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THE INTERRELATIONSHIPS BETWEEN MANGROVE VEGETATION AND SOILS USING MULTIPLE REGRESSION ANALYSIS

ABSTRACT: Vegetation-soil relationships were studied in mangrove stands located on river estuaries and coastal beachridges in southeastern Nigeria. Coverage values of species and soil properties from these stands were measured and used in stepwise multiple regression analysis, the aim being to develop predictive equations for species response to the measured soil properties. The performance of A stratum species was largely explained by the enchangeable cations, particularly magnesium. The B and C strata were largely explained by percentage chloride content, iron and organic carbon. The A, B and C strata indicated selective response to forms of salt concentrations: total salinity was significant in the A stratum while percentage chloride was significant in the B and C strata. Percentage silt + clay indicated favourable site status in terms of nutrient availability in mangrove soils.

KEY WORDS: mangrove vegetation, soil properties, vegetation–soil relationship.

1. INTRODUCTION

Mangroves are trees that occur on accretive intertidal swamps in the tropics and subtropics. The mangrove soils are usually estuarine mud, peat and coastal sands where the species often occur in discrete zones from the shores inland. Hence relationships between the vegetation and the soils in mangroves have always been viewed in terms of the differences in soil properties between monospecific stands of species.

Clarke and Hannon (1967) reported pH in mangrove soils to range from 5.5 to 7.3 in the surface and subsurface soil. Naidoo (1980) reported pH in *Avicennia nitida* zones to range from 5.6 to 6.4, while exchange acidity ranged from 3.0 to 5.7 me/100g. Thom (1967) related the occurrence of *Rhizophora* spp. and *Laguncularia racemosa* to strongly mottled and gleyed soil composed of silt and clays. Variable soil salinity values also characterized the occurrence of species: Jackson (1964) observed the occurrence of *Avicennia africana* in areas of higher soil salinities than *Rhizophora racemosa*. Thom (1967) reported the salinity in *Avicennia* spp. zones to be 2.5% while *Laguncularia racemosa* was restricted to lower salinities of about 1.0%. Organic matter content of soils differ between stands, being 52.4% in *Rhizophora racemosa* stands (Thom 1967), 12.3% in *Avicennia africana* stands and 8.7% in *Rhizophora mangle* stands (Giglioli and Thornton 1965). Clarke and Hannon (1967) reported cation exchange capacity (CEC) of mangrove soils to range from 0.38±0.08 me/100 g in the subsurface to 0.84±0.59 me/100 g in the surface. Giglioli and Thornton (1965) related the occurrence of *Sesuvium portulacastrum* and *Paspalum vaginatum* to soils where 15% of the exchange complex is sodium. Naidoo (1980) found that CEC in *Avicennia* zones ranged from 23.7 to 83.3 me/100 g while values in *Bruguiera* zones ranged from 41.0 to 67.6 me/100 g.

Fundamentally, there are important differences between soils dominated by different species. However, there are overlap in the values of soil properties. Differences within stands are sometimes as great or greater than differences between stands (Clarke and Hannon 1967). But as noted by Naidoo (1980), few studies (with the notable exception of Cintron et al. 1978) have subjected these observed relationships to statistical analyses. Hence the aim of this paper is to establish the precise mathematical forms of the relationship between species and some soil properties considered to be of direct or indirect significance to mangrove performance. A multiple regression solution is used to develop predictive equations for species (coverage) response to the soils. The merits of the regression technique was discussed by Austin et al.(1984). The computer programme (STWMULT) was IBM supplied.

2. STUDY AREA, MATERIALS AND METHOD

The study area for this investigation is the extreme southeastern coastal zone of Nigeria where mangrove vegetation occurs in the marginal estuaries of the Creek Town Creek/Calabar River,Cross River, Kwa Ibo River and Imo River (Fig. 1). The area has a humid tropical climate. Apart from intermittent belts of *Rhizophora racemosa* along the channels, species zonation is not very distinct. The species *Rhizophora racemosa, Rhizophora mangle, Rhizophora harrisonii, Avicennia africana* and several brackish/freshwater associates e.g. *Nypa fruiticans, Acrostichum areum, Sesuvium portulacastrum* and *Raphia vinifera* often occur in mixed stands along the shores and in the inner swamps.

Primary distinguishing revealed two broad mangrove types: (1) alluvial mangroves found in the middle and lower estuaries and (2) beachridge mangrove found on

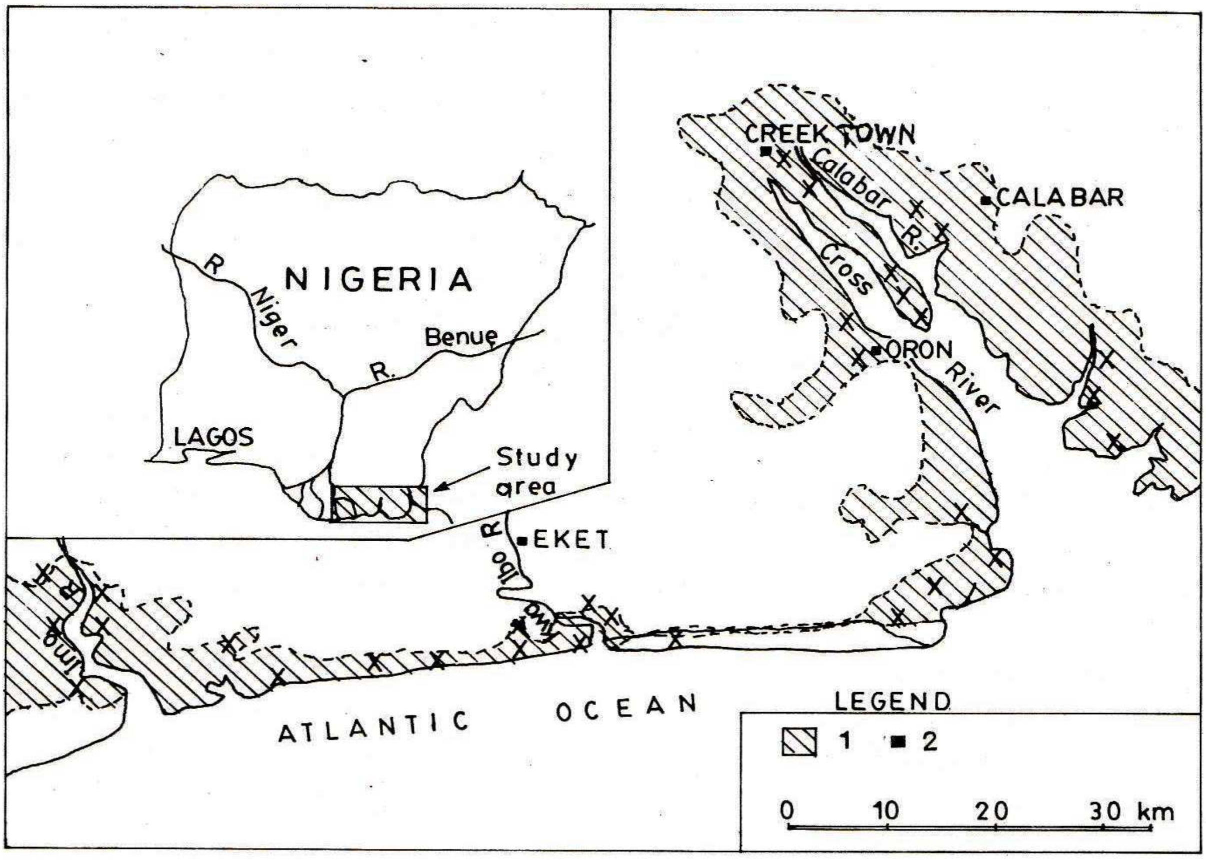

Fig. 1. Mangrove swamps (1) of the study area showing location in Nigeria (insert)
X, ... X indicate approximate position of transects, 2 – towns

the coastal sands and interriverine creeks. The two mangrove types were sampled in $10\times10\ m^2$ quadrats established at regular 20-metre intervals along transects from the shores inland. The mangroves being generally low were categorized into three strata: Trees over 3 m tall were assigned to the A stratum; shrubs and trees between 1-3 m in height were assigned to the B stratum; and those shorter were assigned to the C stratum. Since the alluvial swamps have a relatively open groundlayer, data for C stratum analysis were limited to the coastal beachridge where numerous strand species occur together with shrubby mangroves. The B stratum was sampled in 25 m^2 subquadrats and the C stratum in a further 1×1 metre subplots.Coverage values of the A stratum were determined by the crown-diameter method while those of the B and C strata were determined by visual estimates.

The ecological importance of species in the A and B strata was computed as the station of relative frequency, relative density and relative coverage. This followed the exclusion of basal area as a measure of dominance due to the dense prop roots of the mangrove species. Importance values for C stratum species were the summation of relative frequency and relative coverage since most species in this stratum have undefined stems.

Soil samples were obtained from each quadrat for a rooting depth of 60 cm using profile pits and a "corer" (Giglioli and Thornton 1965). As many as twenty-one soil parameters were originally determined in the laboratory but those selected for this study were: pH in 1:2 soil to water suspension using glass electrode (Jackson 1958); particle size distribution (sand, silt, clay) by the hydrometer method (Bouyoucos 1962); organic carbon, by the Walkley Black wet oxidation method; percentage chloride content, from AgTu extracts and $AgNO_3$ (0.1 M) titration using potassium chromate indicator; total salinity as total water soluble salts (chlorides and sulphates): available phosphorus, by the Bray No. 1 method; exchangeable cations, by extraction in 1 N ammonium acetate at pH 7, then concentrations of magnesium and calcium determined by atomic absorption; cation exchange capacity, by the summation of exchangeable cations and exchange acidity; iron was EDTA extracted and determined by atomic absorption. In order to meet the requirements for parametric statistics, the soil variables, being positively skewed in their distributions (except pH) were transformed to $\log_{10}$ of their original values to approximate normality (Gregory 1973).

Stepwise elimination multiple regression procedures were then used to identify those soil variables having the strongest relationship with each species. The regressions were run such that the order of soil variables was selected using an analysis of variance with each step reducing the variance of the species in each iteration. The "model" linear equation is of the form:

$$Y = a + b_1x_1 + b_2x_2 + \dots bnxn$$

and the datum split into

$$Y = Y + e$$

where Y is the estimated value and e is the residual. Hence Y is equal to a constant term plus a series of powers of an independent variable plus a random error; i.e.

$$Y = a + b_1x_1 \pm b_2x_2 + \dots bnxn \pm SE,$$

where Y – dependent variable (species-criterion); a – Y intercept, b – partial regression coefficient, x – independent variable (soil-predictor), and SE – standard error of estimate.

3. RESULTS

3.1. VEGETATION

Table 1 summarizes the results of vegetation analysis in the sampled stands. Only species that yielded significant multiple regression equations are included. In the A

Table 1. Summary of vegetation analysis (only species yielding significant regression equations are included)
IU = relative frequency + relative density + relative coverage

Stratum	Species	Frequency (%)	Relative frequency (%)	Density (s/ha)	Relative density (%)	Coverage (%)	Relative coverage (%)	Importance value (IV)
A 76 quadrats	*Avicennia africana*	57.9	22.5	161	30.6	22.9	29.3	82.4
	Nypa fruiticans	39.5	15.3	92	17.5	15.9	20.4	53.2
	Rhizophora racemosa	44.7	17.3	89	16.9	12.1	15.5	49.7
	Rh. harrisonii	15.8	6.1	26	4.8	3.2	4.1	15.0
	Phoenix reclinata	13.2	5.1	20	3.8	2.3	2.3	11.2
	Pandanus candelabrum	7.9	3.1	20	3.8	4.9	4.9	11.8
B 80 quadrats	*Avicennia africana*	58.8	23.7	265	28.8	16.0	27.0	79.5
	Rhizophora racemosa	51.3	20.7	216	23.5	11.2	18.2	63.1
	Rh. mangle	41.3	16.7	173	18.8	10.3	17.4	52.9
	Raphia vinifera	12.5	5.0	36	3.9	3.2	5.4	12.8
C 13 quadrats	*Acrostichum aureum*	53.8	26.8	–	–	24.5	28.2	55.0
	Sesuvium portulacastrum	38.5	19.9	–	–	15.5	17.8	37.7
	Cyprus articulatus	30.8	15.4	–	–	14.0	16.1	31.5
	Ipomoae cairica	23.1	11.5	–	–	12.0	13.8	25.3
	Papalum vaginatum	15.5	7.7	–	–	6.0	7.0	14.7

stratum (76 quadrats) *Avicennia africana* is the dominant species (importance value – IV 82.4), with a density of 161 stems/hectare (s/ha) and coverage of 22.9%. *Nypa fruiticans* (IV 53.2) with a density of 92 s/ha is the most important non-mangrove associes. *Avicennia africana, Nypa fruiticans* and *Rhizophora racemosa* are commonly found in mixed stands close to the channels while *Rhizophora harrisonii* (IV 15.0), *Phoenix reclinata* (IV 11.2) and *Pandanus candelabrum* (IV 11.8) are more frequently encountered as mixed stands in the inner swamps.

In the B stratum (80 quadrats), *Avicennia africana* (IV 79.5) is also dominant with 265 stems/hectare but with lower coverage (16%) than in the A stratum. *Rhizophora racemosa* (IV 63.1) with a density of 216 s/ha occurs in pure stands along certain segments of the shoreline. *Raphnia vinifera* (IV 12.8) is a freshwater species that occurs in the mangrove swamps due to large freshwater inputs and intermittent salinities. The species is commonly found in association with *Rhizophora mangle* (IV 52.9) in the inland more elevated sections of swamps.

The C stratum analysis shows *Acrostichum aureum* (IV 55.0) to be the most important species on the beachridge sands. The species also has a high frequency of occurrence in alluvial swamps being particularly restricted to topographic mounds on estuarine levees. *Sesuvium portulacastrum* (IV 37.7), *Cyperus articulatus* (IV 31.5) and *Ipomoea cairica* (IV 25.3) dominate the seaward slopes of the beachridges while *Paspalum vaginatum* (IV 14.7) favours the beach crests. Species zonation is sharper on the beachridges than in the alluvial swamps.

3.2. SOILS

The summary of soil analysis is presented in Table 2. In the alluvial soil, clay is the most variable physical property (19.4 ± 8.1%). However, silt proportion (42.2 ± 3.4%) is higher than either sand (38.4 ± 4.7%) or clay. Percentage chloride content (2.5 ± 0.5%) is less variable than total salinity (3.8 ± 2.4%). Of the exchanegeable cations, magnesium (19.7 ± 4.3 me/100g) has the highest value. Available phosphorus is low (1.8 ± 1.2 $\mu g \cdot ml^{-1}$). Organic carbon (4.8 ± 2.6%) reflects the peaty nature of the soils.

The beachridge soils consist of sand (68.4 ± 2.1%). Silt and clay proportions are relatively low (21.3 ± 4.5%; 10.3 ± 3.7%). Chloride content (3.1 ± 1.1%) and total salinity (4.8 ± 0.8%) are higher than in the alluvial soils. Calcium (18.6 ± 2.8 me/100g) is the predominant cation. Compared to the alluvial soils, CEC is higher in the coastal beachridge (51.3 ± 4.7 me/100 g). Organic carbon (2.2 ± 1.5%) reflects the shrubby nature of the vegetation. Available phosphorus level (0.6 ± 0.2 $\mu g\ ml^{-1}$) is lower than in the alluvial soils. At the acid pH levels for soils from both mangrove types, phosphorus was probably fixed by iron and alluminium.

3.3. STEPWISE MULTIPLE REGRESSION

The significant multiple regression equations based selectively on the highest multiple correlation coefficient are shown in Table 3. For all "models", a multiple

Table 2. Mean and standard deviation of soil properties for rooting depth (0–60 cm)

Soil properties	Alluvial swamps (56)*	Coastal beachridge (12)*
	mean ± SD	mean ± SD
Sand (%)	38.4 ± 4.7	68.4 ± 2.1
Silt (%)	42.2 ± 3.4	21.3 ± 4.5
Clay (%)	19.4 ± 8.1	10.3 ± 3.7
Chloride (%)	2.5 ± 0.5	3.1 ± 1.1
Total salinity (%)	3.8 ± 2.4	4.8 ± 0.8
Magnesium (me/100 g)	19.7 ± 4.3	16.5 ± 2.3
Calcium (me/100 g)	14.4 ± 3.2	18.6 ± 2.8
CEC (me/100 g)	48.6 ± 6.5	51.3 ± 4.7
Iron (ppm)	1680.8 ± 192.5	1976.3 ± 152.4
Av. phosphorus ($\mu g \cdot ml^{-1}$)	1.8 ± 1.2	0.6 ± 0.2
Organic carbon (%)	4.8 ± 2.6	2.2 ± 1.5
pH (air dry)	4.9 ± 2.2	5.2 ± 0.6

*Minimum number of samples.

coefficient of determination (R^2) of 0.22 and higher were included in the equations. This was because below the R^2 = 0.22 level, coefficients were considerably lower being usually less than 0.15. Hence R^2 = 0.22 more or less provided a divide between the higher and lower correlation coefficients. Since R^2 is equal to the percentage of variation which the multiple regression is accountable for, i.e. the level of explanation, it follows that all regression equations presented account for 22 percent or above of the variance.

All soil variables are retained in the equations. However some variables occur more frequently than others (Table 4). The most frequently retained soil variable is percentage silt + clay which occur in eleven out of fifteen equations. Percentage chloride content and iron have similar occurrences being retained in seven equations each, while total salinity, organic carbon and magnesium are retained in six equations. Calcium and CEC are retained in four and three equations respectively. Percentage sand occurs in only one equation. Hence the most important physical soil texture in mangrove swamps relate to silt and clay. There is an indication of selective response of species to forms of salt concentrations; percentage chloride is significant in the B and C strata while total salinity is much more significant in the A stratum. Iron and organic carbon are significant to the performance of the B and C strata vegetation but are relatively unimportant to the A stratum species. Magnesium (in 5 equations), calcium (in 3 equations) and pH (in 2 equations) appear to be the main nutrient status indicators for the A stratum while iron and organic carbon are indicators for the B and C strata.

Table 3. Predictive multiple regression equation based on the performance of species on soil parameters using logarithmic transformations

Stratum	Species	Predictive multiple regression equations
A	*Pandanus candelabrum*	Y = 1.920 + 0.022(Mg) – 0.018(Ca) – 0.023(av.P) – 0.055(sal) – 0.007(si+cl) ± 18.9% (R^2 = 83.7%)
	Rhizophora harrisonni	Y = 2.503 – 0.105(pH) + 0.018(Mg) – 0.072(sal) – 0.011(Ca) – 0.008(si+cl) – 0.007(Fe) – 0.022(sand) ± 19.4% (R^2 = 72.1%)
	Rh. racemosa	Y = 70.855 – 0.821(pH) – 0.658(sal) + 0.118(Mg) – 0.040(si+cl) ± 17.7% (R^2 = 71.0%)
	Avicennia africana	Y = –86.514 + 0.465(Mg) + 0.064(si+cl) + 0.075(Cl^-) ± 17.3% (R^2 = 65.8%)
	Phoenix reclinata	Y = 0.338 + 0.31(Mg) + 0.009(si+cl) – 0.015(av.P) ± 15.8% (R^2 = 51.6%)
	Nypa fruiticans	Y = 78.576 – 0.510(CEC) – 0.272(Fe) + 0.275(Ca) + 0.049(si+cl) ± 22.3% (R^2 = 47.1%)
B	*Avicennia africana*	Y = –27.986 + 0.623(CEC) + 0.135(si + cl) + 0.049(Cl^-) – 0.083(sal) + 0.030(Org. C) ± 19.6% (R^2 = 68.4%)
	Rhizophora racemosa	Y = 21.544 – 0.748(Av.P) –1.198(Cl^-) – 0.085(si+cl) ± 23.1% (R^2 = 48.7%)
	Rh. mangle	Y = 57.502 – 1.828(Fe) + 0.354(Org.C) + 0.244(CEC) ± 20.6% (R^2 = 48.4%)
	Raphia vinifera	Y = 0.662 – 0.200(Cl^-) + 0.622(Fe) ± 25.5% (R^2 = 48.3%)
C	*Paspalum vaginatum*	Y = 0.346 + 0.013(Fe) + 0.014(si+cl) ± 24.7% (R^2 = 75.7%)
	Acrostichum aureum	Y = –0.138 + 0.564(Mg) + 0.042(Org. C) – 0.085(sal) + 0.177(Cl^-) + 0.009(si+cl) ± 22.0% (R^2 = 72.4%)
	Ipomoea cairica	Y = 2.470 – 1.390(Fe) + 0.041(Ca) + 0.031(pH) + 0.029(Org. C) – 0.024(Cl^-) + 0.013(sal) ± 27.0% (R^2 = 58.4%)
	Cyperus articulastus	Y = 0.916 + 0.013(si+cl) + 0.012(Org. C) + 0.011(Cl^-) ± 33.4% (R^2 = 57.5%)
	Sesuvium portulacastrum	Y = 1.948 – 0.873(Fe) + 0.028(Org. C) ± 23.6% (R_2 = 46.8%)

Table 4 also indicate the percentage contribution of each soil variable to the total variance of the multiple regression equations. In the A stratum, the highly significant explanatory variables influencing the performance of *Pandanus candelabrum* are magnesium and calcium which account for 76.0% of the total (83.7%) variance. This level of explanation clearly relate *P. candelabrum* to nutrient availability. *Rhizophora harrisonii* is highly explained by pH (48.0%) and magnesium (18.6%) out of a total variance of 72.1%. This is also a relationship to nutrient indicators, *Rhizophora ra-*

Table 4. Percentage contribution of each explanatory (soil) variable to the total variance of the regression equations

Stratum	Species	Explanatory variables (%)											Total
		Silt + clay	Cl	Fe	org. C	total salinity	Mg	Ca	CEC	pH	av. P	sand	
A	*Pandanus candelabrum*	1.1*				2.9*	52.1**	23.9**			3.7		83.7
	Rhizophora harrisonni	1.0*		0.7		2.0*	18.6**	1.3		48.0**		0.5	72.1
	Rh. racemosa	0.2				16.6**	1.9			52.3**			71.0
	Avicennia africana	7.0**	1.2*				57.6**						65.8
	Phoenix reclinata	9.6**					39.8**				2.2*		51.6
	Nypa fruiticans	1.3*		10.0**				2.4	33.3**				47.1
B	*Avicennia africana*	16.6**	5.3*		0.7	0.8			50.0**				68.4
	Rhizophora racemosa	7.6*	14.0**								27.1**		48.7
	Rh. mangle			33.9**	10.7**				3.8*				48.7
	Raphia vinifera		38.8**	9.5*									48.3
C	*Paspalum vaginatum*	20.6**		55.1**									75.7
	Acrostichum aureum	0.3	1.0		21.5**	1.9	47.7**						72.4
	Ipomoea cairica		0.7	32.1**	1.7	0.5		20.6**		2.8*			58.4
	Cyperus articulastus	34.5**	4.2*		18.8**								57.5
	Sesuvium portulacastrum			29.8**	17.0**								46.8
Total number of occurrences		11	7	7	6	6	6	4	3	3	3	1	

* Significant at the 5% level. ** Significant at the 1% level.

cemosa is highly explained by pH (52.3%) and total salinity (16.6%) from a total variance of 71.0%. The total salinity in this relationship indicates the occurrence of *R. racemosa* along shorelines where salinities are usually stable due to regular tidal inundations. *Avicennia africana* and *Phoenix reclinata* are highly explained by magnesium (57.6%, 39.8%) and percentage silt + clay (7.0%, 9.6%). *Avicennia africana* has been described as pioneer colonizers of mudflats (Giglioli and Thornton 1965) which probably explains the significance of silt and clay. *Phoenix reclinata* usually occurs on intertidal lagoon shores on silty/clayey substrates. The abundance of *Nypa fruiticans* is explained largely by CEC (33.3%) and iron (10%) out of a total variance of 47.1%. The explanation by iron, apart from its possibility as a nutrient, may also relate to horizon differantiation in inland stands.

In the B stratum (Table 4) exchangeable cations are of less significance in determining the performance of species except for *Avicennia africana* in which CEC explains 50% of the total (68.4%)variance. *Rhizophora racemosa* is explained by available phosphorus (27.1%) and chloride (14.0%) out of a total variance of 48.7%.The significance of chloride in this stratum indicate the differential response of *R. racemosa* to forms of salt concentrations. *Rhizophora mangle* is largely explained by iron (33.9%) and organic carbon (10.7%) out of the total (48.4%) variance. The significance of iron clearly relate to increasing swamp elevation since *R. mangle* is most frequent in the backswamps. *Raphia vinifera* is highly explained by percentage chloride (38.8%) and iron (9.5%) out of a total variance of 48.3%. *R. vinifera* is a high forest/freshwater species. Its occurrence in tidal swamps relate to seasonal salinities and increasing adaptation along the mangrove swamp/highforest ecotone. Hence the significance of chloride and iron in the "model" equation.

In the beachridge C stratum (Table 4) the highly significant explanatory variables influencing the performance of *Paspalum vaginatum* are percentage silt + clay (20.6%) and iron (55.1%) out of a total variance of 75.7%. These two variables relate to beach elevation since *P. vaginatum* occurs on beach crests. *Acrostihum aureum*, being a circumestuarine species relate more to organic carbon (21.5%) and magnesium (47.7%) out of the total (72.4%) variance. *Ipomoea cairica* is largely explained by iron (32.1%) and calcium (20.6%) out of a total variance of 58.4%. *Cyperus articulatus* is explained by percentage silt + clay (34.5%) and organic carbon (18.8%) while *Sesuvium portulacastrum* is explained by iron (29.8%) and organic carbon (17.0%). These account for over 50% of the total variance for each species. The strand species relate to soil texture, profile differentiation and organic matter decomposition since they are not regularly inundated by tides.

4. CONCLUSIONS

Alluvial mangrove swamps have a complex hydrology. Hence the relationship between the vegetation and the soil cannot be sought merely by comparison of stand values. A multiple regression solution is recommended for other similar studies in highly dynamic environments.

The relationships between the mangroves and the soils as reported by previous workers were misleading, for example *Avicennia africana* is reported to favour areas of high salinities (C h a p m a n 1976). This is not reflected in the regression "models" just discussed. Generally the salinity factors are underemphasized by the analysis. The implication here is that mangroves are not obligative or salt-loving plants but facultative or salt tolerant plants. It is clear that mangrove performance is most significantly determined by the nutrient elements in swamp soils. From the analyses percentage silt + clay represents the most favourable physical site attribute in terms of nutrient availability for the performance of mangrove vegetation.

5. SUMMARY

Multiple regression analysis is useful in modelling for interrelationships between the vegetation and soils of mangrove swamps (Table 3). This method is an improvement over the comparison of soils from pure stands of different species (Table 2). The mangrove soils in southeastern Nigeria (Fig. 1) differ markedly from those reported for other swamps elsewhere. Due to large freshwater inputs, some non-mangrove highforest species have encroached into the mangrove zone (Table 1). Percentage silt + clay, retained in eleven out of fifteen regression equations indicated the most favourable site in relation to the nutrients – magnesium, calcium and phosphorus (Table 4). The performance of A stratum species are largely explained by the exchangeable cations, particularly magnesium. The A, B and C strata of the vegetation show selective response to forms of salt concentration; total salinity is significant in the A stratum while chloride is significant in the B and C strata (Table 4). The mangroves are facultative rather than obligative halophytes. The performance of the C stratum species also relate to the elevation of the coastal sands and soil horizon differentiation resulting from irregular tidal flooding.

6. POLISH SUMMARY

Analiza regresji wielokrotnej okazała się użyteczna w modelowaniu wzajemnych zależności pomiędzy roślinnością a glebą w siedliskach roślin mangrowych (tab. 3). Ta metoda ma wyraźną przewagę nad porównywaniem gleb z jednogatunkowych stanowisk różnych gatunków (tab. 2). Gleby siedlisk roślin mangrowych w południowo-wschodniej Nigerii (rys. 1) różnią się znacznie od gleb podobnych siedlisk bagiennych. W wyniku znacznego wpływu wód słodkich niektóre gatunki roślin drzewiastych wkraczają w strefę mangrowców (tab. 1). Procentowa zawartość iłu i gliny zakumulowana w tym siedlisku wskazuje, że najbardziej sprzyjające warunki odnośnie związków biogennych otrzymuje się w przypadku magnezu, wapnia i fosforu (tab. 4), jak to wynika z 11 na 15 równań regresji. Występowanie gatunków roślinnych w warstwie A zależy w znacznej mierze od wymienionych kationów, szczególnie magnezu. Roślinność należąca do warstw A, B i C wykazuje wybiórczą reakcję na zmienne stężenia różnych związków mineralnych. Ogólne zasolenie wpływa istotnie na roślinność warstwy A, podczas gdy chlorki – na roślinność warstw B i C (tab. 4). Okazuje się, że rośliny mangrowe są raczej fakultatywnymi niż obligatoryjnymi halofitami. Występowanie roślin w warstwie C zależy również od położenia brzegowych piasków nad poziomem morza i zróżnicowania poziomu glebowego uzależnionego z kolei od zmienności zasięgu wezbrań pływowych.

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