VARIABILITY OF PROPERTIES OF KOROAMA AND NIGER DELTA UNIVERSITY TEACHING AND RESEARCH FARM SOILS FROM THE NIGER DELTA ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT: *As agricultural land in the Niger Delta area is dwindling due to inherent lack of dry and relatively well drained land and increase in population and competition from land for urbanization and industrialization, the need to monitor and manage the limited available land for agriculture becomes very paramount. This study seeks to evaluate the variability of properties of Koroama (KRM) and Niger Delta University (NDU) farm soils on the Nun River plain and the implications for soil management. Soils varied morphologically, including soil colour, mottling and sequential arrangement of horizons within and between physiographic units and between the two locations, KRM1 showing evidence of anthropogenic influence. pH was the least variable characteristics while organic C, total N and available P were highly variable (CV= ≥35) in all the physiographic units. Calcium dominated the exchange complexes of the two locations, showing varying degree of variability while Mg and K were highly variable (CV= ≥35) in all physiographic units of Koroama. Exchangeable Al, acidity, TEB and CEC exhibited varying degree of variability in the different physiographic units of the two locations, reflecting differences in the source of parent materials and possibly, the degree of hydromorphism. The variability in morphological, physical and chemical characteristics reflected the effects of flooding, source of parent materials and the degree of hydromorphism, all of which dictated the pedo-chemical environment and should be considered in managing the soils.*

KEYWORDS: variability, Niger Delta, hydromorphism, flooding

INTRODUCTION

The influence of topography in the variation of soil properties is well documented (Wilson et al., 2004; Sanundi and Mahmud 2014). According to Mahmud et al. (2019), horizons may differ in organic matter content, structure, texture, pH, base saturation, cation exchange capacity (CEC), bulk density and water holding capacity as well as many other soil physical and chemical properties. It has been reported (Okeyo et al., 2006) that spatial variation is capable of not only threatening food security, but reduction in yields (Udoh et al., 2010). Hence, Inman et al. (2005) advocated for the delineation of high degree of variability of soil properties into relatively homogenous units for effective monitoring and quantification for purposes of selecting proper agricultural use and management. In Nigeria, increase in population growth has led to increasing demand and pressure on land resources, resulting in the cultivation marginal land including slopes, hilltops, wetlands, etc. without monitoring and proper management. This is particularly true of Bayelsa State in the Niger Delta ecological zone. Since land for agriculture is uncompromisingly dwindling due to inherent lack of dry and relatively well drained land in the Niger Delta area

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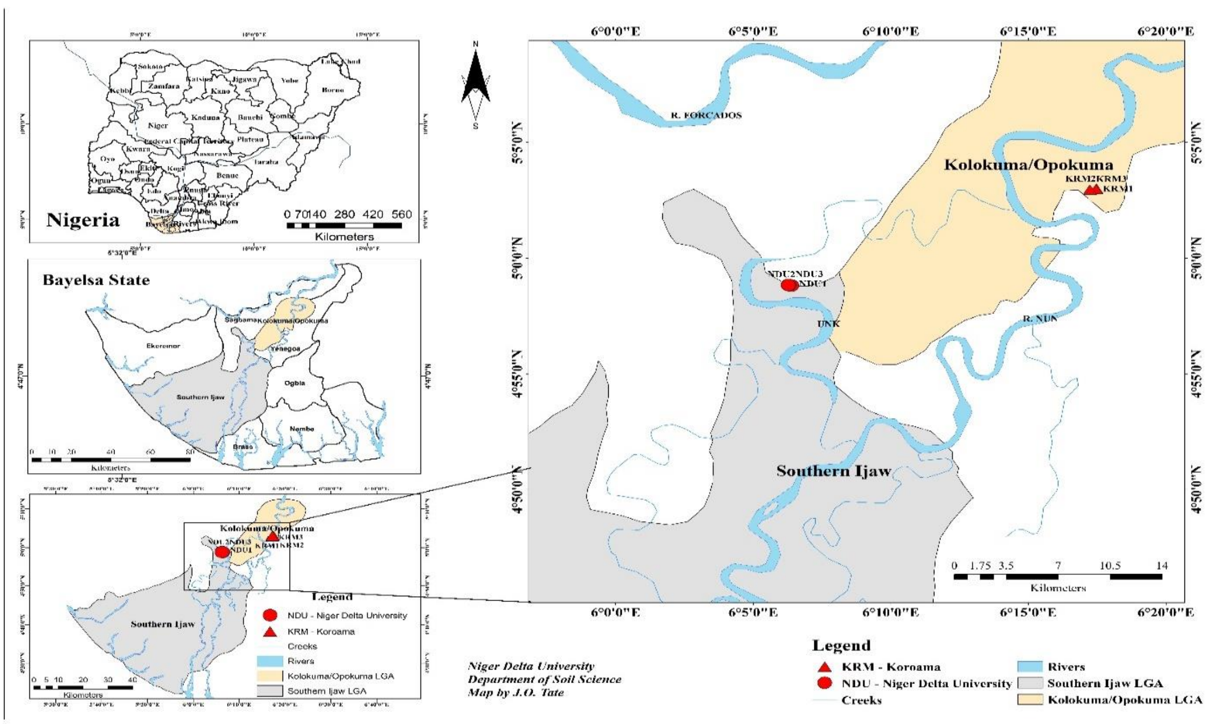
coupled with increase in population and competition with land for urbanization and industrialization (Dickson, 2014), the need to vigorously close-mark and manage the limited available land for agriculture cannot be over-emphasized. In this regard, this study is designed to evaluate the variability of soil properties of the Nun River plain and the implications for soil management.

MATERIALS AND METHODS

This study was carried out in Bayelsa State in the Niger Delta region, Southern Nigeria. The study locations lie between Latitude 05° 22' 03.9" N and 04° 59' 08.9" N and Longitude 006° 30' 21.1" E and 006° 06' 54.1" E. The Niger River traverses Nigeria in a North-western to Southern direction, breaks up into two – the Forcados and Nun Rivers in Bayelsa State. Forcados River demarcating the western border of the state while the Nun River, running north and south down the middle of Bayelsa State, which remains the most direct tributary of the Niger. Koroama in the Yenagoa Local government area, lies by the Taylor Creek, a tributary of Nun River while Amassoma in Southern Ijaw Local government area, where the Niger Delta University situates lies River Niger, a tributary of the Nun River (Figure 1) and these were chosen for the study. The annual rainfall of the study area is 2000 – 4500mm, spread over 8 to 10 months of the year and bimodal, peaking at June and September. The relative humidity averages 80% all over the state and temperature is fairly constant with a maximum of 30ºC. The natural vegetation zone is tropical rainforest.



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Soil sampling and analyses

Detailed soil survey was conducted on agricultural lands from Koroama and Niger Delta University using rigid grids. The designations of the soil mapping units (SMUs) are KRM1, KRM2 and KRM3 for Koroama and NDU1, NDU2 and NDU3 for Niger Delta University soils. Details of the soil mapping units and the land area are presented in Table 1. Soil sampling procedures followed the methods prescribed by the USDA Soil Taxonomy and the World Resource Base. Three representative soil pedons were dug per location, one each on the levee crest, levee slope and recent alluvial soils in the channel of the present active river, giving priority to where farming is concentrated. The soils were morphologically described *in-situ* and samples collected from the different horizons for physico-chemical properties determination following standard procedures. Soil samples collected were air-dried, crushed and sieved to pass through a 2 mm mesh. Analyses were carried out in the Green River Project Laboratory of the Nigerian Agip Oil Company and Zadell Laboratory, Port Harcourt, Nigeria.

Soil Mapping Unit, Profile Pit Location and Land Area

Study Location	Soil Mapping Unit	Geo-reference of Profile Pit	No. of Profile Pit	Land Area (Hectares)	Land Area (%)
Koroama	KRM1	N 05° 02' 59.9", E 006° 17' 28.8"	1	13.182619	1.1
	KRM2	N 05° 02' 59.2",E 006° 17' 26.9"	1	10.647992	0.9
	KRM3	N 05° 02' 58.1", E 006° 17' 14.0"	1	21.428567	1.8
Niger Delta University	NDU1	N 04° 58' 49.1" E 006° 06' 23.7"	1	24.048062	2.0
	NDU2	N 04° 58' 49.9", E 006° 06' 17.5"	1	7.533081	0.6
	NDU3	N 04° 58' 50.5", E 006° 06' 15.7"	1	60.527688	5.0

Standard laboratory methods were used to determine the physical and chemical properties of the soil samples. Soil particle size analysis was determined using (Day, 1965) method, popularly known as hydrometer method. Soil pH both in water and $CaCl_2$ (1:2 ratio) was determined using glass electrode pH meter and electrical conductivity (EC) determined using conductivity meter (Estafan *et.al.*, 2013). Organic carbon was determined using the modified dichromate oxidation method of Walkley-Black as described by Estafan *et al.* (2013) and the values obtained multiplied by 1.724 (van Bemmelen factor) to obtain organic matter. Total N was determined using macro-kjeldahl digestion-distillation method as described by Houba *et al.* (1995) and available P by Bray P-1 method (Bray and Kurtz, 1945). Exchangeable acidity was extracted with 1M KCl and determined by titration with NaOH solution using phenolphthalein indicator (Anderson and Ingram, 1993) and exchangeable Al with 0.01M HCl (Sumner and Stewart, 1992). Exchangeable cations were extracted with neutral normal ammonium acetate solution as described by (Estafan *et al.*, 2013) and potassium and sodium in the extract measured by flame photometry and calcium and magnesium by atomic absorption spectrophotometry. Cation exchange capacity (CEC) was by the summation method (Kamprath, 1970). The soils were classified using the USDA Soil Taxonomy (Soil Survey Staff, 2014) and the World Resource Base (FAO/ISRIC, 2006).

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Data Analysis

Data were subjected to descriptive statistics. Significantly different means were separated by using Least Significant Difference (LSD) and Standard Deviation (SD). Coefficient of variation (CV) was used for variability analysis where CV < 15 is classified as less variable, CV between 15 – 35%, classified as moderately variable and CV > 35%, classified as highly variable. (Wilding and Drees, 1983).

RESULTS AND DISCUSSION

Morphological Properties

Some variation in morphological properties including arrangement of horizons, colour, texture, structure and consistence was observed between locations and physiographic units (Fable 2 and 3). Colour of the surface soil layer of KRM1 is dark yellowish brown (10 YR ¾) while subsurface soil colours varied between brown (10 YR 4/3) through very dark grayish brown (10 YR 3/2), dark grayish brown (10 YR 4/2) to brown (10 YR 4/3) down the profile. The surface soil colour of KRM2 is very dark grayish brown (10 YR 3/2) while subsurface colours are brown (10 YR 5/3), (10 YR 4/3), (10 YR 5/3), through grayish brown (5 YR 5/2) to gray (5 YR 5/1). Generally, value in this profile decreased with increase in depth indicating that moisture influence increases with depth. The surface soil colour of KRM3 is very dark grayish brown (10 YR 3/2) while colour of the remaining layers are grayish brown (10 YR 5/2), very dark brown (10 YR 2/2), and grayish brown (10 YR 5/2) for the remaining layers. The presence of common, medium, distinct, reddish brown (5 YR 4/3), many, coarse, distinct, dark reddish brown (5 YR ¾), many, coarse, prominent,

Table 2: Summary of Morphological Characteristics of the Koroama Soils

Horizon	Depth Cm	Soil Colour	Mottles		Texture	Structure	Consistence		Concret.	Boundary	Mica flakes
			Clour	Pattern			Moist	Wet			
KRM1											
A1	0 – 7	10 YR ¾			Fine silt loam	crumb to weak subangular blocky	friable	non sticky, non plastic	-	Clear smooth	Many
A2	7 – 43	10 YR 4/3			Silt loam	weak subangular blocky	friable	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B1	43 – 86	10 YR 3/2			Silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	Carbon	Clear smooth	Many
B2	86 – 115	10 YR 3/2			Silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
BC	115 – 130	10 YR 4/2	7.5 YR 4/4	M2D	Silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	Fe-Mn	Clear smooth	Many
C	130 – 200+	10 YR 4/3	10 YR 4/6	M3P	silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
KRM2											
Ap	0 -15	10 YR 3/2			silt loam	weak subangular blocky	slightly firm	non sticky, non plastic	-	wavy	Few
Ap2	15 – 23	10 YR 5/3			silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B1	23 – 40	10 YR 5/3			silty clay loam	subangular blocky	moderately firm	moderately sticky, moderately plastic	-	Clear smooth	Many
B2	40 – 64	10 YR 4/3	5 YR 4/3	C2D	silty clay loam	subangular blocky	moderately firm	moderately sticky, moderately plastic	-	Clear smooth	Many
B3	64 – 78	10 YR 5/3	5 YR 3/4	M3D	silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	diffuse wavy	Many
C1	78 – 140	10 YR 5/2	5 YR 3/4	M3P	silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
C2	140 – 194+	10 YR 5/1	7.5 YR 2.5/3	M3P	silt loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-		Common
KRM3											
Ap	0 – 12	10 YR 3/2			fine silt loam	weak subangular blocky	friable	non sticky, non plastic	-	Wavy	Few
Ap2	12 – 39	10 YR 5/2	5 YR 4/3	F2D	silty clay loam	weak subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-	wavy	Few
B1	39 – 59	10 YR 2/2	5 YR 3/4	M2D	silt loam	subangular blocky	moderately firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
B2	59 – 96	10 YR 5/2	7.5 YR 4/6	M3D	silty clay loam	subangular blocky	moderately firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
B3	96 – 135	10 YR 5/2	7.5 YR 4/6	M3P	silty clay loam	subangular blocky	moderately firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
C	135 – 190+	10 YR 5/2	7.5 YR 4/6	M3P	silty clay loam	subangular blocky	slightly firm	Slightly sticky, Slightly plastic	-		Few

Abbreviations: Mottle pattern- The first letter denotes abundance (F=few; C=common; M=many); The centre number denotes size (1=fine; 2=medium; 3=coarse); The second letter denotes contrast (D=distinct; P- prominent)

Table 3: Morphological Characteristics of Niger Delta University Soils

Horizon Design.	Depth Cm	Soil Colour Moist	Mottles		Texture	Structure	Consistence		Concr.	Boundary	Mica flakes
			Clour moist	Pattern			Moist	Wet			
NDU1											
Ap	0 – 19	10 YR 3/3			Fine silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B1	19 – 39	10 YR 4/4			Silt clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Common
B2	39 – 71	10 YR ¾			Silt clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B3	71 – 81	10 YR 5/4			Silt clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
C1	81 – 138	10 YR 5/3	5 YR 4/4	M3D	Fine silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
C2	138 – 195+	10 YR 6/2	5 YR 4/4	M3P	Fine silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-		Many
NDU2											
Ap	0 – 12	10 YR 4/4			Fine silty clay loam	Weak subangular blocky	Friable to slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
Ap2	12 – 26	10 YR 4/4			Silty clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
B1	26 – 36	10 YR 5/3			Silty clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
B2	36 – 53	10 YR ¾	5 YR 3/3	M3D	Silty clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Few
B3	53 – 116	10 YR 5/4	5 YR 5/3	M3P	Clay loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
C	116 – 190+	10 YR 6/2	7.5 YR ¾	M3P	Loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-		Many
NDU3											
A1	0-5	10 YR 3/3		M3D	Fine silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Common
A2	5-13	10 YR4/1	5 YR 5/3	M3P	silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Common
AB	13-20	10 YR4/4	5 YR 5/4	M3P	silt loam	Weak subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B1	20-75	10 YR 5/4	5 YR 4/3	M3P	silt loam	subangular blocky	Slightly firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
B2	75-140	10 YR5/4	5 YR 6/2	M3P	silt loam	subangular blocky	Moderately firm	Slightly sticky, Slightly plastic	-	Clear smooth	Many
C	140-196+	10 YR 6/3	5 YR 6/1	M3P	silt loam	subangular blocky	Moderately firm	Slightly sticky, Slightly plastic	-	Clear smooth	many

Abbreviations: Mottle pattern- The first letter denotes abundance (F=few; C=common; M=many); The centre number denotes size (1=fine; 2=medium; 3=coarse); The second letter denotes contrast (D=distinct; P- prominent).

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reddish brown (5 YR ¾) and many, coarse, prominent, very dark brown (7.5 YR 2.5/3) mottles from the fourth to the bottom horizons and gleying of the two bottom layers of KRM2, corroborated the fact that the soil is under prolonged hydromorphic influence. Gleying was observed in all KRM profiles though at different depths varying with physiographic unit. Prominent black concretions (2.5/N) were present in the third horizon from the mineral soil surface which is an indication of anthropogenic influence. At the second to the bottom layer, common, yellowish brown concretions (10 YR 5/6) occurred which might be related to iron depositions.

The NDU1 soils were free of redoximorphic characteristics to a depth of about 138 cm. Surface layer soil colour of NDU1 was dark brown (10 YR 3/3) while the subsurface soil colours varied from dark yellowish brown (10 YR 4/4) through yellowish brown (10 YR 5/4), brown (10 YR 5/3) to light brownish gray (10 YR 6/2 and surface soil clour of NDU2 is dark yellowish brown (10 YR 4/4) while subsurface colours were dark yellowish brown (10 YR 4/4), brown (10 YR 5/3), dark yellowish brown (10 YR 3/4), yellowish brown (10 YR 5/4) and light brownish gray (10 YR 6/2). The surface soil colour of NDU3 was dark brown (10 YR 3/3) while subsurface soil colours are dark gray (10 YR 4/1), dark yellowish brown (10 YR 4/4), yellowish brown (10 YR 5/4), yellowish brown (10 YR 5/4) and pale brown (10 YR 6/3). Hydromorphic influence from ground water was obvious in all the profiles from the three physiographic units as indicated by the presence of mottles. Alternate wetting and drying conditions resulted in the reduction and release of iron oxides which accumulated in the form of dark reddish brown, pinkish gray and gray mottles in the subsurface horizons of the profile. Dark coloration of the surface horizon suggests the influence of organic matter (Dengiz et al., 2012) while gray colour matrix and chroma of 2 suggested that the soils have aquic conditions for some months in the year which was noticed in KRM3 and NDU3. Gleization therefore, is one of the dominant pedogenic processes in KRM3 and NDU3 as reported by Akpan-Idiok and Ogbaji (2014).

Physical Properties

Silt-sized particles dominated the particle size distribution of Koroama soils followed by sand and lastly clay and for the NDU soils, silt-sized particles similarly dominated the particle size distribution followed by clay and lastly, sand. Though textural class distribution in the Koroama soil profiles showed silt loam as the dominant textural class, slight variation in textural class distribution down the profile occurred in KRM2 and KRM3 (Table 4). In KRM2, texture varied from silt loam in the first two top layers to silty clay loam in the two layers that followed and to silt loam in the succeeding layers. In KRM3, texture similarly varied from silt loam in the surface two layers to silty clay loam in the following layers back to silt loam in the succeeding layer. This indicate that different types of sediments with different textures were deposited yearly according to their sources to form the parent materials of Koroama soils. Using the ratings of Hazelton and Murphy (2007), for Koroama soils (Table 4), silt is rated high in the surface and subsurface layers of all pedons, sand is low to moderate in the surface layers of KRM2 and KRM3, and clay is rated low to moderate in the surface and subsurface layers of KRM2 and KRM3. And for the NDU soils, silt is rated high for all the layers in all the pedons, clay is rated low to moderate in the top and sub

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soil layers of NDU1 and NDU2 but low in NDU3 while sand is rated low in all the pedons. Since the silt concentration in both top and subsoil layers in all the pedons is far above 50%, the KRM and NDU may have strong surface aggregation and have qualities that may resist erosion hazard.

Table 3: Physical Properties of the Koroama and Niger Delta University farm Soils

Horizon	**Depth cm**	**Percent Sand**	**Silt**	**Clay**	**Silt/clay ratio**	Textural Class
KRM1						
A1	0-7	24	61	15	4.1	Silt loam
A2	7-43	20	64	14	4.6	Silt loam
B1	43-86	21	60	19	3.2	Silt loam
B2	86-115	16	69	15	4.6	Silt loam
BC	115-130	16	67	17	3.9	Silt loam
C	130-200+	20	60	19	3.2	Silt loam
KRM2						
	0-15	24	67	9	7.4	Silt loam
Ap2	15-23	27	63	10	6.3	Silt loam
B1	23-40	19	53	28	1.9	Silty clay loam
B2	40-64	18	53	29	1.8	Silty clay loam
B3	64-78	19	67	14	4.8	Silt loam
C1	78-140	18	69	13	5.3	Silt loam
C2	140-194+	18	70	12	5.8	Silt loam
KRM3						
Ap	0-12	30	61	9	6.8	Silt loam
Ap2	12-39	20	64	16	4	Silt loam
B1	39-59	10	60	30	2	Silty clay loam
B2	59-96	17	64	29	2.2	Silty clay loam
B3	96-135	16	54	30	1.8	Silty clay loam
C	135-190+	18	67	25	2.3	Silt loam
NDU1						
Ap	0-19	20	73	7	10.4	Silt loam
B1	19-39	10	61	29	2.1	Silty clay loam
B2	39-71	10	62	28	2.2	Silty clay loam
B3	71-81	11	59	30	2	Silty clay loam
C1	81-138	18	72	10	7.2	Silt loam
C2	138-195+	21	64	15	4.3	Silt loam
NDU2						
Ap	0-12	20	61	19	3.2	Silt loam
Ap2	12-26	22	60	18	3.3	Silt loam
B1	26-36	13	59	28	2.1	Silty clay loam
B2	36-53	15	57	28	2	Silty clay loam
B3	53-116	19	57	24	1.9	Silt loam
C	116-190+	16	70	14	5	Silt loam
NDU3						
A1	0-5	16	69	15	4.6	Silt loam
A2	5-13	17	69	14	4.9	Silt loam
AB	13-20	16	69	15	4.6	Silt loam
B1	20-75	14	67	19	3.5	Silt loam
B2	75-140	15	66	19	3.5	Silt loam
C	140-190+	15	69	16	4.3	Silt loam

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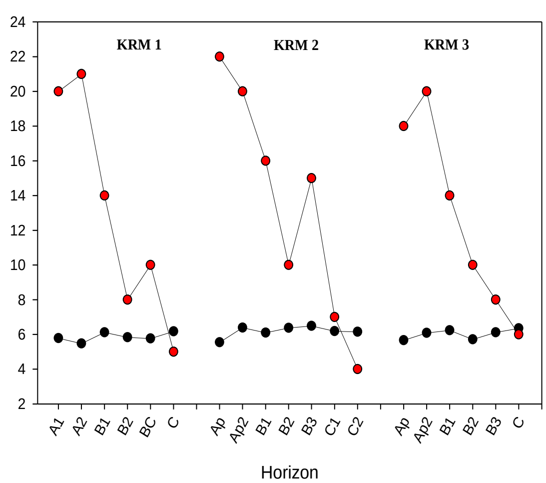
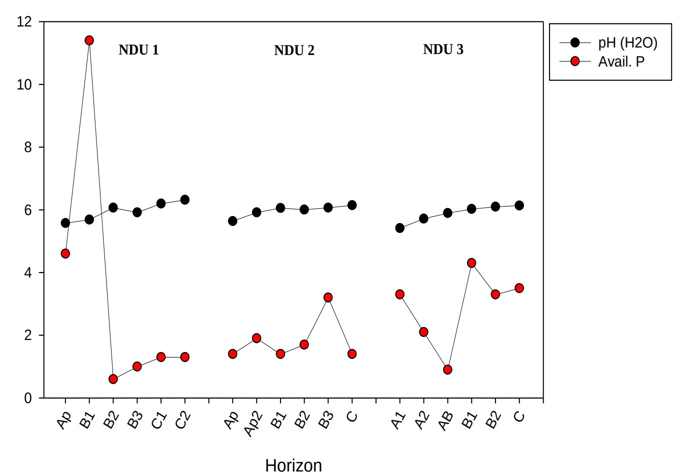
Chemical Properties

The chemical properties of the soils are presented in Figures 2, 3, 4 . pH varied from 5.64 to 6.30 in the KRM soils and 5.64 to 6.13 in the NDU soils. Organic C was 0.13 to 1.81% in the KRM soils 0.23 to 2.81% in the NDU soils. Total N values varied from 0.01-0.11 (0.11 mean) in KRM1 soils while N was 0.02 to 0.22% in the NDU soils. Available P (mg/Kg) in the KRM soils varied from 5-22 and in the NDU soils from 0.6 to 11. The relative abundance of exchangeable bases in the surface and in the subsurface layers were in the decreasing order of Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and K^{+} › Ca^{++} › Mg^{++} › Na^{+} (subsurface) in KRM1; Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › Mg^{++} › K^{+} › Na^{+} (subsurface) in KRM2; Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › Mg^{++} › K^{+} › Na^{+} (subsurface) in KRM3 and in the NDU soils were in the decreasing order of Mg^{++} › Ca^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › Mg^{++} › K^{+} › Na^{+} (subsurface) in NDU1, Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › Mg^{++} › K^{+} › Na^{+} (subsurface) in NDU2 and Ca^{++} › Mg^{++} = K^{+} › Na^{+} (surface) and Ca^{++} › K^{+} › Mg^{++} › Na^{+} in NDU3. The Al saturation in the surface of Koroama SMUs was 20-24 in KRM1, 28-59 in KRM2 and 21-25 in KRM2 and in the subsurface layers, 20-37, 10-30 and 11-25, respectively while base saturation in the surface was 55-57 in KRM1, 21-40 in KRM2 and 36-50 in KRM3 and in the subsurface, 24-66, 41-77 and 40-78, respectively.in the NDU soils, Al saturation in the surface of NDU SMUs was 23-32 in NDU1, 20-44 in NDU2 and 26-31 in NDU3 and in the subsurface layers, 18-31, 16-39 and 22-25, respectively. Base saturation in the surface was 44-48 in NDU1, 33-49 in NDU2 and 30-51 in NDU3 and in the subsurface layers, 43-63, 27-64 and 47-51, respectively.





According to FAO (2006) and Brady and Weil (2005), a pH range of 5.5 to 7.0 is the preferred range for most crops because it is optimal for the overall satisfactory availability of plant nutrients. Using this pH range, only the soil samples from KRM3 (5.48) and NDU3 (5.42) fall below the 5.5 to 7.0 range indicating that the soils generally are suitable for most crops. Increasing soil pH values

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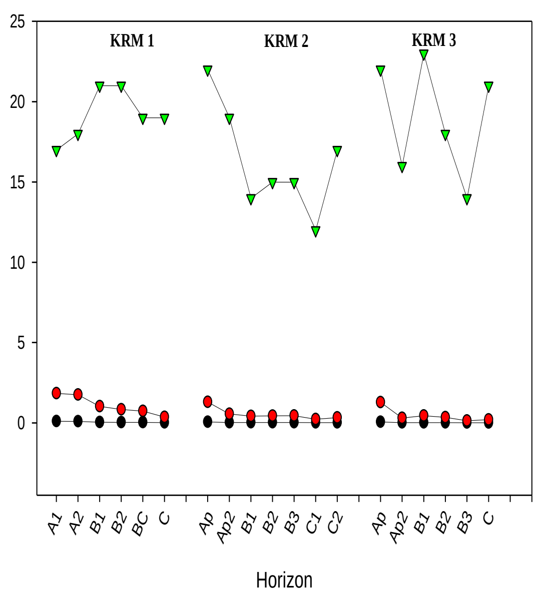
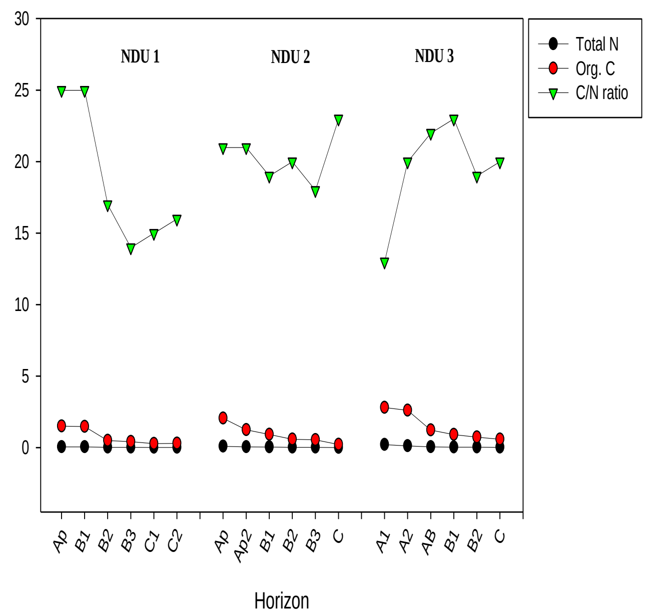
with increasing depth have been attributed to downward translocation of basic cations and leaching (Abate *et al.*, 2014). The results of this study showed noticeable increase in soil pH with increasing soil depth especially within the top 40 cm depth suggesting that there is leaching loss of nutrients with the heavy rainfall experienced in the area.

Generally, organic carbon concentration in the soils of the study area decreased irregularly with increase in soil depth which agreed with the findings of Idoga and Azagaku (2005) and Atofarati *et al* (2012) in Nigeria and Abate *et al* (2014) and Alemayehu *et al* (2014) in Ethiopia. The decrease in organic carbon with increasing depth in most of the soil mapping units was ascribed to low biomass return to the soil, especially during the short fallow periods coupled with cultural practices such as bush burning which destroy most of the organic materials. It is interesting to note that bush burning is the main method of bush clearing in the study area which most likely contributed to the lowering of the organic carbon content. Moreover, continuous cultivation with short fallow periods is now a normal agricultural practice in the study area which hitherto practiced land rotation as a means of restoring fertility of soils. Due to increase in population fallow periods are being shortened.





Total N values are higher in the surface soil layers than in the subsurface layers revealing that organic matter is the main source of total N in the soils. Habtamu *et al.* (2009) and Alemayehu *et al.* (2014), in Ethiopia confirmed that bush burning and removal of crop residue significantly reduced soil organic carbon and total N contents when cultivated and uncultivated land were compared. Hartz (2007) reported that soils with less than 0.07% total N have limited N

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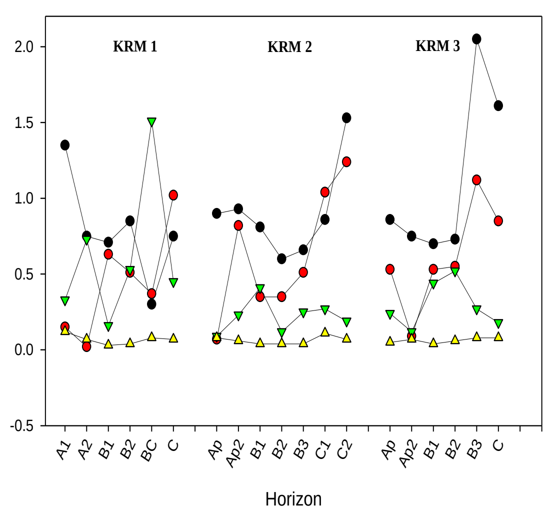
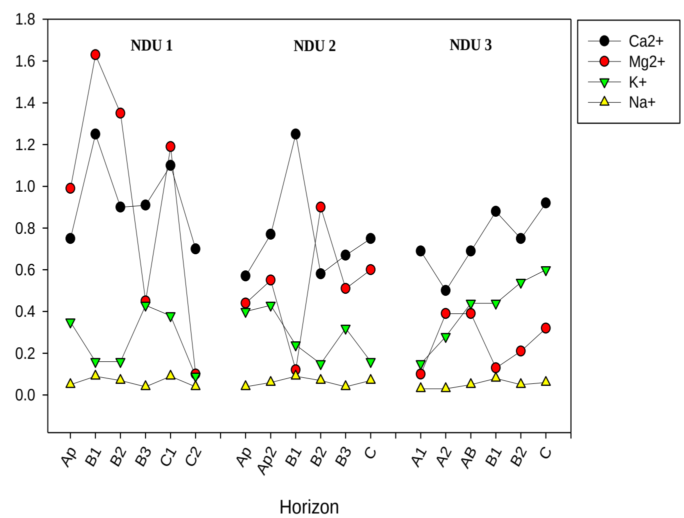
mineralization potential, whereas those with total N higher than 0.15% would be expected to mineralize sufficient amount of N during the succeeding crop cycle. Based on this, the surface 40cm depth of KRM1, NDU2 and NDU3 have high mineralization potential while KRM2, KRM3 and NDU1 have low mineralization potentials.

The results of carbon to nitrogen ratio (C/N) showed irregular distribution with soil depth and topographical position in most of the soils. Most layers of the soils from KRM1, KRM2, KRM3, NDU1, NDU2 and NDU3, C/N ratio especially in the plow zone is relatively higher than the common range (8:1 – 15:1) proposed by Brady and Weil (2005) for arable soils.

Available P concentration in the KRM soils decreased with increase in soil profile depth which showed a close relationship between organic matter and soil P but not in the NDU1, NDU2 and NDU3 soils. Phosphorus concentration in the NDU soils were generally low. The low available P levels in NDU1 NDU2 and NDU3 might be attributed to high exchangeable acidity in these soils in comparison to total exchangeable bases. Alemayehu *et al* (2014) considered high soil available P concentration as a reflection of slightly acidic to neutral soil reaction and low contents of exchangeable Al.

Comparing to FAO (2006) ratings for Ca^{++} and Mg^{++}, the results indicate that surface 40 cm and subsurface exchangeable Ca^{++} in soils are very low while exchangeable Mg^{++} contents are low to medium based. Low exchangeable bases in soils (Ca, Mg, K and Na) have been attributed to acidifying properties of organic matter, high aluminum concentration and leaching loss of exchangeable bases (Tisdale *et al.*, 2004). The low exchangeable Ca and Mg in these soils may be attributed to low nutrient retentive capacity, high exchangeable Al and Fe and leaching loss of the nutrients due to high rainfall.





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Exchangeable K in the soils unlike exchangeable Ca and Mg varied from low to very high (FAO, 2006). Most of values fall within medium to very high rating indicating that most of the soils have sufficient K for crop growth. This is understandable because common to many and/or abundant mica flakes were seen during the field sampling. According to FAO (2006), soils with exchangeable K greater than 1.2 is very high, 1.2 - 0.6 high, 0.6 – 0.3 medium, 0.3 - 0.2 low and less than 0.2 very low. Comparing the mean K values obtained in this study with FAO (2006) rating, K concentration was medium in KRM1 (surface and subsurface) KRM3 (subsurface), NDU2 (surface) and NDU3 (subsurface) and low in KRM2 (surface and subsurface), KRM3 (surface), NDU1 (surface and subsurface), NDU2 (subsurface) and NDU3 (subsurface). The K concentration in most of the soils from KRM and NDU are low to medium. This development is difficult to explain since mica flakes presence was noticed in all the profile pits.

Sum of the bases in the soils was low which reflects the low concentration of basic cations in the soils. Also, effective cation exchange capacity of the soils across the pedons was generally low. Exchangeable acidity values obtained in these soils vary from low to high based on the critical limits for interpreting analytical parameters by Esu (1991). Exchangeable Al and exchangeable H make up the exchangeable acidity in soils. In the Koroama soils, exchangeable Al (cmol/kg) values for the surface 40 cm are 0.7 (0.7 mean) for KRM1, 0.8-3.8 (2.0 mean) for KRM2 and 0.7 (0.7 mean) for KRM3 and in the subsurface layers, the values are 0.6-2.4 (1.5 mean), 0.3-0.9 (0.7 mean) and 0.5-1.0 (0.8 mean) for the respective soils. Exchangeable Al (cmol/kg) in the surface 40 cm of Niger Delta University Farm soils varied from 1.0-2.3 (1.8 mean), 0.7-2.0 (1.5 mean) and 0.8-1.0 (0.9 mean) for NDU1, NDU2 and NDU3 and in the subsurface layers 0.6-1.8 (1.1 mean), 0.4-2.4 (1.6 mean) and 0.7-0.8 (0.8 mean) for the respective soils. The highest value (3.8cmol/kg) is recorded in the middle slope of Koroama (KRM2). Generally, exchangeable Al distribution down the profiles studied is irregular, suggesting no movement of Al from the surface to the bottom layers, corroborating the fact that the soils are in their early stages of development. Moreover, exchangeable H is contributing more to the total exchangeable acidity of the soils studied than exchangeable Al which may well mean that weathering is not advanced enough to release more quantity of Al to the soils.

Variability of the Soil Properties

The complexity of soil property variability in the Koroama and Niger Delta University Teaching and Research farm soils was indisputable given the results generated in this study (Tables 2, 3 4, 5 and 6). There were variations in soil colour, sequential arrangement of horizons within and between physiographic units and among the two locations and mottling patterns and depths between locations and physiographic units. Moreover, only KRM1 gave indication of anthropogenic influence in the profile as indicated by prominent black concretions (2.5/N) present in the third horizon from the mineral soil surface and at the second to the bottom layer, common, yellowish brown concretions (10 YR 5/6) occurred which might be related to iron depositions.

As reported by previous authors (Mulla and McBratney, 2001l; Effiom *et al.*, 2010) in the humid region of Nigeria, pH was the least variable among the topographic units. The variability of the

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sand, silt and clay in the three different physiographic units of the two locations showed some similarity and dissimilarity. Sand was moderately variable (CV=) in all the physiographic units of Koroama soils and moderately variable in the upper and middle slopes of NDU soils but not variable in the lower slope, silt was not variable in all the physiographic units of both locations, while clay was not variable in the upper and middle slopes of Koroama but highly variable (CV= ≥35)in the lower slope, in the NDU soils, clay was highly variable in the upper slope, moderately variable in the middle slope and not variable in the lower slope. Clay was the most variable in the soil mapping units and among the three soil separates (sand, silt and clay). Owing to the fact that fluvial parent materials were deposited by the annual floods form the Niger River, sand is expected to be deposited under fast moving current followed by silt when the current slows down to an extent and lastly, clay, under standing water one expected clay to be dominant in the in the upper and middle slopes. The very fact that clay is highly variable in these soils did not reflect that. It is possible the recorded clay distribution is due to variation in parent material or clay distribution has changed due to weathering of the parent materials.

Organic C, total N and available P were highly variable (CV= ≥35) in all the soil mapping units and in physiographic units, reflecting the positive relationship between organic matter and total N as well as available P (Figures 2 and 3). This explains the fact that total N in these soils is a function of organic matter as N is stored in organic matter. It is also possible that organic matter predominantly contributed to available P in the soils. Also, calcium in Koroama soils was highly variable in the upper and lower slopes and moderately variable in the middle slope while in the NDU soils, Ca was moderately variable in the upper and middle slope but highly variable in the lower slope. On the other hand, Mg was highly variable in the different physiographic units of the two locations while K was highly variable in all physiographic units of Koroama soil, in the NDU soil, it was highly variable in the upper and middle slopes and moderately variable in the lower slope. Exchangeable Al and acidity were moderately variable in the lower slope and highly variable in the upper and middle slopes of Koroama soils while in the NDU soils, exchangeable Al was not variable in the lower slope and highly variable in the upper and middle slopes. Exchangeable acidity was moderately variable in the lower slope of NDU soils and highly variable in the upper and middle slopes. The TEB variability in the Koroama soils was moderate in the upper slope, highly variably middle and lower slopes while in the NDU soils, it was highly variable in the upper slope, not variable in the middle slope and moderately variable in the lower slope.

Table 5: Variability of some physical and chemical Properties of Koroama Soils

Soil Properties	KRM1 Range	Ẋ	SD	CV (%)	KRM2 Range	Ẋ	SD	CV (%)	KRM3 Range	Ẋ	SD	CV (%)
pH (H2O)	5.48-6.18	5.86	0.26	4.37a	5.55-6.49	6.18	0.31	5.05a	5.67-6.35	6.03	0.28	4.59a
pH ($CaCl_2$)	5.02-5.55	5.29	0.21	3.96a	4.27-5.52	5.05	0.46	9.17a	4.15-5.52	5.22	0.53	10.12a
Org. C (%)	0.37-1.84	1.10	0.59	53.42c	0.23-1.30	0.53	0.35	66.10c	0.14-1.29	0.46	0.42	92.14c
Total N (%)	0.02-0.11	0.06	0.04	60.50c	0.02-0.06	0.03	0.01	42.79c	0.01-0.06	0.02	0.02	79.81c
C/N ratio	17-21	19.17	1.60	60.50c	12-22	16.29	3.35	29.56b	14-23	19.00	3.58	18.84b
Avail P (mg/kg)	5-21	13.00	6.51	50.08c	12-22	13.43	6.68	49.74c	14-23	12.67	5.61	44.29c
Ca^{2+}	0.30-1.35	0.79	0.34	42.93c	0.60-1.53	0.90	0.30	33.82b	0.70-2.05	1.12	0.57	51.21c
Mg^{2+}	0.02-1.02	0.45	0.36	79.56c	0.07-1.24	0.63	0.42	67.25c	0.09-1.12	0.61	0.35	56.86c
K^{+}	0.16-1.51	0.62	0.48	77.18c	0.09-0.41	0.22	0.11	47.51c	0.12-0.52	0.30	0.15	52.34c
Na^{+}	0.03-0.12	0.07	0.03	46.71c	0.04-0.11	0.06	0.03	41.81c	0.04-0.08	0.06	0.02	25.79b
TEB (cmol/kg)	1.53-2.29	1.92	0.33	16.91b	1.11-3.03	1.78	0.71	39.61c	1.03-3.32	2.09	0.89	42.50c
Acidity (cmol/kg)	1.00-4.90	2.35	1.51	64.17c	0.70-5.40	2.30	1.53	66.52c	1.00-2.10	1.75	0.57	32.46b
Exch. Al (cmol/kg)	0.60-2.40	1.22	0.73	60.07c	0.30-3.80	1.27	1.16	91.27c	0.50-1.00	0.75	0.21	27.65b
ECEC(cmol/kg)	2.87-6.43	4.27	1.49	34.76b	2.71-6.80	4.08	1.59	38.87c	2.83-4.52	3.84	0.63	16.33b
BS (%)	24-66	49.17	14.91	30.32b	21-77	46.60	17.58	37.75c	36-78	53.17	16.45	30.94b
Al (%)	20-37	26.50	6.80	25.66b	10-59	28.86	15.19	52.63c	11-25	20.00	5.76	28.80b
Sand (%)	16-24	19.50	3.08	15.81b	18-28	20.43	3.60	17.62b	10-30	18.50	6.57	35.49b
Silt (%)	60-69	63.50	3.83	6.04a	53-70	63.14	7.27	11.51a	54-67	61.67	4.50	7.30a
Clay (%)	14-19	16.50	2.17	13.14a	9-29	16.43	8.42	3.18a	51.27c	9-30	23.17	37.77c

Ẋ = mean, SD = standard deviation, CV = coefficient of variation, where 'a' is ‹15% = least variable, 'b' is 15-35% = moderately variable, 'c' is ›35% = highly variable.

Table 6: Variability of some physical and chemical Properties of Niger Delta University Farm Soils

Soil Properties	NDU1				NDU2				NDU3			
	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)
pH (H2O)	5.58-6.55	5.96	0.29	4.85a	5.64-6.15	5.98	0.18	3.01a	5.42-6.14	5.89	0.30	4.70a
pH ($CaCl_2$)	4.28-5.49	4.86	0.55	11.31a	4.22-5.50	5.16	0.51	9.98a	5.20-5.55	5.40	0.15	2.70a
Org. C (%)	0.29-1.51	0.75	0.58	77.26c	0.23-2.06	0.94	0.65	69.52c	0.59-2.81	1.50	1.00	65.80c
Total N (%)	0.02-0.06	0.04	0.02	50.78c	0.01-0.10	0.05	0.03	64.24c	0.03-0.22	0.10	0.10	86.20c
C/N ratio	14-25	18.67	5.01	26.83	0.40-3.56	1.61	1.13	70.06c	1.02-4.84	2.60	1.00	65.80c
Avail P (mg/kg)	0.60-11	3.37	4.19	124.33c	1.4-1.9	1.83	0.70	38.19c	0.9-4	2.90	1.20	41.60c
Ca^{2+}	0.70-1.25	0.94	0.21	22.32b	0.57-1.25	0.77	0.25	32.68b	0.50-0.92	0.75	0.20	20.50b
Mg^{2+}	0.10-1.63	0.95	0.58	60.40c	0.12-0.90	0.52	0.25	48.08c	0.10-0.39	0.30	0.13	50.00c
K^{+}	0.09-0.43	0.26	0.14	54.11c	0.15-0.43	0.28	0.12	42.36c	0.15-0.60	0.41	0.17	20.50b
Na^{+}	0.04-0.09	0.06	0.02	36.92c	0.04-0.09	0.06	0.02	32.43b	0.03-0.08	0.05	0.02	37.90c
TEB (cmol/kg)	0.93-3.13	2.21	0.78	35.08c	1.45-1.81	1.63	0.13	7.58a	0.97-1.90	1.50	0.30	22.30b
Acidity (cmol/kg)	1.10-4.00	2.38	1.08	45.45c	0.90-4.50	2.88	1.33	46.13c	1.50-2.30	1.80	0.30	15.22b
Exch. Al(cmol/kg)	0.60-2.30	1.25	0.66	52.56c	0.40-2.40	1.58	0.82	51.80c	0.80-1.00	0.83	0.10	12.39a
ECEC(cmol/kg)	2.03-7.14	4.60	1.74	37.83c	2.48-6.20	4.51	1.36	30.14b	2.90-3.70	3.24	0.27	8.26a
BS (%)	43-63	48.67	7.31	15.02a	27-64	39.50	14.28	36.15c	30-51	44.67	8.07	18.05b
Al (%)	18-32	26.67	5.43	20.36a	16-44	32.67	11.62	35.57c	22-31	25.67	3.50	13.65a
Sand (%)	10-20	15.00	5.22	34.77b	13-28	17.50	3.39	19.83b	14-17	15.50	1.05	6.77a
Silt (%)	59-73	65.17	5.91	9.07a	57-70	60.67	4.84	7.99a	66-69	68.17	1.33	1.95a
Clay (%)	7-30	19.83	10.38	52.34c	14-28	21.83	5.74	26.30b	14-19	16.33	2.16	13.22a

Ẋ = mean, SD = standard deviation, CV = coefficient of variation, where 'a' is ‹15% = least variable, 'b' is 15-35% = moderately variable, 'c' is ›35% = highly variable.
40.86

CEC variability in Koroama soil was moderate in the upper and lower slopes and highly variable in the middle slope while in the NDU soil, it was highly variable in the upper slope, moderately variable in the middle slope and not variable in the lower slope, reflecting differences in the source of parent materials and possibly, the degree of hydromorphism.

CONCLUSIONS

The Koroama and NDU soils exhibited varying degree of variability in morphological, physical and chemical properties. Variability reflected the degree and the pattern of flooding, the source of parent materials and degree of hydromorphism which mould the pedo-chemical environment. Parent materials of mixed origin, seasonal inundation by the flood water and dry spell in the dry season set the stage for alternate oxidation and reduction, providing unique soil properties. Flooding, wetness and soil fertility are major constraints to agricultural intensification.

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