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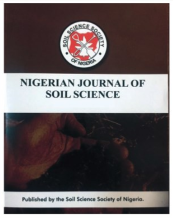

# Effect of *Nypa fruticans* and Mangrove species on Soil Properties in Eastern Obolo, Akwa Ibom State

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## ABSTRACT

The study was conducted to evaluate the effect of nypa and mangrove on soil properties to determine whether nypa in displacing mangrove was degrading or aggrading the underlying soil, in Okorombokho Community in Eastern Obolo Area of Akwa Ibom State. The study was carried out in three contiguous locations, namely, mangrove (M) forest, *nypa* and mangrove (N&M) forest, and bare plot with neither mangrove nor nypa as control (C). In each location, undisturbed and bulk soil samples were collected from the 0-15 cm and 15-30 cm depth at 20 m intervals along a 60-m transect, for soil physical and chemical properties and micronutrients concentrations. The result showed that among the particle-size fractions, sand was significantly ($p<0.05$) greater in the 0-15 cm than 15-30 cm depth. Soil texture was sandy loam in N.M., M, and C. Soil density was significantly ($p<0.01$) higher in C (1.64 Mg m-3) than in M (1.54 Mg m-3) andN&M (1.52 Mg/$m^3$), while 0-15 cm and 15-30 cm were similar. Saturated hydraulic conductivity was significantly ($p<0.01$) greater inN&M (6.04 cm $h^{-1}$)by 66.4% than C 3.63 cm $h^{-1}$; M (5.17 cm $h^{-1}$) andN&M, and M and C were similar, but M was greater than C by 42.4%;0-15 cm (5.44 cmh-1) and 15-30 cm (4.45 cmh-1) soil depths were similar in Ksat. Soil pHwas significantly ($p<0.05$) higher in C than M andN&M, and also, higher ($p<0.01$) in 15-30 cm than 0-15 cm soil depth.The ECEC was significantly ($p<0.05$) greater in N&M (14.93 cmol $kg^{-1}$) and C (13.74 cmol $kg^{-1}$) than M (12.07 cmol $kg^{-1}$); C and M and C and N&M were not statistically different. It was also greater ($p<0.01$) in 0-15 cm (14.23 cmol$kg^{-1}$) than 15-30 cm (12.73 cmol$kg^{-1}$) depth. Concentrations of Cu, Zn, Mn and Fe were generally low and lower than their permissible limits in the soil environment. Because the soil was neither aggrading nor degrading, it could be said that the invasion and virtual elimination of the native mangrove by nypa did not have an adverse impact on the physical and chemical fertility status of the soil and would, favour the regeneration of the native mangrove ecosystem.

## 1.0 Introduction

Mangrove forests dominate the coastlines of tropical and subtropical climates of the world (Hossain & Nuruddin, 2016). Mangroves provide ecosystem services of great social, economic and environmental importance (MEA, 2005; Barbier, 2007). They are nurseries for several species of birds, fish and shellfish; they hold a complex community supporting benthic organisms that live in saltwater and, they are sources of a substantial part of the proteins (shellfish, crustaceans and fish) consumed or marketed by the riverside communities, as well as protect beaches and coastlines from storms, waves, and floods and reduction of beach and soil erosion, and sequester carbon (Barbier, 2007; Nagelkerken *et al.,*2008; Walters *et al.,* 2008; Alongi, 2009, 2014; Lee *et al.*, 2014; Duke and Schmitt, 2015). Despite their ecologic, social and economic functions, and benefits to coastal communities, mangroves are disappearing worldwide at the rate of 1–2% per year due to industrial development, rapid urbanization, population growth and anthropogenic activities (Duke *et al.*, 2007). The greatest threat to the mangrove ecosystem; however, is the displacement of the native mangrove species by *Nypa frusticans*.

*Nypa fruticans* or nipa palm is a mangrove palm that grows well in calm estuaries and coastal zones. It is Indo-Pacific in origin, occurring as part of the mangrove vegetation. It was introduced into the coastal areas of Nigeria in

1906 (Mercer and Hamilton, 1984) as a measure against creek bank erosion (Halos, 1981). Although *Nypa fruticans* is also known for its economic importance, for example, with regards to vinegar, cigarette wrappers and roof thatch (Fong, 1982), however, today the plant with its extensive rhizomatous growth, has aggressively dominated most of the coastline with pronounced impact on the native mangrove macrophytes (including *Rhizophora* spp.) eliminating the latter in the wake of its establishment and spread (Udoidiong and Ekwu, 2011). Consequently, biodiversity is lost, and people's livelihoods are adversely affected. Wilcox (1985) reported that apart from colonization of beaches, *Nypa* has virtually taken over the estuaries and creeks.

Mangroves ecosystems are located in lower landscape environments. Mangroves generally apply to an association of trees that are found in wet, loose soils in tropical tidal waters. The soils of mangrove ecosystems are the result of complex interactions between abiotic factors, such as tidal oscillations and biotic factors as the activities of the species and organisms (Hossain & Nuruddin, 2016). That is, the soils are originated from sedimentary material (mineral and organic material) deposited by fluvial and marine actions or from the alteration of the sedimentary substrate (parent material). However, substantial differences occur between mangrove forests concerning soil pH, salinity, bulk density, CEC, nutrients, carbon and organic matter contents of the mangrove soils.

For instance, Ukpong (2002) observed that nypa soils have a high bulk density which impairs penetration of roots of other plant species, and that soil texture in nypa groves was dominantly silt-loam compared to soils in mangrove ecologies where soil texture was reported to vary from silt-loam to loam. This indicates that the effect of nypa on tidal soils is mainly reflected in the physical characteristics of the soils. Thus, nypa modifies the mangrove habitat, making it less suitable for mangroves but itself. This study aimed to determine the effect of *Nypa fruticans* on soil properties about environmental health in the Okorombokho community in the Eastern Obolo area of Akwa Ibom State.

## 2.0. Materials and methods

### *2.1 Environment of study*

The study was conducted in the swamplands occurring in the Okorombokho community in the Eastern Obolo Local Government Area of Akwa Ibom State. The area lies between latitudes $4^{o}$ 28¢ and $4^{o}$ 53¢ N and longitudes $7^{o}$ 51¢ and $7^{o}$ 55¢ East in Akwa Ibom State. The climate of the study area is hot humid tropical and is divided into two seasons, the rainy(March to October) and the dry (November to February) seasons. Rainfall is heavy and averages about 3500 mm per annum. Temperatures are uniformly high, ranging from $24^{o}$C to $32^{o}$C.

In terms of physiography, the mangrove swamps occupy tidal mudflats, laced with tidal channels and winding waterways of about 20 m wide. Large tracts of the swamp and floodplain environments with their wetland characteristics flank the Kwa Iboe River, Imo River and Cross River estuaries. The physiography is a mostly flat mangrove swamp, which is inundated periodically by tidal floods. Soil texture generally varies from sand to sandy loam in the surface overlying clayey subsoil. The soils are poorly structured even though they have high organic matter content. The vegetation was originally mangrove swamp forest, but is almost eliminated and replaced by the *Nypa fruticans* with its extensive rhizomatous growth, and thus a menace and a source of concern in the area. Land use in the upland is mainly crop production like cassava, vegetable, yam and fish farming. The common activity in the study site is fishing. The mangrove provides considerable fuelwood which is extensively exploited for sale and other domestic uses (Petters *et al*., 1989). This necessitates the need to restore the mangrove vegetation to restore soil stability, increase fish production and its unique biodiversity, as well as control erosion in the area.

### *2.2 Field studies*

The study was conducted in three locations: (1)mangrove was the predominant vegetation (M); (2)nipa growing in association with mangrove (N&M); and (3) neither nypa nor mangrove was growing and therefore served as the control (C). In each location, a 60-m transect was taken through the middle of the area. Undisturbed and bulk soil samples were collected from the 0-15 and 15-30 cm depths at 20 m intervals along the transect. Each undisturbed soil sample was collected with a 5 cm height and 5 cm internal diameter metal cylinder and secured with a piece of calico cloth and rubber band, and used for the determination of saturated hydraulic conductivity, field capacity water content, permanent wilting point water content, and bulk density. Each bulk soil sample comprised three random soil samples collected with an auger around the sampling point and bulked into a labelled poly bag and used to determine particle size fractions and chemical properties. A total of 18 undisturbed and bulk soil samples were collected and taken to the Department of Soil Science and the Land Resources Management Laboratory University of Uyo, for the analysis of soil physical and chemical properties including heavy metals (micronutrients).

### *2.3 Laboratory Analysis*

The bulk soil samples were air-dried and sieved through a 2-mm sieve and used for the following analysis. Particle-size fractions were determined with the Bouyoucos hydrometer method after dispersing soil with sodium hexametaphosphate solution (Calgon)(Gee and Or, 2002). The following determinations were also made: saturated hydraulic conductivity ($K_s$) (Reynolds and Elrick, 2002), and field capacity water content ($FC_{0.01bar}$), wilting point water content ($PWP_{15bar}$) and available water capacity (AWC) using laboratory approximations (Dane and Hopmans, 2002). Bulk density (Bd) was determined as described by Grossman and Reinsch (2002), and total porosity (Tp) was computed from bulk density values and an assumed particle density of 2.65 Mg $m^{-3}$. The total available water capacity of each depth was calculated from the following relationship:

$$AWC = \theta_g(0.1) - \theta_g(15)(\rho_b/\rho_w)d \quad \text{.........1}$$

where AWC = total available water capacity, cm; $\theta_g(0.1)$ = gravimetric water content retained at 0.1 bar suction; $\theta_g(15)$ = gravimetric water content retained at 15 bar suction; $\rho_b$ = dry soil bulk density, g $cm^{-3}$; $\rho_w$ = density of water, g $cm^{-3}$; $d$ = soil depth zone, cm.

Soil pH was determined in 1:2.5 soil to water suspension and read with a glass electrode pH meter (Udo et *al.,* 2009). Soil organic matter was determined by the Walkley -Black wet-oxidation method (Nelson and Sommers, 1996). Total Nitrogen was determined by the micro-Kjeldahl digestion and distillation method (Udo *et al.*, 2009). Available P was extracted by the Bray P1 method and P extract by the method of Murphy and Riley (1962). Exchangeable bases (Ca, Mg, K, and Na) were extracted with IM $NH_4OA_C$ (pH=7). The Ca and Mg were determined by EDTA titration while K and Na were determined by flame photometry. Exchangeable acidity was determined with IM KCl (Udo *et al.,* 2009). Effective cation exchange capacity (ECEC) was determined by the IITA summation method (IITA, 1979) by summing up the exchangeable cations (TEB) and exchangeable acidity.

Concentrations of extractable heavy metals, copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) were determined on the Atomic Absorption Spectrophotometer, and the concentrations compared with the FAO/WHO safety limits for heavy metals in soils and sediments (FAO/WHO, 2011).

### *2.4 Statistical analysis*

The data generated were subjected to descriptive statistics and analysis of variance (ANOVA). Duncan multiple range tests (DMRT) was used for mean separation. Also, variation in soil properties was determined with the coefficient of variation (Wilding *et al.*, 1994) in which <15% is low variability; 15-35% is moderate variability; >35% is high variability. The degree of relation between heavy metals and soil properties was determined using correlation analysis.

## 3.0. Results and Discusion

### *3.1 Effect of* nypa *and mangrove on soil physical properties*

The data on the effect of nypa and mangrove on soil physical properties are shown in Table 1. The results indicated that the particle-size fractions (psf) were not statistically different across the sampling locations, i.e., in the control plot (C) (no nypa or mangrove), mangrove (M) only, and nypa and mangrove (N&M). However, averaged over each location, the sand separate was higher in C, followed by M and N&M, while the silt and clay fractions had the highest values in M and N&M, and lowest values in N&M and C, respectively. The lack of significant differences in psf was attributed to the originating source of the soil material; the mudflat (Ahukaemere *et al.,*2012) and continual supplies in tidal inundations. However, there was a significant ($p<0.05$) difference in the depth distribution of the sand fraction, being higher in 0-15 cm than 15-30 cm depth; while the silt and clay fractions were similar but lower in 0-15 than 15-30 cm depths.

The high silt and clay fractions observed with depth may be due to dispersion and migration of these finer materials from the 0-15 to the 15-30 cm depth (Chikezie *et al.,* 2009; Idoga and Azagaku, 2005). The interaction of location and soil depth was not significant, probably supporting the thesis of similarity in the parent material. The texture of the soil in all locations is sandy loam. Sukardjo (1994), Ukpong (1997) and Sah *et al.* (1989) reported psf of less than 35, 40 and 45% sand, silt and clay, respectively, in different mangrove forests. The high sand content in this study indicated the receipt of fluvial materials (Petters *et al.*, 1989) since the mangroves ecosystems are located in lower landscape environments. Clough (1992) also reported a higher sand fraction in his study. With increased clay content with depth in all locations, the data also showed that there were little or no marine additions of mineral and organic material to their soil surface (aggradation).

Average over each location, bulk density was significantly ($p<0.01$) higher in C than in M and N&M, while 0-15 cm and 15-30 cm were similar (Table 1). The high soil density (>1.50 Mg m$^{-3}$) in the mangrove mudflat appears unusual because mangrove soils are soft muds; a mixture of silt and clay, in which the cohesion forces, like those of adhesion, are at a minimum. In other words, they are soils that are permanently at the upper plastic or liquid limit on Atterberg's scale. In other words, they are soils in which the double layer expands, the water films become thicker to produce a lubrication effect between the particles, and the soil mass flows under an applied force with high susceptibility to puddling or structural change (Baver *et al.*, 1972; Lal and Shukla, 2005). However, the higher bulk density in C or the generally high values of soil density was probably because evaporative and transpiratory drying during the frequent cyclical low-tide facilitated the withdrawal of water from within the soil thereby causing the soil particles to be drawn closer together, increasing shrinkage and the cohesion forces, and, thus, increased bulk density or compactibility in the wetland soil. It is for this reason that Lal and Shukla (2005) stated that aggregate strength increases with a decrease in moisture content.

Variable bulk density values have been reported in mangrove soils ranging from 0.73 Mgm$^{-3}$ (Ukpong, 1997; Ogban *et al.*, 2020 (*In Print*)) to 1.42 Mg m$^{-3}$ (Sah *et al.,*1989). The increase in bulk density with depth has also been reported by Onweremadu *et al.* (2007) and Chikezie *et al.* (2009) for upland well-drained soils. The moderately high values of soil density indicated a moderately high level of

Table 1: Effect of nypa & mangrove and soil depth on soil physical properties

| | A (locations) | | | B (soil depth) | | Significance | | |
|---|---|---|---|---|---|---|---|---|
| **Soil parameters** | 1 | 2 | 3 | 1 | 2 | A | B | AB |
| Sand (g/kg) | 723 | 691 | 671 | 729$^{a}$ | 660$^{b}$ | ns | * | ns |
| Silt (g/kg) | 179 | 177 | 215 | 177 | 204 | ns | ns | ns |
| Clay (g/kg) | 98 | 133 | 108 | 94 | 132 | ns | ns | ns |
| Soil texture | sl | sl | sl | sl | sl | | | |
| Bulk density (Mgm$^{-3}$) | 1.64$^{a}$ | 1.54$^{b}$ | 1.52$^{b}$ | 1.56 | 1.58 | ** | ns | ns |
| Total porosity (m$^{3}$m$^{-3}$) | 0.38 | 0.42 | 0.43 | 0.41 | 0.40 | ns | ns | ns |
| Saturated hydraulic conductivity (cm/h) | 3.63$^{b}$ | 5.17$^{ab}$ | 6.04$^{a}$ | 5.44 | 4.45 | ** | ns | ns |
| Saturated water content (m$^{3}$m$^{-3}$) | 0.32$^{b}$ | 0.39$^{a}$ | 0.35$^{ab}$ | 0.36 | 0.35 | * | ns | ns |
| Field capacity (m$^{3}$m$^{-3}$) | 0.23$^{b}$ | 0.28$^{a}$ | 0.24$^{ab}$ | 0.24 | 0.26 | * | ns | ns |
| Permanent wilting point (m$^{3}$m$^{-3}$ | 0.13 | 0.15 | 0.15 | 0.14 | 0.16 | ns | ns | ns |
| Available water (cm$^{3}$cm$^{-3}$) | 0.10 | 0.11 | 0.10 | 0.09 | 0.11 | ns | ns | ns |

A1 = control; A2 = mangrove only; A3 = nypa& mangrove; B1 = 0-15 cm; B2 = 15-30cm; AB = interaction between locationsand soil depth;ns = not significant.Means followed by different letters are significantly ($p<0.05$) different, while same letters are not significantly ($p<0.05$) different; **significant at 0.01;*significant at 0.05.

soil compaction, which could impair root penetration (Ukpong, 2002). However, the bulk density values in this study were less than 1.75-1.85 Mg $m^{-3}$critical limits for root restriction (Soil Survey Staff, 1996). The lower soil density in M and N&M compared to C was attributed to the effect of nypa and mangrove vegetation on soil structural properties. Similarly, total porosity, the volume of pores per volume of soil, was high but not different among the sampling locations and between the soil depths.

Saturated hydraulic conductivity, Ksat, the index of soil resistance to the flow of water, was significantly ($p<0.01$) greater in N&Mby 66.4% than C; M and N&M, and M and C were similar, but M was higher than C by 42.4%;0-15 cm and 15-30 cm soil depths were similar in Ksat. Although M and N&M were not different in Ksat, the resistance to flow was less in the latter than the former. The higher resistance to flow in the control (C) sampling location tended to reflect the higher soil bulk density. The values of Ksat were generally low, which may be due to the generally high soil bulk density observed in the wetland swamps. With frequent inundation by tidal floods and water table at shallow depths, however, the observed values of Ksat were perhaps adequate to facilitate evaporative drying during inter-tidal periods.

Similarly, saturated water content, the maximum amount of water the soil can hold in the absence of flooding, and field water capacity were statistically ($p<0.05$) higher in N&M than C; M and N&M, and M and C were similar. The soil depths and the interaction of sampling location and soil depth were similar in their effect on saturated water content, field water capacity and available water capacity but the values generally decreased with depth, as also observed by Johnston and Alongi (1995) and Chowdhury *et al.* (2007). Permanent wilting water content was also similar among the locations and soil depths. Irrespective of the observed differences, water availability to meet evaporative demands and plant uptake was not a problem.

### *3.2 Effect of Nypa and Mangrove on Soil Chemical Properties*

The effects of M, N&M and C on soil chemical properties are shown in Table 2. The results showed variations in chemical properties, which, except for pH and ECEC, were not different among the locations and soil depths. Soil pH was significantly ($p<0.05$) higher in C than M and N&M, and also, higher ($p<0.01$) in 15-30 cm than 0-15 cm soil depth. High soil pH has also been reported in mangrove soils in Asia by Sah *et al.* (1989), Das *et al.* (2012), and Hossain *et al.* (2012). Judging from the ratings of USDA (1993), soil pH was moderately alkaline in N.M. and M and strongly alkaline in C because of saltwater intrusion but suitable to mangrove that tolerates high pH values.

The E.C. was equally high and higher in C, followed by M and N&M, and higher in 15-30 cm than 0-15 cm depth. E.C. measures the concentration of soluble salts and the ability of the soil solution to conduct electricity. When ions (salts) are present, the E.C. of the solution increases (Hanlon, 1993). Thus, the soils were generally saline, given the fact that E.C. values were >4 $dSm^{-1}$ (Abrol *et al.,* 1988). The high E.C. in this study reflected saline soil conditions or the concentration of salts on the exchange complex, irrespective of plant ecology. It also indicated that the higher value in C was due to the absence of vegetation because plant uptake of cations reduces their concentrations in the soil, and consequently, the lower values in M and N&M.

The soil organic matter content was moderately high among the locations and in the order C<M<N&M, and between the soil depths but higher in 0-15 than 15-30 cm. The soil organic matter contents were generally high according to the ratings of Chude *et al.,* (2012) for upland well-drained soils. The observed values in the swamplands were generally low (Hossain and Nuruddin, 2016) for the soil whether in control or where plants were growing because wetland soils are usually characterized by high organic matter content due to low temperatures and the exclusion of aerobic decomposition, limiting decomposition to inefficient anaerobic processes. Sa *et al.* (2001) have reported that the soil of the mangrove forest acts as a reservoir of carbon that is in interaction with the atmosphere, storing about three times the biomass that makes up the vegetation and structure of mangroves. However, the higher values in the N&M combination could be due to the extensive rhizomatous growth of Nypa whose death and decay added organic matter to the soil, compared to M. The pattern of concentration of total N was similar to organic matter (Table 2).

The pattern of changes in available P decreased from C, through M to N&M, and from 0-15 to 15-30 cm depth (Table 2). Available P was generally low based on the ratings of Chude *et al.*(2012)for upland well-drained soils. Reich and Oleksyn (2004) reported limited phosphorus

Table 2: Effect of nypa & mangrove and soil depth on soil chemical properties

| | A (Location) | | | B (Soil depth) | | Significance | | |
|---|---|---|---|---|---|---|---|---|
| Soil parameters | 1 | 2 | 3 | 0-15 | 15-30 | A | B | AB |
| pH ($H_20$) | $7.92^{a}$ | $7.13^{b}$ | $7.25^{b}$ | $6.92^{b}$ | $7.92^{a}$ | * | ** | ns |
| Electrical conductivity (dS/m) | 6.04 | 5.17 | 4.63 | 4.99 | 5.56 | ns | ns | ns |
| Organic matter ( $gkg^{-1}$) | 17.09 | 20.77 | 22.69 | 22.62 | 17.74 | ns | ns | ns |
| Total nitrogen ( $gkg^{-1}$) | 4.27 | 5.19 | 5.67 | 5.66 | 4.44 | ns | ns | ns |
| Available phosphorus ( mg/kg) | 3.06 | 2.91 | 2.25 | 2.95 | 2.54 | ns | ns | ns |
| Ca (cmol/kg) | 8.49 | 7.10 | 6.88 | 7.21 | 7.77 | ns | ns | ns |
| Mg (cmol/kg) | 2.37 | 5.62 | 2.83 | 4.62 | 2.59 | ns | ns | ns |
| K (cmol/kg) | 0.57 | 0.52 | 0.52 | 0.52 | 0.55 | ns | ns | ns |
| Na (cmol/kg) | 0.37 | 0.27 | 0.28 | 0.30 | 0.31 | ns | ns | ns |
| TEB (cmol/kg) | 12.25 | 10.26 | 13.30 | 12.66 | 11.22 | ns | ns | ns |
| Exchange acidity (cmol/kg) | 1.49 | 1.81 | 1.63 | 1.77 | 1.52 | ns | ns | ns |
| Ex. aluminum (cmol/kg) | 1.30 | 1.50 | 1.42 | 1.49 | 1.31 | ns | ns | ns |
| ECEC (cmol/kg) | $13.74^{ab}$ | $12.07^{b}$ | $14.93^{a}$ | $14.23^{a}$ | $12.73^{b}$ | * | ** | ns |
| Base saturation (%) | 84.97 | 83.92 | 86.99 | 85.02 | 85.56 | ns | ns | ns |

A1 = control; A2 = mangrove only; A3 = nypa&mangrove; B1 = 0-15cm; B2 = 15-30cm; AB = interaction between location and soil depth;ns = not significant;Means with different letters are significantly ($p<0.05$) different, while same letters are not significantly ($p<0.05$) different;**significant at 0.01;*significant at 0.05.

availability in mangrove soils. Prapagar *et al.*(2015) found decreasing availability of phosphorus with increasing salt concentrations, and that P deficiency is a well-known nutrient constraint in salt-affected soils.

The predominant exchangeable cation in the soil was Ca, and its concentration occurred in the order C>M>N&M, and 15-30>0-15 cm depth. The high concentration of Ca be associated with the high pH and E.C. in the soil. Changes in other exchangeable and total exchangeable bases were different from Ca. The higher concentration of exchangeable bases in the 0-15 cm depth was linked to the pattern of organic matter concentration and to the ability of organic matter to retain and protect cations from leaching (Bot and Benites, 2005). Reid and Dirou (2004) gave the concentrations of basic cations in the soil as follows: Ca (>5 cmolkg$^{-1}$), Mg (>1.6 cmolkg$^{-1}$), K (>0.5 cmolkg$^{-1}$) and Na (<1 cmolkg$^{-1}$). Both exchangeable acidity and exchangeable aluminium were high in the soil and may not be deleterious to plant in an alkaline environment. Meriga *et al.* (2003) observation that among phytotoxic species, Al$^{+3}$ions are the most potent in inhibiting root growth and uptake of nutrients may not apply in this soil.

The ECEC was significantly ($p<0.05$) greater in C and N&M than M; C and M and C and N&M were not statistically different. It was also higher ($p<0.01$) in 0-15 cm than 15-30 cm depth. The cation exchange capacity of soil represents the total amount of exchangeable cations that a soil can retain (Olorunfemi *et al.,* 2016). The study indicated that the soil was not deficient in the exchangeable cations. Nevertheless, the ECEC obtained classified as moderate in the scheme of Udo *et al.,* (2009). Base saturation was similar among the locations and between the soil depths, and generally >80%. Reich and Oleksyn (2004) and Lovelock *et al.* (2005, 2007) that many mangrove soils have extremely low nutrient availability, particularly in N and P, while Feller *et al.* (2003) observed that nutrient availability varies significantly between and within mangroves and, and it is (Ukpong, 1997) one of the significant components influencing mangrove growth. This study, however, showed that not all mangrove soils are deficient in nutrient availability; the only challenge was the aggressive invasion by Nypa palms in the area.

*3.3 Effects of Nypa and Mangrove on Heavy Metal concentrations in the soil*

The data of the effect of nypa, mangrove and soil depth on micronutrient concentrations (Table 3)show that only Zn and Mn were significantly affected by location (Zn: $p<0.01$) and soil depth (Mn: $p<0.05$). The data showed that Zn concentration was statistically higher in M than C and N&M; differences in C and N&M were similar. Similarly, Mn was significantly higher in 15-30 than 0-15 cm in depth. Also, while the trend in Cu and Fe was C<M<N&M, the pattern in Mn was C>M>N&M in the reducing wetland soil. When compared with WHO standards (Table 4), the concentrations of all four micronutrients were lower than and therefore posed no toxicity problem in the area.

Table 3: Effect of nypa & mangrove and soil depth on heavy metals (micronutrients)

| Soil Parameters | A(location) 1 | 2 | 3 | B (Soil depth) 1 | 2 | Significance A | B | AB |
|---|---|---|---|---|---|---|---|---|
| Cu (mg/kg) | 1.91 | 2.13 | 2.29 | 2.12 | 2.11 | ns | ns | ns |
| Zn (mg/kg) | $6.22^{b}$ | $8.44^{a}$ | $5.33^{b}$ | 6.41 | 6.91 | ** | ns | ns |
| Mn (mg/kg) | 1.92 | 1.63 | 1.46 | $1.46^{b}$ | $1.89^{a}$ | ns | * | ns |
| Fe (mg/kg) | 147.49 | 154.61 | 167.66 | 159.06 | 154.11 | ns | ns | ns |

A1 = control; A2 = mangrove only; A3 = nypa & mangrove; B1 = 0-15cm; B2 = 15-30cm; AB = interaction between location and soil depth. ns = not significant.Means followed by differentletters are significantly ($p<0.05$) different;while same letters are not significantly ($p<0.05$) different;**significant at 0.01;*significant at 0.05.

*3.4 Relationship between heavy metals and soil properties*

There were 93 interactions between the four micronutrients and the other soil properties, out of nine or 9.7% were significant, and from which four or 4.3% were positive and five or 5.4% were negative, indicating very poor relationships between the nutrients and soil properties. Cu had a negative relationship with sand and Na and a positive relationship with clay and E.C. This indicated that Cu is easily leached in the soil. The positive relationship between clay and E.C. indicated that Cu is an integral of the Stern layer on the clay micelle and that its availability is favoured by the alkaline conditions which prevail in the soil. Zn was positively ($p<0.01$) correlated with SWC; that is, its availability is favoured by tidal inundation. Mn was negatively correlated with silt, T.P. and B.S. but positively correlated with B.D., indicating that its leaching loss is favoured by increases in B.S. but inhibited by the high soil density obtained in the study. Fe, which is readily available wetland soils, was not related to any soil property probably because it is already reduced and available in the soil water.

Table 4: Maximum levels of trace metals in unpolluted soils

| | Trace Element (mgkg$^{-1}$) Cu | Zn | Mn | Fe |
|---|---|---|---|---|
| Critical Limits in Soil | 36 | 50 | 850 | 2000 |

Source: WHO (1996).

## 4.0. Conclusion

The study was conducted to evaluate the effect of nypa and mangrove on soil properties to determine whether nypa in displacing mangrove was degrading or aggrading the underlying soil.

The study was conducted in a bare (C), mangrove forest (M) and mixed nypa and mangrove forest (N&M). Results show that most of the soil physical and chemical properties, as well as micronutrients evaluated, were not significantly affected by M and N&M. Because the soil was neither aggrading nor degrading, it could be said that the invasion and virtual elimination of the native mangrove by nypa did not have an adverse impact on the physical and chemical fertility status of the soil for the native mangrove ecosystem. However, a joint programme is needed to regenerate the native mangrove ecosystem because of its benefits to the livelihoods of the people and the environment.

Table 5: Correlation matrix of micronutrients and soil properties

| | **Cu** | **Zn** | **Mn** | **Fe** |
|---|---|---|---|---|
| Cu | 1 | | | |
| Zn | -0.074 | 1 | | |
| Mn | 0.180 | 0.167 | 1 | |
| Fe | 0.178 | -0.430 | -0.142 | 1 |
| Sand | -0.469* | 0.163 | 0.351 | -0.240 |
| Silt | 0.107 | -0.313 | -0.569* | 0.318 |
| Clay | 0.578* | 0.205 | 0.287 | -0.091 |
| BD | -0.133 | -0.048 | 0.595** | -0.305 |
| TP | 0.149 | 0.026 | -0.534* | 0.353 |
| Ksat | 0.295 | -0.163 | -0.138 | 0.397 |
| SWC | 0.018 | 0.520* | -0.368 | 0.120 |
| FC | 0.152 | 0.348 | -0.142 | 0.262 |
| PWP | 0.023 | 0.380 | -0.311 | 0.170 |
| AWC | 0.188 | 0.087 | 0.262 | 0.216 |
| pH | -0.336 | -0.420 | -0.028 | 0.090 |
| EC | 0.520* | -0.132 | -0.213 | 0.235 |
| OM | 0.459 | 0.036 | -0.372 | -0.148 |
| TN | 0.458 | 0.036 | -0.372 | -0.149 |
| Av. P | -0.250 | 0.368 | -0.103 | -0.196 |
| Ca | -0.316 | -0.097 | 0.002 | -0.226 |
| Mg | 0.068 | -0.264 | -0.338 | -0.014 |
| K | 0.209 | -0.128 | 0.458 | -0.023 |
| Na | -0.563* | -0.201 | 0.245 | -0.281 |
| EA | 0.051 | 0.023 | 0.405 | 0.007 |
| Ex. Al | 0.051 | 0.282 | 0.348 | 0.005 |
| ECEC | 0.087 | -0.073 | 0.246 | -0.021 |
| BS | 0.015 | -0.348 | -0.562* | 0.064 |

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