1967). Total nitrogen, available phosphorus and organic carbon, and were determined using the MicroKjeldahl method, Bray No 1 method and Walkey Black wet oxidation method (Jackson, 1962). Ca and Mg were determined using EDTA titration method while photometry method was utilized for sodium and potassium determination. 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. Sand, silt and clay were determined using Hydrometer method**.**

2.5 Statistical Data Analysis

Means and standard errors for floristic and soil variables as well as ANOVA were computed using Graphpad Prism 6.0. Principal Component Analysis (PCA) was perform using Minitab software version 17.0 to show the correlation between the vegetation and the environmental variables (soil). Standardization and transformation of data to meet the requirements for normality necessary in parametric statistics were performed (Greig-Smith, 1973).

3. Results and Discussion

3.1 Floristic Assemblage of the Mangrove

The floristic components of the mangrove as presented in Table 1 showed that a total of 10 species belonging to 8 families were found in this mangrove. The family Arecaceae had the highest species representation (3) in the mangrove. Species density ranged between 13.41±0.54 st/ha in *Mytragyna ciliata* and 120.41±16.04 st/ha in *Rhizophora mangle*. *Nypa fruticans*, *Rhizophora mangle* and *Paspalum vaginatum* respectively had the highest frequency of occurrence (100%) while the species with the least frequency of occurrence of 20% were *Achrosticum aureum*, *Fimbristylis ferruginea*, *Mytragyna ciliata* and *Staudtia stipitata*. *Rhizophora mangle* was the tallest species (11.50±1.37 m) as well as the species with the widest coverage (10.68±1.08 m^2/ha). *Mytragyna ciliata* was the shortest species (3.08±0.24 m) while *Avicennia africana* had the least crown cover (0.48±0.001 m^2/ha). *Elaeis guineensis* and *Mytragyna ciliata* had the largest (1.79±0.05 m^2/ha) and least basal area (0.13±0.04 m^2/ha) values, respectively.

Table 1: Floristic assemblage of the mangrove

Plant Species	Family	Density (st/ha)	Frequency (%)	Height (m)	Basal Area (m^2/ha)	Crown Cover (m^2/ha)
Acrostichum aureum L.	Pteridaceae	25.00±4.70	20	4.12±0.54	-	-
Avicennia africana P. Beau	Avicenniaceae	45.00±3.18	80	5.02±0.85	0.18±0.02	0.48±0.001
Cocus nucifera L.	Arecaceae	17.00±2.58	60	6.58±1.85	1.31±0.05	6.09±0.04
Elaeis guineensis Jacq.	Arecaceae	30.00±5.18	60	8.50± 0.5	1.79±0.05	9.72±0.58
Fimbristylis ferruginea (L) Vahl	Cyperaceae	32.10±3.65	20	-	-	-
Mytragyna ciliata (Aubrev and Pellegr)	Rubiaceae	13.41±0.54	20	3.08±0.24	0.13±0.04	2.10±0.26
Nypa fruticans Wurmb.	Arecaceae	109.32±11.92	100	4.41±0.81	0.21±0.05	4.23±0.14
Paspalum vaginatum Sw.	Poaceae	51.30±10.15	100	-	-	-
Rhizophora mangle L.	Rhizophoraceae	120.41±16.04	100	11.50±1.37	0.92±0.05	10.68±1.08
Staudtia stipitata Warb.	Myristicaceae	15.36±2.30	20	7.20±0.99	0.80±0.04	3.24±0.41

3.2 Physicochemical Attributes of the Mangrove Soil

The physicochemical attributes of the soil is presented spatially in Table 2. The pH of the soil ranged from 7.10 in station 1 to 7.30 in station 2. Electrical conductivity ranged from 10.30 to 15.12 with the highest and least values in stations 3 and 1.

Organic carbon (7.30±0.25), available phosphorus (8.36±0.07), magnesium (4.76±0.08) and sand (66.46±3.10) had the highest values in station 3 while station 2 recorded the highest values for total nitrogen (0.21±0.03), calcium (10.20±0.45), potassium (1.76±0.01), ECEC (20.42±0.78), base saturation (84.82±3.00) and clay (33.24±0.86). Station 1 recorded highest values for sodium (0.93±0.005) and silt (16.30±0.87).

Table 2: Physicochemical attributes of the soil

Parameters	Station 1	Station 2	Station 3
pH	7.10±1.10^a	7.30±1.15^a	7.21±1.04^a
Ec (ds/m)	10.30±2.30^a	12.34±2.00a	15.12±2.86
Organic carbon (%)	6.30±0.14^a	7.14±0.21^a	7.30±0.25^a
Total nitrogen (%)	0.16±0.04^a	0.21±0.03^a	0.19±0.03^a
Available Phosphorus (mg/kg)	5.12±0.03^a	6.41±0.05^a	8.36±0.07^b
Calcium (cmol/kg)	8.00±0.25^a	10.20±0.45^a	9.40±0.35^a
Magnesium (cmol/kg)	4.00±0.05^a	4.68±0.06^a	4.76±0.08^a
Sodium (cmol/kg)	0.93±0.005^a	0.68±0.003^a	0.47±0.001^a
Potassium (cmol/kg)	1.40±0.00^a	1.76±0.01^a	0.45±0.01^a
Exchange acidity	3.22±0.05^a	3.10±0.04^a	2.80±0.01^a
ECEC (cmol/kg)	17.55±1.45^a	20.42±0.78^b	17.88±1.75^a
Base saturation (%)	81.65±2.14^a	84.82±3.00^b	84.34±3.05^b
Sand (%)	60.36±2.63^a	60.46±2.50^a	66.46±3.10^b
Silt (%)	16.30±0.87^a	6.30±0.41^b	11.30±0.67^c
Clay (%)	23.34±0.95^a	33.24±0.86^b	22.24±0.92^a

± S. E = Standard Error.

3.3 Vegetation – Soil Ordination

Ordination by PCA extracted 3 components and these accounted for 100% of the total variance (55.668 %, 27.208 % and 17.124 %) (Table 3). The component loadings and the scree plot are shown in Figures 2 and 3. The first two (2) initial components bear vital information required for explaining most of the variations in the data set. For convenience, the components have the designation "VS" and their factor loadings (positively and negatively) are shown in Table 4.

The first principal component (VS_1) had 15 variables which loaded highly. Silt (-0.985), Na (-0.941), K (-0.870**)** *Cocus nucifera* (-0.706) and *Fimbrystylis ferruginea* (-0.975) loaded negatively while clay (0.958), EC (0.989), total nitrogen (0.843), available phosphorus (0.934), Ca (0.896), Mg (0.683), *Nypa fruticans* (0.940), *Rhizophora mangle* (0.998), *Acrostichum aureum* (0.996) and *Avicennia africana* (0.964).

The second principal component (VS_2) had 10 variables loading highly. Sand (0.505), pH (0.684), organic carbon (0.931), Mg (0.503), ECEC (0.803), base saturation (0.749), *Elaeis guineensis* (0.999) loaded positively while total nitrogen (-0.528), exchangeable acidity (-0.992) and *Mytragyna ciliata* (-0.875).

The third principal component (VS_3) had 8 components loading highly. Sand (-0.735) and pH (-0.501) loaded negatively while Mg (0.530), ECEC (0.587), base saturation (0.633), *Cocus nucifera* (0.647), *Paspalum vaginatum* (0.866) and *Staudtia stipita* (0.834).

Table 3: Eigen values and cumulative percentage variance of data for the first three PCA axes obtained from 25 measured variables

Principal components	Eigenvalues	Percentage variation	Cumulative percentage
1	13.917	55.668	55.668
2	6.802	27.208	82.876
3	4.281	17.124	100.000

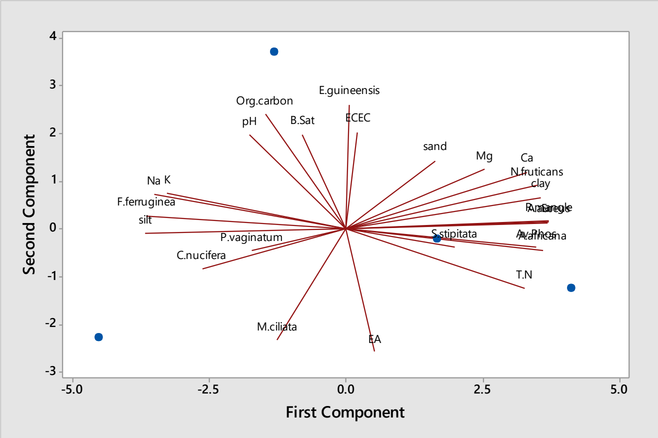

Figure 2: Loadings of the first two components of all variables measured in the mangrove

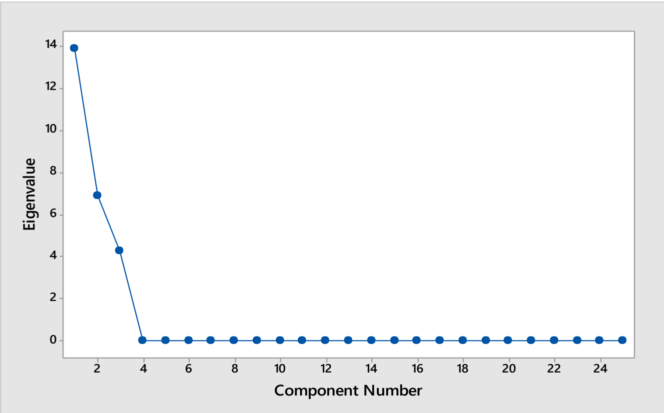

Figure 3: Scree plot for all variables (soil and vegetation) measured in the mangrove

Table 4: Factor loadings of the three (3) components obtained from the measured variables

Parameters	**Components**		
	VS_1	**VS_2**	**VS_3**
Sand	.452	**.505**	**-.735**
Silt	**-.985**	-.021	.170
Clay	**.958**	.239	.158
pH	-.490	**.684**	**-.501**
EC	**.989**	.046	.140
Organic carbon	-.362	**.931**	-.050
Total nitrogen	**.843**	**-.528**	-.104
Available phosphorus	**.934**	-.139	.330
Ca	**.896**	.445	.006
Mg	**.683**	**.503**	**.530**
Na	**-.941**	.279	.191
K	**-.870**	.300	.391
EA	.095	**-.992**	-.082
ECEC	.101	**.803**	**.587**
Base Saturation	-.197	**.749**	**.633**
Cocus nucifera	**-.706**	-.286	**.647**
Nypa fruticans	**.940**	.337	.054
Rhizophora mangle	**.998**	.049	-.041
Acrostichum aureus	**.996**	.052	.074
Avicennia africana	**.964**	-.174	.202
Elaeis guineensis	.036	**.999**	.009
Fimbristylis ferruginea	**-.975**	.104	-.195
Paspalum vaginatum	-.473	-.161	**.866**
Staudtia stipitata	.498	-.126	**.834**
Mytragyna ciliata	-.343	**-.875**	.343
Total	13.917	6.802	4.281
% of Variance	55.668	27.208	17.124
Cumulative %	55.668	82.876	100.000

4. Discussion

The floristic assemblage of the mangrove forest is highly variable comprising of mixed stands of true and associate mangrove species growing with each other. This interrelationship is not unprecedented but rather upholds the view that plants do not occur singly or in isolation in various habitats (Clark and Warwick, 2001). The occurrence of these species (mangrove and non-mangrove) in this habitat suggests that these species have some ability to tolerate salinity which is a predominant factor in any mangrove environment. Even though the non-mangrove species grew and became established in association with the core mangrove species, their tolerance to salinity varied. This was evidenced in this study as the obligate mangrove species (*Rhizophora mangle*, *Nypa fruticans*, *Avicennia africana*) had higher density value than the non-mangroves species. The higher density values evidenced among these species may suggest their intrinsic abilities to thrive, colonize mud flats and adapt favourably to prevalent environmental conditions such as salinity, frequent tidal inundations, anoxic and water-logged conditions (Ogbemudia and Ita, 2016; Ita et al., 2019). The low density values in species such as *Mytragyna ciliata*, *Staudtia stipitata* and *Cocus nucifera* may pinpoint their inability to structurally adapt and flourish in this habitat. Their low density in this mangrove is not surprising but may rather justify that these species perform best in habitats devoid of salinity.

The high frequency values observed among the obligate mangrove species may be an indication of their wide ecological amplitudes to varying environmental conditions. The low frequency of the mangrove associes may imply that their spread and establishment were restricted due to their low ecological amplitudes and inability to colonize mud flats. The presence of only few core mangrove species in this ecosystem may underscore that they are true natives of this ecosystem. It may also accentuate the various influences of anthropogenic upheavals such as deforestation, selective exploitation and timber logging. Furthermore, the persistent invasiveness of *Nypa fruticans* may further account for the low number of core mangrove species recorded in this study. This aligns with the view of (Ukpong, 1992) that *Nypa fruticans* after its colonization tends to displace various true native mangrove species inland along the zonation to the inner swamps making the environmental gradients not ideal for their propagation and growth. The presence of *Elaeis guineensis* and *Cocus nucifera* in various plots across the mangrove may be a reflection of prolonged human incursions and perturbations. The presence of *Nypa fruticans* in increasing numbers may invariably point to the successional sequence of this estuary. The marked variations in height, basal area and crown cover of species may suggest their age, growth form as well as the level of biomass production in the mangrove.

The use of PCA in this study discerned the pattern of species variation in mangrove swamps. Thus, PCA is a useful tool for simplifying the multivariate vegetation subsystem to reveal the major interspecies variation. This was clearly seen in this study as three (3) main principal factor components (VS_1 – VS_3) were delineated. The first principal component (VS_1) which had 17 variables loading highly could be grouped first into a vegetation adaptation to salinity gradient in view of the fact that the true mangrove species such as *Rhizophora mangle*, *Acrostichum aureum*, *Avicennia africana and Nypa fruticans* loaded positively with increasing EC level while *Cocus nucifera* and *Fimbristylis ferruginea* loaded negatively with increasing levels of EC. This may signify that the true mangrove species had high ecological adaptability to stress factor (salinity) than the mangrove associes. This may further connote that while the former species were insensitive to salinity, the latter species were highly sensitive to salinity. This could also be explained that these species had wide ecological amplitudes to salinity.

The performances of non-mangrove species (*Cocus nucifera* and *Fimbristylis ferruginea*) are expected to increase with a decrease in salinity (Ukpong and Areola, 1995). However, considering the variability of the swamp, other secondary gradients were delineated. A nutrient competition gradient was further established considering the high loadings for Ca, Mg, available phosphorus and total nitrogen. From this, it was seen that *Rhizophora mangle*, *Acrostichum aureum*, *Avicennia africana* and *Nypa fruticans* increased with increasing levels of the aforementioned nutrients while *Cocus nucifera* and *Fimbristylis ferruginea* decreased with increase in these nutrients. This may imply that species (true mangroves) with good adaptation and tolerance abilities to increasing salinity levels outcompeted taxa (strand or non-mangroves) with low tolerance ability for these nutrients.

The positive loading of true mangrove species with increasing clay and decreasing silt particles and the negative and positive loadings of non-mangroves (*Cocus nucifera* and *Fimbristylis ferruginea*) with increasing clay and silt may further confirm a substrate preference gradient along this axis. This shows the preference of clay substrate by true mangrove species over silt due to its distinctive ability to retain vital nutrients in the soil in high amounts. The preference of silt particles over clay by the non-mangrove species may suggest that the mangrove soil was too muddy for their root penetration due to high clay content and hence, needed a less muddy substrate (silt) which will aid their better root penetration. The preference of silt particles over clay by the non-mangrove species in this axis may further confirm their indirect association with nutrients (total nitrogen, available phosphorus, calcium and magnesium) as this textural class tend to hold less nutrient when compared to clay (Roselle et al., 2011).

The second component (VS_3) termed as niche preference gradient had 10 variables loading highly positively and negatively. *Elaeis guineensis*, organic carbon, ECEC, base saturation, pH, sand and Mg, loaded positively while *Mytragyna ciliata* loaded negatively to these soil variables. This may imply that *Elaeis guineensis* increased in density by inhabiting specific mangrove sites where nutrients (organic carbon and Mg), ECEC and base saturation levels were high, pH of the soil was slightly alkaline and sandy substrate was high for easy penetration of roots. Still on this axis, exchangeable acidity, *Mytragyna ciliata*, and total nitrogen loaded positively while *Elaeis guineensis* had negative loadings for these soil parameters. This may insinuate that the *Mytragyna ciliata* was specifically restricted to sites where exchangeable acidity and nitrogen levels were copious. This site preference by this species might have been brought about by deposition and decomposition of leaf litter which facilitated the release of nitrogen and other acidified substances (humic and fulvic acids) (Stevenson, 1991). A group researchers found out that nitrogen increased with increased loading rate of organic carbon in the soil (Bailey et al., 2007). Studies have also shown that upon the release of humic and fulvic acids due to litter decomposition, the growth of plants is enhanced directly through physiological and nutritional effects.

The third component (VS_3) termed residual niche preference gradient had 8 components loading highly. *Paspalum vaginatum*, *Staudtia stipitata*, *Cocus nucifera*, base saturation, ECEC and Mg loaded positively while sand and pH loaded negatively with these species. This component may connote that these species share similarities in habitat requirements in this ecosystem. It clearly delineated that the abundance and distribution of these non-mangrove species were restricted to sites or niches where the capacity of the soil to hold plant nutrients and exchangeable bases so that they are easily released or "exchanged" into the soil solution was high. The negative relationships of these species with soil variables like sand and pH may invariably point to the fact that the slightly alkaline pH was ideal for their growth while a reduction in sandy substrates in the mangrove helped in improved retention of water and nutrients in sites where these are needed for the growth of these species. This result agrees with the findings where in a similar study reported that the non-mangrove species make higher nutrient demands on the soils than true mangroves (Ukpong, 1995).

5. Conclusion

The study shows that the floristic inventory of the mangrove swamp varied from species to species. While high density values were observed among the true mangroves, low density values were evidenced among the strand or associate species (non-mangroves). Due to varying tolerance levels, these species exclusively occurred at different niches in the ecosystem. The characterization of the soil variables showed slight variations spatially. Using Principal Component Analysis (PCA), the soil-vegetation relationships were established and this delineated three principal component axes (VS_1, VS_2 and VS_3). The first, second and third axes were grouped as vegetation adaptation to salinity gradient, niche preference gradient and residual niche preference gradient, respectively. Positive associations showed nutrient levels that enhanced growth while negative relationships showed levels of nutrients that were limiting to plant performance.

Conclusively, this study shows that the vegetation and soil factors in this mangrove swamp are highly interrelated, as shown by the magnitudes of correlations between them. It also highlights that the abundance and performance of species are governed by the species affinity to soil nutrients. These interactions existing between plant species with soil properties thus indicate their importance in the diverse ecosystems. This study suggests that the interactions that govern mangrove abundance may produce different zonation patterns depending on the underlying pedological conditions. These results have practical implications for environmental monitoring, Impact assessment and ecosystems functioning.

References

Araujo, Q.R., Krause, R.L.O., Santana, S.O., Araujo, T.G., Mendonça, J.R., Trindade, A.V., 2010. Caracterização de Solo de Manguezal na Bacia Hidrográfia do Rio Graciosa, Bahia, Brasil [Internet]. Long Beach, Califórnia: Encontro Internacional Anual 2010 das Sociedades Americanas de Agronomia, Fitotecnica e Ciência do Solo. Retrieved from: http://www.ateffaba.org.br/?p=6930. Accessed April 21, 2020.

Bailey, D.E., Perry, J.E., Daniels, W. L., 2007. Vegetation dynamics in response to organic matter loading rates in a created freshwater wetland in southeastern Virginia. Wetlands, 27(4), Pp. 936 – 950.

Bernini, E., Silva, M.A. Carmo, T.M. Cuzzuol, G.R.F., 2006. Composição química do sedimento e de folhas das espécies do manguezal do estuário do rio São Mateus, Espírito Santo, Brasil. Rev Bras Bot, 29(4), Pp. 686–699.

Boto, K.G., Wellington, J.T., 1984 Soil characteristics and nutrient status in a northern Australian mangrove forest. Estuaries, 7, Pp. 61 – 69

Clarke, G.B., Warwick, J.K., 2001. A Directory of African Wetlands, UNEP, Nairobi and IUCN, Gland Switzerland/WC/MC, Cambridge, Pp. 56.

Cochran, W.G., 1963. Sampling techniques. 2nd ed. New Delhi: Wiley Eastern Limited, Pp. 413.

Ferreira, T.O., Vidal-Torrado, P., Otero, X.L., Macias, F., 2007. Are mangrove forest substrates sediments or soils? A case study in southeastern Brazil. Catena, 70, Pp. 79 – 91.

Greig-Smith, P., 1975. Quantitative Plant Ecology. Butterworth, London, Pp. 256.

Ita, R.E., Ogbemudia, F.O., Kekere, O., Udo, E.D., 2019. Plant species as influenced by soil relations in a mangrove ecosystem of Lower Imo River Estuary, Niger Delta, Nigeria. MOJ Ecology and Environmental Sciences, 4 (3), Pp. 92 – 98.

Jackson, M. I., 1962. Soil Chemical Analysis. Prentice-Hall Inc, New Jersey: Englewood Cliffs., Pp. 498.

Kramprath, E. J., 1967. Conservation of soils and Tissue Testing for accessing the phosphorus status of soils. In: Khagwnch, editor. The Role of phosphorus in Agriculture. American Society of Agronomy, 5, Pp. 433–469.

Lugo A.E., Snedaker S.C., 1974. The ecology of mangroves. Annual Review of Ecology and Systematics, 5, Pp. 39-64.

Matthijs, S., Tack, J., van Speybroeck, D., Koedam, N., 1999 Mangrove species zonation and soil redox state, sulphide concentration and salinity in Gazi Bay (Kenya), a preliminary study. Mangroves and Saltmarshes, 3, Pp. 243 – 249.

McClean, T., 1961. Soil science made easy. Washington DC: Vinyl Press, Pp 169–223.

Muller-Dombois, D., Ellenberg, H., 1974. Aims and Methods of Vegetation Ecology. London: John Wiley, Pp. 98.

Ogbemudia, F.O., Ita, R.E., 2016. Macrophyte Abundance and Water Quality Status of Three Impacted Inlet Streams Along Ikpa River Basin, Akwa Ibom State, Nigeria. Tropical Freshwater Biology, 25, Pp. 67 – 84.

Pool, D., 1977. Structure of Mangrove Forests in Florida, Puerto Rico, Mexico, and Costa Rica. Biotropica, 9(3), Pp. 195-212.

Roselle, L., Launchbaugh, K., Jones, T., Babcock, L., Ambrosek, R., Stebleton, A., Brewer, T., Sanders, K., Mink, J., Haley, J., Hyde, G., 2011. Rangelands: an Introduction to Idaho's Wild Open Spaces Rangeland Centre, Idaho Rangeland Resource Commission (IRRC), Pp. 114 – 120.

Sherman, R.E., Fahey, T.J. Martinez, P., 2003. Spatial patterns of biomass and aboveground net primary productivity in a mangrove ecosystem in the Dominican Republic. Ecosystem, 6, Pp. 384–398.

Sherman, R.E., Fahey, T.J., Howarth, R.W., 1998. Soil–plant interactions in a neotropical mangroves forest: iron, phosphorus and sulfur dynamics. Oecologia, 115, Pp. 553–563.

Stevenson, F.J., 1991. Organic Matter Micro-Nutrient Reactions in the Soil. In: Mortvedt, J. J., Cox, F. R. Shuamm, L. M. and Welch, R. M. (eds.) Micronutrients in Agriculture. Madison: SSSA, Pp. 145 – 186.

Ukpong, I.E., 1991. The performance and distribution of species along soil salinity gradients of mangrove swamps in Southeastern Nigeria. Plant Ecology, 95, Pp. 63 – 70.

Ukpong, I.E., 1992. Structure and soil relations of Avicennia mangrove swamps in southeastern Nigeria. Tropical Ecology, 33, Pp. 1-16.

Ukpong, I.E., 1995. Classification–analytic models for vegetation and nutrient relations of mangrove swamps in West Africa. Acta Botanica Hungarica, 39, Pp. 17–29.

Ukpong, I.E., Areola, O.O., 1995. Relationships between vegetation gradients and soil variables of mangrove swamps in southeastern Nigeria. African Journal of Ecology, 33, Pp. 14 – 24.

Ukpong, I.E., Essien, J.N., 1999. Principal Component Analysis of Data from the Stubbs Creek Forest Reserve 1: The vegetation sub-system. Environmental Analar, 4, Pp. 268 – 283.

Vilarrúbia, T. V., 2000. Zonation pattern of an isolated mangrove community at Playa Medina, Venezuela. Wetl Ecol Manage, 8, Pp. 9–17.