CHARACTERIZATION, CLASSIFICATION AND SOIL MANAGEMENT STRATEGIES OF EJULE – OJEBE WETLAND SOILS IN IBAJI LOCAL GOVERNMENT AREA OF KOGI STATE, NIGERIA

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ABSTRACT
An investigative studywas carried out in Ejule-Ojebe wetland soils in Ibaji Local Government Area of Kogi State, Nigeria. The aim was to characterize and classify the wetland soils in the area. A reconnaissance survey was conducted and three distinct locations were identified based on the relief. In each location, one modal profile pitwas dug, georeferenced and characterized. The profiles were denoted as EJ_1, EJ_2 and EJ_3.Disturbed and undisturbedsoil samples were collected from identifiedpedogenic horizons for the analysis of physicochemical properties. Results of the morphological features of the soilsshowed that the soils had colour (moist)range of 10YR through 7.5YR to 2.5YR which typifies the soils with variation of colours such as brown, brownish gray, and dull yellow brown, for EJ1, EJ2, and EJ3, respectively.It also showed that the soils were generally deep to shallow; moderately drained to poorly drained. Soil texture showed a range ofsilty loam, clay loam to loam at the surface and clay to loamy sand in the subsurface soils. The soil structure varied frommoderate or strong medium to coarse sub angular and angular blocky. Mean Bulk density of the soils ranged from 1.19 to 1.44 g/cm^3 for surface and subsurface horizons, while the mean total porosity varied between 36.6 and 55.3 percent at the surface and subsurface soils, respectively. Chemical properties evaluated indicated that the soils were strongly acidic with mean soil pH(water) varying between 4.7 and 5.3 at the surface and subsurface soils, respectively, while the organic carbon varied between 4.9 and 27.9g/kg.The total nitrogen varied between 0.1 and 0.6 g/kg. The available phosphorus ranged from 9.39 to 18.23 mg/kg while the exchangeable bases (Ca, Mg, K and Na) had ranges of 3.98 - 5.99, 2.29 - 4.15, 1.87 - 3.68 and 0.58 - 0.75 cmol/kg, respectively. The values of the cation exchange capacity ranged from 8.81 to 14.58 cmol/kg while the base saturation ranged from 83.0 to 93.0%. Based on USDA soil taxonomy, the soils were classified as *FluventicUstropept* following the observed properties.

Key words: Soil properties, Soil horizon, Soil profile, Soil structure, Soil texture, Pedon

INTRODUCTION
Characterizing the wetland soils for agricultural purposes does not only establish relationship between soil properties and the landscape parameters, but also provides preliminary information on the nutrient status, limitations and ensure sound judgment on the behaviour or response of the soil to specific uses (Esu, 2010). Soil characterization is the measurement of soil properties by laboratory procedures, using samples from pedons, the morphology of which has been described by standard procedures and nomenclature (Brady and Weil, 2002). Thus,it is conducted to classify soils, determine chemical and physical properties not visible in field extermination, and to obtain a better understanding of soil genesis and potential.

The classification of soils has to do with the systematic arrangement of soils into groups or categories on the basis of their characteristics (Esu, 2010). This contributes to the alleviation of adverse effects of soil diversity,aid precision agriculture, land use planning and management (Ogunkunle, 2005). This is achieved through the provision of information for the understanding of the morphological, physical, chemical, mineralogical and microbiological properties of the soil through characterization (Ogunkunle, 2005).

Wetlands are characterized by presence of standing water, either at the surface or within the root zone, during all or part of the year, a unique soil type which is known as hydric soil (Brady and Weil, 2002). At wetlands, there is presence of hydrophytic vegetation and fauna which are adapted to surviving under unique saturated conditions. (Brady and Weil,2002). Wetland soils are extensive throughout the world except in major deserts (Brady and Weil,2002). In temperate zones, large areas of wetlands suitable for food production have been developed (Charles *et al*., 2007). In South America and Africa, large wetland areas with potentials for food production remain undeveloped (Aroh, 2003). The tropical climate and increasingly demand for food including rice makeswetland soils attractive for agricultural development in most parts of Africa including Nigeria (Ogban and Babalola, 2009).

Wetland soils are hydromorphic, which are characterized by excess water at least for a short period of time (Ibanga*et al.,* 2005). The soil processes, which operate under such conditions, are called gleying and ferrolysis and these are induced by water saturation if organic matter and soil temperature allow microbial activity (Brady and Weil, 2002). These soils have gleying horizons, and pseudogley horizons, where mottles and concretions of re-oxidized compounds occur. These gley or pseudogley horizons are found either near the surface or at depth depending on the flunctuating water table regime (Ibanga*et al*., 2005). The principal suborders of wetland soils are *Aquent*s, *Aquept*s, *Alboll*s, *Aquod*s and *Aquult*s (Soil Survey Staff, 1999). In Nigeria, about 65,783 ha of wetlands constituting about 7.2% of the total land area have been identified (Ojanuga*et al.,* 2003). The major wetland soils in Nigeria have been classified into Gleysols/Fluvisols and Alfisols, Inceptisols, Entisols, Histisols and Vertisols (Ojanuga*et al*., 2003).

Wetland soils have distinct advantages for rice production. In addition to their water supply, they are usually level and often occur in large land units, making large-scale farming feasible (Brady and Weil, 2002). Other advantages include low erosion hazard and moderate to high inherent fertility (Igwe*et al*., 2004). In order to explore these advantages for improved food production in Ibaji area, this study was conducted with the objective to characterize and classify the wetland soils of Ejule-Ojebe in Ibaji Local Government Area of Kogi State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area is EjuleOjebe in Ibaji Local Government Area of Kogi State, Nigeria. EjuleOjebe is located between Latitudes 06°52'00"N and 06°87'00"N of the equator, and Longitudes 06°48'00"E and 06°80'00"E of the Greenwich meridian. Ibaji is located in the eastern part of Kogi state and has an area of 1, 377 km². The elevation ranges from 30.8 to 36.8 m. It is separated from Edo state to the west by the river Niger, and bordering Delta state in the south. The climate of the study area is humid tropical and the distribution has been studied by Nigeria Metrological Services (2006) as quoted by Ukabiala (2012). There are essentially two major seasons - the rainy and the dry seasons. The former, which lasts from March to October, is characterized by high rainfall with 1523mm – 1625 mm as the range of the annual mean rainfall (Ukabiala, 2019). The distribution is with peaks in July and September. The dry season lasts from November to February. The temperature is generally high and rarely falls to 21^{o} C throughout the year (Ukabiala, 2019). The mean annual maximum temperature ranges from 29^{o} C – 32^{o} C (Ukabiala, 2022).

The relative humidity ranges from 58 to 85% except during the desiccating period of the The vegetation of the area is Guinea savanna with grasses and herbaceous undergrowth. There are only a few stands of remnant forest trees in the area. The main vegetative cover is secondary due to the influence of man through bush burning, clearing and land cultivation (Akamigbo, 2009). The soils of the area are generally derived from mainly alluvium, colluvium and Agwu Shale Group (Asadu and Eze, 2003). These geological formations usually give rise to sandy and clayey soils respectively (Akamigbo and Asadu, 1983). The soils of the lowlands show strong mottling of gray and red colour due to periodical water logging (Akamigbo, 2005). They have a dominance of sandy materials due to the nature of the alluvial parent materials (Akamigbo, 2005).

The landscape adjoining the River Niger at Ejule – Ojebe in Ibaji Local Government Area of Kogi State is low – lying with a nearly level physiography, and an average elevation of 26 m above mean seal level. The soils are deep and poorly to moderately drained (Tables 1).

Field Work

Field reconnaissance was done with a base map produced at a scale of 1: 25,000. The identification and sitting of positions for the soil profiles on the plain were done by free survey method. Three (3) profiles representing soils on the wetland plain were denoted as EJ_1, EJ_2 and EJ_3. The freshly dug profile pits were geo-referenced. The profile pits and their environs were described (field characterization) following USDA guidelines forsoil profile description and soil sampling (Schoenebergerer*et al*., 2012). The identified pedogenetic soil horizons were sampled from the lowest horizon to the top to avoid contamination. The materials that were used in the field work include spade, hand trowel, cutlass, global positioning system (Garmin Etrex 10), tape, Abney level and munsell soil colour chart). Properties such as soil colour, soil structure, soil texture, root consistency, horizon boundary and faunal activity were observed morphologically. Soil samples (disturbed) were collected from the bottom of the soil profiles to the surface to avoid soil contamination while undisturbed soil samples were collected with soil cores from each soil horizon.

LABORATORY ANALYSES

Sample Preparation

The disturbed and undisturbed soil samples were transported to soil science laboratory for the physical and chemical analyses. In the laboratory, the disturbed soil samples were air-dried under shade and sieved through a 2mm sieve prior to the routine laboratory analyses while the undisturbed soil samples were saturated in water for determination of K_{sat} and other physical parameters.

Physical Properties

Particle size analysis was done by the hydrometer method as described by Juo (1979) using sodium hexametaphosphate (Calgon) as the dispersant. The bulk density, moisture content and total porosity were determined by the procedure outlined by Arshad *et al.* (1996) as thus:

$$\text{Bulk Density } = \frac{\text{Mass of oven dry soil}}{bulk\ volume\ of\ soil} \ldots\ldots\ldots\ldots 1$$

In determining the soil moisture content, ten (10) grams of the soil samples was weighed into a can of known weight, dried in an oven at 105°C for 24 hours and reweighed. Moisture content was calculated as:

$$\text{Moisture Content (\%)} = \frac{\text{fresh weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \text{X100} \ldots\ldots\ldots 2$$

The total porosity, macro porosity and the micro porosity were calculated using this formula;

$$\text{Total porosity} = \frac{\text{Saturation wt} - \text{Oven dry wt}}{\text{Volume of core}} \ldots\ldots 3$$

Chemical Properties

Soil pH was determined in duplicates, both in distilled water and 0.1N KCl solution, using a solid: liquid ratio of 1: 2.5 as outlined inMcleans(1982). The exchangeable acidity was determined by titrimetric method using 1N KCl extract as outlined in Mclean(1982). The total nitrogen was determined by micro-kjeldahl method (Bremmer and Mulvaney, 1982). The soil organic carbon was determined using the method explained inNelson and Sommers (1982). The available phosphorus was determined using the Bray II method (Olsen and Sommers, 1982). The exchangeable calcium and magnesium were determined by the titration method (Jackson, 1962). The determination of exchangeable sodium and potassium were from 1N NH_4OAc (Ammoniun acetate) at pH 7 of the leachate using the flame photometer. Cation exchange capacity (CEC) was determined by Ammonium acetate method of Rhoades (1982).Fifty milliliters of the leachate was pipepetted and 20mls of 20% formaldehyde was added to it and then titrated with 0.1N NaOH until pink color is shown. Effective cation exchange capacity (ECEC) was estimated by summing the exchangeable bases (Ca, Mg, K and Na) and Exchangeable Acidity. The percentage base saturation (PBS) was calculated by summing up the exchangeable bases and dividing by the respective CEC and multiplying the quotient by 100.

$$BS = \frac{TEB}{ECEC} X\ 100 \ldots\ldots\ldots\ldots.. 4$$

Where TEB = Total exchangeable bases

ECEC = Effective Cation exchange capacity

The Carbon-Nitrogen ratio was calculated by finding the quotient of the carbon and nitrogen in the samples.

Statistical Analysis

The data collected were analyzed using descriptive statistics with the help of SPSS software.

Soil classification

The soils were classified in accordance with the USDA Key to Soil Taxonomy (2014) and approximately correlated with FAO/UNESCO of the World Reference Base (2015).

RESULTS AND DISCUSSION

Morphological Characteristics of the soils

The morphological properties of the soils are presented in Tables I. The table shows a range of hues of 10YR through 7.5YR to 2.5YR which typifies the soils with variation of colours such as Brown, Brownish gray and Grayish yellow brown. This finding is in consistent with the work of Ukabiala (2022) who reported colour gradation as a good criterion for interpreting drainage conditions and had dominant rank of colours from very dark grayish and brown at the surface to different shades of brown in the sub-surface layers having hues of 10YR and 7.5YR and values less than 7. The dominant hue of 10YR typifies hydromorphism of the soils (Okusami*et al*., 1987, Ukabiala, 2019). The colour variation might have originated from the shale parent materials, poor drainage condition and organic carbon contents. Similar range of colour was also recorded by Akpan – Idiok*et al.* (2013) for wet soils of Kpata in Bassa Local Government Area of Kogi State, Nigeria.

Mottles were observed in $EJ_1$and EJ_2, which were distinct colour variations of bright yellowish brown, orange and dull yellowish brown. This interprets the seasonal flooding that occurs in the soils, as well as fluctuating water table. The implication of redoximorphic features are that EJ_1 and EJ_2 had alternate wetting and drying conditions that resulted in the reduction and subsequent release of iron oxides, which gave rise to reddish yellow or brown and red mottles. Redoximorphic features associated with flooding/wetness resulted which led to alternating periods of reduction and oxidation of iron and manganese compound in the soils (Ukabiala*et al*. 2022). Horizon delineation varied between clear smooth, clear wavy, gradual smooth and diffuse broken boundaries.

The soil texture of the plain varied between silty loam, clay loam and clay in the surface and subsurface soil layers. This reflects typical soil texture of wetland soils (Ukabiala, 2019).The soils had dominantly moderate and strong medium to coarse sub angular and angular blocky and crumb soil. The consistency was commonly non-sticky and non-plastic in the surface layers but sticky and plastic in the subsurface layers where there are much clay.

Table 1:Morphological characteristics of Ejule-Ojebe wetland soils in Ibaji Local Government Area of Kogi State, Nigeria

Profile/Location/Elevation	Horizon designation	Depth (cm)	Soil colour (Moist)		Texture	Structure	Consistence	Boundary	Others
			Matrix	Mottles					
EJ$_1$ **06^{0}58$^'$18.23$^{''}$N, 06^{0}43$^'$27.7$^{''}$ E Elevation: 30.8 m**	Ap	0 – 9	10YR 4/4 (Brown)	10YR6/8(Bright yellowish brown)	SL	momcr	nsnp	CW	Common fine pores, many fine root
	AB	9 – 75	10YR 6/2(Grayish yellow brown)	-	SC	momsbk	sp	CW	Few irregular fine pores, few very fine roots
	B	75 – 130	2.5YR 7/4 (Light yellow)	-	S	sg	nsnp	GS	Moderate irregular fine pores, few very fine roots.
	Bwg	130-200	10YR 6/2(Grayish yellow brown)	-	C	smabk	vsvp		Few irregular fine pores, very few fine roots
EJ$_2$ **06^0 59$^'$ 35.9$^{''}$ N, 06^0 43$^'$ 42.1$^{''}$E Elevation= 36.8m**	Apg	0-17	7.5YR 5/1 (Brownish gray)	7.5YR 6/8 (Orange)	CL	scocrsbk	sp	CW	Many irregular fine pores, many fine roots
	Bwg1	17-38	10YR 5/3 (Dull yellowish brown)	10YR 7/8 (yellow orange)	CL	momsbk	sp	DS	Many irregular fine pores, many fine roots
	Bwg2	38-71	10YR 5/1 (Brownish gray)	10YR 6/8 (Bright yellowish brown)	C	wmofm sbk	vsvp	DS	Few irregular very fine pores, few fine roots
	Bwg3	71-110	10YR 5/2 (Grayish yellow brown)	10YR 5/4 (Dull yellowish brown)	C	wmofm sbk	vsvp	DS	Very few irregular pores, few very fine roots
	Cg1	110-162	10YR 6/1 (Brownish gray)	10YR 5/4 (Dull yellowish brown)	C	wfmsbk	vsvp	DS	Very few irregular fine pores, very few roots, few ants
	Cg2	162-200	10YR 6/2 (Grayish yellow brown)	-	C	momsbk	vsvp		Very few irregular fine pores, few very fine roots.
EJ$_3$ **07^0 1$^'$25.3$^{''}$ N, 06^0 44$^'$ 1.8$^{''}$ E. Elevation= 31.8m**	Apg	0 – 17	10YR 4/3 (Dull yellow brown)	-	L	mofmcrg	nsnp	CW	very few fine pores, common fine roots
	Bwg1	17- 48	10YR 4/4 (Brown)	-	L	mofmcrg	nsnp	CW	Few irregular fine pores, few very fine roots
	Bwg2	48-117	10YR 5/4 (Dull yellowish brown)	-	LS	wmofm crsbk	nsnp	GW	Few very irregular fine pores, few very fine roots
	Bwg3	117-150	10YR 5/8	-	LS	wfmcrs	nsnp	GS	Few irregular fine pores, few very fine

		(Yellowish brown)				bk		roots
Cg	150-200	10YR (Yellow brown)	7/8	-	S	sg	nsnp	Very few irregular fine pores, few very fine roots

LS: loam sand; SCL: sandy clay loam; LS: Loamy Sand; CL: Clay Loam; SL: Silty Loam; SC: Silty Loam; C: Clay; L: Loam; S: Sand; f: fine; g: granular; vf: very fine; m: medium; mo: moderate; ; f: few; c: coarse; m: many sbk: sub angular blocky;sg: single grained; ns: not sticky; np: not plastic; ss: slightly sticky; sp: sticky and plastic; vsvp: very sticky and very plastic; CW: clear wavy; GS: gradual smooth; DS: Diffuse Smooth; GW: gradual wavy; AW: abrupt wavy;

Other pedological significant inclusions such as roots, ants, manganese, concretions, mica flakes, among others were identified in the soils of Ejule-OJebe wetlands.Akpan-Idiok*et al*. (2006) reported similar findings on wet soils of Abini in Southeast of Nigeria.

Physical Characteristics of the Soils

The soil physical characteristics of the soils are presented in Table 2. The mean g/kg of sand, silt and clay in the surface soils are 621.4, 119.9 and 258.7 while the subsurface soils had 596.2, 71.2 and 332.6, respectively. This pattern of particle size distribution gave rise to the dominant sandy clay loam texture in the surface; sandy clay and clay in the subsurface soils.With the clay contents more than 20% in the surface and subsurface soils, the wetland has the capacity to retain adequate moisture for crop plants during dry season. The study has revealed that the soils have characteristics of wetlands in which the vertical and horizontal variation in texture is due to sedimentation and micro-topography (Akpan-Idiok*et al*., 2013; Ukabiala, 2012).

The silt/clay ratios ranged from 0.25 to 0.78 with mean value of 0.49 and 0.02-.0.49 with mean value of 0.20 in the surface and subsurface soils, respectively.Silt/Clay ratios of any given soil that is below 0.15 is an indication that the soils are of old parent materials, while those above 0.15 are indicative of young parent materials with low degree of weathering (Van Diepen, 1985). This implies that, the wetland soils in Ejule –Ojebe under investigation are of young parent materials and the degree of weathering are low. Furthermore, the study revealed that the sand/silt ratio, which were 5.89 (surface mean value) and 43.43 (subsurface mean value) refers to the relative amount of sand and silt in soils. The ratios obtained indicate the parent materials of the wetland as alluvium and that the poorly drained profiles are under low degree of weathering (Brady and Weil, 2002).

Bulk density ranged from 1.19 - 1.24 g/cm^3 with mean value of 1.22g/cm^3 and 1.21-1.53g/cm^3 with mean value of 1.41g/cm^3 in the surface and subsurface soils respectively, and increased gradually with depth. This could be as a result of decreased organic matter contents of the soils down the profile, less aggregation and compaction caused by the weight of overlying soil layers. These values fall within the range of 1.00-1.60 g/cm^3 given by Brady and Weil (2002) for most mineral soils. The study also has shown that the total porosity ranged from 18 to 54 percent with mean value of 41.7 percent, and 16 to 51 percent with mean value of 35.6 percent. This is consistent with the finding of Ojanuga*et al*. (2003) who studied wetland soils of Nigeria, and reported average total porosity of about 50%. The moisture content of the soils ranged from 5 to 18 percent and 3 to 25 percent with mean values of 11 and 13.5 percent in the surface and subsurface soils respectively. This is consistent with the finding of Akpan*et al.*, (2006) on wetland and coastal plain soils in Calabar, Cross River State.

Chemical Characteristics of the Soil

The chemical characteristics of the soils are presented in Table 3. The soil pH ranged from 4.4 to 5.1 and 4.6 to 6.2 with mean values of 4.8 and 4.9 in the surface and subsurface soils, respectively. This indicates that the soils were strongly acidic. The acidic nature of the soils could be attributed to the characteristic high rainfall nature of the environment and excessive leaching. The acidic nature of similar soils was reported by several authors (Akpan – Idiok, 2002) The low values of pH (<5) could be due to the dominance of $A1^{3+}$ and H^+ ions in the soils exchange complex (Soil Survey Staff, 2003). Also, it could be inferred that the acidic condition of the wetland soils studied is attributed to greater oxidation of anions like sulphides and nitrites. The difference between values of soil pH determined in 1NKCl solution and in distilled water is referred to as delta pH. It illustrates that all the layers of the soil profiles possessed net negative charges. In the soils studied, the delta pH values ranged from -0.6 to -0.5 in the surface soils and -0.7 to -0.5in the subsurface soils. In all the horizons of the profiles, the pH values determined in distilled water were higher than the corresponding samples measured in 1KCl solution. This indicates that the soils bear negative surface charges and such soils can retain basic nutrients for subsequent release into the soil solution for plant absorption.

Table 2: Physical Characteristics of Ejule – Ojebe Wetland Soils in Ibaji Local Government Areas of Kogi State, Nigeria.

Profile location	Horizon depth (cm)	Practice size distribution			Textural class	Silt/clay ratio	Sand/silt ratio	Bulk density (g/cm^3)	Porosity (%)	Moisture content (%)
		Sand (g/kg)	Silt (g/kg)	Clay (g/kg)						
EJ_1	0-9	594.0	178.4	227.6	SCL	0.78	3.33	1.24	53	10
$0.6^0$58’18.23’’N,	9-75	484.0	158.4	357.6	SC	0.44	3.06	1.31	51	13
$06^0$43’27.7’’E	75-130	822.4	5.6	172.0	SL	0.03	146.86	1.43	46	3
Elevation: 30.8m	130-200	484.0	158.4	357.6	SC	0.44	3.06	1.51	43	15
EJ_2	0-17	618.0	75.6	306.4	SCL	0.25	8.17	1.19	18	18
$06^0$59’35.9’’N,	17-38	742.4	85.6	172.0	SL	0.49	8.67	1.21	25	25
$06^0$43’42.1’’E	38-71	424.0	108.4	467.6	C	0.23	3.91	1.33	21	21
Elevation: 36.8m	71-110	418.0	115.6	466.4	C	0.25	3.62	1.40	16	16
	110-162	412.4	115.6	472.0	C	0.24	3.56	1.47	20	20
	162-200	438.0	55.6	506.4	C	0.11	7.88	1.53	22	22
EJ_3	0-17	652.4	105.6	242.0	SCL	0.44	6.18	1.23	54	5
$07^0$1’25.3’’N,	17-48	594.0	28.4	377.6	SC	0.08	20.92	1.37	48	12
$06^0$44’1.8’’E	48-117	698.0	5.6	296.4	SCL	0.02	124.64	1.40	47	9
Elevation: 31.8m	117-150	814.0	8.4	177.6	SL	0.05	96.90	1.46	45	3
	150-200	824.0	8.4	167.6	SL	0.05	98.09	1.52	43	3
Surface range		594.0-652.4	75.6-178.4	227.6-306.4		0.25-0.78	3.33-8.17	1.19-1.24	18-54	5-18
Surface mean		621.4	119.9	258.7	SCL	0.49	5.89	1.22	41.7	11
Subsurface range		412.4-824.0	5.6-158.4	167.6-506.4		0.02-0.49	3.06-146.86	1.21-1.53	16-51	3-25
Subsurface mean		596.2	71.2	332.6	SCL	0.20	43.43	1.41	35.6	13.5

SCL: sandy clay loam, SC: sandy clay, SL: sandy loam, C: clay

The organic carbon content in the soils ranged from 20.7 to 39.4 g/kg with mean value of 27.9 g/kg at the surface soil and 2.5 to 9.9 g/kg with mean value of 5.5 g/kg in the subsurface soil. The values tend to decline with depth. The organic carbon contents were high in the surface depth of the pedons but declined with depth, judging from the critical level of 15.0g/kg by Landon (1981). The high organic carbon content in the wetland soils could be attributed to high amount of plant litter and slow decomposition processes that usually accompany wetland environment (Patrick, 1990).The organic matter content ranged from 35.7 to 67.9 g/kg with mean value of 48.1 g/kg. The reason for this range is similar to that for the organic carbon.

Total Nitrogen was low across the pedons with mean values of 0.4 and 0.3 g/kg in the surface and subsurface soils respectively. The low nitrogen level may be associated with intermitted flooding and drying which is known to favour nitrogen loss through denitrification process. Similar finding was reported by Onweremadu*et al.*, 2007) on wetland soils in Nigeria.

The carbon – nitrogen ratio values ranged from 20 to 21 with mean value of 21 in the surface layers, 15 to 25 with mean value of 21 in the subsurface soils. The C: N ratios were narrow as the values were less than 25 (Akamigbo, 2005), being the separating index for mineralization and immobilization of nitrogen in the soils. The implication of narrow C:N ratio reflected high microbial activity and humification process for the release of nutrient elements for crops plants. Similar findings were reported for wetland soils of Obubra, and Onwuriver in Cross River State (Akpan – Idiok*et al.*, 2006; Ogbaji, 2010). Available phosphorus in the soils ranged from 16.21 to 21.20 mg/kg with mean value of 18.23 mg/kg, and 6.87 to 15.48 mg/kg with mean value of 11.04 mg/kg in the surface and sub-surface soils respectively. The available phosphorus content was generally moderate as the values were below the critical value of 15 mg/kg (FPDD, 1989).
The low values could be associated with high contents of sesquioxides, high phosphorus absorption capacity and the acidic nature of the soils. Exchangeable Calcium was moderate and ranged from 4.87-7.28 cmol/kg with mean of 5.99cm/kg and 3.33-6.11 cmol/kg with mean of 4.52 cmol/kg in the surface and sub-surface soils. Exchangeable magnesium ranged from 3.29 to 4.83 cmol/kg with mean value of 4.15 cmol/kg in the surface soils and 1.94 to 3.82 cmol/kg with mean of 2.69 cmol/kg in the subsurface soils. Exchangeable potassium in the soils ranged from 2.81 to 4.20 cmol/kg with mean value of 3.68 cmol/kg in the surface while the subsurface had 1.60 - 3.46 cmol/kg with mean value of 2.36 cmolkg. The exchangeable sodium ranged from 0.51 to 0.89 cmol/kg with mean value of 0.73 cmol/kg as well as 0.51 to 1.15 cmol/kg with a mean value of 0.72 cmol/kg in the surface and sub-surface soils.

Exchangeable Ca, Mg and K generally decreased with soil depth in all the soil profiles. Calcium, magnesium and potassium were the predominant exchangeable bases and the cation distribution was of the order Ca> Mg > K > Na in the soils. The total exchangeable acidity (TEA) in the soils ranged from 0.89 to 1.22 cmol/kg with mean value of 1.06 cmol/kg in the surface soil layers while the subsurface had 1.29 to 1.93 cmol/kg with mean of 1.64 cmol/kg. Akpan-Idiok, (2002) recorded similar results in his work on mangrove swamp soils in Cross River.Cation exchange capacity in the soils ranged from 11.56 to 17.20cmol/kg with mean of 14.58cmol/kg in the surface soils, and 7.55-13.98cmol/kg with mean of 10.31 cmol/kg in the sub-surface soils. The CEC decreased consistently from the surface to the subsurface horizons in accordance with the organic carbon content. The effective Cation Exchange Capacity (ECEC) ranged from 12.78 to 18.09 cmol/kg with mean of 15.64cmol/kg in the surface soils and 9.48 to 15.29 cmol/kg with mean of 11.95 cmol/kg in the sub-surface soils. The soils are rated medium (>4.0cmol/kg) to high (>10.0cmol/kg) in effective cation exchange capacity and are therefore productive soils. Similar results were obtained in the wetland soils of Itigidi and Akraba-Itekpa in Cross River State of Nigeria (Akpan-Idiok*et al.*, 2006; Ogbaji, 2010). The last but not the least is the percentage base saturation which ranged from 90.0 to 95.0 % with mean of 93.0% at the surface and 80.0 to 91.0 % with mean of 86.0% in the sub-surface soils. Base saturation values were generally high which indicates that the basic cations are in soluble forms for crop plant absorption.

Table 3: Chemical Characteristics of Ejule – Ojebe Wetland Soils in Ibaji Local Government Areas of Kogi State, Nigeria.

Pedon/location and Elevation	Horizon depth (cm)	pH			OC (g/kg)	OM (g/kg)	TN (g/kg)	C:N	EC (dS/m^1)	Av. P (mg/kg^1)
		KCl	H_20	ΔpH						
EJ_1	0-9	3.8	4.4	-0.6	20.7	35.7	1.0	21	0.10	16.21
	9-75	4.0	4.6	-0.6	7.9	13.6	0.4	20	0.03	14.89
0.6^{0}58`18.23''N,	75-130	4.5	5.1	-0.6	3.0	5.2	0.2	15	0.41	10.05
06^{0}43`27.7``E Elevation: 30.8m	130-200	5.0	5.7	-0.7	4.7	8.1	0.2	24	0.01	8.11
EJ_2	0-17	4.3	4.8	-0.5	39.4	67.9	1.9	21	0.14	21.20
06^{0}59'35.9`` N,	17-38	4.7	5.3	-0.6	9.9	17.1	0.5	20	0.09	15.48
06^{0}43`42.1''E	38-71	5.0	5.7	-0.7	6.1	10.5	0.3	20	0.08	18.06
Elevation: 36.8m	71-110	5.7	6.2	-0.5	6.8	11.7	0.3	23	0.12	11.32
	110-162	5.1	5.8	-0.7	6.8	11.7	0.3	23	0.14	10.11
	162-200	5.0	5.5	-0.5	6.3	10.9	0.3	21	0.31	8.07
EJ_3	0-17	4.6	5.1	-0.5	23.6	40.7	1.2	20	0.05	17.28
07^{0}1'25.3``N,	17-48	4.2	4.9	-0.7	9.4	16.2	0.5	19	0.02	14.22
06^{0}44`1.8''E	48-117	5.5	6.1	-0.6	2.5	4.3	0.1	25	0.01	12.08
Elevation: 31.8m	117-150	4.3	4.8	-0.5	4.1	7.1	0.2	21	0.01	9.20
	150-200	4.3	4.9	-0.6	4.9	8.4	0.2	25	0.08	6.87
Surface range		3.8-4.6	4.4-5.1	-0.5- -0.6	20.7-39.4	35.7-67.9	1.0-1.9	20-21	0.05-0.14	16.21-21.20
Surface mean		4.2	4.8	-0.5	27.9	48.1	1.4	21	0.09	18.23
Subsurface range		4.0-5.7	4.6-6.2	-0.5- -0.7	2.5-9.9	4.3-17.1	0.1-0.5	15-25	0.01-0.41	6.87-15.48
Subsurface mean		4.8	4.9	-0.6	5.5	10.4	0.3	21	0.11	11.04

OM: organic matter; TN: total nitrogen; Av. P available phosphorus; EC: Electrical Conductivity; C:N: Carbon Nitrogen ratio

Table 3 continued

Profile Location	Horizon depth (cm)	Exchangeable Bases Cmol (+) kg^{-1}				EA($cmolkg^{-1}$)	CEC ($cmolkg^{-1}$)	ECEC ($cmolkg^{-1}$)	PBS (%)
		Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	(H^{+} + Al^{3+})			
EJ_1	0-9	4.87	3.29	2.81	0.51	1.22	11.56	12.78	90.0
0.6⁰58'18.23''N,	9-75	4.53	2.74	2.28	0.55	1.53	10.10	11.63	87.0
06⁰43'27.7''E Elevation:	75-130	4.36	2.27	1.83	0.69	1.73	9.15	10.88	84.0
30.8m	130-200	4.06	2.11	1.60	0.69	1.63	8.46	10.09	83.0
EJ_2	0-17	7.28	4.83	4.20	0.89	0.89	17.20	18.09	95.0
06⁰59'35.9''N,	17-38	6.11	3.82	3.43	0.62	1.31	13.98	15.29	91.0
06⁰43'42.1''E	38-71	5.14	3.29	2.84	0.81	1.56	12.08	13.64	89.0
Elevation: 36.8m	71-110	4.80	2.68	2.51	0.93	1.70	10.92	12.62	87.0
	110-162	4.22	2.46	2.01	1.10	1.84	9.70	11.54	84.0
	162-200	4.07	2.42	1.89	1.15	1.91	9.53	11.44	83.0
EJ_3	0-17	5.84	4.32	4.02	0.80	1.06	14.98	16.04	93.0
07⁰1'25.3''N,	17-48	5.08	3.51	3.46	0.59	1.29	12.56	13.85	91.0
06⁰44'1.8''E	48-117	4.46	2.81	2.52	0.62	1.58	10.41	11.99	87.0
Elevation: 31.8m	117-150	4.14	2.33	2.19	0.59	1.72	9.23	10.95	84.0
	150-200	3.33	1.94	1.77	0.51	1.93	7.55	9.48	80.0
Surface range		4.87-7.28	3.29-4.83	2.81-4.20	0.51-0.89	0.89-1.22	11.56-17.20	12.78-18.90	90.0-95.0
Surface mean		5.99	4.15	3.68	0.73	1.06	14.58	15.64	93.0
Subsurface range		3.33-6.11	1.94-3.82	1.60-3.46	0.51-1.15	1.29-1.93	7.55-13.98	9.48-15.29	80.0-91.0
Subsurface mean		4.52	2.69	2.36	0.72	1.64	10.31	11.95	86.0

H^{+}: exchangeable hydrogen; Al^{3+}: exchangeable aluminum; Ca^{2+}: exchangeable calcium; Mg^{2+}: exchangeable magnesium; Na^{+}: exchangeable sodium; K^{+}: exchangeable potassium; EA: exchangeable acidity; CEC: cation exchange capacity; ECEC: effective cation exchange capacity; BS: base saturation

Taxonomic Classification

The profiles had umbricepipedon and cambic horizon with moist colour value of 4 or more, chroma of 4 and was seasonally flooded with minimal horizon development and was placed in the order of Inceptisol according to the criteria of USDA soil taxonomy (Soil Survey Staff, 2014). The pedon had ustic moisture regime for most part of a normal year and was classified in the suborder as Ustepts and being a pedon in the tropical environment it was further placed in the great group as Ustropept. With brown to grayish brown (10YR 4/4)colour at the surface and light yellow (2.5YR 7/4)colour in the surface with redox concentration as magnified by common medium to coarse distinct bright yellowish brown mottles (10 YR 6/8)colour at the depth of 0- 9cm, the soil was classified at the subgroup level as FluventicUstropept (USDA) which correlated with EutricFluvisol of the FAO – World Reference Base.

Potential of the Soils for Agricultural Production

Characterizing wetland soils in relation to food production requires taking into account the factors that influence the potential productivity of the soils. Among them are nearly level topography, minimal soil erosion, natural fertility and location in climatic region of adequate rainfall for most groups (Akpan – Idiok, 2002). The wetland soils at EjuleOjebe in Ibaji Local Government Area are on nearby level terrain, having poor natural drainage and may favour rice production under mechanized farming operations. The soils are derived from shale and alluvial material. Such soils are clayey in nature and have retention capacity for basic nutrients and low infiltration rates that can support surface irrigation for paddy rice cultivation.

The effective cation exchange capacity of the soils exceeds 10.00 Cmolkg^{-1}(please be consistent in your style of SI units e.g. either Cmol / kg or Cmol kg^{-1})required for productive soil in the ecological zone. The extensive soil area with loamy texture is slightly acidic or neutral in reactions, indicating that the basic nutrient (Ca, Mg, K) are in soluble forms for crop absorption. Such level of pH favours microbial activities, so the soils have high potential for crop production. Organic carbon contents exceed 1.00% in all the surface soils, indicating that the soils can sustain production of paddy rice and other crops in the area.

Soil Management Strategies

The soil could be regarded as "special use land" for proper management for profitability under irrigated agriculture once the flood water recedes during the dry seasons in the area. The management strategies may include the following;

Drainage

Whenever irrigation is carried out, drainage must be done. Drainage controls excess water accumulation and makes the soil more stable for crop growth. It also provides a healthier surrounding and prevents the danger of soil erosion. The open drainage system using ditches may be suitable, if the soils are put into irrigation for cultivation of paddy rice.

Soil conservation measures

Soil erosion causes land degradation which involves the detachment and transport of soil constituent by water. In the study area, human activities that accelerate soil erosion include indiscriminate destruction of vegetation cover through bush burning, deforestation and wood collection. The surface soils should be protected by adopting cultural practices such as cultivation of legumes and incorporation of organic matter into the soils.

Maintenance of soil fertility

The fertility of soils in the area is rated moderate to high. Therefore, the proper soil management strategies to maintain the fertility of the soils should include spreading of crop residue on the soils after harvesting, inclusion of grasses and legumes during fallow. The strongly acidic soils can be controlled by liming. This increases available P, supplies Ca and Mg and eliminates any toxic substances such as Al^{3+} ions. Periodic soil tests are recommended to ascertain pH levels at a time in order to avoid over-limming. The use of limestone is preferable because they are cheap and abundant in Nigeria. Where soil reaction is strongly acidic such as soils within the back swamps (depressions), liming could be applied to enhance the productivity of the soils.

Planting of suitable crops

It is more profitable to cultivate crop most fitted to a particular land. Some inherent qualities of a land that may not easily be adjusted will natural support crops best for it. For instance, soil characteristics like texture cannot easily change. Ukabiala (2022) evaluated the suitability of wetland soils, and observed that the soils are highly suitable for rice, and moderately suitable for maize, cassava and oil palm production. This means that rice can be cultivated all year round with good drainage in the rainy season and irrigation in the dry season. Short season crops like vegetables can be cultivated during the dry spell with irrigation since the land is adjacent to the water body.

Conclusion

The wetland soils of EjuleOjebe in Ibaji Local Government area of Kogi State were studied based on the morphological, physical and chemical properties of these soils. Theses soils were formed from shale and recent alluvial deposits. They are poorly drained with light to heavy textural materials and various shades of brown. Result of the physical properties, showed sand as the dominant particle size fraction, also using sand/silt ratio of 0.2, the high sand/silt ratio obtained indicate the parent materials of wetland as alluvium and that the poorly drained profiles are under low degree of weathering. The soils are also characterized as strongly to slightly acidic in reaction. The values of effective cation exchange capacity and percentage based saturation conferred to these soils as moderate to high in fertility status.

Recommendation

The wetland soils of EjuleOjebe can serve as a medium for crop cultivation if properly managed. Hence, there is the need to continually monitor the fertility status of the soils for effective optimization of the potential of these soils for food security and sustainable agriculture.

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