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Characterization And Suitability Variation Between The Levee And Backswamp Of Floodplain With Respect To Rice Cultivation: A Case Study Of Ibaji Floodplain Soils In Kogi State Of Nigeria

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Abstract
Floodplain soils and the usual high fertility status have always drawn the attentions of agriculture experts towards their sustainable and optimum use and development. However, little attention has been drawn to possible fertility variations that occur along the landscape. Thus, this study was designed to ascertain variations that may occur between the levee and backswamp parts of floodplain, using Ibaji floodplain as a case study. The soil texture was sandy clay loam in the surface horizons while the soil bulk density varied between 1.24 and 1.20 g cm^{-3}. The soil moisture content in levee surface soil was 54% as against the backswamp (11%). The soil pH of Backswamp is lower (3.8) while the highest organic carbon content was recorded in the levee (32.1 g kg^{-1}). The available phosphorus ranged from 13.13 to 14.84 mg kg^{-1} while the levee recorded highest cation exchange capacity (14.69 $cmol_c$ kg^{-1}). Coefficient of variation (CV) above 75% was expressed in silt, sand:silt ratio and soil moisture content while <2% CV was recorded for porosity. The suitability evaluation of the soils revealed that the levee soil was moderately suitable (S_2) while the backswamp was marginally suitable ((S_3) for rice cultivation.
Keywords: Floodplain, Suitability, Rice, Characterization, Soil characteristics, pseudogley

Introduction

Soil characterization is the measurement of soil properties using samples from pedons. Characterizing floodplain 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 suitability evaluation according to Ande (2011) involves characterizing the soils in a given area for specific land use type. Land suitability is the fitness of a given type of land for a defined use, which may be considered in its present condition or after improvements (Akamigbo, 2010). The suitability of a given piece of land is its natural ability to support a given or specific purpose. Akamigbo (2010) viewed land suitability evaluation as a statement of the adaptability of a given area for a specific kind of land use. It is also function of crop requirements and soil characteristics (Khan and Khan, 2014). Matching the soil characteristics with the crop requirements provides suitability. Akamigbo, (ibid) summarized that hence, suitability with respect to specific crop is a measure of how well the qualities of a soil unit match the requirements of that particular form of soil use/land use, which aims at evaluating and classifying land units on the basis of specific land and soil features as well as their limitations.

Floodplains 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 is formed which is known as hydric soils. There are commonly presence of hydrophytic vegetation and fauna which are adapted to surviving under unique saturated conditions (hydrophytes), and absence of flooding intolerant vegetation (Akpan-Idiok *et al*., 2013). Large floodplain areas with potential for food production are undeveloped in Nigeria according to Aroh (2003).

The soil processes, which operate in hydric soil conditions are called gleying which is induced by water saturation if organic matter and soil temperature allow microbial activity. These soils have gleying and pseudogley horizons, where mottles and concretion 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 (Akpan-Idiok *et al*., 2013). Floodplain soils have distinct advantages for rice production. The tropical climate and increasingly demand for food including rice makes floodplain soils attractive for agriculture development (Akpan-Idiok *et al*., 2013). In addition to their ample water supply, they are usually level and often occur in large land units, making large-scale farming feasible. Other advantages include low erosion hazard and moderate to high inherent fertility (Ukabiala, 2012).

A build-up of alluvium on the banks of a river can create levees, which raise the river bank. Levees are formed by the repeated flooding of the river. When the river floods, the biggest, most coarse materials will be dumped close to the river banks, while the less coarse materials are transported further on the backswamp of the floodplain. This will continue to build up the levee over time. Because natural levees form during high-flow events, their soil texture is coarser than adjacent backswamp deposits (Cazanacli and Smith, 1998). Newman and Keim (2012) also reported that natural levees are potentially locally important zones of lateral seepage between stream channels and floodplain backswamps, because their relatively coarser soils provide pathways of high hydraulic conductivity in an otherwise low conductivity system. Thus, therefore every tendency that fertility of the levee and the backswamp of the floodplain will vary due to the established textural variation, which will subsequently influence their productivity. Following this concept, this study aimed at establishing the fact of variation that may exist between these two parts of the landscape, with respect to productivity through suitability evaluation.

Materials and Methods

Study Area

The study was conducted at Ejule-Ojebe in Ibaji Local Government Area of Kogi State, Nigeria. Ejule Ojebe is located between Latitude 06°52'00"N 06°87'00"N of the equator, and Longitude 06°48'00"E 06°80'00"E of the Greenwich meridian. Ibaji is located in the eastern part of Kogi state (Figure 1) and has an extension of 1, 377 km². It is separated from Edo state to the west by the river Niger, and bordering Delta state in the south.

Climate of the Study Area

The climate of the study area is characteristic of the humid tropics, and the distribution has been studied by Nigeria Metrological Services (2006) as quoted by Ukabiala *et al*. (2021). There are essentially two major seasons - the rainy and the dry seasons. The rainy season lasts from March to October, is characterized by high rainfall with 1523mm – 1625 mm as the range of the maximum annual mean rainfall. The distribution is with peaks in July and September. The dry season extends from November to February. The temperature is generally high and rarely falls to 21^{0}C throughout the year (Ukabiala, 2019). The mean annual maximum temperature ranges from 29^{0}C - 32^{0}C (Ukabiala, 2019).

Field Work

The study adopted a free survey technique. On a trip to the site, profile points were selected one each along the levee and the backswamp of the floodplain. The profiles were dug to specification and described following USDA guidelines for description and sampling soils (Schoeneberger *et al*., 2012). Each soil profile was also geo-reference and noted as Levee ($0.6^{0}58'34.6''$N, $06^{0}42'36.6''$E) and Floodplan ($0.6^{0}58'32.15''$N, $06^{0}43'55.28''$E).

Figure 1: Map of Nigeria showing Kogi and Ibaji Local Government Area

The elevation of the points were 29.9 m and 25.5 m at the levee and floodplain, respectively. The equipments/materials used for the field work includes a hand-held Etrex high sensitivity Global Positioning System (GPS), Abney level, Core samplers, sampling bags, Trowel, sampling bowel, masking tape and measuring tape. Soil samples were collected from each identified horizon, packed in well-labelled polyethylene bags and transported to Soil Science Laboratory for physicochemical analyses.

Physico-chemical Analyses of Soils from the Study Area

Particle size distribution was determined on the < 2 mm fraction of the air-dry and sieved samples using Bouyoucous (1962) hydrometer method, using sodium hydroxide as a dispersant while the soil textural classes were read out from the USDA soil textural triangle. The soil bulk density was determined by the core method as outlined in Landon (1981). The expression is as thus;

Soil bulk density = oven dry weight of soil / volume of soil……….eq 1

Soil porosity was calculated with the values of the bulk density using the method outlined by Vomicil (1965) and Brady and Weil (2002):

Total porosity (%) = (1 − Bulk Density /Particle Density) × 100 /1…….eg 2

Soil saturated hydraulic conductivity (*Ksat*) was determined following the method described in Klute and Dirksen (1986). This is the transposed Darcy's equation for vertical flows of liquids;

Ksat = QL/At.ΔH

where *Ksat* is saturated hydraulic conductivity (cm h−1),

Q is steady-state volume of water outflow from the entire soil column (cm3), *A* is cross-sectional area (cm2), *t* is time interval (h), *L* is length of the sample

(cm), and ΔH is change in the hydraulic head (cm).

Soil pH was determined in water and 1N KCl solution using a soil solution ratio of 1:2.5 with the aid of a glass electrode pH meter (McLean, 1982) while the organic carbon was determined by wet dichromate acid oxidation method explained in Nelson and Sommers (1982). Total nitrogen was estimated by the macro-kjeldahl digestion method (Bremner and Mulvaney, 1982) while the available phosphorus was obtained using Bray II bicarbonate extraction method as shown in Olsen and Sommers, 1982). The phosphorus in the extract was determined with a photo-electric colorimeter. The exchangeable bases (Ca, Mg, K and Na) were extracted with 1N NH4OAc (pH 7.0) using 1:10 soil-water ratio. The exchangeable potassium and sodium in the extract were determined with Flame Photometer while the exchangeable calcium and magnesium were determined by atomic absorption spectrophotometry (Thomas, 1982). Exchangeable sodium percentage (ESP) was calculated by the formula of Soil Survey Staff (1999):

ESP = Exchangeable Sodium/Cation Exchange Capacity × 100/1

The titration method, as outlined in selected methods for soil and plant analysis (Thomas, 1982) was used in the determination of the exchangeable acidity (EA). The samples were extracted with 1N KCl solution and the extract titrated with 0.05 NaOH to a permanent pink end point using phenolphthalein indicator. Total exchangeable bases (TEB) in the samples was obtained by the summation of the four basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) (Rhoades, 1982). Cation exchange capacity (CEC) of the soils was determined with 1N NH4OAc, pH 7.0 (Rhoades, 1982). The effective CEC (ECEC) of the soil was estimated by the summation of the TEB and EA (Rhoades, 1982). The percentage base saturation (PBS) was derived by dividing the TEB by the CEC obtained and multiplying by 100 (Rhoades, 1982). Aluminium saturation percentage (ASP) was obtained as the ratio of aluminium concentration in the soil to the ECEC of the soil multiplied by 100 (Soil Survey Staff, 1999). The interpretations of the soil parameters were done using the classifications in Tables 1 to 3.

Land Suitability Evaluation

The suitability of the soils for rice was evaluated using the qualitative method (Ukabiala, 2012;Ukabiala and Obazi, 2022).). This approach involves the matching of the crop requirements with the soil characteristics. The most limiting characteristic was identified which determined the class of suitability of each pedon for rice and maize. Under this approach, the soils are classified as being highly suitable (S_1), moderately suitable (S_2), marginally suitable (S_3), currently not suitable (N_1) or permanently not suitable (N_2), based on the limitations. The limitations were indicated by lower-case letters with mnemonic significance. The numerical rating of selected land qualities on a scale of 0 to 100 indicating very low to optimum values and according to the intended land utilization type (Table 4), were ratings referenced to the established land requirements for the crop (Tables 5). The average values of the ratings were used to find the level of limitation of the parameters.

Table 1: Classifications for interpreting some soil physical and chemical characteristics
(Source: Enwezor *et al.*, 1989)

Parameter	Very low	Low	Moderate	High	Very High
Ex Calcium (cmol kg^{-1})		< 2.00	2.10 – 5.00	> 5.00	
Ex Magnesium (cmol kg^{-1})		< 0.30	0.31 – 1.00	> 1.00	
Ex Potassium (cmol kg^{-1})		< 0.15	0.16 – 0.30	> 0.30	
Ex Sodium (cmol kg^{-1})		< 0.10	0.11 – 0.30	> 0.30	
CEC (cmol kg^{-1})	<6.00	6.00 – 12.00	12.10 – 25.00	25.10 – 40.00	> 40.00
ECEC (cmol kg^{-1})		< 6.00	6.10 – 12.00	> 12.00	
Ex Acidity (cmol kg^{-1})		< 2.00	2.10 – 5.00	> 5.00	
Organic Carbon (%)	< 4.00	4.00 – 10.00	11.00 – 14.00	15.00 – 20.00	
Total Nitrogen (%)	< 0.50	0.60 – 1.00	1.10 – 1.50	1.60 – 2.00	> 2.00
Av. P (mg kg^{-1})	< 3.00	3.00 – 7.00	7.10 – 20.00	> 20.00	
Base Saturation (%)	< 20	20 – 40	41 – 60	60 – 80	80 – 100
Ex Sodium Percentage (%)	< 0.10	0.10 – 2.00	2.10 – 8.00	8.10 – 15.00	> 15.00

Ex = Exchangeable, CEC = Cation Exchange Capacity, ECEC = Effective Cation Exchange Capacity, Av. P = Available Phosphorus

Table 2 : Classifications for interpreting soil depth

Soil depth (cm)	Interpretation
< 25	Very shallow
25 – 50	Shallow
50 – 100	Moderately deep
100 – 150	Deep
> 150	Very deep

(Source: Soil Survey Staff, 1999)

Table 3: Classifications for interpreting soil pH

Soil reaction pH	Interpretation
< 4.5	Extremely acid
4.5 – 5.0	Very strongly acid
5.1 – 5.5	Strongly acid
5.6 – 6.0	Moderately acid
6.1 – 6.5	Slightly acid
6.6 – 7.3	Neutral
7.4 – 7.8	Slightly alkaline
7.9 – 8.4	Moderately alkaline
8.5 – 9.0	Strongly alkaline
> 9.0	Very strongly alkaline

(Source: Soil Survey Staff, 1999)

Table 4: Class rates of soil suitability classes and agricultural uses

Classes	Suitability classes	Rates	Potential agricultural uses
Class 1 (S_1)	Highly Suitable	85-100	Excellent
Class 2 (S_2)	Moderately Suitable	84-60	Good
Class 3 (S_3)	Marginally Suitable	59-40	Fair
Class4 (N_1)	Currently Not Suitable	39-20	Poor
Class 5 (N_2)	Permanently Not Suitable	<20	Very Poor

(Ezeaku, 2011)

Table 5 : Land/Crop requirements for rain-fed rice cultivation (Sys, 1985)

Land qualities	Land Characteristics	Unit	S_1 (100-85)	S_2 (84-60)	S_3 (59-40)	N_1 (39-20)	N_2 (19-0)
Climate (c)	Annual Rainfall	mm	> 1400	1200 -1400	950 - 1100	850 – 900	< 850
Soil physical characteristics (s)	Soil Depth	cm	> 20	10 - 20	5 - 10	1 – 5	< 1
	Clay	$g\ kg^{-1}$	250 - 450	150 - 250	50 - 150	10 – 50	< 10
	Texture	-	Loam	Clay loam	Clay	Sandy clay	Sandy clay loam/ Sand
Wetness (w)	Drainage	-	VPD	PD	MD	MWD	WD
	F.D	months	> 4	3 - 4	2 - 3	1 – 2	< 1
	G.W.T	Cm	0 - 15	16 - 30	31 - 60	61 - 90	> 90
Fertility status (f)							
	pH(H_2O)	-	5.5 - 7.5	5.2 - 5.5	≤ 5.2, ≥ 8.2	≤ 5.0, ≥ 7.2	< 3.0, > 9.0
	Total Nitrogen	$g\ kg^{-1}$	> 2.0	1.0 - 2.0	0.5- 1.0	0.1 – 0.5	< 0.1
	Organic carbon	$g\ kg^{-1}$	50.0 – 60.0	30.0 – 40.0	10.0 – 20.0	1.0 – 9.0	< 1.0
	Available Phosphorus	$mg\ kg^{-1}$	> 20	15-20	10-15	5 - 10	< 5
	Exchangeable Ca	$cmol_c\ kg^{-1}$	10-15	5-10	1-5	< 1; > 15	< 1; > 15
	Exchangeable Mg	$cmol_c\ kg^{-1}$	2-5	1-2	< 1	< 1; > 5	< 1; > 5
	Exchangeable K	$cmol_c\ kg^{-1}$	> 0.2	0.1 - 0.2	< 0.1	< 0.1	< 0.1
	CEC (Soil)	$cmol_c\ kg^{-1}$	> 16	10 - 16	5 - 10	< 5	< 5

F. D = Flooding Duration
G. W. T= Ground Water Table
VPD= Very poorly drained; PD= Poorly drained; MD= Moderately drained; MWD= Moderately well drained WD= Well drained
CEC= Cation exchange capacity, Ca = Calcium, Mg = Magnesium, K = Potassium

Results and Discussion

Morphological Characteristics of the soils

A diagrammatic sketch of the levee and backswamp on the floodplain at Ibaji is represented in Figure 2. The summary of soil morphological features are shown in Tables 6. The morphology of these soils is distinct and diagnostic characteristic of floodplain soils.

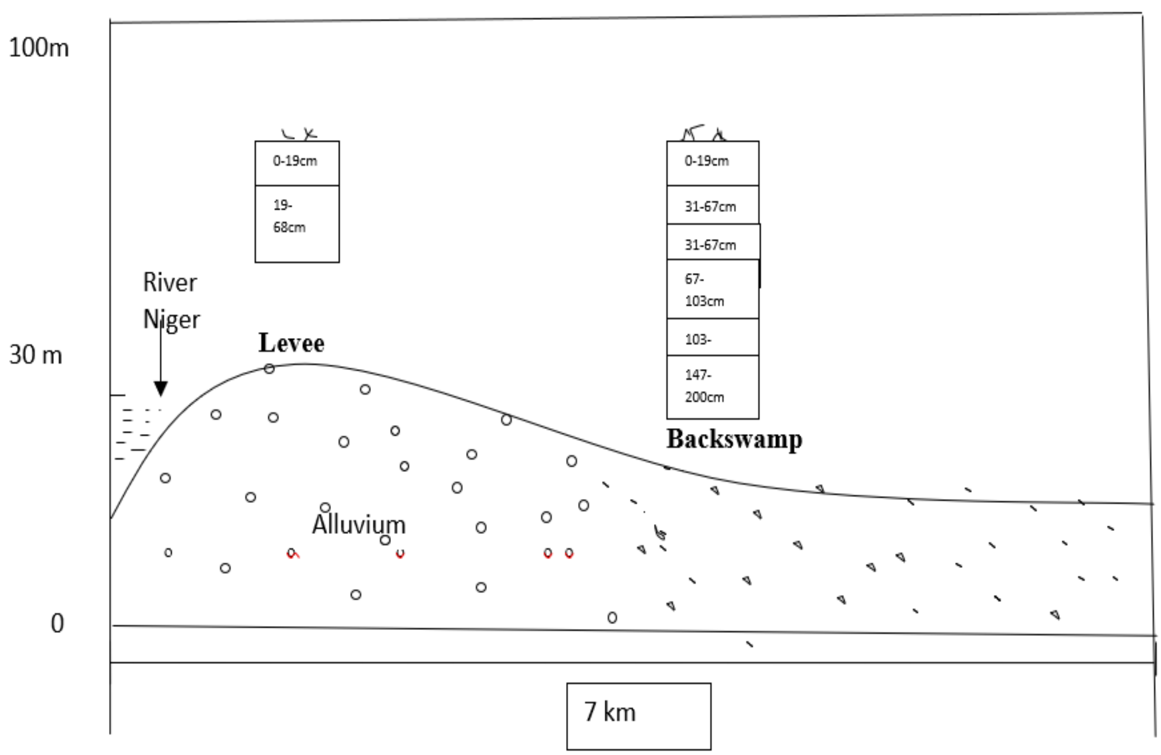

Figure 2: Schematic representation of Ibaji Floodplain

Table 6: Morphological characteristics of Levee and Floodplain soils in the study area

	Horizon designation	Depth (cm)	Soil Colour		Texture	Structure	Consistence	Boundary	Others
			Matrix	Mottles					
Levee soil	A1	0-19	10YR 1.7/1 (black)	-	scl	mofg	nsnp	cw	Few irregular fine pores, common very roots
	A2	19-68	10YR 4/1 (Brownish gray)	-	scl	momsbk	vsvp		Very few irregular fine pores, very few very fine roots
Backswamp soil	Ap	0 – 31	10YR4/4 (Brown)	-	scl	momcr	sssp	cw	very few irregular fine pores, common very fine roots
	A	31- 67	10YR 5/3 (dull yellowish brown)	-	sc	momcr	sssp	cw	Few irregular fine pores, moderate to very fine roots, common medium Mn concretion
	Ag	67-103	10YR 6/3 (dull yellow orange)	7.5YR 4/6 (brown)	sc	mofsbk	sssp	gw	Few irregular very fine pores, few very fine roots.
	Bg1	103-147	10YR 7/2 (dull yellow orange)	10YR 7/8 (yellow orange)	scl	momsbk	sssp	dw	Few irregular fine pores, few very fine roots
	Bg2	147-200	10YR 7/2 (dull yellow orange)	10YR 7/8 (yellow orange)	scl	momsbk	sssp		Few irregular fine pores, few very fine roots

Structure: mo=moderate, f=fine, m=medium, cr=crumb, g=granular, sbk=sub angular blocky
Consistence: nsnp= non- sticky and non-plastic, vsvp= very sticky and very plastic, sssp= slightly sticky and slightly plastic.
Boundary: c= clear, d= diffuse, g= gradual, w= wavy
Texture: scl=sandy clay loam, sc = sandy clay
Inclusions: Mn = Manganese
Horizon designation: A and B = Soil Master Horizons, p = Plough layer, g = gleying

The levee soil is moderately deep (68 cm), while the Backswamp had a very deep soil profile (200 cm). The depth of the levee soil was limited by standing water table at 68 cm depth. However, the presence of mottles from the 67 to 200 cm in the Backswamp soil profile is an indication of fluctuating water table through the layers. This is consistent with the observation made by Ukabiala (2013). The matrix soil colour varied between black and brown in the surface soil of levee and backswamp respectively, which may have resulted from variations in the level, type and decomposition of organic matter. In the subsurface soils, the variation is between brownish gray and dull yellow orange. The variation may have been due to the frequency of ground water table fluctuations.

The variation in the soil structure is expressed by the observation of granular and crumb structure in the levee and backswamp soils respectively. The subsurface soils of the two profiles were both characterized by sub-angular blocky structure. The surface soils of the levee is non-sticky and non-plastic which varied with the slightly sticky and slightly plastic consistence of the backswamp surface soils, which is an indication of low clay content in the surface soils. The surface soil of the levee is very sticky and very plastic while the backswamp is slightly sticky and slightly plastic. The variation may have resulted from the nature of clay formed. The boundaries between the horizons in both profiles are clear and wavy, though a diffuse boundary distinctness occurred between Bg1 and Bg2 in the subsurface soils of the backswamp. This may have resulted due to the varying depositional process of the soil materials in the floodplain. Both soil profiles are characterized by averagely fine and irregular pores. Manganese concretions were spotted in A horizon of the floodplain soil.

Physical Characteristics of Soils of the Levee and Floodplain

Some physical characteristics of the soils of the levee and backswamp are presented in Table 7. The results show that sand proportion was highest in the surface soil of the levee (764 g kg^{-1}). On the contrary, sand content is highest I the subsurface soil of the backswamp (Bg2), recording 688 g kg^{-1} which is higher than the 572 g kg^{-1} recorded at the surface Ap horizon.

Table 7: Physical Characteristics of the levee and floodplain soils of the study area

	Horizon depth	Practice size Distribution			Textural class	Silt/clay ratio	Sand/silt ratio	Bulk density	Porosity	Moisture content
		Sand	Silt	Clay						
	(cm)	(g kg^{-1})						(g cm^{-3})	(%)	(%)
Levee soil	0-19	764	28.4	207.6	scl	0.14	26.90	1.24	54	66
	19-68	674	48.4	277.6	scl	0.17	13.93	1.33	50	59
Backswamp soil	0-31	572.4	95.6	332	scl	0.29	5.99	1.20	55	11
	31-67	492.4	115.6	392	Sc	0.29	4.26	1.23	54	14
	67-103	512.4	115.6	372	Sc	0.31	4.43	1.40	47	14
	103-147	638	15.6	346.4	Scl	0.05	40.89	1.45	45	8
	147-200	688	5.6	306.4	Scl	0.02	122.86	1.47	45	13

scl = sandy clay loam, sc = sandy clay

The values of silt in g kg^{-1} recorded in the backswamp soil are averagely higher than in the levee. Similar trend was also observed in the clay content of the soils where the surface soils have 207.6 g kg^{-1} and 332 g kg^{-1} for the levee and backswamp soils respectively. The general explanation for this has always been reported to be that the flood water carrying sediments reduces in energy further away from the river and the levee into the backswamp. Thus, heavier soil particles (sand) are dropped around the levee while the finer soil particles (silt and clay) are carried farther away into the backswamp (Newman and Keim, 2012). The proportions of sand, silt and clay in the soils gave rise to the dominant sandy clay loam soil texture in the surface soils, and the sandy clay in the subsurface soils of the levee and backswamp. The proportion also influenced the variations in the variations in silt:clay and sand:silt ratios which are indices of the level of weathering of the soils.

Generally, the values of bulk density increased irregularly down the soil profiles. This has always been reported to be due to the effect of over-burden of the over-lying soil layers (Ukabiala, 2019, Ukabiala *et al*., 2021). Higher soil organic matter in the surface soils may have also influenced the lower bulk density. Higher soil porosity values recorded in the surface soils of the levee and backswamp (54 and 55 % respectively) is due to the higher organic matter contents in the layers. Futhermore, the moisture content which is higher in the levee soil than in the backswamp soil may have resulted from the influence of the water table which was encountered nearer to the mineral soil surface in the levee profile.

Chemical Characteristics of the Soils of the Study Area

The values of the chemical characteristics of the studied soils are presented in Table 8. The pH of the surface levee soils is higher (4.6) than in the subsurface (4.1). The low pH of the soil generally ranged from very strongly acid to extremely acid which will require some amendments for improved crop production. The pH is characteristic of other floodplains in similar agroecolocal zones of agto-ecological zones of Nigeria characterized by rainfall above 1400 mm per annum. The pH observed in H_2O is generally higher than the one in KCl which gave rise to negative delta pH values.

The organic carbon is highest in surface soil layers of levee (32.1 g kg^{-1}), followed by 17.3 g kg^{-1} recorded in the surface layer of backswamp soil. Possibly at the levee, the organic matter has no enough time for decomposition.

Table 8: Chemical Characteristics of the levee and floodplain soils of the study area

	Horizon depth (cm)	pH			Org C	Org. M	Total N	C: N Ratio	E C	Avail P
		KCl	H_2O	ΔpH	….. (g kg^{-1}) …...				(ds m^{-1})	(mg kg^{-1})
Levee	0-19	4.0	4.6	-0.6	32.1	55.3	1.6	20	0.23	14.84
	19-68	3.6	4.1	-0.5	29.5	50.9	1.5	20	0.13	11.35
Backswamp	0-31	3.8	4.4	-0.6	17.3	29.8	0.9	19	0.22	13.13
	31-67	3.6	4.2	-0.6	8.5	14.7	0.4	21	0.13	12.06
	67-103	3.8	4.3	-0.5	6.8	11.7	0.3	23	0.29	10.38
	103-147	7.3	7.9	-0.6	1.6	2.8	0.08	20	0.12	8.22

147-200	4.4	5.1	-0.7	0.9	1.6	0.05	18	0.01	7.14

Org C = Organic Carbon, Organic Matter, Organic Nitrogen, Total N = Total Nitrogen, C:N = Carbon and Nitrogen, E.C = Electrical Conductivity, Avail P = Available Phosphorus

However, the organic carbon and organic matter generally decreased down the profile which may due to reduced leaf litter in the surface. High nitrogen contents were recorded in soil surface layers of the soils which may have been as a result of influence by high organic matter in the surface soils. The total nitrogen are higher in the surface soils and decreased down the profile. The C:N ratio, electrical conductivity and available phosphorus are higher in the surface soils of the levee than in the backswamp. The difference in the electrical conductivity may be connected to the type of clay deposited. USDA-NRCS-EC-Guide (2014) stated that Soils that have a higher content of smaller soil particles (higher content of clay) conduct more electrical current than do soils that have a higher content of larger silt and sand particles (lower content of clay). It further stated that Soils that consist dominantly of clay minerals that have a high cation-exchange capacity (CEC), such as smectite, can have higher EC than soils that consist dominantly of clay minerals that have a low CEC, such as kaolinite. Lower pH in the surface soils of the levee may have contributed to the higher value of the available phosphorus. Higher values of the exchangeable bases are found in the surface soils of the levee than in the backswamp. This contributed to higher values of the percentage base saturation (91%) in the levee than in the backswamp (89%). Similar trend was observed also in the subsurface soils. The cation exchange capacity differed, having values of 14.69 and 10.78 cmol kg^{-1} in the surface soils of the levee and the backswamp respectively. This may also be reflecting the type of clay deposited.

Soil Suitability Evaluation

Table 9 shows the suitability of the levee and the backswamp soils of the Ibaji floodplain with their limitations. The aggregate class scores of the levee and backswamp soils are 64 and 50, leading to moderate (S_2) and marginal (S_3) suitability classes for rice production, respectively. The backswamp soils have fertility limitations, owing to the low levels of most of the chemical parameters. The implication of S_2 (Moderately suitable) soil is that it has limitations which will reduce production levels and/or increase costs, but which is physically and economically suitable for rice cultivation, while the S_3 (Marginally suitable) soil has limitations which will reduce production levels and/or increase costs such that it is economically marginal for the cultivation of rice (Akamigbo, 2010).

Table 9: Suitability class scores of levee and floodplain soils in Ibaji of Kogi State, Nigeria for rain-fed rice cultivation

Land Characteristics/units	Levee soil	Backswamp soil
Climate (c)		
Annual Rainfall (mm)	80	80
Mean	**80**	**80**
Soil Physical characteristics (s)		
Soil Depth(cm)	80	80
Clay (%)	70	60
Texture	60	50
Mean	**70**	**63**
Wetness (w)		
Drainage	60	40
F.D (months)	50	30
G.W.T (cm)	35	30
Mean	**48**	**33**
Fertility status (f)		
pH(H_2O)	60	20
Total Nitrogen (g kg^{-1})	60	20
Organic carbon (g kg^{-1})	80	30
Available Phosphorus (mg kg^{-1})	50	20
Exchangeable Ca ($cmol_c$ kg^{-1})	70	30
Exchangeable Mg ($cmol_c$ kg^{-1})	60	20
Exchangeable K ($cmol_c$ kg^{-1})	70	30

CEC ($cmol_c\ kg^{-1}$)	60	40
Mean	**74**	**26**
Mean of Means score	**64**	**50**
Suitability class	**S_2**	**S_3 f**

Ca= Calcium, Mg = Magnesium, K= Potassium, CEC = Cation Exchange Capacity, S_2 = Moderately Suitable, S_3 = Marginally Suitable, F.D = Flood Duration, G.W.T = Ground Water Table

Variability of the Physico-chemical properties of the soils

The results of the test for variability of the physic-chemical properties of the levee and backswamp soils of Ibaji floodplain are presented in Table 10 and Figure 2. Table 10 shows the standard deviation of the physico-chemical properties of the soils, while Figure 2 presents the coefficient of variation (CV) of the studied parameters. Very high CV values (> 50%) were observed for silt (77%), sand:silt (89%) and moisture content (99%). High CV values (20 -50%) were obtained for sand (20%), clay (33%), silt:clay (47%), organic carbon (42%), organic matter (42%), total nitrogen (32%), exchangeable magnesium (28%), exchangeable potassium (34%) exchangeable sodium (30%), cation exchange capacity and effective cation exchange capacity which were respectively 22 and 20 percent. These values reflect the fact that the values of the properties are generally far from the mean. The higher the coefficient of variation, the greater the level of dispersion around the mean. This is in consistent with Cazanacli and Smith (1998) who stated that natural levees form during high-flow events, their soil texture is coarser than adjacent backswamp deposits. The variability observed in moisture content may have risen from soil depth variation as well as the geo-spatial variation from the adjacent water body. Natural levees are potentially locally important zones of lateral seepage between stream channels and floodplain backswamps, because their relatively coarser soils provide pathways of high hydraulic conductivity in an otherwise low conductivity system (Newman and Keim, 2012). The organic carbon and organic matter accumulations accrued from alluvial sediments. (Onweremadu, 2007) similarly observed variability of soil carbon in floodplain soils of southeastern Nigeria. However, it is suggested that some of the reasons for variation are stand age, elevation, cultivation, vegetation and litter (Diane, Saint-Laurent *et al*., 2014).

The other physic-chemical properties have less than 20% coefficient of variation. These parameters include the ephemeral soil chemical properties soil pH (4), available phosphorus (9%) and percentage base saturation (2%). Some were even less than 0.1. Low coefficient of variation indicates that values are clustered close to the mean. They may have also been influenced by same climatic factors, since both soils occur within same climatic region. Another factor that may be considered is the fact that they are of almost same origin (alluvial parent material).

Table 10: Standard deviation of the physico-chemical properties of soil of Ibaji floodplain in Kogi state

S/N	Physico-Chemical Parameters	Unit	Standard Deviation
1	Sand	$g\ kg^{-1}$	135.5
2	Silt	$g\ kg^{-1}$	47.5
3	Clay	$g\ kg^{-1}$	87.9
4	Silt:Clay	-	0.10
5	Sand:silt	-	14.7
6	Bulk density	$g\ cm^{-3}$	0.02
7	Porosity	%	0.71
8	Moisture content	%	38.9
9	pH (H_20)	-	0.14
10	pH (KCl)	-	0.14
11	Organic carbon	$g\ kg^{-1}$	10.46
12	Organic matter	$g\ kg^{-1}$	18.0
13	Total nitrogen	$g\ kg^{-1}$	0.49
14	Cabon:Nitrogen	-	0.71
15	Electrical conductivity	$ds\ m^{-1}$	0.01
16	Available phosphorus	$mg\ kg^{-1}$	1.21
17	Exchangeable calcium	$cmol_c\ kg^{-1}$	0.55
18	Exchangeable magnesium	$cmol_c\ kg^{-1}$	0.98
19	Exchangeable potassium	$cmol_c\ kg^{-1}$	1.06

20	Exchangeable sodium	cmol$_c$ kg^{-1}	0.17
21	Exchangeable acidity	cmol$_c$ kg^{-1}	0.04
22	Cation exchange capacity	cmol$_c$ kg^{-1}	2.76
23	Effective cation exchange capacity	cmol$_c$ kg^{-1}	2.80
24	Percentage base saturation	%	1.41

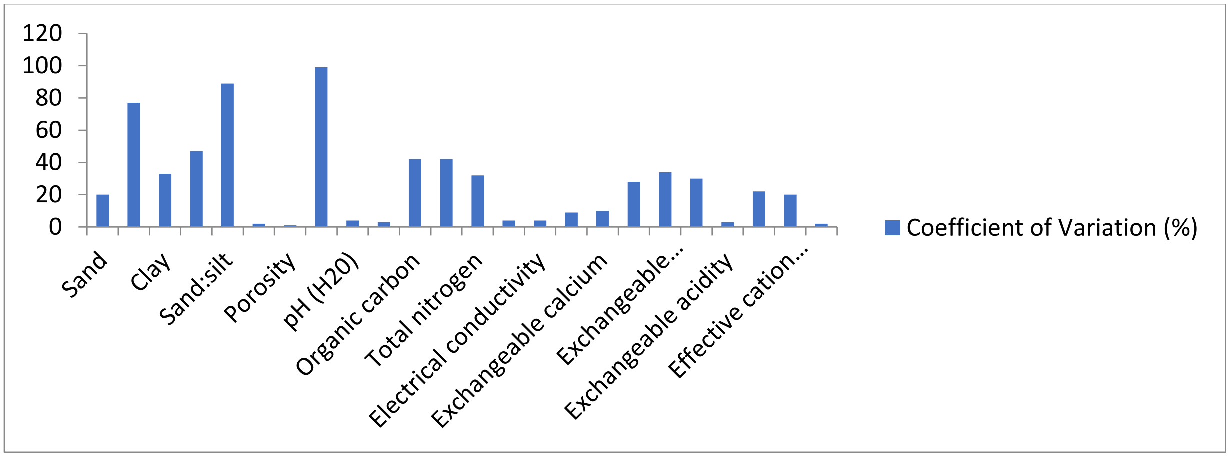

Figure 2: Coefficient of Variation (CV) of Soil Physico-chemical Properties of Ibaji Floodplain in Kogi State

Conclusion

This study was carried out to examine the variability that exists between the levee and the backswamp of floodplain. The indices compared were selected morphological, physical and chemical properties of the soils. The findings revealed that sandy clay soil texture dominates the surface soil but the consistence of the soils read non-sticky and non-plastic for the levee, and slightly sticky and slightly plastic for the backswamp soils. The soil colour of the two sites varied due to difference in the chroma and value of the 10YR (Hue). There is also a clear difference in the sand/silt ratio and the moisture content of the levee and backswamp soils. The analysis of the chemical characteristics of the soils revealed clearly that the organic carbon varied between the levee and backswamp soils of the studied floodplain. Though the exchangeable calcium showed very little variation, there is wide gap between the values of the cation exchange capacity and percentage base saturation. Thus, The highest coefficient of variation (> 75%) was observed for silt, sand:silt ratio and moisture content of the soils, while available phosphorus levels had CV of < 2 %. Nevertheless, the dynamics of these parameters showed a decreasing trend down the soil profiles. These variations in the state of the soil physico-chemical parameters are indeed tantamount to the suitability variation that occurred with respect to rice production. The ratings derived from these soil properties classified the levee soils as being moderately suitable (S_2), and the backswamp soil as marginally suitable (S_3).

References

Akamigbo, F.O.R. (2010). *Fundamental Methods of Soil Resource Survey, Classification, Interpretation and Application*. University of Nigeria. Press Ltd, UNN, pp81.

Akpan-Idiok, A.U., Ukabiala, M.E. and Amhakhian, S.O. (2013). Characterization and classification of River Benue floodplain soils in Bassa Local Government Area of Kogi State, Nigeria. *International Journal of Soil Science*, 8(2):32-46.

Ande O.T. (2011). Soil suitability evaluation and management for cassava production in the derived savannah area of south-western Nigeria. *Int. J. Soil Sci.,* **6,** 142-149.

Aroh, J.E.K. (2003). Classification of Ogoni sands in the Niger Delta in Nigeria: (I) Taxonomic. *Proceedings of the 28th Annual Conference of the Soil Science Society of Nigeria*. pp 353 -364.

Bouyoucos, G.J. (1962). Hydrometer Method Improved for Making Particle Size Analysis of Soils. *Agronomy Journal*. 54:464-465.

Brady, N.C. and Weil, R.R. (2002). *The Nature and Properties of Soils*. Pearson Education, Inc. New Jessy, USA.

Bremmer, J.M. and Mulvaney, C.S. (1982). Total nitrogen, pp895-926. In Page *et* al. (eds). Methods of Soil Analysis. Part 2. 2nd ed. *Agronomy Monogragh* 9, ASA and Soil Science Society of America*,* Madison WI.

Cazanacli, D. and Smith, N. D.(1998) A study of morphology and texture of natural levees – Cumberland Marshes, Saskatchewan, Canada, Geomorphology, 25:43–55.

Diane, Saint-Laurent, Vernhar, Gervais-Beaulac, Jean-Sébastien Berthelot (2014). Variability of soil properties in different flood-risk zones and link with hydroclimatic changes (Southern Québec, Canada), Geoderma, Volumes 214–215 (80 -90)

Enwezor, W.O., Udo, E.J., Usoro, N.J., Ayotade, K.A., Adepetu, J.A., Chude, V.O. and Udegbe, C.I. (1989) Fertizer use and management practices for crops in Nigeria. *Series 2. Federal Procurement and Distribution Division, Federal Ministry of Agriculture, Water Resources and Rural Development, Lagos.* pp163.

Esu. I. E. 2010. *Soil Characterization, Classification and Survey*. HEBN Publishers Plc. Ibadan, Nigeria.

Ezeaku, P.I. (2011). *Methodologies for Agricultural Land-Use Planning – Sustainable Soil Management and Productivity*. Great AP Express Publishers Ltd, Nsukka, Nigeria. pp69.

FAO (1976). A frame work for land evaluation. *FAO Soils Bulletin* 32, Rome.

Khan, M.S.N. and Khan, M.M. (2014). Land Suitability Analysis for sustainable agricultural land use planning in Bulandshahr district of Uttar Pradesh. *International Journal of Scientific and Research Publications*, 4(3):1-11.

Klute, A. and Dirksen, C. (1986). Hydraulic conductivity and diffusivity laboratory methods. In Klute, A. Ed. Methods of Soil Analyses. *American Society of Agronomy-Soil Science Society of America*, Madison, pp635-662.

Landon J.R. (ed). (1981). *Booker Tropical Soil Manual* (pp. 78-80) Booker Agric. Int. Ltd. London.

McLean, E.O. (1982). Soil pH and Lime Requirement. P. 199-224. In: Page *et al.*(eds) Method of Soil Analysis part 2. Chemical and Microbial Properties. 2nd 288 ed. Agronomy Monograph 9, ASA and SSSA, Madison WI.

Nelson, D.W. and Sommers, C.E. (1982). Total carbon, organic carbon and organic matter, In: A.C. Page and C.A. Black (eds). Methods of Soil Analysis Part 2, 2nd ed. *Agronomic Monograph* 9 ASA and SSA, Madison, W.I. pp. 539 – 579.

Newman, A. and Keim, R. (2012). Mesoscale Connectivity Through a Natural Levee. Hydrology and Earth System Sciences Discussions. 9. 10.5194/hessd-9-7761-2012.

Olson, S.R. and Sommers, L.E. (1982). Phosphorus. pp403-434. In Page *et* al. (eds). Methods of Soil Analysis. Part 2. *Agronomy Monogragh 9*, ASA and Soil Science Society of America, Madison WI.

Onweremadu. E.U. (2007). Spatial Variability of Soil Carbon in Floodplain Soils of Southeastern Nigeria. International Journal of Agricultural Research, 2: 552 – 558.

Rhoades, J.D. (1982). Cation exchange capacity In: Page, A.L. (Ed.), Methods of Soil Analysis Part 2. 2nd Edition, Agronomy Monograph 9. ASA, Madison, W.I. pp403-434.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. (2012). Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Soil Survey Staff (1999). *Soil Taxonomy*: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Second Edition. United States Department of Agriculture, Natural Resources Conservation Service, Agriculture Handbook, Number 436.

Sys, C. (1985). *Land Evaluation Parts 1,II and III*. Agricultural Publications, No. 7. Administration for Development Crops (ABOS), Brussels.

Thomas, G.W. (1982). Exchangeable cations, pp 159 – 165. In: Page *et al*. (eds) Methods of Soil Analysis. Part 2. 2nd . *Agronomy Monograph* 9. ASA and SSSA, Madison, WI.

Ukabiala M.E. (2019). *Characterization, Classification and Suitability Evaluation of Soils of Eastern Kogi State of Nigeria for Rice, Maize, Cassava and Oil Palm Production.* Thesis, Department of Soil Science, University of Nigeria, Nsukka

Ukabiala M.E., Kolo J., Obalum S.E., Amhakhian S.O., Igwe C.A. and Hermensah. (2021). Pysicochemical properties as related to mineralogical composition of floodplain soils in humid tropical environment and the pedological significance. *Environ. Monit. Assess.* **(2021) 193:** 569. https://doi.org/10.1007/s10661-021-09329-y

Ukabiala, M. E. (2012). *Characterization and Classificationof River Benue Floodplain Soils in Bassa Local Government Area of Kogi State, Nigeria*. M.Sc. Thesis Submitted to the School of PostGraduate Studies, Kogi State University, Anyigba.

Ukabiala, M.E., and Obazi, S.A. (2022). Characterization and Suitability Evaluation of Upland Soils for Maize, Cassava and Oil Palm Production in Kogi East, igeria. J Soil Water Sci 6(1):272-285

USDA-NRCS-EC-Guide (2014). Soil Electrical Conductivity: Guide to Educators.

Vomicil, J.A. (1965). Porosity, In Black, C.A ed, methods of Soil analysis Part 1, *Agronomy Monograph* 9, ASA and SSSA, Madison, WI, pp 299-314.