INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 19, No. 2, p. 217-229, 2021

RESEARCH PAPER OPEN ACCESS

Physicochemical and pedological features of swampland soils and productive potentials within a coastal system in Akwa-Ibom State

Alama Ifeakachukwu Sunday*, Egbuchua Collins, Emuh Fidelis Nduka, Akparobi Sunday Oba

Department of Agronomy, Delta State University, Abraka, Nigeria

Key words: Pedological features, Physicochemical properties, Productive potentials, Coastal system

http://dx.doi.org/10.12692/ijb/19.2.217-229 Article published on August 30, 2021

Abstract

Soil pedological information is vital for land use planning and sustainable fertility management. The study was carried out with the objective of characterizing and classifying the soils of Ikpe-Ikotnkon, Ini L.G.A. of Akwa Ibom State. Representative soil pedons were delineated along topographic positions using a detailed (1:25,000) soil survey and described based on their genetic horizon in the field for their morphological characteristics and analyzed in the laboratory for selected physical and chemical soil properties. The soils were classified According to Soil Survey Staff (2014). The morphological properties depicted that the soils were characterize by a low chroma of <10 and a hue value < 4 with significant mottles in the pedogenetic horizons, the particle size distribution showed that clay fraction was dominant in the surface and subsurface horizons and range from 43-64% across the pedon; the bulk density values ranged from 1.69-1.90gcm^{-3}. The general chemical characteristics the soils were extremely to slightly acidic ranging from 4.01-4.79; the organic matter content values were low and ranged from 0.18-0.68%; while total nitrogen were low and mean values ranged from 0.10-0.23%; the available phosphorus values were low to moderate and ranged from 6.12-14.32mgkg^{-1}; the exchangeable bases were low to moderate and ranged from 69.43-84.60cmolkg^{-1}; exchangeable sodium percentage was high across the pedon and values ranged from 0.11–0.24cmolkg^{-1} depicting salinity nature of the soils, base saturation across the pedon were generally moderate to high and ranged from 67.53–82.00cmolkg^{-1}. The soils in Ikpe-Ikotnkon, were generally classified as Typic Argiaqualf in the subgroup level and were correlated in FAO/UNESCO soil legend as Gleysols. The soils productive potentials showed that the maximum economic yield of rice in Ikpe-Ikotnkon were 5.34t/ha. Based on the result obtained from the study optimum rates of organic and inorganic amendments should be applied in the soil to reduce the level of acidity, and improve the fertility level of the soils for better crop performance.

* **Corresponding Author:** Alama Ifeakachukwu Sunday ✉ ask.ifeakachukwu@gmail.com

Introduction

Swampland soils are developed in areas aided by low wave energy regime such as Estuaries River, river banks and the coaster interface (Okonji, 2002). They are two basic morphological units of swamp area: the outer belt, which is flooded annually, and the main swamp, which is permanently flooded and covered with floating vegetation found in terrines that are flat floored or low relief which include inland basin, valley flux, and flood plains where most complex swamplands are depositional (Okoji, 2002). Swampland can also be artificially developed by human activities resulting to water logging particularly where there is poor drainage infrastructure due to lateral seepage flooding or high water table (Akamigbo, 2001),

Generally the outer belt are usually derived from Fluvu-marine deposits with strapping characteristics of complex hydrology, such as tidal flows, outflows and seepage characterized by soaring accumulation of exchangeable Na and other soluble salts that can impair plant growth and change the aggregate and structure of the soils (Egbuchua and Ojobor, 2012). Swamps are perennially submerged in most time of the year, and are largely influenced by the factors of topographic locations, parent material and more importantly the submergence of water in excess amount that can cause anaerobic condition in soil profile (Okoji, 2002). Thus, swampland soils infer intra zonal soils developed due to the local dominance of drainage conditions (rigorous wetness), strictly hydromorphic billed to their poorly drained condition with reduced condition often association to Histosols (organic soils) and the constant presence of water in the soil causes the development of gleyzation associated with swampland soils (Brady and Weil, 2015).

To assess the soil physiochemical properties and productivity potentials in the study area for specific land use based on the nature and the properties of soils. Rice was grown in wide range of soil, from the podzolic alluvium to the impermeable heavy clay, fertile swampland soils are best for rice cultivation (Ayehu and Besufekad, 2015). Udo (2007) observed that swampy soils are suitable for rice although Ogban and Ibia (1998) noted that little studies have been made on swampland soils and are underutilized. Udo *et al.* (2008) suggested that this might be the effect of their complexities in chemical properties, which are the major determinants of nutrients requirements by crops. Aquic moisture regime which is a major characteristic of swampland soils make the environments chemically dynamic; as such need regular testing of soil properties for management practice. Research showed that soils in this area have not been clearly characterized and classified for such land management where agriculture has been widely practiced for decades, there is need to study the soils in Ikpe-Nkotnkon in order to provide the area with needed soil management decisions and information's with site-specific management recommendations for commercial rice production purposes. Therefore, there soils were characterized to identify their constraints and potentials to support swamp rice production.

Materials and methods

The Study Area

The study was carried out in Ikpe-Ikotnkon, Ini local government area of Akwa Ibom State. The area lies between UTM coordinates of Longitude: 7° 47' 21" E and Latitude: 4° 58' 56" N DMS. In the rain forest zone with a mean annual rainfall of over 2500mm. The areas have relatively high temperature values with the mean annual temperature ranging from 26-28° C. The area is positioned on a sloping; gently undulating coastal plain that lacks remarkable features of relief (Barbour *et al.*, 1982) with huge potentials in tourism and Agriculture in the southernmost part of Nigeria within the wetlands of 70,000km² formed primarily from alluvial and colluvial deposits.

Soil Survey Procedure

A detailed soil surveys were conducted using a scale of 1:25,000. The geographic and topographic map of the respective areas that shows the geomorphology, topography and other physical and cultural features were collected in a stratified method of sampling and studied for the purpose of delineating the soil boundaries, identification and observation. The areas excavated were duly characterized from the surface to the subsurface horizon.

The profile pits were examined and described for morphological differentiation in terms of drainage using GIS (Geographic information system), presence of mottles by comparing the Mottle colour to the Matrix or background colour of the soil as they occur in the profiles, the texture using the textural triangle, structure, colour using Munsell Colour Charts, consistency using simple test or laboratory procedure, depth of water table, presence of weather able mineral and horizon boundaries.

Physicochemical characterization of soil profiles

Soils samples collected were air-dried and sieved to 2mm before taken to the laboratory for analysis (Balduff, 2007). The particle size distribution (PSD) was determined by Bouyoucos (1951) method, using sodium hexa meta phosphate (calgon NaPO3) solution as the dispersant. Soil pH was determined using glass electrode pH meter in a 1:1 soil/H2O suspension. The exchangeable bases were extracted with 1N neutral ammonium acetate (NH4CH2CO2) and determined in the flame photometer and Diethylenetriaminepentaacetic acid (DTPA) titration. Exchangeable cations (Ca,mg, K and Na) were leached from the soil sample using1N NH4 OAc (pH 7.0) buffer. The Na and K were measured with a flame photometer while the Ca andmg were determined by EDTA titration as outlined by (Esu, 2010). The exchangeable acidity (Al and H+) was determined using the method outlined by Mclean (1965), the organic carbon was determined by Walkley and Black (1934) metods as described by Allison (1965), and was converted to organic matter by multiplying the percentage carbon by Van Bermelen factor (1.724). Cation exchange capacity (CEC) was determined after exchange with ammonium acetate (pH 7) according to Vittori Antisari *et al.* (2015). Effective cation exchange capacity (ECEC) was obtained by adding Total Exchangeable Bases (TEB) and Total Exchangeable Acidity (TEA). The available phosphorous (P) was ascertained using Bray I method (Bray and Kurtz 1945). Total nitrogen (N) was determined by Kjeldahl wet oxidation method or colorimetric method using sodium phanate, sodium hypo chloride, sodium potassium tartrate and standard nitrogen stock solution.

Extractable micro nutrient was determined using the hydrochloric acid method (Isirimah *et al.,* 2003).

Field Experiment

Field experiments were carried out to assess the effect of soil on rice growth and yield in three selected soil mapping units which include: Ikpe Ikotnkon (Grass area outer belt), Ikpe Ikotnkon (shrub area outer belt) and Ikpe Ikotnkon (Valley bottom outer belt). The trial was conducted in two wet season to evaluate the suitability potentials of swampland soils. The experiment was carried out in a randomized complete block design (RCBD) and a rice cultivar (FARO 44) as test crop. The plot size was 4m by 4m at spacing of 20 x 20cm, seed were sowed manually on soils at five (5) seed per hill and thinning was done up to 3 weeks to maintain one plant per stand. Weed control were manually done when necessary. Data collected at 2, 4, 6, 8, 10, and 12 weeks were leaf area, plant girth, number of leaves and plant height after planting. Number of leaves was counted manually, plant height and girth was measured by meter rule. Leaf area was calculated by K (L*W), where L is the length of leaf, W is maximum width of leaf and K is 0.75 conversion factor for wet-seasons according to Palaniswamy and Gomez. (1974). Grain was threshed manually, air dried for two to three days, weighed and calculated in tons per hectare.

Statistical analysis

Simple statistics were used and data collected were subjected to Analysis of variance (ANOVA) and means showing significance differences were separated using LSD at $P<0.05$ (SAS 2012).

Results

The Result of the morphological properties of Ikpe-Ikotnkon

The results showed that the morphological properties in Ikpe-Ikotnkon are presented in Table 1. The soil depth were usually 0-140cm, the colour ranged from dark grayish (2.5YR2/1) at 0-20cm to light grey (10R6/1) at 20-100cm and (2.5YR3/1) at 100-140cm depth in that order. The swampland has a contrasting reddish brown (10R4/12) mottle at the surface and subsurface horizons 20-140cm (BA to BR) horizons respectively.

The area was dominated by clay and clay loam from the surface to the subsurface horizons. The structure was mainly moderately sub-angular blocky at the surface, sub-angular blocky and crumbly structure with very sticky and very plastic consistency at the subsurface horizons. The rootlets ranged from fabric, many, few to fine whilst boundary ranged from diffused, gradual to smooth boundary at depth surface horizons (0-40cm) and clear smooth boundary at the subsurface horizons (40-140cm) in mapping unit A; in mapping unit B the boundary ranged from wavy to gradual smooth boundary and clear smooth boundary 0-140cm in mapping unit B and C.

Table 1. Distribution of Soil Morphological Properties of Ikpe-Ikotnkon in Ini Local Government of AkwaIbom State.

Horizon	Depth	Colour	Mottles	Texture	Structure	Consistence	Rootlets	Boundary
Mapping	Unit A							
A	0-20	2.5YR2/1	Nil	c	msbk	Slst,	fa	D
BA	20-40	10R6/1	10R4/12	c	msbk	slst	fw	gs
Bt_1	40-60	10R6/1	10R4/12	C	Sbk	st, p	f	cs
Bt_2	60-80	10R6/1	10R4/12	C	Sbk	vst, vp	f	cs
Bt_3	80-100	10R6/1	10R4/12	C	Sbk	vst, vp	f	cs
BR	100-120	2.5YR2/0	10R4/12	C	Sbk	vst, vp	f	cs
BR	120-140	2.5YR2/0	10R4/12	C	Sbk	vst, vp	f	cs
Mapping	Unit B							
Ai	0-20	2.5YR2/1	Nil	c	Mosbk	slst	m	w
AB	20-40	10R6/1	10R4/12	C	mosbk	slst	fw	w
BA	40-60	10R6/1	10R4/12	C	mobk	slst, p	fw	gs
Bt_1	60-80	10R6/1	10R4/12	C	cbk	vst, vp	f	cs
BR	80-100	10R6/1	10R4/12	C	cbk	vst, vp	f	cs
BR	100-120	2.5YR2/0	10R4/12	C	cbk	vst, vp	f	cs
BR	120-140	2.5YR2/0	10R4/12	C	cbk	vst, vp	f	cs
Mapping	Unit C							
Ao	0-20	2.5YR2/1	Nil	cl	sbk	st	fa	a
Ap	20-40	10R6/1	10R4/12	c	sbk	st	fw	as
AB	40-60	10R6/1	10R4/12	c	sbk	st, p	f	gs
Bt1	60-80	10R6/1	10R4/12	C	cbk	vst, vp	f	cs
Bt2	80-100	10R6/1	10R4/12	C	cbk	vst, vp	f	cs
Bt3	100-120	2.5YR2/0	10R4/12	C	cbk	vst, vp	f	cs
BR	120-140	2.5YR2/0	10R4/12	C	Mbk	vst, vp	f	cs

Legend: Texture: S (Sand); C (Clay); L (Loam); SL (Sandy Loam); LS (Loam Sand); SCL (Sand Clay Loam). Structure: D: (Structure less); W (Weak); M (Moderate); S: (Strong); M: (Medium). Consistence: Fr (Friable); SP (slightly plastic); VP (Very plastic); S (Sticky); P (Plastic). Boundary: a (abrupt) C (Clear), W (Wavy), Ir (Irregular), D (diffused); S (Smooth), g (Gradual). Root Concentration M (Many), Ab (abundant); fw (Few); F (Fine); C (Common); Fa (Fabric).

Physical properties

The PSB in Ikpe-Ikotnkon are clear distinctive characteristics of soil physical properties in the study areas. The sand fraction also ranged from 14 -40%, mean 27.67%, with standard deviation of 8.65% and a coefficient of variation 31.27%. Silt faction also ranged from 16-24%, mean 20.24%, with standard deviation of 2.47% and a coefficient of variation 12.19%. The results showed that clay content ranged from 42-64%, mean 52.10%, with standard deviation of 6.73% and a coefficient of variation 12.92% respectively while bulk density varied with depth in the study areas and the values ranged from 1.69-1.90gcm^{-3}, mean 1.80gcm^{-3} with standard deviation 0.06gcm^{-3} and a coefficient of variation of 3.46%9 (Table 2). The particle density in the study area varied and ranged from 2.10-2.46gcm^{-3}, mean 2.29gcm^{-3} with standard deviation 0.13gcm^{-3} and a coefficient of variation of 5.54%. The porosity also varied and ranged from 10.48-32.42%, mean 21.02% with standard deviation 5.91% and a coefficient of variation of 28.13% in Table 2. The hydraulic conductivity values ranged from 0.9-5.1cm/hr in the surface to the subsurface horizons, mean 3.12cm with standard deviation 1.12cm/hr and a coefficient of variation of 35.8% (Table 2)

Table 2. Distribution of Soil Physical Properties of Ikpe-Ikotnkon in Ini Local Government of Akwa-Ibom State.

Horizon	Depth (cm)	% Sand	% Silt	% Clay	T C	B/d gcm-3	P/d gcm3	Porosity%	k-sat cm/hr
Mapping	Unit A								
A	0-20	40	17	43	C	1.70	2.38	28.56	4.3
BA	20-40	38	17	45	C	1.73	2.33	25.75	3.7
Bt_1	40-60	35	18	47	C	1.76	2.30	23.48	3.4
Bt_2	60-80	31	20	49	C	1.79	2.27	21.15	3.1
Bt_3	80-100	26	22	52	C	1.82	2.24	18.75	2.8
BR	100-120	21	23	56	C	1.85	2.21	16.29	2.3
BR	120-140	16	24	60	C	1.89	2.19	13.70	1.7
Mapping	Unit B								
Ai	0-20	38	17	45	C	1.73	2.56	32.42	5.1
AB	20-40	36	16	48	C	1.75	2.51	30.28	4.2
BA	40-60	32	19	49	C	1.78	2.46	27.64	3.7
Bt_1	60-80	28	18	54	C	1.80	2.40	25.00	3.6
BR	80-100	24	19	57	C	1.83	2.39	20.78	3.7
BR	100-120	20	21	59	C	1.86	2.32	19.83	3.3
BR	120-140	14	23	63	C	1.90	2.26	15.93	2.2
Mapping	Unit C								
Ao	0-20	39	19	42	CL	1.69	2.25	24.39	4.9
Ap	20-40	35	20	45	C	1.73	2.21	21.72	3.8
AB	40-60	30	22	48	C	1.76	2.18	19.27	3.1
Bt1	60-80	26	22	52	C	1.79	2.16	17.13	2.3
Bt2	80-100	21	23	56	C	1.81	2.15	15.81	2.0
Bt3	100-120	17	23	60	C	1.85	2.13	13.15	1.4
BR	120-140	14	22	64	C	1.88	2.10	10.48	0.9
Mean		27.67	20.24	52.10		1.80	2.29	21.02	3.12
Sd		8.65	2.47	6.73		0.06	0.13	5.91	1.12
CV		31.27	12.19	12.92		3.46	5.54	28.13	3.58

TC= Textural Class, P/d=particle density; Bd= Bulk density and k-sat= Hydraulic conductivity

The Results of Chemical Properties of Ikpe-Ikotnkon

The results of the chemical properties in Ikpe-Ikotnkon are presented in table 3. The pH values ranged from 4.0-4.9 mean 4.40 with standard deviation 0.25 and a coefficient of variation of 5.57%. The values of OM content ranged from 0.16-0.65%, mean 0.38 with standard deviation 0.18 and a coefficient of variation of 46.30% (Table 3). The nitrogen values ranged from 0.09-0.24gkg^{-1} from the surface to the subsurface horizons, mean 0.15gkg^{-1} with standard deviation 0.18gkg^{-1} and a coefficient of variation of 29.83%.

The phosphorus values ranged from 6.03-14.00mgkg^{-1}, mean 9.86mgkg^{-1} with standard deviation 3.12mgkg^{-1} and a coefficient of variation of 31.63%. The values of calcium ranged from 1.79-6.72cmlkg^{-1}, mean 3.92cmlkg^{-1} with standard deviation 1.61cmlkg^{-1} and a coefficient of variation of 41.09%. While the result also showed magnesium ranged from 4.12-6.40cmlkg^{-1}, mean 25.64cmlkg^{-1} with standard deviation 0.58cmlkg^{-1} and a coefficient of variation of 10.24%.

The values of sodium ranged from 0.11-0.24cmlkg^{-1}, mean 0.16cmlkg^{-1} with standard deviation 0.04cmlkg^{-1} and a coefficient of variation of 24.29%. The result also showed that potassium values ranged from 0.12-0.32cmlkg^{-1}, mean 0.26cmlkg^{-1} with standard deviation 0.08cmlkg^{-1} and a coefficient of variation of 28.45%. The TEB values also ranged from 1.92-11.57cmlkg^{-1}, mean 9.44cmlkg^{-1}, with standard deviation 2.04cmlkg^{-1}, and a coefficient of variation of 21.63% while TEA ranged from 4.90-8.75cmlkg^{-1}, mean 6.54cmlkg^{-1}, with standard deviation 1.03cmlkg^{-1}, and a coefficient of variation of 15.82%. The values of ECEC also ranged from 9.32-17.73cmlkg^{-1}, mean 16.10cmlkg^{-1}, with standard deviation 1.65cmlkg^{-1}, and a coefficient of variation of 10.27%. CEC values also ranged from 14.12-16.96cmlkg^{-1}, mean 16.64cmlkg^{-1}, with standard deviation 0.94cmlkg^{-1}, and a coefficient of variation of 6.01%. The values of BS ranged from 47.42-69.41%, mean 59.57% with standard deviation 6.52% and a coefficient of variation of 10.94%. The values of Zn varied and ranged from 1.15-5.20, mean 2.68 with standard deviation 0.89 and a coefficient of variation of 33.1. The values of Iron ranged from 0.22--10.65mgkg-1, a mean of 2.55mgkg-1 with standard deviation 2.75mgkg-1 and a coefficient of variation of 107%.

Table 3. Effect of Depth on the Distribution of Soil Chemical Properties of Ikpe-Ikotnkon in Ini Local Government of AkwaIbom State.

Horizon	Depth	pH	OM	N	Av.P	$Ca2^+$	$Mg2^+$	Na^+	K^+	TEB	TEA	CEC	ECEC	EC	BS	Zn	Fe
		(H_2O)	(g/ kg¹)	(g/ kg¹)	Mg/k g	------	→	Cmol/ kg	←	-----	------	-----	------	dS/ m	%	ppm	mg/ kg
Mapping	Unit A																
A	0-20	4.66	0.65	0.20	13.11	6.72	4.48	0.22	0.15	11.57	5.10	14.12	16.67	4.53	81.94	4.60	10.65
BA	20-40	4.50	0.65	0.21	5.44	5.68	5.38	0.19	0.28	11.53	6.20	14.67	17.73	4.59	78.60	1.15	3.70
Bt_1	40-60	4.78	0.45	0.15	15.22	4.32	5.68	0.19	0.29	10.48	6.90	15.20	17.38	476	68.95	2.35	1.35
Bt_2	60-80	4.65	0.37	0.13	13.22	5.76	5.86	0.17	0.31	11.92	7.10	15.70	19.02	4.83	75.92	2.50	1.00
Bt_3	80-100	4.53	0.25	0.10	11.11	6.34	5.99	0.14	0.33	12.82	7.80	16.13	20.62	4.89	79.48	2,75	0.85
BR	100-120	4.42	0.19	0.09	9.12	6.54	6.00	0.11	0.35	13.00	8.11	16.33	21.11	5.12	79.61	2.30	0.65
BR	120-140	4.22	0.18	0.09	9.10	6.67	6.12	0.11	0.36	13.26	8.75	16.44	22.01	5.15	80.66	2.95	0.50
Mapping	Unit B																
Ai	0-20	4.45	0.60	0.24	6.03	6.50	4.12	0.18	0.12	1.92	4.90	14.09	9.32	4.62	84.60	5.20	7.54
AB	20-40	4.30	0.46	0.22	5.66	5.66	5.08	0.17	0.16	11.07	5.10	14.70	16.17	4.67	76.68	1.45	3.90
BA	40-60	4.17	0.32	0.19	6.45	5.78	5.75	0.17	0.21	11.90	5.90	15.23	17.80	4.73	73.60	2.18	2.33
Bt_1	60-80	4.20	0.26	0.17	7.34	6.23	5.95	0.15	0.24	12.57	6.20	15.78	18.77	4.84	79.66	2.55	1.23
BR	80-100	4.10	0.20	0.15	8.30	6.60	5.99	0.13	0.28	13.00	6.30	16.34	19.30	4.91	79.75	2.72	1.05
BR	100-120	4.09	0.16	0.12	7.09	6.87	6.01	0.12	0.30	13.30	6.90	16.52	20.20	5.11	80.51	2.99	0.44
BR	120-140	4.00	0.16	0.09	6.80	6.89	6.09	0.12	0.34	13.44	7.12	16.57	20.56	5.23	81.11	2.89	0.55
Mapping	Unit C																
Ao	0-20	4.87	0.63	0.19	14.00	5.50	5.08	0.24	0.17	10.99	5.10	14.21	16.09	5.11	77.34	2.30	6.00
Ap	20-40	4.70	0.60	0.19	13.87	5.25	5.02	0.22	0.17	10.66	5.80	14.78	16.46	5.14	72.12	2.05	5.00
AB	40-60	4.55	0.57	0.17	13.40	4.50	5.66	0.19	0.19	1054	6.12	15.18	16.66	5.34	69.43	2.18	3.50
Bt1	60-80	4.45	0.46	0.16	12.20	4.90	5.78	0.16	0.25	11.09	6.50	16.00	17.59	5.45	69.31	2.45	1.34
Bt2	80-100	4.34	0.36	0.14	10.44	5.67	5.97	0.14	0.27	12.05	6.91	16.65	18.96	5.23	72.37	2.68	1.08
Bt3	100-120	4.28	0.27	0.13	10.11	5.89	6.00	0.12	0.31	12.14	7.12	16.80	19.26	5.56	72.26	2.98	0.72
BR	120-140	4.15	0.25	0.10	9.14	6.05	6.40	0.12	0.32	12.89	7.40	16.96	20.29	5.45	76.00	3.13	0.22
Mean		4.40	0.38	0.15	9.86	5.92	25.64	0.16	0.26	11.96	6.54	15.64	18.19	5.01	76.66	2.68	2.55
Sd		0.25	0.18	0.18	3.12	0.74	0.58	0.04	0.08	0.99	1.03	0.94	2.68	0.31	4.56	0.89	2.75
Cv		5.57	46.30	29.83	31.63	12.52	10.24	24.29	28.45	8.29	15.82	6.01	14.72	6.09	5.95	33.12	107

Where: TN = Total Nitrogen; OC = Organic Carbon; OM = organic Matter; Avail. P. = Available Phosphorous; Ca = Calcium; mg = Magnesium; K = Potassium; Na = Sodium; TEA = Total Exchangeable Acidity; TEB = Total Exchangeable Base; ion Exchange capacity CEC= Cation Exchange Capacity; ECEC = Effective Cation Exchange Capacity; EC= Electrical Conductivity %BS = Percentage Base Saturation.

The Results of Growth and Yield of rice in Ikpe-Ikotnkon

The results showed that leaf area were 5.30cm (shrub area soils), 4.66cm (valley area soils) and 4.30cm (grass area soils) the leaf observed showed that shrub area soils contributed significantly to leaf area development of rice. The plant heights were 57.30cm (shrub area soils), 51.22cm (valley area soils) and 50.44cm (Grass area Soils) best plant height were also observed in shrub area soils. In relation to yield in tones per hectares result were 5.42tn/ha (shrub area Soils), 5.09tn/ha (Valley area soils) and 3.56 tn/ha (Grass area Soils). The suitability evaluations were based on the effect of swampland soils on rice growth and yield parameters. The plant height, plant girth, number of leaves and leaf area were significantly influenced by the characteristics of swampland soils (shrub area Soils > Valley area soils > Grass area Soils). This finding agreed with Acquaah (2005) who reported that soils with perched water environment are prerequisite for growth and yield of rice in swampland soils. Udo *et al.,,* (2009) opined that soils that are characteristically wet in most part of the year with low to moderate fertility are capable of supporting swamp rice, provided adequate liming and fertilizer are used. These results therefore mean that the soils n Ikpe-Ikotnkon could significantly support swamp rice production.

Table 4. Effect of Swampland Soil on Growth Indices and Rice Yield.

Treatments	Plant height (cm)	Plant girth (cm)	No of leaves	Leaf area (cm)	Yield (tn/ha)
Grass area Soils	50.44	0.42	4	4.30	3.56
shrub area Soils	57.30	0.46	5	5.30	5.42
Valley area soils	51.22	0.43	5	4.66	5.09
LSD (0.05)	8.6	0.31	2	1.18	1.02

Soil Classifications

The soils were classified as Alfisols and the classification into the suborders Aqualfs (Soil Survey Staff, 2014) was driven by the hydromophic condition of the pedons. However, the soils mapping units were characterized by aquic conditions at a depth between 20 and 100cm (Aqualfs). They are characterized by Argillic clays horizons and cation holding capacity <16cmol/kg and a Bt horizons allowed the pedons to be classified as Argiaqualf in the great group level. The area been saturation and virtually free of gaseous oxygen for sufficient periods and poor aeration resulting to gleyzation and mottling in the sub surface horizon also allowed the pedons to be classified as Typic Argiaqualf in the subgroup level and pedons dominated with clay across the mapping units. The soils were correlated in FAO/UNESCO soil legend as Gleysols (FAO/UNESCO 2017).

Discussions

The morphological characteristics

The morphological characteristics of various pedons studied showed that the soils occurred on level to gentle sloppy topography essentially developed from alluvial and colluvial deposits. The soils were relatively deep and in most cases greater than 50cm in depth. The implication of this soil depth as observed in the study showed that the soil could be comfortably used for crop production purposes. Richards, (2008) reported that increase in soil depth of above 50cm was considered favorable for crop production. Whitmore and Whalley (2009) reported that root distribution at a greater depth contributes to improving yield especially in water stress area since rice is a shallow rooted crop it implies that the various area studied could be used for rice production other characteristics notwithstanding.

The soil colour of the individual pedons varied from mapping units to another, the dominant soil colours ranged from very dark grey to black with predominant 2.5Y and 5Y hues with a chroma values of less than 2 across the pedons studied. This is an indication that the soils are under water logged condition and depositional pedogetic processes is gleyzation. The variation in color change among the pedons and within a pedon could be attributed to difference in OM content, parent material, and drainage conditions. This finding agreed with Nahusenay *et al.* (2014), who reported that colour changes could be a resultant effect on organic matter and drainage conditions. The pedons studied were darker at the surface horizons than the B horizon, which were attributed to comparatively high organic matter in the surface horizon. Generally, in the study the value and chroma indices increased with depth of profiles and hue was redder. In contrast, Kehinde, *et al.* (2019) confirmed that higher organic matter in the surface horizon could be adduced to illuviation of Fe oxides (sesquioxides) into subsurface horizon, which is often accountable to reddish soil coloration as observed in the study.

The results of the morphological properties were indications that the colours associated with the pedogenetic horizons are product of the climatic variables and the time of soil formation promoting illuviation of clay and eluviations of organic parent material and the prolonged period of wetness, inundation and the mobilization of Fe and Al and the characteristics of gleyzation and clay synthesis. These findings are in agreement with IRRI (1985) who reported that the main processes that could affect soil colour that seem active among this swampland soils are seasonal wetting and drying, fluctuating water table, textural differentiation and clay illuviation, glayzation, clay synthesis, accumulation of carbonates and possible mobilization of Fe and Mn. The pedogenetic horizons showed they were remarkable evidence of mottling and changes in soil colours from the surface to the subsurface horizon.

Physical properties

The particle size distribution across the mapping units studied predominantly dominated by clay in the surface to subsurface horizons. This tends to increase with depth in clay content indicating illuviation of clay (Ogunwole *et al.,* 2010). Again Lekwa *et al.* (2001) affirmed that increase in clay with depth showed that clay migration into subsurface horizon to pronouns Agilic horizon which characterized most swampland soils. Secondly, Ayoloha (2001) described the high concentration of clay in subsurface horizons as an indication of irregular distribution and stratification of clay which suggested different periods of deposition of sediments. The result of this study clearly followed the trend of the researchers in which clay weigh far to dominate in subsurface horizons indicating illuviation processes of the swampland soils (Alem *et al.*, 2015, Sekhar *et al.,* 2014). Moreover, clay content observed in B horizons in all the pedon were higher than the surface horizons. The general increases in content of clay with depth across pedogenetic horizons were attributed to the vertical translocation of clay through the processes of lessivage and illuviation. Higher content of clay in the B subsurface horizon were attributed to clay illuviation, predominant *in situ* pedogenetic formation of clay in the subsoil, and destruction of clay at the surface horizon, have been reported (Chukwu, 2013; Yitbarek *et al.*, 2016; Kebede *et al.,* 2017; Kehinde *et al.*, 2020).

The values of bulk density in the different soil mapping units were high from the surface to sub surface horizons. Generally, bulk densities increased with depth and were adduced to illuviation of clay into the subsurface horizon along with poor structural development, compaction and weathered parent material. Chaudhari *et al.* (2013) reported increase in bulk density with profile depth, due to changes in soil organic matter content, porosity, and soil compaction. According to Donahue (1990); Hazelton and Murphy, (2007) plant performs best in bulk density below 1.4mg/m^s and 1.6mg/ms for clay and sandy soils respectively. Bulk density value between 1.47 and 1.85mg/ms for sand clay soils had been reported to inhibit root growth (Jin *et al.*, 2017). Root growth is inhibited due to high bulk density because of soil resistance to root penetration, poor aeration, slow movement of nutrient and water and buildup of toxic gasses and root exudates (Odunze 2006). According to Kramer and Chardwick (2016), Tillage can decrease bulk density. Soil bulk density as well as soil texture play very important role in water retention and preservation of carbon and nutrient (Stockman *et al.,* 2013 and Jilling *et al.,* 2018). They were remarkable evidence of high bulk densities in the surface horizon in Ikpe-nkotukon and even higher at the subsurface horizons. This could be the movement of heavy equipment leading to increase in bulk density and reduce pore spaces and associated consequences.

This finding also agreed with Ayolagha, (2001) who reported that bulk density increases with increasing depth in the pedogenetic horizon and soil physical properties, such as bulk density and soil texture, play a very important role in water retention and the preservation of carbon (C) and nutrients (Stockmann *et al.,* 2013; Jilling *et al.,* 2018). Physically, there were remarkable evidence of high bulk density in the surface horizon in most soils mapping units in Ikpe-Ikotnkon and even more higher in the subsurface horizons due to the development of argillic horizon from surface to subsurface horizons.

Chemical properties

The content of organic matter (OM) studied were generally low and ranged from 0.16 – 0.65%. These finding agreed with FDALR (2004) and Teferi *et al.* (2016) who reported low to medium OM content in swampland soils and was attributed to low decomposition of organic matter. The high level of organic matter associated to the pedogenetic horizons were attributed to biomass turnover of plant remains; this means that swampland soil favor lower rate of decomposition and a relatively higher accumulation of organic carbon which however have a strong relationship with organic matter in the soils. This finding was also in agreement with Endalkachew *et al.* (2018) who reported higher rate of organic matter in the upper horizons. Moreover, the low organic matter in all the pedons may be credited to the combined effect of land use, vegetation and climate,.

In addition, Dexter *et al.* (2008) established that organic matter significantly influences the behavior of soil physical properties (i.e., matrix and structural porosity) this is possible when the content of clay is above a threshold relative to carbon. There is an indication that climate variables, mean annual temperature and mean annual precipitation were the strongest predictors of soil organic carbon density; this is in agreement with the findings of Gray *et al.* (2009).

The soil total nitrogen across the pedons are generally low (0.09 – 0.24gkg^{-1}) in the pedogenetic horizons. Higher content of total nitrogen were generally observed at the surface horizon and tend to decrease with profile depth following organic matter trend of in the studied areas. These results were also observed by Meysner *et al.* (2006) and Endalkachew *et al.* (2018). The nitrogen contents as observed in the study could be attributed to high bulk density and compaction due to heavy duty machinery used across the area which may affects nutrient uptake and availability; however, Nitrogen is affected in so many ways by compaction: (i) poorer internal soil drainage will cause more de-nitrification losses and less mineralization of nitrogen (organic); (ii) nitrate losses by leaching will decrease; (iii) loss of organic nitrogen (in organic matter) and surface-applied nitrogen fertilizer may increase; and (iv) diffusion of nitrate and ammonium to the plant roots will be slower in compacted soils that are wet.

The available phosphorus which is most limiting nutrients element (Sharma *et al.,* 2017) after nitrogen were low to medium and ranged from 6.80-15.22mgkg-1 across the pedons. The higher phosphorus was established more at the surface than the subsurface horizons. According to Almed (2013) soil available phosphorus has direct relationship with soil organic matter. This is because organic matter in the soil contributes about 70-75% of organic phosphorus in decomposed form. The observed low phosphorus value in the area studied could be attributed to lost from genetic profile through surface flow both in solution (soluble P) and bounded to eroded sediment particle density (particulate P and N) as opined by Donahue *et al.* (1990). Again, low phosphorus content studied was attributed to fixation of P by seseqoxide in acid soils condition. The same process was reported by Akamigbo (2001). In the study low to medium level of phosphorus was observed and were attributed to slow solubility /mobility and decomposition of phosphorus in the subsurface soils. In addition, Orgi and Amaechi (2019) reported medium to high phosphorus in swampland area and was adduced to increase in phosphorus availability during flooding regime in most part of the year.

The total exchangeable bases (TEB) are usually defined in terms of Ca, mg, Na and K. Calcium was the principal saturating cation across the pedons studied, the cation distribution is in the order: Ca >Mg >Na >K across the pedons, the exchangeable cations with exception of Na where relatively high, at the surface horizons. This could be attributed to the nature of the parent material in the location, intense leaching, weathering activities (Nahusuna, *et al.,* 2014, Ashenali 2010). This authors opined that leaching and excessive rainfall where among factors that can affect TEB in a given soils. The result obtained for Na were moderate to high (0.11-0.24cmolkg-1), such high Na level as observed may induce sodicity in the soils which is a major limitation since such soils dispersed easily when saturated with water and blown always when the soils are dried (Alka *et al.,* 2012).

In similar studies Egbuchua (2007) observed some high level of Na in his characterization of wetland soils in Delta state. The result of this study also followed the same trend and gave an indication that most of the swampland soils could be saline in nature and may have high soluble salt. Exchangeablemg contents varied from 4.22-6.12cmolkg^{-1} and were rated as low to very high in the exchange site across the pedons. Similar trend was also observed in the studied area Orji and Amaechi, (2019) and kehinde (2019) also reported that lower value of mg than Ca contents of the soils is an indication of how greater magnesium may be removed from the exchange complex. However, magnesium is the second most abundant cation in living plant cells, and involved in many metabolic process (Tanol and Kobayashi, 2015).

The cation exchange capacity (CEC) was low to moderate (0.24-14.5cmolkg-1) these values indicated the dominance of Kaolinite in the fine earth fractions in the location. It also reflected the low level of exchangeable cation which is also an index of the low chemical weathering activities of the mapping units. The low to moderately CEC as observed could be adduced to 2:1 clay minerals and suggested mixed mineralogy in the soil colloid.

Generally, across the mapping units the higher values of CEC were observed at the surface horizon. This could be the influence of soil organic matter present at the surface horizon. The increase in CEC in sub surface horizons was adduced to high clay content in the subsurface horizons. Similar trend was reported by Endalkachew *et al.* (2018) who attributed increase in CEC to the high organic matter content and lower slope position which is a major characteristic of swampland soils.

Conclusion

Sufficient information on swampland soil and land use planning. characterization, classification and mapping of soils were conducted at the swampland area within a coastal plain in Ikpe-Ikotnkon in Akwa-Ibom State. Soil formations across the pedon were characterized by clay illuviation from the surface to the subsurface soil horizons. The swampland soils were characterized by inundated depression developed due to the local dominance of drainage conditions (severe wetness) poorly drained in a reduced condition and continuous presence of water causes the development of features of gleying in a typical coastal transition system. These features well define the morphological, diagnostic properties, physical and chemical properties of swampland soils, because they clearly highlight the pedogenetic features in suborder (Typic Argiaqualfs) classification level according to the criteria of the Soil Taxonomy. The result obtained from the study showed that optimum rate of compost, bio-fertilizers, and lime integrated with inorganic fertilizers containing N, P and K may help to reduce the level of soil acidity, and improve the fertility level of the soils for better swamp rice production.

References

Acquaah G. 2005. Principles of Crop Production. 'Prentice Hall, New Delhi, India. 3rd Edition 205pp.

Ahmed W, Jing H, Kaillou L, Qaswar M, Khan MN, Jin C, Sun Geng, Huang Qinghai, Liu Y, Liu G, Sun M, Li C, Li D, Sehrish A, Yodgar N, Sajid M, Huimin Z. 2019. Changes in phosphorus fractions associated with soil chemical properties under long-term organic and inorganic fertilization in paddy soils of southern China. Bui E, editor. PLoS ONE **14(5),** 1-7

Akamigbo FOR. 2001Survey, classification and land-use potentials of wetlands in Proceedding of the 27th annual conference of the soil science society of Nigeria 5-9th November, Calabar, Nigeria 327pp.

Alem S, Pavlis J, Urban J, Kucera J. 2015. Pure and mixed plantations of *Eucalyptus camaldulensis* and *Cupressus lusitanica*: their growth interactions and effect on diversity and density of undergrowth woody plants in relation to light Open J. For **5(4),** 375-386.

Alka U, Satyendra T, Pandey SN. 2012. Effects of Soil Sodicity on Growth, Nutrients Uptake and Bio-chemical responses of *Ammi majus* L. Research Journal of Soil Biology **4,** 69-80.

Allison CE. 1965. Organic Carbon Methods of soil Analysis part 2 (Ed) CA. Black, *et al.* Amer. Society. Agron Madison **13,** 40-78.

Ayehu GT, Besufekad SA. 2015. "Land SuitabilityAnalysis for Rice Production: A GIS Based Multi-criteria Decision Approach." American Journal of Geography Information System **4(3),** 95-104.

Ayolagha GA. 2001. Survey and classification of Yenagoa-Meandar belt soils in the Niger-Delta. In proceeding of the 27th Annual Conference of the soil society of Nigeria 5th - 9th November 2001, Calabar, Nigeria.

Balduff DM. 2007. Pedogenesis, Inventory, and Utilization of Subaqueous Soils in Chincoteague Bay. University of Maryland, Maryland.

Barbour KM, Oguntoyinbo JS, Onyemelukwe JOC, Nwafor JCr. 1982. Nigeria in Maps. London: Hodder and Stoughton.

Bouyoucos GB. 1951. A Calibration of the Hydrometer Method for making Mechanical analysis of soils. Agronomy **43,** 424-488.

Brady NC, Weil RR. 2015. The Nature and Properties of Soils. Printed in Idia by Idia binding house. Fifteenth impression 293pp

Bray RB, Kurts LT. 1945. Determination of total organic and Available form of Phosphorus in soil. Soil science **59,** 39-45.

Chukwu GO. 2013. Soil survey and classification of Ikwuano Abia state Nigeria. Journal of Environmental Science and Water Resources **2(5),** 150-156.

Dexter AR, Richard G, Arrouays D, Czyz EA, Jolivet C, Duval O. 2008. Complexed organic matter controls soil physical properties. Geoderma **144(3-4),** 620-627

Donahue RL, Raymond MW, Schickluna JC (ed.). 1990. Soils: An introduction to soils and plant growth. 5th Edition; Prentice Hall of India New Delhi. 667 pp

Egbuchua CN. 2007. Pedogenetic Characterization and Evaluation of Wetland Soils in Delta State. PhD Thesis Submitted To Delta State University, Abraka Nigeria Pp 6-70.

Egbuchua CN, Ojobor S. 2012. Characterization of some hydric soil in Niger Delta region of Nigeria for land evaluation purpose. Int. Adv. Biol. Res **1,** 77-82.

Endalkachew F, Kibebew K, Bobe B, Asmare M. 2018. Characterization and classification of soils of Yikalo subwatershed in Lay-Gayint district, Northwestern Highlands of Ethiopia. Eurasian Journal of Soil Science **7,** 151-166

FAO: Food and Agriculture Organization of the United Nations. 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations. Rome, Italy. pp 2-8

FDALR (Federal Department of Agric and Resources). 2004. Handbook on Soil Test- Based Fertilizer Recommendation for Extension Workers. National special programme for food security 39pp

Gray JM, Humphreys GS, Deckers JA. 2009. Relationships in soil distribution as revealed by a global soil database, Geoderma **150,** 309-323.

Hazelton P, Murphy B. 2007. Interpreting Soil Test Results. 2nd ed. CSIRO Publisher, Australia. 152p.

International Rice Research Institute (IRRI). 1985. Wetland soils: characterization, Classification, and utilization. Soil management support services Los Banos, Laguna, Philippines 491-493 pp.

Jilling A, Keiluweit M, Contosta AR, Frey S, Schimel J, Schnecker J, Smith RG, Tiemann L, Grandy AS. 2018. Minerals in the rhizosphere: over looked mediators of soil nitrogen availability to plants and microbes, Biogeochemistry **139,** 103-122.

Jin K, White PJ, Whalley WR, Shen J, Shi L. 2017. Shaping an optimal soil by root–soil interaction. Trends in Plant Science **22,** 823-829

Kebede M, Shimbir T, Kasa G, Abera D, Girma T. 2017. Description, characterization and classification of the major soils in Jinka Agricultural Research Center, South Western Ethiopia. Journal of Soil Science and Environmental Management **8(3),** 61-69.

Kehinde A Adegbite, Millicent Okafor E, Aruna Adekiya O, Elizabeth T, Alori, Ojo Adebiyi TV. 2019. Characterization and Classification of Soils of a Toposequence in a Derived Savannah Agroecological Zone of Nigeria. The Open Agriculture Journal **13,** 44-50.

Lekwa MU, Akamigbo FOR, Lekwa G. 2001. A detailed soil survey of the soil of Igwu river floodplain, Arochukwu local government area, Abia state, Nigeria, for swamp rice production. In: Ojeniyi SO, IE Esu, UC Amalu, FOR Akamigbo, IJ Ibanga and BA Raji (eds.), Management of Wetland Soils for Sustainable Agriculture and Environment. Proceedings of the 27 th Annual Conference of the Soil Science Society of Nigeria held at Calabar, 5th - 9th November, 2000. 78-89 pp

Mclean EO. 1965. Aluminum methods of soil Analysis part 2. Soc. Agronomy, C. A Blacks ed. Pp 988.

Meysner T, Szajdak L, Kus J. 2006. Impact of the farming systems on the content of biologically active substances and the forms of nitrogen in the soils. Agronomy Research **4,** 531-542.

Nahusenay A, Kibebew K, Heluf G, Abayneh E. 2014. Characterization and classification of soils along the toposequence at the Wadla Delanta Massif, north central highlands of Ethiopia. Journal of Ecology and the Natural Environment **6(9),** 304-320.

Odunze AC. 2006 Soil properties and management strategies for some sub-humid savanna zone Alfisols in Kaduna State, Nigeria. Samaru Journal of Agricultural Research **22,** 3-14

Ogban PI, Ibia TO. 1998. Characteristics and crop production Potentials of wetland Soils from South Eastern Nigeria. Nig. J. Agric. Tech **7,** 78-84.

Ogunwole JO, Iwuafor ENO, Eche NM, Diels J. 2010. Effect of organic and inorganic soil amendments on soil physical and chemical properties in a West African savanna Agroecosystem. Tropical and Sub tropical Agroecosystems **12,** 247-255

Okoji MA. 2002. Strategies for Sustainable Utilization of Wet land soils in Akwa Iborn State. The ISCO Conference Beijing 59-62 Pp

Orji OA, Amaechi PU. 2019. Selected Properties of Two Soil Groups in Rivers State Nigeria IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) **12,** 19-24.

Palaniswamy KM, Gomez KA. 1974. Length-Width Method for Estimating Leaf Area of Rice. Agron. J **66,** 430-433.

Richards R. 2008. Genetic opportunities to improve cereal root systems for dryland agriculture. Plant Production Science **11,** 12-16.

SAS. 2012. Statistical analytical system for linear models: A guide to the ANOVA and GLM procedures SAS Inst. Cary, N.C

Schoeneberger PJ, Wysocki DA, Benham EC (eds) and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln

Sekhar CC, Balaguravaiah D, Naidu MVS. 2014. Studies on genesis, characterization and classification of soils in central and Eastern parts of Prakasam district in Andhra Pradesh. Agropedology **24,** 125-137.

Sharma M, Tarafdar A, Ghosh R, Gopalakrishanan S. 2017. "Biological Control as a Tool for Eco-friendly Management of Plant Pathogens", in *Advances in Soil Microbiology: Recent Trends and Future Prospects*. Eds. Adhaya, T. K., Mishra, B. B., Annapurna, K., Verma, D. K., Kumar, U. (Singapore: Springer Nature Singapore), 153-189.

Soil Survey Staff. 2014. Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 51, Version 2.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Stockman CA, Collins T, Barnes AL, Miller D, Wickham SL, Beatty DT, Blache D, Wemelsfelder F, Fleming PA. 2013. Flooring and driving conditions during road transport influence the behavioral expression of cattle. Applied Animal Behaviour Science **143,** 18-30.

Teferi E, Bewket W, Simane B. 2016. Effects of land use and land cover on selected soil quality indicators in the headwater area of the Blue Nile basin of Ethiopia Environ. Monit. Assess p. 83-188

Udo Bassey, Utip U, Kufre Inyang E, Monday T, Idungafa Monday A. 2009. Fertility Assessment Of Some Inland Depression And Floodplain (Wetland) Soils In Akwa Ibom State. Journal of Tropical Agriculture, Food, Environment and Extension **8(1),** 14-19

Vittori Antisari L, Falsone G, Carbone S, Marinari S, Vianello G. 2015. Douglas-fir reforestation in North Apennine (Italy): performance on soil carbon sequestration, nutrients stock and microbial activity. Appl. Soil Ecol **86,** 82-90. http://dx.doi.org/10.1016/japsoil.2014.09.009.

Walkley AJ, Black IA. 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. **37,** 29-38

Whitmore AP, Whalley WR. 2009. Physical effects of soil drying on roots and crop growth. Journal of Experimental Botany **60,** 2845-2857.

Yitbarek T, Beyene S, Kibret K. 2016. Characterization and classification of soils of Abobo Area, Western Ethiopia. Applied and Environmental Soil Science Article ID 4708235.