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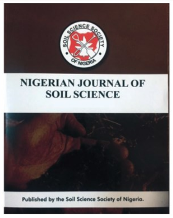

Effect of *Nypa fruticans* pruning regime and soil properties on regeneration of Mangrove species (*Rhizophora racemosa*) in Eastern Obolo, Akwa Ibom State

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ABSTRACT

The study was conducted to evaluate the effect of *Nypa fruticans* pruning regimes on the regeneration of mangrove (*Rhizophora racemosa*) at Okorombokho in Eastern Obolo, Akwa Ibom State, Nigeria. The Nypa was pruned at a uniform height of 10 cm and the area protected with used fishing nets against infiltration by *Nypa* seeds in tidal floods. Mangrove plants of similar height were interplanted among pre-existing stands, out of which ten plants were tagged in each sub-plot for the measurement of plant height, leaf area index, and stem girth. Three pruning regimes (0, 4, and 6 weekly pruning (WPR) were adopted and soil samples were collected from 0-15 and 15-30 cm depths. The study was a 3x2 factorial in randomized complete block design with three replications. Soil properties showed consistent differences with depth than with pruning regimes. Bulk density (BD) was statistically similar, averaging 1.04 and 1.06 Mgm^{-3} in 0-15 and 15-30 cm, respectively, while saturated hydraulic conductivity (Ksat), respectively averaged 0.64 and 0.27 cm h^{-1}. Electrical conductivity (EC), available phosphorous (Av.P) and base saturation (BS) were significantly ($p \leq 0.05$) greater in 4WPR (5.77 dS m^{-1}; 30.07 mg g^{-1}; 85.4%) than 6WPR (4.54 dS m^{-1}; 25.82 mg g^{-1}; 76.2%) and 0WPR (3.57 dS m^{-1}; 23.02 mg g^{-1}; 74.3%). Plant height (PH) of mangrove averaged throughout the study was significantly ($p \leq 0.05$) greater in 4WPR (80.3 cm) than 0WPR (62.5 cm) but similar to 6WPR (73.4 cm). Stem girth (SG) of mangrove was similar but in the order 4WPR (1.06 cm)>6WPR (0.98 cm)>0WPR(0.86 cm). The pattern of variation in other mangrove growth parameters was similar to plant height and stem girth. The study also showed that PH and SG were negatively correlated with sand, Av.P, and EA but positively correlated with silt and clay, EC, and BS. Results indicated that mangrove species (*Rhizophora racemosa*) growth was optimum 4WPR than 0WPR and 6WPR and could, therefore, be recommended as a management practice for controlling the growth of *Nypa fruticans* and regenerating mangrove (*Rhizophora racemosa)* in the study area.

1.0. Introduction

Mangrove vegetation, along with the animal species they shelter, represents, globally, significant sources of biodiversity and provides humanity with valuable ecosystem services. They are used by mammals, reptiles and migratory birds as feeding and breeding grounds, and provide crucial habitats for fish and crustacean species of commercial importance.

The roots of the mangrove physically buffer shorelines from the erosive impacts of ocean waves and storms (Millennium Ecosystem Assessment, 2012). Additionally, they protect riparian zones by absorbing floodwaters and slowing down the flow of sediment-loaded river water. This allows sediments to drop to the bottom where they are held in place, thus containing potentially toxic waste products and improving the quality of water and sanitation in coastal communities. To the human communities who rely on them, mangrove forests represent local sources of sustainable income from the harvest of fish and timber, as well as non-timber forest products such as medicinal plants, palm leaves, and honey.

On a global scale, they have been shown to sequester carbon in quantities comparable to higher-canopy terrestrial rainforests, which means that they may play a role in climate change mitigation (Spalding *et al*., 2010*)*. In addition to physically protecting coastlines from the projected sea-level rise associated with climate change (Millennium Ecosystem Assessment, 2012), mangrove is valuable to the society because it performs ecosystem services (Williams, 1996; Costanza *et al.*, 1997; Kohn 1994; Zedler, 2003) that humans depend on. The benefits provided by these services include flood abatement, water filtration, and habitat that support biodiversity (Zedler, 2003). Mangrove benefits also include less tangible services, such as the cultural significance of a salt marsh, or the natural beauty provided by a bogland. Costanza *et al.* (1997) concluded that ecosystem services and natural capital were worth 33 trillion dollars per year in the US.

Economically, mangroves are a great source of timber, poles, thatch, and fuel, and the bark is used for tanning materials; some species have food or medicinal value (Hamilton and Murphy, 2008). Mangroves are sensitive to changes in response to ecological alteration, storms, sediment blockage, and fluctuations in sea levels and such changes present enormous challenges to regeneration efforts. Different regeneration approaches encounter these challenges in different ways. The most common method simply consists of planting single-species stands of mangrove in areas thought to be suitable, without consideration of whether or not they supported mangrove in the past. This led to the introduction of Nypa palm to Asian mangrove (Shahidullah, 2001) which has damaged mangrove area through a decline in natural processes of secondary succession.

Nypa palm (*Nypa fruticans,* Wurmb Arecaceae) is an essential component of the East Asian mangrove vegetation. It is one of the oldest living palms (Badve and Sakurkar, 2003). It grows along coastlines and estuarine habitats in the Indian and Pacific Ocean. It is a stem-less palm with tall erect fronds and underground rhizomatous stem (Shahidullah, 2001) possessing an extensive root system, well suited to resist swift running water.

Due to its vigorous and extensive root system, Nypa palm has colonised the Okorombokho mangrove eliminating other mangrove plants because its root system chokes out other plants. In other to maintain biodiversity which is essential in the sustainability and productivity of mangrove, it becomes necessary to regenerate other plant species which are on the decline in the mangrove due to the alarming growth rate of *Nypa fruticans*.

The dominance of *Nypa fruticans* in Okorombokho mangrove swamp has completely impeded the existence of other flora species in the mangrove leading to biodiversity loss, and as well, a reduction in economic values of this mangrove ecosystem in the coastal areas (Theerawitaya *et al.*, 2014). At Okorombokho, the secondary regrowth of the mangrove is almost completely lost due to dominance of Nypa palm thereby creating an ecological imbalance on the mangrove which is detrimental to biodiversity conservation, reduction in aquatic population due to alteration in the food chain, increase in coastal erosion and deterioration in water quality. Therefore, this study was conducted to determine (i) the effect of physical pruning of *Nypa fruticans* on some soil properties; (ii) the regeneration of mangrove species (*Rhizophora racemosa*); (iii) the optimum pruning period that could enhance secondary succession in the mangrove, and (iv) the relationship between mangrove regeneration parameters and soil properties at Okorombokho in Akwa Ibom State.

2.0. Materials and Methods

The study was conducted in the mangrove swamplands in Okorombokho Community in Eastern Obolo local government area of Akwa Ibom State. The area lies between latitudes 4^0 28' and 4^0 53'N and longitudes 7^0 51' and 7^0 53' East. The climate of the area is hot humid tropical and is divided into two seasons, the rainy and the dry seasons. The rain lasts from March to October while the dry season lasts from November to February, varying slightly from year to year. The rainfall is heavy and averages about 3500 mm per annum. Temperatures are uniformly high ranging from 24°C to 32°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*. The 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).

2.1. Field Studies

The study site was cleared of growing *Nypa fruticans* by pruning to a uniform height of 0.10 m above ground level one week before planting. The site measured approximately 60 x 32.8 m^2, out of which a 30 x 51 m^2 area was used for the study. The experimental area was sub-divided into three plots of 30 x 15 m^2 separated by 3 m strips. Each plot was further sub-divided into 10 m long sub-plots of 10 x 15 m^2.

Three Nypa pruning treatments were maintained throughout the study: 0 (i.e., the day the site was pruned and only pruning throughout the study period), and 4 and 6 weekly intervals, each of which was replicated three times. The pruning regimes were 0WPR, 4 WPR, and 6 WPR (WPR = weekly pruning regime). There were also two soil sampling depths: 0-15 and 15-30 cm intervals. The study was therefore a 3x2 factorial in a randomized complete block (RCB). The study site was cordoned off with used fishing nets and sticks to a height of about 2 m above the ground surface to protect the experimental site from being infiltrated by *Nypa fruticans* seeds in tidal floods.

Ten (10) mangrove plants (*Rhizophora racemos* sp) of similar height and collected from an adjacent location about 500 m away, were inter-planted among pre-existing stands after pruning, from which ten (10) plants were tagged in each sub-plot for the measurement of plant height using a metal tape, leaf area index, and girth (with vernier calipers at 0.10 m above the soil surface) at two weekly intervals to 10 weeks after planting (WAP). There were a total of five measurements of plant growth parameters. The study was terminated 10WAP because of communal trouble and infringement.

Bulk soil samples for particle-size and chemical analyses were collected from the designated soil depths (0-15 and 15-30 cm) with an auger. A separate set of soil samples were collected from the same depths with the auger for the determination of moisture content. Also, undisturbed soil samples were collected from the depth zones with 5 cm high and 5 cm diameter metal cylinders at the start of the study for physical and chemical analyses, in the laboratory of the Department of Soil Science and Land Resources Management.

2.2. Laboratory Analysis

The bulk samples were air-dried and sieved through a 2 mm sieve and stored in re-labeled polythene bags for the following analyses. Particle size (sand, silt, and clay) distribution was done with the Bouyoucos hydrometer method (Khakural and Sharma, 1984). Bulk density was computed from the relationship between the mass of oven-dry soil and the volume of soil obtained from the internal dimensions of the metal cylinder. Total porosity was calculated from the bulk density values and an assumed particle density of 2.65 Mg m^{-3}. Macroporosity was calculated from the following relationship:

$$MP = TP - \theta_v(0.1) \qquad (1)$$

where, MP = macroporosity, m^3 m^{-3}; TP = total porosity, m^3 m^{-3}; $\theta_v(0.1)$= percentage volume of water held at 0.1 bar suction (field capacity), m^3 m^{-3}. Soil moisture content was determined by the method of weight loss.

The total available water capacity of each depth was calculated from the following relationship:

$$AWC = \theta_g\ (0.1) - \theta_g\ (15)(\rho_b/\rho_w)\ d \qquad (2)$$

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

The void ratio (VR) was inferred from the relationship:

$$VR = (TP / 1 - TP) \qquad (3)$$

where VR and TP are as defined above.

The saturated hydraulic conductivity, Ksat (cm h^{-1}), was calculated by using the transposed Darcy's equation for vertical flows of liquids:

$$Ksat = [Q(\Delta Z)] / [A(\Delta t)(\Delta H)] \qquad (4)$$

where, Q = volume of water, m^3 that flows through a sample of cross-sectional area A, m^2 in time Δt, minutes; and ΔH = the hydraulic head difference L imposed across the sample of length ΔZ (L).

Soil pH was determined in 1:2.5 soil/water suspension and the pH read using a pH meter. Electrical conductivity was determined in the 1:2.5 soil/water mixture and read using a conductivity bridge (Rhoades, 1982). Soil organic carbon was determined using the Walkley-Black (1934) wet oxidation method. 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 (Bray and Kurtz, 1945; Murphy and Riley, 1962) and P extracted by the method of Murphy and Riley (1962). Exchangeable bases (Ca, Mg, K, and Na) were extracted with IM NH_4OA_C (pH=7). 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.

2.3. Statistical Analysis

The data of soil properties and growth parameters (plant height, stem diameter, and leaf area) were subjected to one-way analysis of variance (ANOVA) at the 5% level to detect differences among the treatments, and therefore the effect of pruning on *Nypa fruticans* growth and regeneration of mangrove.

3.0. Result and Discussion

3.1. Effect of pruning regime on soil physical properties

Changes in soil properties due to Nypa pruning regimes and soil depth and their interaction are presented in Table 1. The data showed that particle-size distribution was dominated by the sand fraction, about 70%, while silt and clay constituted about 30%. Also, the silt fraction comprised more than 20% of the soil separates in the study area. Furthermore, while the sand content was higher in 15-30 cm depth, silt and clay fractions were higher in the 0-15 cm depth and indicated that the silt and clay separates were associated with the phenomenon of flooding and deposition rather than pedological processes in the area. However, the differences between the depths were not significant ($p \leq 0.05$).

The sand fraction was significantly ($p \leq 0.0\ 5$) higher in the plot that receives no further pruning, at 0WPR, followed by 6WPR and 4WPR. The higher sand content 0WPR could not have been due to pruning interval since particle fractions (texture) are an intrinsic property of the soil (Hillel, 2003) and do not change easily with management practices. The significant ($p \leq 0.05$) difference could be attributed to localized differences in sand content and not necessarily an effect of pruning interval.

Silt fraction was not different between 4WPR and 6WPR, but significantly ($p \leq 0.05$) higher than 0WAP. The silt content in 0-15 cm and 15-30 cm was similar (Table 1). The observed differences in the silt fraction may have been caused by localized variability in the transport and deposition of the silt separate. It may also be said that the similarity in silt fraction could be due to uniformity in the deposition by the tidal inundations. Clay content was similar but higher at 4WPR, followed by 6WPR and 0WPR. Clay content in 0-15 and 15-30 cm depth were also similar but higher in 0-15 cm depth than the subsequent 15-30 cm indicating accumulation of the finer materials on the soil surface through tidal waves. The pattern of clay distribution in the soil corroborates Crouse (2017). The clay content of 0–15 at 0WPR was higher than at 4WPR probably because repeated pruning may have enhanced soil detachment and movement by the tidal waves.

The interaction of the Nypa pruning regime and soil depth did not significantly ($p \leq 0.05$) affect the sand and silt fractions in all pruning regimes and soil depths, but the clay separate was significantly ($p \leq 0.05$) higher at 0–15 cm depth than 15-30 cm depth in the 4WPR. The silt-clay ratio was marginally higher in 0-15 cm soil depth of 0WPR and 6WPR, but higher in the 15-30 cm depth of 4WPR. In all pruning regimes, the silt-clay ratio was similar, but on average the order of differences was 4WPR>6WPR>0WPR. The lack of interaction effect of pruning regime and soil depth could be because particle-size distribution derived from the tidal mudflats was more critical than the pruning treatment imposed in the mangrove swampland. Generally, the soil was sandy loam in texture, which may not have moisture retention problems but might facilitate nutrient losses in the frequent tidal flood flows and leaching through the saturated rooting depth. Onofiok (2002) observed that the soil may have low plant nutrient levels due to frequent cycles of oxidation of organic matter and low silt and clay contents thus limiting surface activity mainly to the predominant non-reactive finer sand fraction.

The effect of pruning and soil depth and their interaction on soil structural characteristics are presented in Table 1. Bulk density was low and lower than the 1.2 Mg m-3 generally ascribed to crumbly, porous topsoil (Ahn, 1974), and indicated that the soil was dominated by fine micro aggregates, that is particle size fractions <0.02 mm diameter. Bulk density has a reciprocal relationship with total pore space; the lower the bulk density the higher the total pore space (Ahn, 1974); consequently, the moderately high total porosity observed in the study. Bulk density was higher in the 15-30 cm depth than 0-15 cm depth, while the pattern in total porosity was the reverse. Water weakens the cohesion forces among and disperses soil aggregates and allows particle rearrangement and resettlement and together with overburden pressure, excluding the effect of soil use practices and human traffic on the surface soil, causes bulk density to increase with soil depth, and could explain the higher bulk density in 15-30 cm than 0-15 cm soil depth (McKenzie, 2010). Also, soil bulk density usually increases with soil depth due to low organic matter content even in soils subject to periodic oxidation, less aggregation, and compression from the weight of the overlying soil (Brown, 1980). These reasons underscored the higher bulk density and associated lower total porosity observed at 15-30 cm compared to the 0-15cm depth. However, both bulk density and total porosity were not significantly ($p \leq 0.05$) affected by Nipa pruning interval, soil depth, and their interactions. The data showed that the trend in bulk density was 0WPR>6WPR>4WPR, while the reverse trend was obtained for total porosity. Macroporosity or aeration porosity was everywhere higher than the 10% (Baver *et al*., 1972) required for non-restrictive root proliferation and activity. Macroporosity and void ratio were not significantly ($p \leq 0.05$) affected by Nypa pruning, soil depth, and their interactions.

The effects of pruning interval, soil depth, and their interaction on soil hydrological properties are also presented in Table 1. Soil moisture content (MC) was higher in 15-30 cm than 0-15 cm depth and higher in 4WPR, followed by 6WPR and 0WPR. In both soil depth and pruning regimes, MC was similar. Similarly, there was no significant interaction effect of pruning regime, and soil depth on MC, which was attributed to similarity in soil texture, irrespective of the soil surface management treatments. Although the MC is not necessarily high for the mangrove swampland, the water table was shallow, about 40 cm below the surface, and not a constraint to the survival of the mangrove species. Saturated hydraulic conductivity, (Ksat), was similar between 0-15 cm and 15-30 cm but about 137.0% greater in the latter than the former. Similarly, the effect of pruning regime, as well as the interaction of pruning regime and soil depth on Ksat was not significant, but for every pruning regime, Ksat was higher in 0-15 cm than 15-30 cm soil depth. Ksat is a hydraulic resistance factor, which indicates how readily a soil can drain. In the context of this study, it indicates how readily the water table recedes and not as it may adversely affect water availability to the mangrove plants. However, the variation in Ksat was of the order 4WPR>6WPR>0WPR.

Saturation water content (SWC), field capacity moisture content (FC), permanent wilting point (PWP) and available water capacity (AWC) were not significantly ($p \leq 0.05$) affected by pruning regimes, soil depth, and their interactions. The hydrology (surface flooding and subsurface recharge) of the mangrove swamp provides adequate water for wetland plants. In other words, the availability of water in the wetland may not be related to soil texture and organic matter content of the soil, especially as the latter is low in the wetland soil. It thus does not matter that soils with high organic matter content have high water retention capacity (Bot and Benites, 2005; Bryant, 2015).

32. Effect of pruning regime on soil chemical properties

Soil pH was similar between 0-15 and 15-30 cm soil depth but significantly ($p \leq 0.05$) higher in 0WPR than in 4 and 6WPR (Table 2). There was no interaction effect of pruning regime and soil depth on soil pH. Soil pH was slightly

Table 1: Effect of Nypa pruning and soil depth on soil physical properties

Pruning regime	Soil depth (cm)	Sand ←	Silt g kg^{-1}	→ Clay	Texture	SCR	BD Mg m^{-3}	TP m^{3} m^{-3}	MP cm h^{-1}	VR	MC m^{3} m^{-3}	Ksat cm h^{-1}	m^{-3} m^{-3}	FC m^{-3} m^{-3}	PWP m^{-3} m^{-3}	AWC cm
0 WPR		784	155	61	Ls	2.53	1.10	0.58	0.40	1.43	0.187	0.09	0.390	0.310	0.180	0.13
4 WPR		644	285	71	Sl	4.24	0.97	0.64	0.36	1.78	0.281	0.75	0.360	0.290	0.160	0.13
6 WPR		714	220	66	Sl	3.43	1.07	0.60	0.39	1.56	0.237	0.53	0.370	0.310	0.180	0.13
LSD (0.05)		68.4**	74.6*	ns		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	0 – 15	704	228	68	Sl	3.44	1.04	0.61	0.38	1.61	0.224	0.64	0.37	0.290	0.170	0.12
	15 – 30	723	212	65	Sl	3.36	1.06	0.60	0.38	1.57	0.246	0.27	0.38	0.300	0.180	0.12
Sig.		0.47	0.58	0.42		0.89	0.81	0.82	0.86	0.87	0.67	0.33	0.25	0.49	0.35	0.36
LSD (0.05)			ns	ns		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nypa pruning interval x soil depth interaction																
0 WPR	0 – 15	779	160	61	Ls	2.61	1.07	0.60	0.40	1.48	0.190	0.13	0.37	0.300	0.170	0.13
	15- 30	789	150	61	Ls	2.45	1.13	0.57	0.39	1.38	0.180	0.05	0.41	0.310	0.190	0.12
4 WPR	0 – 15	625	293	81	Sl	3.96	0.97	0.64	0.37	1.76	0.270	1.12	0.36	0.290	0.160	0.13
	15- 30	662	276	61	Sl	4.52	0.97	0.63	0.34	1.80	0.290	0.37	0.36	0.290	0.170	0.12
6 WPR	0 – 15	709	230	61	Sl	3.76	1.07	0.59	0.38	1.59	0.210	0.66	0.37	0.300	0.170	0.13
	15- 30	719	210	71	Sl	3.11	1.07	0.60	0.40	1.54	0.260	0.40	0.38	0.310	0.190	0.12
Sig.		0.88	0.99	0.03		0.68	0.94	0.91	0.59	0.96	0.88	0.75	0.54	0.95	0.84	0.40
LSD (0.05)			106	15		2.12	0.33	0.12	0.07	0.85	19.0	1.39	0.05	0.05	0.06	6.33
CV (%)			34.7	16.6		38.8	15.2	9.9	9.9	25.2		39.1	154.8		8.6	10.3

WPR = weekly pruning regime; SCR = silt/clay ratio; SWC = saturated water content; FC = field capacity; PWP = permanent wilting point; Ksat = saturated hydraulic conductivity; BD = bulk density; TP = total porosity; MP = macroporosity; VR = void ratio; MC = moisture content; AWC = available water content.

above neutral, that is alkaline (USDA, 1993), and may derive from salts frequently infiltrated into the area through tidal waters (Kunhikrishnan *et al*., 2016). Udo *et al.* (2009), categorized the soil in low fertility class for crop production. However, the mangrove is well adapted to the ecology except for the aggressive Nypa palm. Similarly, the electrical conductivity (EC) of the soil solution extract was significantly ($p \leq 0.05$) higher in 4WPR than in 0 and 6 WPR (Table 2) and similar between 0-15 and 15-30 cm depths. The soils were saline with EC generally >4 dSm^{-1} (Abrol *et al.,* 1988). This high salinity value is indicative of the high concentration of soluble salts which is a general characteristic of the soils of the study area. However, it did not appear to be a constraint to plant growth in the mangrove ecology.

Soil organic carbon (SOC) and Total Nitrogen (TN) were similar between the designated depth zones, and among the pruning regimes and their interaction with soil depth (Table 2). Generally, SOC was low and indicated that periodic tidal inundation and saturation of the soil did not impede organic matter decomposition. Garten *et al.* (1994), Xu *et al*. (2002), and Yong-Kwon and Su-Young (2012) had attributed the variations in organic matter decomposition and mineralization to site variations, temperature, and soil water availability. Similarly, the C/N ratios, although moderately high, indicating the accumulation of high molecular weight organic matter, were not significantly different.

Available phosphorous (Av.P) was similar in 0-15 and 15-30 cm depths but higher in the former than the latter (Table 2). Phosphorous availability was significantly higher in 4WPR than in 0WPR and 6WPR, but similar between 0WPR and 6WPR. The data showed that available phosphorous increased from 0WPR to 4WPR and declined to 6WPR. Tropical soils, and especially upland well-drained soils, are reputed to be deficient in Av.P due to adsorption to positively charged surfaces of hydrous oxides of iron and aluminum characterized by low solubility at low pH (Baver *et al*., 1972; Sanchez, 1976). On the contrary, tropical wetland soils are high in Av.P due to flooding and saturation of the soil pore space and the associated reduction of iron and rise in pH as well as dissociation of P from the exchange sites; P availability increases as pH approaches neutrality (Sanchez, 1976). Phosphorous availability was generally high in the studied wetland soil and was attributed to flooding by tidal waters and the high pH values. The significant Avail.P in 4WPR was therefore associated with prolonged flooding and dissociation of P from the exchange sites. The status of the exchangeable cations reflected the increased concentration of salts in the soil solution phase and base saturation (%BS) was everywhere greater than 70% suitable to the mangrove species.

Effect of Nypa pruning regime on the regeneration of mangrove flora

The data of the regeneration parameters of mangrove (plant height, stem girth, number of leaves, leaf length, leaf width, leaf area and number of newly formed leaves) are presented in Table 3. Plant height of mangrove species at 2, 4, 6, 8, and 10 weeks after planting (WAP) generally increased in all three pruning regimes. However, the increase in height was significantly different between 4WPR and 0WPR, and similar between 4WPR and 6WPR. The significant difference between 4WPR and 0WPR indicated the need to eliminate the aggressive Nypa to enhance the regeneration of the mangrove flora and ecology, and that pruning is one technique for achieving that objective. Of note, is that the growth rate was not significant but it was remarkable that the mangrove plant demonstrated resilience; the ability to restore from a perturbation, the scourge of Nypa. The similarity in the effect of 4WPR and 6WPR showed that 4WPR could be the optimum pruning period as demonstrated by plant performance and that extending the interval beyond that period may not produce significant economic effects. Downer (2017) observed a higher

Table 2: Effect of nypa pruning regime and soil depth on soil chemical properties

Pruning regime	**Soil depth (cm)**	**pH**	**EC dSm^{-1}**	**gkg^{-1}**	**TN gkg^{-1}**	**C/N**	**AvP $mgkg^{-1}$**	**Ca** ←	**Mg**	**K**	**Na cmol kg^{-1}**	**ExAl**	**E A**	**ECEC** →	**BS %**
0 WPR		7.6	3.57	10.72	0.47	23	23.02	6.99	2.33	0.57	0.40	3.56	6.22	13.85	74.3
4 WPR		7.2	5.77	12.76	0.55	23	30.07	7.08	2.36	0.51	0.28	1.74	2.99	11.97	85.4
6 WPR		7.2	4.54	11.10	0.48	23	25.82	6.24	2.08	0.50	0.26	2.84	6.51	11.92	76.2
Sig.		0.01	0.00	0.24	0.24	0.14	<.001	0.72	0.72	0.00	0.01	0.05	0.00	0.28	<.001
LSD (0.05)		0.26	1.04	2.64	0.12	0.20	3.50	2.49	2.49	0.03	0.08	0.87	1.69	1.69	4.29
	0 – 15	7.3	5.03	11.58	0.50	23	27.99	7.29	2.43	0.51	0.31	2.57	5.58	13.11	80.4
	15 – 30	7.3	4.22	11.47	0.49	23	24.61	6.25	2.08	0.54	0.32	2.85	4.90	12.04	76.3
Sig.		0.54	0.06	0.91	0.82	0.02	0.18	0.28	0.29	0.09	0.70	0.61	0.30	0.85	0.69
LSD (0.05)		0.22	0.85	2.15	0.09	0.16	3.41	2.03	2.03	0.68	0.03	0.37	1.18	1.38	3.95
Nipa pruning interval x soil depth interaction															
0WPR	0 – 15	7.7	3.66	11.26	0.50	23	23.23	5.99	2.00	0.59	0.40	2.33	6.12	11.31	79.4
	15- 30	7.5	3.49	10.17	0.44	23	22.80	7.99	2.67	0.56	0.41	4.79	6.32	16.42	70.8
4WPR	0 – 15	7.2	6.69	13.86	0.60	23	33.22	8.21	2.73	0.49	0.27	2.33	3.85	14.03	83.4
	15- 30	7.1	4.85	11.65	0.50	23	26.92	5.94	1.98	0.53	0.29	1.15	2.13	9.89	88.3
6WPR	0 – 15	7.1	4.75	9.61	0.41	23	27.54	7.66	2.55	0.47	0.26	3.06	6.78	14.00	78.1
	15- 30	7.2	4.32	12.58	0.54	23	24.11	4.83	1.61	0.53	0.27	2.61	6.25	9.85	73.5
Sig.		0.47	0.21	0.12	0.11	0.14	0.03	0.11	0.11	0.05	1.00	0.04	0.47	0.06	0.04
LSD (0.05)		0.37	1.47	3.73	0.16	0.28	0.71	3.52	3.52	0.05	0.12	1.52	2.39	9.32	7.31
SD (±)		0.31	1.28	2.17	0.10	0.22	0.78	2.16	0.72	0.07	0.08	4.60	2.27	6.90	11.35
CV (%)		9.39	27.61	18.79	19.12	0.95	27.11	31.86	31.89	12.93	26.15	56.53	43.26	38.35	19.83

WPR = weeks after pruning; EC = electrical conductivity; OM = organic carbon; TN = total Nitrogen; C/N= C/N ratio; Av.P = available phosphorus; Ca = exchangeable calcium; Mg = exchangeable magnesium; Na = exchangeable sodium; K = exchangeable potassium; EA = exchange acidity; exchangeable Al; EA = exchangeable acidity; ECEC = effective cation exchange capacity; BS = base saturation.

growth rate, photosynthetic activity, and regeneration at shorter pruning regimes than when pruning was prolonged. In their study, Hendrickson *et al.* (2004) reported no differences in the effect of pruning regimes on plant growth. However, they observed that delayed or long pruning intervals allowed the undergrowth to regain a competitive ability for radiant energy, water, and nutrients and affected the performance of the plants in their study. They, therefore, recommended shortened pruning regimes to enhance profitable plant growth.

Stem girth of mangrove at 2, 4, 6, 8, and 10 weeks after planting (WAP) were not significantly affected by the pruning regimes. However, the pattern of differences was similar to plant height, increasing from 2WAP to 10WAP, and greater in 4WPR followed by 6WPR and 0WPR. Hendrickson *et al.* (2004) attributed changes in stem girth to the photosynthetic ability of the plants in their study.

The number of leaves per mangrove plant increased from 2-10WAP in all three WPR, with statistical significance in leaf numbers between 4WPR and 0WPR in 6 and 10WAP. The number of leaves was low in the first four WAP probably because plant roots needed to establish hydraulic contact in the transplanted soil environment for root activity and plant growth. However, leaf growth became exponential from 6WAP to 10WAP with more significant numbers in the 4WPR followed by 6WPR and 0WPR. The trend in the growth of leaves was also similar to plant height and stem girth. Powers (1990), Garten *et al.* (1994), Fassnacht and Grower (1999), and Hendrickson *et al.* (2004) reported that the interlude between planting and increases in leaf numbers was for root adaptation to meet the physiological requirements of the plant. The pattern of variation in leaf length, leaf width, and leaf area as well as new leaves was similar to mangrove plant height, stem girth, and leaf numbers. The growth of new leaves was not consistent with the other plant growth parameters. Therefore, measurements were made 6WAP and 10WAP allowing new leaves to form.

3.3. Correlation of mangrove growth parameters and soil properties

The correlation matrix of mangrove growth parameters and soil properties (Table 4) showed that plant height was negatively correlated ($p<0.05$) with the sand fraction, Av. P, EA, and Mn but positively correlated with silt and clay fractions, EC, BS, and Fe. The negative relationship with Av.P indicated that the growth of mangrove might be impeded but not impaired by the high amount of P in the high or neutral pH soil, as shown by the luxuriant growth of mangrove species in adjacent areas not degraded by the Nypa. The positive relation with silt and clay, EC and BS indicated that the abundant silt, which, to some extent, is similar to clay in reactivity, may combine with the latter and provide the exchange surfaces for the adsorption and release of the mineral elements or salts needed for mangrove nutrition in the wetland soil. This pattern of relationships was reproduced by the number of new leaves developed within the period.

4.0. Conclusion

The study was conducted to determine the optimum pruning regime that would facilitate the regeneration of the mangrove ecology at Okorombokho community in Eastern Obolo area of Akwa Ibom State. Three pruning regimes were tested, namely, 0WPR, 4WPR, and 6WPR. The re-

Table 3: Effect of Nypa pruning regime on the regeneration of mangrove flora

	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
	Plant Height (cm)				
0 WPR	62.3	62.4	62.5	62.6	62.8
4 WPR	79.8	79.9	80.3	80.5	80.9
6 WPR	73.0	73.0	73.5	73.6	74.0
Sig	0.06	0.06	0.06	0.06	0.06
LSD	14.3	14.2	14.3	14.1	14.0
	Stem Girth (cm)				
0WPR	0.77	0.80	0.91	0.91	0.92
4WPR	0.94	1.08	1.09	1.09	1.09
6WPR	0.93	0.97	1.00	1.00	1.00
Sig	0.18	0.32	0.54	0.55	0.57
LSD	0.22	0.45	0.42	0.42	0.42
	Number of Leaves				
0WPR	6.31	7.13	8.34	10.33	10.74
4WPR	7.77	7.97	11.10	11.77	16.63
6WPR	7.87	7.87	10.73	10.87	12.80
Sig	0.12	0.32	0.08	0.61	0.05
LSD	1.77	1.46	2.58	3.83	4.49
	Leaf Length (cm)				
0WPR	4.18	4.18	4.21	4.21	4.22
4WPR	4.31	4.32	4.32	4.33	4.33
6WPR	4.29	4.29	4.29	4.29	4.29
Sig	0.87	0.86	0.92	0.90	0.91
LSD	0.70	0.71	0.71	0.70	0.71
	Leaf Width (cm)				
0 WPR	1.48	1.48	1.48	1.48	1.48
4 WPR	1.52	1.56	1.57	1.57	1.57
6 WPR	1.48	1.49	1.51	1.51	1.53
Sig	0.95	0.87	0.85	0.85	0.85
LSD	0.45	0.45	0.46	0.46	0.45
	Leaf Area (cm2)				
0 WPR	6.13	6.13	6.17	6.17	6.18
4 WPR	6.59	6.75	6.81	6.82	6.82
6 WPR	6.32	6.36	6.44	6.44	6.55
Sig	0.72	0.57	0.55	0.54	0.54
LSD	1.55	1.52	1.50	1.48	1.48
Number of Newly Formed Leaves					
0 WPR	-	-	3	-	3
4 WPR	-	-	5	-	4
6 WPR	-	-	4	-	3
Sig	-	-	0.02	-	0.05
LSD	-	-	1	-	1

WAP = weeks after planting; WPR = weekly pruning regime

Table 4: Correlation matrix of mangrove growth parameters and soil properties

	PH	SG	NL	LL	LW	LA	NFL
Sand	-0.705*	-0.475	-0.625	-0.212	-0.342	-0.541	-0.848**
Silt	0.647*	0.458	0.593	0.224	0.375	0.580	0.812**
Clay	0.708*	0.279	0.450	-0.048	-0.209	-0.217	0.546
SCR	0.462	0.422	0.515	0.259	0.411	0.632	0.684*
SWC	-0.517	0.217	-0.566	0.312	-0.303	-0.149	-0.493
FC	-0.379	0.590	-0.361	0.138	0.004	0.069	-0.459
PWP	-0.352	0.588	-0.372	0.105	0.043	0.090	-0.455
Ksat	0.515	0.573	0.135	0.264	0.473	.693*	0.449
BD	-0.376	0.459	-0.566	-0.015	0.105	0.077	-0.514
TP	0.368	-0.452	0.572	0.049	-0.107	-0.056	0.519
MP	-0.449	0.254	-0.561	0.108	-0.222	-0.191	-0.655
VR	0.422	-0.468	0.570	-0.062	-0.027	-0.046	0.551
MC	0.374	-0.263	0.773*	0.124	-0.141	-0.049	0.567
AWC	0.087	0.193	0.796*	0.571	-0.440	-0.083	0.317
pH	-0.489	-0.386	-0.471	-0.226	-0.382	-0.573	-0.646
EC	0.707*	0.457	0.709*	0.223	0.374	0.578	0.870**
OC	0.490	0.147	0.410	-0.194	0.656	0.558	0.567
TN	0.483	0.141	0.383	-0.203	0.644	0.538	0.552
CN	-0.153	0.161	0.264	0.546	-0.144	0.216	0.048
Av.P	-0.635*	-0.405	-0.547	-0.156	-0.191	-0.352	-0.741*
Ca	-0.060	0.129	-0.315	0.038	0.145	0.207	0.031
Mg	-0.063	0.124	-0.324	0.034	0.141	0.200	0.025
K	-0.101	-0.310	-0.381	-0.468	-0.129	-0.466	-0.351
Na	-0.600	-0.289	-0.609	-0.020	-0.508	-0.547	-0.685*
EA	-0.707*	-0.230	-0.677*	0.106	-0.387	-0.342	-0.714*
Ex Al	-0.510	-0.202	-0.691*	-0.109	-0.046	-0.139	-0.557
ECEC	-0.591	-0.147	-0.659*	0.089	-0.267	-0.216	-0.570
BS	0.748*	0.318	0.536	-0.099	0.342	0.326	0.764*

PH = plant height; SG = stem girth; NL = number of leaves; LL = leaf length; LA = leaf area; NFL = newly formed leaves; SCR = silt clay ratio; SWC = saturated water content; FC = field capacity; PWP = permanent wilting point; Ksat = saturated hydraulic conductivity; BD = bulk density; TP = total porosity; MP = macroporosity; VR = void ratio; MC = moisture content; AWC = available water capacity; EC = electrical conductivity; OM = organic carbon; TN = total nitrogen; C/N= carbon/nitrogen ratio; Av.P = available phosphorus; Ca= exchangeable calcium; Mg = exchangeable magnesium; Na= exchangeable sodium; K = exchangeable potassium; EA = exchange acidity; Ex Al = exchange aluminum; ECEC = effective cation exchange capacity; BS = base saturation.

sults of the assessment of soil and plant parameters indicated that the 4WPR of *Nypa frusticans* was the time-period that would allow the gradual re-establishment of mangrove flora, *Rhizophora racemos,* and other species, in the study area and other places where the mangrove ecology has been degraded by the *Nypa frusticans*.

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