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# CLASSIFICATION-ANALYTIC MODELS FOR VEGETATION AND NUTRIENT RELATIONS OF MANGROVE SWAMPS IN WEST AFRICA

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Vegetation-nutrient relations in mangrove swamps were modelled by classification of species according to occurrence within certain ranges of soil nutrient values. Although overlap was observed in the distribution of most species, restricted occurrences were noted particularly within one range of magnesium values. Simple correlation analysis revealed mangroves as related to soil nutrients at highly statistically significant levels. The sum of exchangeable cations, at concentrations present in the soils was observed to be limiting to mangrove performance, while saturation of the exchange complex by magnesium promoted the performance of species. Multiple regression analysis revealed the performance of canopy species to be highly explained by magnesium and calcium while the groundlayer was explained by iron, organic, carbon and manganese. The analyses indicated species performance to be significantly determined by varying levels and proportions of nutrients in mangrove soils.

## Introduction

Mangroves are trees which occur along brackish/saline intertidal estuaries and shorelines in the tropics and subtropics. The mangrove soils consist of peat, calcareous mud and sandy deposits in which nutrient levels fluctuate due to the complex hydrology of the estuaries and littoral areas. For example, cation concentrations in magrove soils have been observed to correlate with extent of tidal inundation and seepage (NAIDOO (1980). But since mangrove species often exhibit zonation in a spatial context from the shores inland, the relationships between the mangroves and nutrient factors are often viewed in terms of differences in values of soil nutrients between monospecific zones of species (CLARKE and HANNON 1967; MOORMAN and PONS 1974; HUYNN-CONG-THO and EGASHIRA 1976).

In South Africa, Naidoo (1980) related the occurrence of the mangrove species Avicennia nitida to a cation exchange capacity (CEC) range of 23.7 me/100 g to 83.3 me/100 g, while Bruguiera spp. occurred within a CEC range

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41.0 me/100 g to 67.6 me/100 g. But in Australia, CLARKE and HANNON (1967) maintained that the CEC in mangrove soils ranged from 0.38 $\pm$ 0.08 me/100 g at the surface to 0.84 $\pm$ 0-59 me/100 g in the subsurface. In the Gambia, West Africa, GIGLIOLI and THORNTON (1965) found that Sesuvium portulacastrum and Paspalum vaginatum occurred where 15% of the exchange complex was sodium. In Mexico, THOM (1967) related the occurrence of Rhizophora spp. to soils with very high organic matter content (52.4%) while GIGLIOLI and THRONTON (1965) found that the same species occurred in soils with organic matter values ranging from 8.7% to 12.3%. The fundamental observation is that there exists a considerable overlap in values for soil nutrient from mangrove stands dominated by different species. Sometimes the differences in values within stands are as great or greater than differences between stands. Hence the aims of this paper are to establish the strength of the relationship and to determine the precise mathematical forms of these relationships between mangroves and soil nutrient based on vegetation and soil measurements at the same sites. The basic approach is quantitative, involving the use of simple correlation coefficients and multiple regression analysis.

## Study area

The study area for this investigation is the coastal zone of Nigeria in West Africa, which lies between the River Niger delta (7°30'E) and Rio del Ray (8°30'E) in the Cameroon Republic. Within this coastal stretch, magroves occur in the estuaries of the Imo River, Kwa Ibo River and Cross River (Fig. 1). The three estuaries, connected to each other by means of interriverine creeks constitute a homogeneous ecological unit. Mangroves generally occur in mixed stands in the swamps although SAVORY (1953) recognized Rhizophora racemosa as the pioneer species along certain channel segments. The area has a humid tropical climate with a mean annual rainfall of 4021 mm and average relative humidity of about 80%. Temperatures are high throughout the year with a maximum of 30 °C and a minimum of 22 °C. The coastal beachridge sands lying between the estuaries are influenced by Atlantic strom waves. Within the estuaries, tidal flushing may occur up to 20 km upstream. However, tidal amplitude is generally low, averaging 2.01 m at spring tides and 1.07 m at neap tides (RAMANATHAN 1981). The estuarine mangroves are the most complex in West Africa in terms of the number of species present (CHAPMAN 1976).



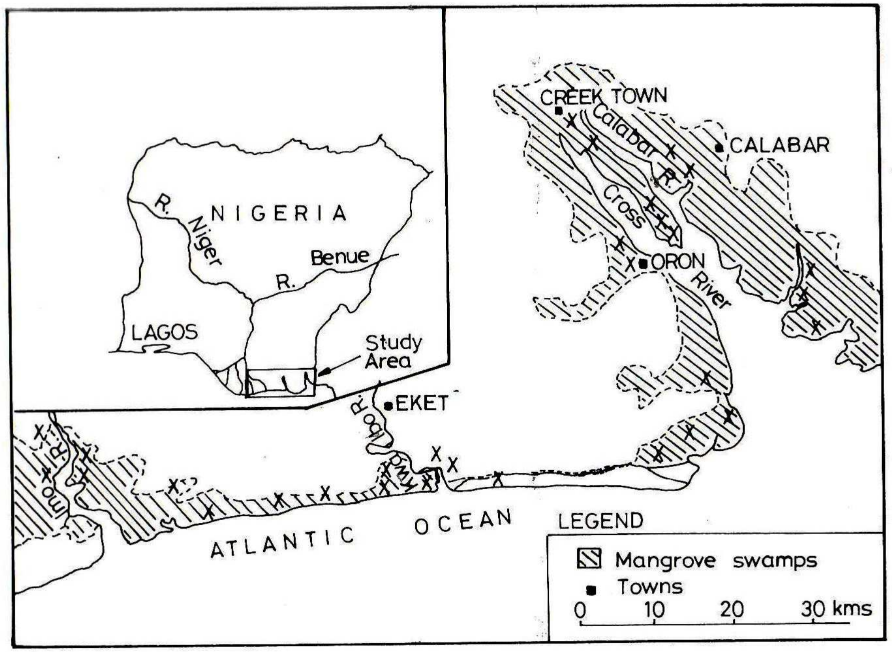


Fig. 1. Mangrove swamps of the study area, showing location along the Nigerian coast. XX ... X represent approximate transect positions

## Methods

### Vegetation

The vegetation was sampled in 10 x 10 m quadrat's regularly spaced at 20-m intervals along transects established from the shores inland. Transect length was determined by the width of swamp but each contained at least two quadrats. The vegetation, of generally low stature was stratified into A stratum (> 3 m tall), B stratum (1-3 m tall) and C stratum (< 1 m tall). The frequency of occurrence of species in each stratum was noted. Coverage values of A stratum species were determined in the 10 x 10 m quadrats using the crown-diameter method (MUELLER-DOMBOIS and ELLENBERG 1974). Each 10 x 10 m quadrat was subdivided into 5 x 5 m subquadrats to facilitate visual covarage estimates of the B stratum species while a further 1 x 1 m subdivision enabled estimates for the C stratum to be obtained.

### Soils

Soil sampling was performed in each quadrat using a "corer" (GIGLIOLI and THORNTON 1965) to obtain core samples to a depth of 40 cm. The samples were analysed in the laboratory for the following nutrient factors: pH, in 1:2 soil to water suspension using glass electrode (JACKSON 1962); organic carbon, by the Walkley-Black wet oxidation method (JACKSON 1962); available phosphorus, by the Bray No. 1 method (JACKSON 1962); exchangeable cations ($Ca^{++}$, $Mg^{++}$, $K^+$, $Na^+$), by extraction with 1 N ammonium acetate at pH 7, and concentrations of cations determined by atomic absorption and flame photometry; cation exchange capacity (CEC) was the summation of exchangeable cations and exchange acidity; micronutrient levels (manganese and iron) were determined from total elemental analysis digestion extracts of samples using atomic absorption spectrophotometry.

## Analysis

To meet the requirements for parametric statistics, species coverage values were transformed to the square-rott of the original values while the nutrient variables approximated normal distribution after $\log_{10}$ transformations (GREGORY 1973).

The simple correlation coefficient (r) was used to examine the strength of the relationship between species and the nutrient variables. The possibilities as to the meaning of a significant correlation were regarded in terms of (i) direct causal relationship or partial causal relationships, and (ii) indirect causal relationship or mutual interaction of the two variables. Hence a significant correlation served as an indication of a relationship most unlikely to have occurred by chance.

Predictive multiple linear regression analysis was used to determine the precise mathematical forms of the relationship between the species and the soil nutrients. The linear "model" is of the form:

$$Y = a + b_1X_1 + b_2X_2 + \ldots b_nX_n + SE$$

where Y = dependent (species-estimated) variable, plus a residual e; a = Y intercept; b = partial regression coefficients; X = independent (nutrient-predictor) variable; and SE = standard error of estimate. Stepwise elimination multiple regression procedures were used to develop the predictive "models". Multicollinearity between the nutrient variables was elminated using HAUSER's (1974) criterion. The computer programme (STWMULT) was IBM supplied.

## Results

### Distribution of mangroves within specified ranges of nutrient values in the swamps

Of the 68 plant species encountered in the tidal estuaries and coastal beachridge zone, only the occurrence of fourteeen species with frequency greater than 5% (Table 1) could be classified within arbitrary ranges of some nutrient variables, and these excluded duplications of occurrences in the A and B strata. Mangrove samplings, treated as a single item within the C stratum occurred across all ranges of nutrient values and was excluded from the classification. Inclusions of same species in the A, B and C strata also created complications in the classification as it was difficult to establish ranges of nutrient values for exclusive occurrences of the species. Hence a species was idealized as representative if its occurrence in at least one of the strata clearly related to the range of nutrient values.

Within the A stratum, only Rhizophora mangle (freq. 48.7%) and Rhizophora harrisonii (freq. 15.8%) were restricted to a field moist pH range of



Table 1

Species grouped according to occurrence within ranges of some nutrient determinants and factors in mangrove swamps

| Species | | pH (field moist) | | | Organic carbon (%) | | P (μgml⁻¹) | | | Ca (me/100 g) | | Mg (me/100 g) | | CEC (me/100 g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5.0–5.5 | 5.6–6.0 | 6.1–6.5 | 3.5–5.0 | 5.1–12.0 | 1.5–5.0 | 5.1–10.0 | 10.1–15.5 | 5.5–10.5 | 10.6–15.5 | 10.5–15.5 | 15.6–25.5 | 15.5–25.5 | 25.6–45.5 |
| Avicennia africana | (A) | | X | X** | X | X** | X | | | X | X | | X | X | X** |
| Rhizophora mangle | (A) | | X | | X | X | | X | | | X | | X | | X |
| Rhizophora racemosa | (A) | X* | X | | | X | | X | | X | X | | X | X | X** |
| Nypa fruticans | (A) | X* | X | | X | X** | X | X | | X | X | X | | X | X** |
| Raphia vinifera | (A) | | X | X** | | X | X | X | | X* | | | X | X | X |
| Rhizophora harrisonii | (A) | | X | | X | | | X | | | X | | X | | X |
| Conocarpus erectus | (B) | | | X | X | X | | | X | | | | X | X | X |
| Pandanus candelabrum | (B) | X | | | X* | X | | | X | X | | | X | | X |
| Phoenix reclinata | (B) | X | | X | X | X | | X | | X | X | | X | | X |
| Triumfetta rhomboidea | (C) | | X | | X | | X | X | | X | | X* | | X | |
| Acrostichum aureum | (C) | X | | X | | X | X | | | X | X | | X | | X** |
| Sesuvium portulacastrum | (C) | | X | | X | | X | | | X | X | X | | X | X |
| Vossia cuspidata | (C) | | X | X** | X | X | | X | | X* | | X | | X* | |
| Acutas afer | (C) | | | X** | X | X | X | X | | X* | | X | | X* | |

*Occurrence may fall below the specified range.

**Occurrence may fall above the specified range.

(A), (B), (C) = Vegetation strata.

5.6 to 6.0 (Table 1). Rhizophora racemosa (freq. 51.3%) and Nypa fruticans (freq. 30.0%) occurred at the lowest pH range (5.0-5.5), while Avicennia africana (freq. 58.8%) and Raphia vinifera (freq. 12.5%) occurred at the highest pH values (6.1-6.5). HESSE (1961) had also observed that A. africana souls were associated with lower acid conditions than Rhizophora spp. soils. An observation made in the present study was that R. racemosa and N. fruticans usually occurred in mixed stands along shorelines in the mangrove zone while Raphia spp. is basically an upland species with low frequency of occurrence in the mangrove zone. Hence Raphia soils are less acidic, and are similar to A. africana soils. In the B stratum, Conocarpus erectus (freq. 5.8%) occurred within the highest pH range while Pandanus candelabrum (freq. 7.9%) occurred within the lowest range. Two species in the C stratum (Triumfetta rhomboidea, freq. 8.3%; Sesuvium portulacastrum, freq. 26.6%) were restricted to a pH range of 5.6 to 6.0 while Acutas afer (freq. 8.3%) exceeded the highest range of 6.1 to 6.5. Overlap was observed for the occurrences of Acrostichum auerum (freq. 30.6%) and Vossia cuspidata (freq. 8.6%).

Apart from Rhizophora racemosa, Raphia vinifera and Rhizophora harrisonii, the occurrences of other species in the A stratum were not restricted to the classified ranges of organic carbon values (Table 1). Avicennia africana and Nypa fruticans were associated with the highest organic carbon values exceeding the range of 5.1% to 12.0%, probably due to the dense pneumatophores of A. africana and the fibrous root mats of N. fruticans. In the B stratum, R. harrisonii was restricted to low organic carbon range (3.5%-5.0%). Three C stratum species (Triumfetta rhomboidea, Acrostichum aureum and Sesuvium portulacastrum) occurred within exclusive ranges of organic carbon values. A. aureum which occurred within the highest range (5.1%-12.0%) was observed to possess more extensive fibrous root systems than T. rhomboidea and S. portulacastrum.

Magnesium and available phosphorus were the nutrient variables to which species showed the least variation in niche relations (Table 1). In the A stratum, Nypa fruticans and Raphia vinifera occurred within an overlapping phosphorus range (1.5-10.0 $\mu gml^{-1}$) as Triumfetta rhomboidea and Acutas afer in the C stratum. There was no variation in species occurrences across the ranges for magnesium values, although T. rhomboidea also occurred below the lowest range of 10.5 to 15.5 me/100 g.

A similarity was observed in species occurrences within the ranges for calcium and cation exchange capacity, particularly in the A stratum where Rhizophora mangle and Rhizophora harrisonii were restricted to the highest



values (Table 1). However, in the B stratum, Pandanus candelabrum was also restricted to an exclusive range of calcium and CEC while Phoenix reclinata (freq. 5.0%) occurred within the highest CEC range (25.6-45.5 me/100 g). In the C stratum, occurrence of A. aureum exceeded the highest range for CEC, while occurrences of Vossia cuspidata and Acutas afer were observed below the lowest range for both calcium and magnesium.

Since many classes of nutrient values as desired may be obtained for mangrove occurrences, the importance of the aforegoing analysis lies in recognizing idealized ecological groups and species niche relations to soil nutrients. The realibility of the established relations is affected by the complex hydrology of the estuaries and coastal areas.

## Bivariate correlation solution

Table 2 presents the correlation coefficients between species coverage values and soil nutrient variables. Only correlation "models" at significance P = 0.01 and above are reported. Two species in the A stratum (Rhizophora mangle and Rhizophora racemosa) show strong negative relationships with pH (P = 0.001), while Conocarpus erectus and Vossia cuspidata in the B and C strata respectively relate positively with pH. R. mangle and R. racemosa are often associated in mixed stands along channel levees. Hence regulation of acid conditions by tidal flushing may be responsible for the strong negative relationships. C. erectus and V. cuspidata are positively correlated with pH (P = 0.001) since the species occur most frequently in the inner and upland swamps that experience lesser tidal flushing than the shorelines.

Several species are highly correlated with organic carbon (Table 2). The strongest positive relationships are achieved by Avicennia africana, Rhizophora mangle and Nypa fruticans in the A stratum, and Acrostichum aureum and Sesuvium portulacastrum in the C stratum. The dense pneumatophores of A. africana and the extensive fibrous roots of N. fruticans, A. aureum and S. portulacastrum probably account for the high organic carbon content of soils associated with these species. Apart from Rhizophora racemosa, the negatively correlated species (Raphia vinifera, C. erectus and P. candelabrum) do not develop extensive root mats in tidal swamps.

Available phosphorus and CEC are highly correlated with A stratum and C stratum species. The strongest positive relationships with phosphorus are achieved by R. vinifera and Rhizophora racemosa (P = 0.001) in the A stratum

Table 2

Coefficients of correlation between selected species and soil nutrient factors

| Species | | Percentage coverage | | Correlation coefficients (r)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean ± SD | pH | Org. C. | P | Ca | Mg | CEC | Mn | Fe |
| Avicennia africana | (A)* | 5.5–98.5 | 22.9 ± 19.4 | | 0.63 | -0.40 | -0.52 | | -0.48 | | 0.47 |
| Rhizophora mangle | (A) | 5.0–80.4 | 12.6 ± 10.2 | -0.52 | 0.57 | | | | -0.58 | | 0.55 |
| Rhizophora racemosa | (A) | 4.5–82.5 | 12.1 ± 9.6 | -0.56 | -0.40 | 0.54 | | | -0.65 | | -0.45 |
| Nypa fruticans | (A) | 4.0–96.5 | 15.9 ± 10.8 | | 0.64 | -0.58 | 0.50 | | -0.63 | | |
| Raphia vinifera | (A) | 1.5–77.2 | 4.3 ± 3.6 | | -0.38 | 0.60 | 0.47 | 0.62 | | | 0.58 |
| Rhizophora harrisonii | (A) | 2.5–33.4 | 3.8 ± 4.2 | | | -0.36 | | 0.55 | | | -0.43 |
| Conocarpus erectus | (B) | 0.8– 2.6 | 1.2 ± 0.8 | 0.49 | -0.36 | | | | | -0.36 | |
| Pandanus candelabrum | (B) | 0.6– 3.8 | 1.4 ± 1.2 | | -0.34 | | | | | -0.36 | |
| Phoenix reclinata | (B) | 0.5– 1.8 | 0.9 ± 0.6 | | | | -0.39 | 0.35 | | | -0.61 |
| Triumfetta rhomboidea | (C) | 0.5– 2.7 | 0.9 ± 1.5 | | | | 0.57 | | | 0.54 | 0.40 |
| Acrostichum aureum | (C) | 4.0–14.3 | 6.6 ± 4.8 | | 0.49 | | -0.40 | 0.54 | 0.35 | 0.39 | 0.52 |
| Sesuvium portulacastrum | (C) | 3.5–12.0 | 8.4 ± 2.2 | | 0.35 | 0.55 | 0.62 | 0.50 | | 0.53 | 0.50 |
| Vossia cuspidata | (C) | 2.5– 6.4 | 3.2 ± 2.4 | 0.38 | | 0.43 | | 0.46 | | | 0.58 |
| Acutas afer | (C) | 0.5– 2.6 | 1.8 ± 0.9 | | | | 0.38 | 0.45 | | 0.52 | 0.47 |

* (A), (B), (C) = Vegetation strata.

** $r > 0.26$, $P = 0.01$; $r > 0.34$, $P = 0.001$.



and S. portulacastrum and V. cuspidata (P = 0.001) in the C stratum. R. racemosa and Raphia vinifera are dominant along shorelines although the latter species is also an upland species. Similarly, Sesuvium portulacastrum is most frequent in saline swamps while Vossia cuspidata is also a freshwater/upland species. The negatively correlated species (A. africana, N. fruticans, R. harrisonii) dominate in brackish/saline areas as mixed stands on point-bars and tributary channels. CEC shows strong netative relationships with A stratum species but a positive relationship with Acrostichum aureum in the C stratum. This is an indication that the sum of cation concentrations at the levels occurring in the swamps soils may constitute stress to mangrove performance. Considering the positive relationships of all species with magnesium, and the positive and negative relationships of species with calcium, it is clear that mangroves are selective in terms of cation requirements. Saturation of the exchange complex by magnesium apparently increases mangrove performance.

Manganese is negatively correlated with B stratum species (C. erectus, P. candelabrum) but positively correlated with C stratum species (mainly strand species). Iron shows positive relationships the C stratum species and may also be related to soil profile differentiation in the irregularly inundated strand zone. Positive relationships of iron wiht A. africana, R. mangle and Raphia vinifera in the A stratum also indicate differentiation of soil horizons on the levees and inner/upland swamps where these species are frequently encountered.

## Multiple regression solution

The significant multiple regression equations based on the highest multiple correlation coefficient are presented in Table 3. For all regression "models", a multiple coefficient of determination ($R^2$) of 0.52 and above were included in the equations. 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 52% or above of the variance.

The most frequently retained soil nutrient variable is magnesium, in ten out of fourteen equations (Table 4). Calcium, phosphorus and iron occur in eight equations each while organic carbon and manganese are retained in six and five equations respectively. pH occurs in three equations. Apart from pH which is not significant in the B stratum, all nutrient factors are

Table 3

Predictive multiple regression equations based on performance of species along soil nutrient parameters using logarithmic transformations

A stratum

<u>Avicennia africana</u> $Y = -2.360 - 1.081(Mg) + 0.832(Fe) + 0.621(Ca) + 0.301(P) + + 0.265\ (R^2 = 79.8\%)$.

<u>Rhizophora mangle</u> $Y = -4.254 - 1.343(Ca) + 1.025(pH) + 0.931(Mn) + 0.176\ (R^2 = = 83.7\%)$.

<u>Rhizophora racemosa</u> $Y = -1.362 + 1.738(Ca) + 0.696(Mg) - 0.312(P) - 0.271 (Org.\ C.) \pm 0.246\ (R^2 = 76.4\%)$.

<u>Nypa fruticans</u> $Y = 8.932 - 0.748(Mg) + 0.003(Ca) - 0.402\ (Org.\ C.) + 0.146\ (R^2 = 63.8\%)$.

<u>Raphia vinifera</u> $Y = 10.327 + 0.386(P) + 0.511(Mg) - 0.628(Fe) - 0.314(pH) + + 0.436\ (R^2 = 60.8\%)$.

<u>Rhizophora harrisonii</u> $Y = 3.111 + 0.783(Mg) + 0.692(Ca) - 0.019(Fe) + 0.298\ (R^2 = 52.6\%)$.

B stratum

<u>Conocarpus erectus</u> $Y = 1.619 + 1.298(Mn) + 0.537(P) - 0.976(Mg) - 0.012(Ca) + + 0.368\ (R^2 = 74.5\%)$.

<u>Pandanus candelabrum</u> $Y = -0.412 - 0\text{-}120(Org.\ C.) + 0.026(P) \pm 0.367\ (R^2 = 57.3\%)$.

<u>Phoenix reclinata</u> $Y = -1.163 - 1.828(Mg) + 2.159(Ca) \pm 0.414\ (R^2 = 56.5\%)$.

C stratum

<u>Triumfetta rhomboidea</u> $Y = -4.196 + 0.013(Mg) + 0.018(Fe) - 0.008(Org.\ C.) + + 0.022(P) - 0.029(pH) \pm 0.335\ (R^2 = 70.8\%)$.

<u>Acrostichum aureum</u> $Y = 4.595 - 0.366(Fe) - 0.842(Mg) - 0.026(P) - 0.007 (Org.\ C.) \pm 0.192\ (R^2 = 89.1\%)$.

<u>Sesuvium portulacastrum</u> $Y = -0.539 - 0.020(Org.\ C.) + 0.012(Mn) + 0.004(Fe) + 0.338\ (R^2 = 59.8\%)$.

<u>Vossia cuspidata</u> $Y = -5.396 + 1.041(Mg) - 0.442(Fe) + 0.017(Mn) + 0.009(P) \pm \pm 0.396\ (R^2 = 63.8\%)$.

<u>Acutas afer</u> $Y = 1.554 + 1.386(Mn) - 1.407(Fe) \pm 0.418\ (R^2 = 59.2\%)$.

significant to the performance of species across all strata of the vegetation. However, calcium is more significant to the performance of the A and B strata than to C stratum species, while iron and manganese are more significant to the performance of the C stratum than to A and B strata species. Magnesium is highly significant across all strata of the vegetation.

Table 4 also indicates the percentage contribution of each nutrient variable to the total variance of the regression equations. In the A



Table 4

Percentage contribution of each explanatory nutrient variable to the total variance of regression equations

| Species | | Contribution of each explanatory variable (%) | | | | | | | Total % explanation |
|---|---|---|---|---|---|---|---|---|---|
| | | Mg | Ca | P | Fe | Org. C. | Mn | pH | |
| <u>Avicennia africana</u> | (A) | 43.6** | 10.3** | 3.5* | 21.4** | | | | 79.8 |
| <u>Rhizophora mangle</u> | (A) | | 70.4** | | | | 5.9** | 7.4** | 83.7 |
| <u>Rhizophora racemosa</u> | (A) | 21.2** | 44.1** | 7.9* | | 5.2* | | | 76.4 |
| <u>Nypa fruticans</u> | (A) | 55.6** | 7.0* | | | 1.2 | | | 63.8 |
| <u>Raphia vinifera</u> | (A) | 3.1* | | 52.6** | 2.7* | | | 2.4* | 60.8 |
| <u>Rhizophora harrisonii</u> | (A) | 40.8** | 9.6* | | 2.2* | | | | 52.6 |
| <u>Conocarpus erectus</u> | (B) | 4.2** | 3.1* | 5.1** | | | 62.1** | | 74.5 |
| <u>Pandanus candelabrum</u> | (B) | | | 4.2* | | 53.1** | | | 57.3 |
| <u>Phoenix reclinata</u> | (B) | 52.7** | 3.8** | | | | | | 56.5 |
| <u>Triumfetta rhomboidea</u> | (C) | 48.0** | | 1.3 | 18.5** | 2.0* | | 1.2 | 70.8 |
| <u>Acrostichum aureum</u> | (C) | 7.9** | 5.4* | 5.8* | 65.2** | 4.8* | | | 89.1 |
| <u>Sesuvium portulacastrum</u> | (C) | | | | 6.0** | 44.6** | 9.2** | | 59.8 |
| <u>Vossia cuspidata</u> | (C) | 46.7** | | 1.7* | 12.0** | | 3.4** | | 63.8 |
| <u>Acutas afer</u> | (C) | | | | 8.6** | | 50.6** | | 59.2 |
| Total number of occurrences | | 10 | 8 | 8 | 8 | 6 | 5 | 3 | |

**Significant at the 1% level.
*Significant at the 5% level.
(A), (B), (C) = Vegetation strata.

stratum, the performance of N. fruticans relates to nutrient availability in terms of magnesium (55.6%) and calcium (7.0%) from the total variance of 63.8%. A. africana is related to magnesium (43.6%), iron (21.4%) and calcium (10.3%) from a total variance of 79.8%. The performance of R. mangle is highly explained by calcium (70.4%), pH (7.4%) and manganese (5.9%) while R. racemosa is related to calcium (42.1%), magnesium (21.2%) and phosphorus (7.9%) out of a total variance of 76.4%. The performance of R. harrisonii is highly related to magnesium (40.8%) and calcium (9.6%). Differences in nutrient relations for Rhizophora spp. are accounted for by the spatial segregation of Rhizophora in the swamps. Raphia vinifera which is also an upland species is highly explained by available phosphorus (52.6%), while other nutrient factors are of lesser significance. Magnesium, calcium and phosphorus have been selected by the regression procedure as the most important soil nutrients with respect to canopy species performance.

In the B stratum, the performance of P. reclinata is highly explained by magnesium (52.7%) out of a total variance of 56.5%. The other species (C. erectus, P. candelabrum) are related to manganese and organic carbon which account for much more than 50% of the total variance.

The performance of T. rhomboideae is explained by magnesium (48.0%) and iron (18.5%) from a total variance of 70.8%. Organic carbon is significant to the performance of S. portulacastrum (44.6%) while A. aureum is explained by iron (65.2%). V. cuspidata and A. afer which are basically upland species are highly explained by magnesium (46.7%) and manganese (50.6%) respectively. The two species are spatially segregated in that Vossia is flood tolerant while Acutas dominate on topographic mounds (UKPONG 1989).

## Conclusion

Classification of mangrove species according to occurrence within certain ranges of nutrient factors revealed overlap in species-nutrient relations. However, restricted occurrences of species were observed for ranges of magnesium values. Magnesium although abundant in sea water did not correlate with extent of tidal inundation and therefore spatial location of stands from the ocean. Simple correlations of species coverage with nutrients revealed strong relationships between the nutrients and vegetation performance at highly statistically significant levels. Negative relationships indicated levels of nutrient availability that were limiting to mangrove performance while positive relationships indicated essential nutrient levels. Multiple regression analysis, used as a search procedure identified the order of those soil variables having the strongest relationship with the mangrove species. The results show clearly that species performance relate significantly to varying proportions of nutrient levels in mangrove swamp soils.



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