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Variability of some properties of the Nun River plain soils in Bayelsa State, Nigeria

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ABSTRACT

Whereas studies on spatial variability of soil properties on toposequences are well documented, information on the variability of characteristics of floodplain soils is lacking. This study, therefore, evaluates the status and variability of the soil properties in three physiographic units in two locations on the Nun River floodplain. Silt-sized particles dominated soil texture and soil texture variability due to stratification associated with fluvial parent materials and the recentness of the deposits. The pH values ranged from 5.76 to 6.30, and pH was the least variable characteristic. Organic C, total N and available P were highly variable in all the physiographic units of Odoni. Odi soils and the distribution of these properties decreased irregularly down the profiles, revealing organic matter as the primary source of total N and available P. Calcium was the dominant cation in the exchange complexes of the soils, and Ca2+ variability was irregular. At the same time, primary, Mg^{2+} and K^{+} were highly variable (CV≥35%) in all the physiographic units of the two locations. Though exchangeable acidity values were high (above 1cmol/kg) across depths, physiographic unit and location, pH values were above 5.5, and no soil acidity problem is envisaged in these soils. Exchangeable bases and acidity variability results reflected differences in the source of parent materials and possibly, the degree of hydromorphism. Bush burning and removal of crop residues should be avoided to maintain organic matter in these soils. The most significant constraints to agricultural intensification are flooding, wetness and fertility constraints.

1.0 Introduction

Soil's physical, chemical, and biological properties vary tremendously in horizontal and vertical directions. Spatial variation in soil properties is influenced by several environmental factors, including topography, microclimatic differences, parent materials, and vegetation (Yimer et al., 2006; Dickson, 2018). A study on variation in soil properties is useful because Okeyo et al. (2006), in their report, emphasized the ability of spatial variation to become a threat to food security. According to Udoh et al. (2010), the effects of spatial variability are not limited to differences within-field crop growth alone but also a reduction in yields. Hence, Imman et al. (2005) proposed that fields identified with a high degree of spatial variability of soil properties be delineated into relatively homogenous units for better management. This allows monitoring and quantification to select appropriate agricultural use and management (Ojobor, 2017). The key to the generation of relevant information is a soil survey.

In the Meander Belt geomorphic region of Bayelsa State, agricultural production is blanketly carried out solely on alluvial soils (the upper slope, middle slope, lower slope and back swamps of major rivers and on channels of present active rivers without soil technical information guiding the use. It has been reported that the diverse nature of the soil is a major reason behind the allocation of land for wrong uses (Dickson, 2018). Increasing demographic pressures, urbanization, and industrialization places increasing demand on land resources. And UNDP (2006) emphasized that scarcity of land for agriculture remains a major constraint as the area is inherently lacking in relatively well-drained land for agriculture due to the many rivers, rivulets and creeks crisscrossing the area. In comparison, information and knowledge on the current nutrient status, capability, and potential suitability of the land for various uses are inadequate and obsolete, which makes the management of the soils difficult. Elsewhere, studies on spatial variability of soil properties on toposequences have been well documented (Okeyo et al., 2006; Udoh et al., 2010; Ojobor, 2017), but such information is lacking in the Nun River floodplain soils. Therefore, this study evaluates the status and variability of the soil properties in three physiographic units in two locations

2.0 Materials and Methods

2.1. Description of the Study Areas

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, with the attendant sediment load ensuring that the delta platform ends up as flat terrain, making it a unique geologic environment. The Niger River flows southward and breaks up into the Forcados and Nun Rivers in Bayelsa State. Forcados River demarcates the western border of the state and the Nun River, running north and south down the middle of Bayelsa State, which remains the most direct tributary of the Niger. Odoni community on the eastern bank and Odi on the western bank of the Nun River (Figure 1) were studied. The annual rainfall of the study area is 2000 – 4500mm, spread over 8 to 10 months of the year and bimodal, peaking in June and September. The relative humidity averages 80% all over the state, and the temperature is relatively constant with a maximum of 30^{o}C. The natural vegetation zone is the tropical rainforest.

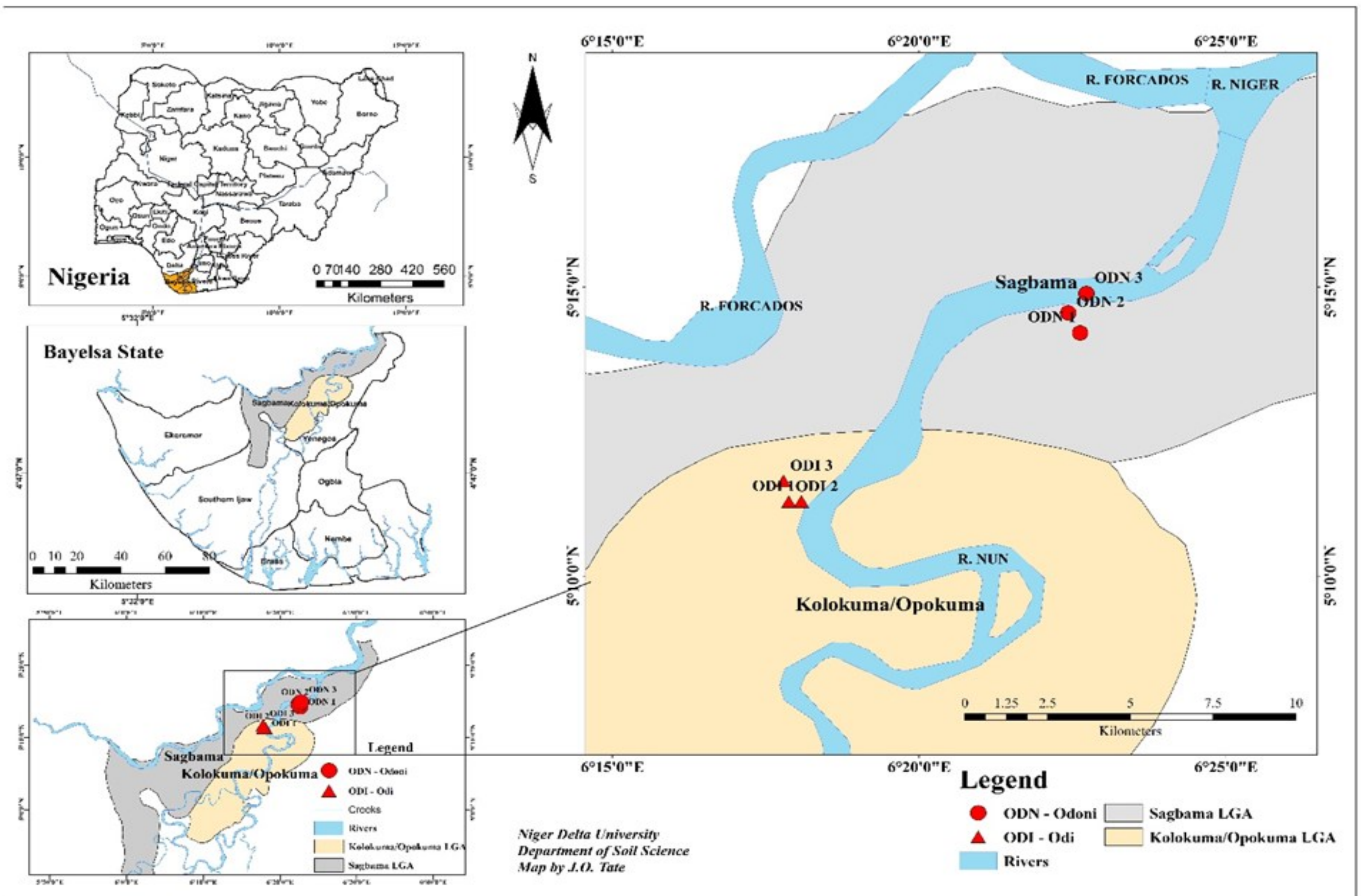

Figure 1: Map of Bayelsa State Showing Sampling Locations

2.2. Soil sampling and analyses

A detailed soil survey was conducted on agricultural lands from Odoni and Odi using rigid grids. The soil mapping units (SMUs) include ODN1, ODN2 and ODN3 for Odoni and ODI1, ODI2 and ODI3 for Odi soils. Odoni lies on the eastern bank of the Nun River, while Odi is on the western bank. 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 were collected from the different horizons for physicochemical properties determination following standard procedures. The soil samples 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. Standard laboratory methods were used to determine the physical and chemical properties of the soils. Soil particle size analysis was determined

Table 1: 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 (%)
Odoni	ODN1	N 05° 14' 12.4" E 006° 22' 37.2"	1	89.94	7.4
	ODN2	N 05° 14'33.3" E 006° 22' 25.5"	1	52.10	4.3
	ODN3	N 05° 14' 53.3" E 006° 22' 43.4"	1	90.57	7.4
Odi	ODI1	N 05° 11' 17.4" E 006° 18' 04.6"	1	142.49	11.7
	ODI2	N 05° 11' 17.1", E006° 17' 52.3"	1	65.06	5.3
	ODI3	N 05° 11' 38.7"" E 006° 17' 47.0"	1	138.65	11.4

using the method described by (Udo (2009), popularly known as the hydrometer method. Soil pH both in water and $CaCl_2$ (1:2 ratio) was determined using a glass electrode pH meter, and electrical conductivity (EC) was determined using a conductivity meter (Estafan *et al.,* 2013). Organic carbon was determined using the modified dichromate oxidation method of Walkley-Black described by Estafan *et al.* (2013), and the values obtained were multiplied by 1.724 (van Bemmelen factor) to obtain organic matter. Total N was determined using the macro-Kjeldahl digestion-distillation method described by (Udo, 2009) and available P by the Bray P-1 method described by Udo (2009). 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 were 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).

2.3. Data Analysis

Data were subjected to descriptive statistics. Significantly different means were separated 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).

3.0 Results and Discussion

3.1. Status and variability of soil particle size

Surface and subsurface textures in Odoni soils were predominantly silt loam followed by loam. The percentage of sand in the surface layers varied from 19 in ODN3 soil to 35 in ODN1, silt from 53 in ODN2 to 65 ODN1 and clay from 12 in ODN1 to 22 in ODN3. In the subsurface horizons, sand varied from 21 in ODN3 to 48 in ODN2, silt, 38 in ODN2 to 55 in ODN1 and clay, 6 in ODN1 to 29 in ODN3 (Table 2). The silt/clay ratio of the surface soil horizons varied from 2.4 to 5.4 and 1.7 to 8.8 in the subsurface layers. The soils of ODI were dominated by silt-sized particles, followed by sand and then clay. On the surface, percentage silt ranged from 45 to 57, sand, 31 to 41 and clay, 8 to 14 (Table 2). In the subsurface horizons, percentage silt ranged from 41 to 67, sand, 11 to 42 and clay, 10 to 22.

In the Odoni soils, sand was moderately variable in all the physiographic units, silt was moderately variable in the middle slope (CV=17.3), and clay was highly variable in the upper slope (CV= 47.9) and moderately variable in the middle slope (CV= 16.52) and the lower slope (CV= 26.57) (Tables 3 and 4). In the Odi soils, sand was highly variable in the middle slope (CV=35.31) and moderately variable in the upper slope (CV= 18.79) and lower slope (CV= 33.26), silt was highly variable in the upper slope (CV= 37.92) and moderately variable in the middle slope (CV= 16.58) and lowly variable in the lower slope (CV= 7.69). The dominance of silt over sand and clay may indicate that the soils are young, and there is the possibility of the breakdown of the silt fraction into the clay fraction to release nutrients. Generally, the variation in textural separates was dissimilar. Abua (2012), in southern Nigeria, recorded a dissimilar trend of variation in the texture of soils and attributed it to differences in the parent material and topography. However, Dickson (2018) attributed irregular distribution of the clay fraction with depth to stratification associated with fluvial parent

The silt/clay ratios recorded in this study (Tables 2) indicated that the soils were of young parent materials. Materials and the recentness of the deposits were yet to undergo serious soil development. Obviously, there was no sign of clay illuviation from surface horizon to subsurface horizon, supporting the fact that the soils are young and soil development is not in an advanced stage. It has been reported (Egbuchua and Ojobor, 2011) that old parent materials usually have a silt/clay ratio below 0.15, while silt/clay ratios above 0.15 are indicative of young" parent materials.

Status and variability and distribution of pH, organic C, total N and available phosphorus

The chemical properties of Odoni and Odi soils are presented in Figures 1 to 4. In the Odoni soils, the pH (H_2O) of the topsoil ranged from 5.76 to 6.04 and in the subsurface horizons, from 6.04 to 6.30 (Figure 2). For the Odi soils, pH ranged from 5.83 to 6.30 in the surface layers and the subsurface horizons, 6.00 to 6.03. Organic C in the topsoil of Odoni soils varied from 0.31 to 2.33%, and in the subsurface, 0.01 to 0.99%. While in the Odi soils, organic C was 5.25% in the surface layers and in the subsurface layers, 0.11 to 0.93%. Total N values for the surface layers were 0.03 to 0.21 and in the subsurface layers, 0.01 to 0.09% in the Odoni soils, while in Odi soils, total N in the surface layers were 0.04 to 0.45 and in the subsurface layers, 0.01 to 0.04 (Figure 3). Available P in the topsoil of Odoni soils varied from 8 to 22mg/kg and in the subsurface, 1 to 9mg/kg and in the surface layer of Odi soils, available P was 7 to 21mg/kg, and in the subsurface layers, 2 to 19mg/kg (Figure 2).

Table 2: Some Physical Properties of the Odoni and Odi Soils

Horizon Design.	Depth (cm)	Percent			Silt/clay ratio	Textural Class
		Sand	Silt	Clay		
			ODN1			
Ap	0-23	25.0	65.0	12.0	5.4	Silt loam
Ap2	23-30	22.0	65.0	13.0	5	Silt loam
B1	30-63	31.0	55.0	14.0	3.9	Silt loam
B2	63-117	41.0	53.0	6.0	8.8	Silt loam
B3	117-160	29.0	53.0	18.0	2.9	Silt loam
C	160-200+	32.0	52.0	16.0	3.3	Silt loam
			ODN2			
Ap	0-10	21.0	60.0	19.0	3.2	Silt loam
Ah	10-20	35.0	53.0	12.0	4.4	Silt loam
B1	20-40	31.0	55.0	14.0	3.9	Silt loam
B2	40-110	27.0	58.0	15.0	3.9	Silt loam
BC	110-141	35.0	53.0	12.0	4.4	Silt loam
C1	141-180	47.0	39.0	14.0	2.8	Loam
C2	180-200+	48.0	38.0	14.0	2.7	Loam
			ODN3			
A	0-5	19.0	63.0	18.0	3.5	Silt loam
Ap1	5-11	23.0	65.0	12.0	5.4	Silt loam
Ap2	11-25	21.0	61.0	18.0	3.4	Silt loam
B1	25-41	25.0	53.0	22.0	2.4	Silt loam
B2	41-48	21.0	51.0	28.0	1.8	Silty clay loam
B3	48-56	22.0	49.0	29.0	1.7	Silty clay loam
C1	56-122	29.0	49.0	22.0	2.2	Loam
C2	122-200+	33.0	48.0	19.0	2.5	Loam
			ODI1			
Ap	0-26	31.0	56.0	13.0	4.3	Silt loam
A	26-60	41.0	44.0	15.0	2.9	Loam
B1	60-78	31.0	49.0	20.0	2.5	Loam
B2	78-120	17.0	67.0	16.0	4.2	Silt loam
B3	120-135	39.0	41.0	20.0	2.1	Loam
C1	135-163	25.0	63.0	12.0	5.3	Silt loam
C2	163-186	11.0	67.0	22.0	3	Silt loam
C3	186-200+	23.0	65.0	12.0	5.4	Silt loam
			ODI2			
Ap	0-20	41.0	45.0	14.0	3.2	Loam
A	20-40	42.0	47.0	11.0	4.3	Loam
B1	40-110	31.0	57.0	12.0	4.8	Silt loam
B2	110-141	35.0	51.0	14.0	3.6	Silt loam
B3	141-180	21.0	61.0	18.0	4.4	Silt loam
C	180-200+	15.0	69.0	16.0	4.3	Silt loam
			ODI3			
Ah	0-3	35.0	57.0	8.0	7.1	Silt loam
Ap	3-20	21.0	63.0	16.0	3.9	Silt loam
Ap2	20-46	27.0	58.0	15.0	3.9	Silt loam
B1	46-60	37.0	53.0	10.0	5.3	Silt loam
B2	60-94	21.0	65.0	14.0	4.6	Silt loam
B3	94-145	21.0	65.0	14.0	4.6	Silt loam
C1	145-158	17.0	65.0	18.0	3.6	Silt loam
C2	158-200+	15.0	65.0	20.0	3.3	Silt loam

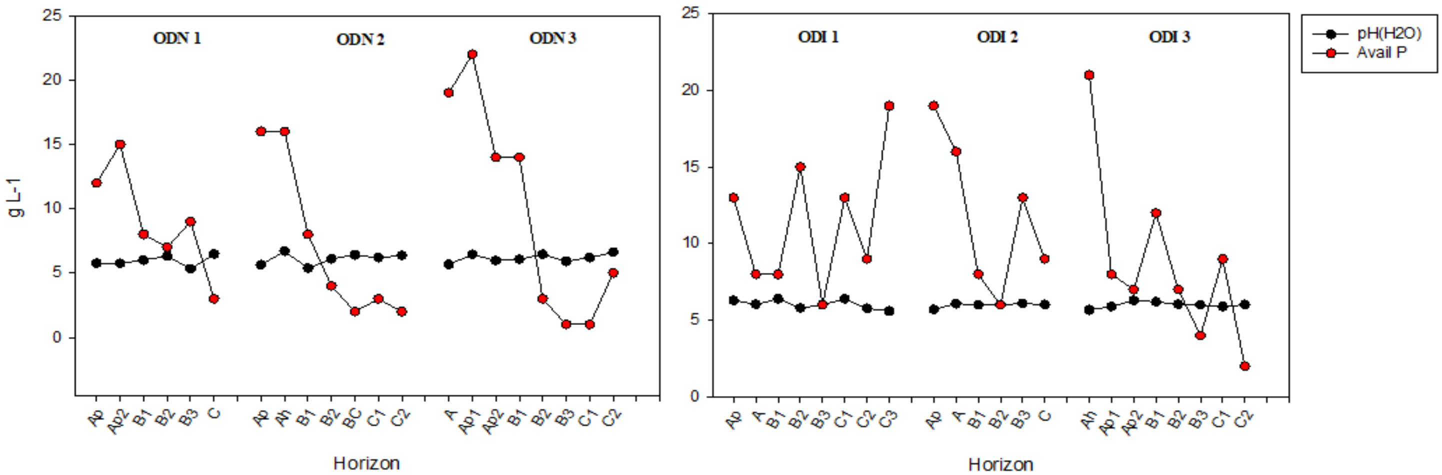

Figure 2: pH and Available Concentration in the Soils

The pH values encountered in this study based on the Fertilizer Procurement and Distribution Department (FPDD) (2012) of the Federal Ministry of Agriculture, Nigeria, were moderate to slightly acid. As previously reported (Mulla and McBratney, 2001; Effiom *et al.,* 2010; Mahmud et al., 2019) Nigeria, pH was the least variable among the topographic units.

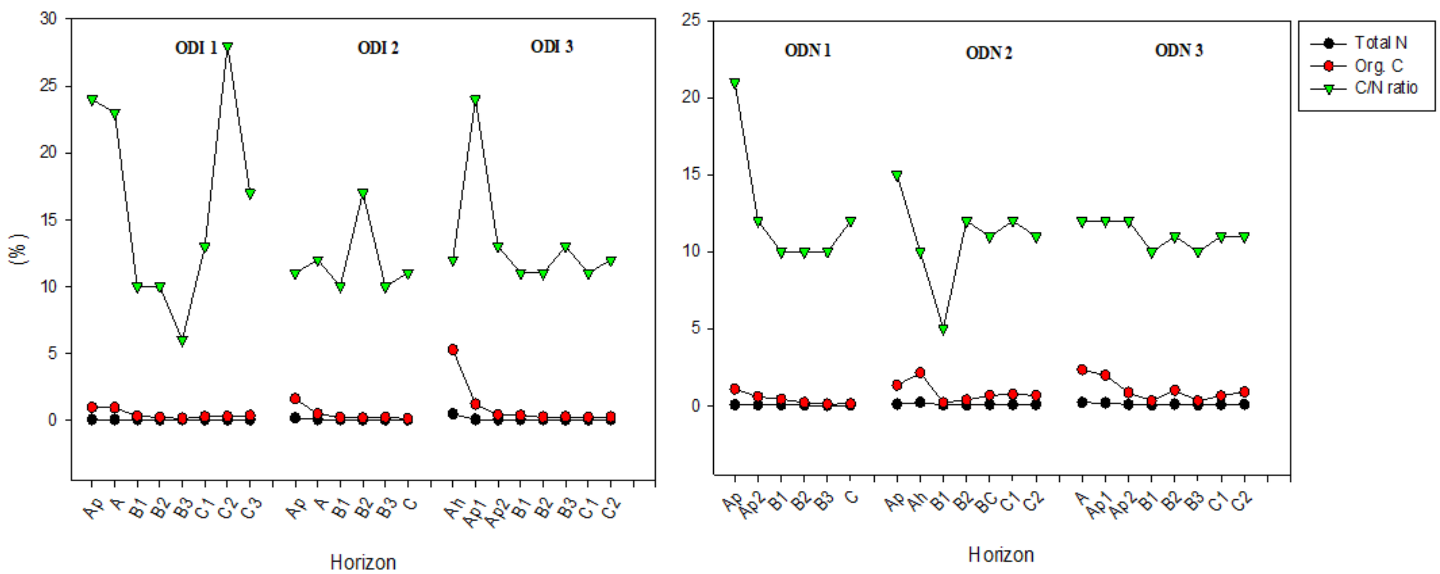

Figure 3: Total N, org. C and C/N ratio in the soils

Organic C, total N and available P were highly variable in all the physiographic units of Odoni and Odi soils (Tables 3 and 4) which is also reflected in figures 2 and 3. The distribution of these chemical properties also decreased irregularly down the profiles with increasing depth revealing that organic matter is the main source of total N and available P in the soils. The highest (0.45%) value of total N was recorded in the surface layer of ODI3 soil from Odi designated "'Ah', where the highest organic C content (5.25%) was recorded. Total N content in all locations, except ODN2, was higher in the surface soil layers than the underlying horizon, which is attributed to higher organic C contents on the surface. Studies in Ethiopia (Habtamu et al., 2009; Alemayehu et al., 2014) confirmed that bush burning and removal of crop residue significantly reduce soil organic carbon and total N contents as cultivated and uncultivated land were compared. This indicated high N release from the organic matter sources since soil N is positively associated with soil organic matter content. The irregular decrease in organic carbon down the profile may indicate variation in the source of parent materials.

Available P concentration decreased with an increase in soil profile depth in the soils, which showed a close relationship between organic matter. Abate et al. (2014), in a study of soils along a toposequence in Ethiopia, reported that available P showed an increasing trend down the topographic position and a decreasing trend with depth which they attributed to an increase in clay content and a decrease in soil organic matter content. In this study, soil organic matter content in the various horizons showed a positive relationship with available P as both of them decreased with depth, indicating that P decrease is due to decreasing concentration of organic matter with depth.

Status, variability and distribution of exchangeable bases and acidity

The relative abundance of exchangeable cations in the top soil layer and in the subsurface were in the decreasing order of Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › K^{+} › Mg^{++} › Na^{+} (subsurface) in ODN1; Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca++ › Mg++ › K+ › Na^{+} (subsurface) in ODN2; Ca++ › K+ › Mg++ › Na^{+} (surface) and K+ › Ca^{++} › Na^{+} › Mg^{++} (subsurface) in ODN3. In the Odi soil, exchangeable bases relative abundance in the surface layer and in the subsurface layers were in the decreasing order of K^{+} › Ca^{++} › Mg^{++} › Na^{+} (surface) and Ca^{++} › K^{+}› Mg^{++} › Na^{+} (subsurface) in ODI1; Ca^{++} › K^{+} › Mg^{++} › Na^{+} (surface) and Mg^{++} › Ca^{++} › K^{+} › Na^{+} (subsurface) in ODI2; Ca^{++} › Mg^{++} › K^{+} › Na^{+} (surface) and Ca^{++} › K^{+} › Mg^{++} › Na^{+} (subsurface) in ODI3. Potassium concentration (cmol/kg) in the soils was 0.33 to 1.22 cmolkg^{-1} in Odoni and 0.2 to 1.51 cmolkg^{-1} in Odi. Exchangeable acidity ranged from 1.10 to 6.20 in Odoni soils and 0.90 to 5.00 in Odi soils. Most soil samples recorded exchangeable acidity values below the critical value of 2.0 cmolkg^{-1}

Calcium was the dominant cation in the exchange complexes of the soils in both location and physiographic units. Variability of Ca was low in the middle slope, moderate in the upper slope and high in the lower slope, while in the Odi, variability was low in the upper and lower slopes and moderate in the middle slope of Odi soil. The variability of Mg in the Odoni and Odi soils, unlike Ca, was high in the upper, middle and lower slopes. An accumulation of Mg over Ca result in the exchange complexes

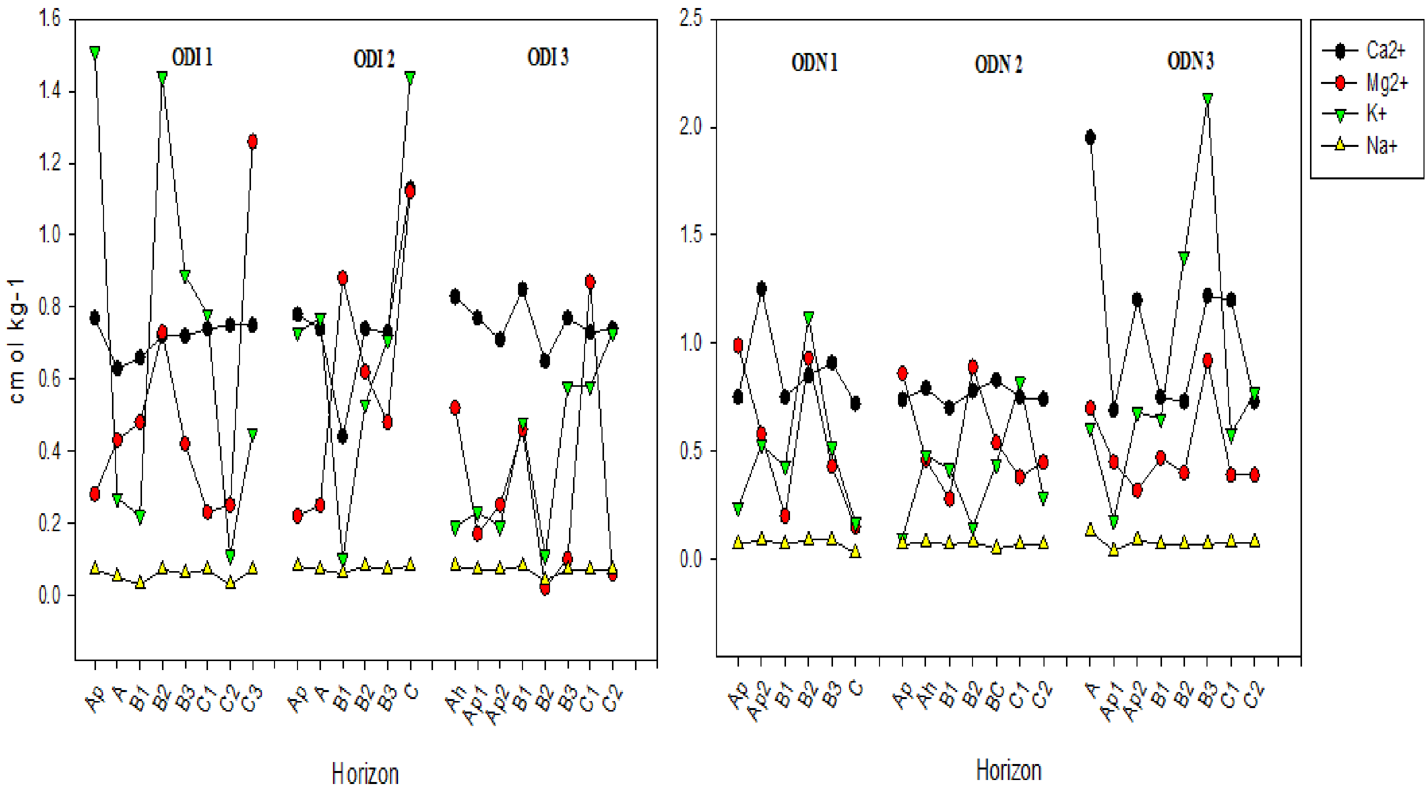

Figure 4: Concentration of Exchangeable bases in the soils

of some profiles were observed, which seem uncomfortable because soils with high Mg tend to have poor structure (Lawal et al., 2013; Sharu et al., 2013). According to Garcia-Ocampo (2003), accumulation of Mg in the soil causes deterioration of soil structure, lower water intake rates and affects chemical and biological properties of soils. Appropriate Ca/Mg ratios in soils will improve soil structure, reduce leaching loss of other nutrients, reduce weed population and generally improve the balance of most nutrients (Sharu et al., 2013). Similar to FAO (2006) report, exchangeable K varied from low to high and in the variability analysis, exchangeable K in all the locations and every physiographic unit was highly variable (Table 4 and 5), which is also reflected in Figure 3. Exchangeable acidity variability in Odoni soils was high in the middle slope and moderate in the upper and lower slopes, while in the Odi soil, it was high in the lower slope and moderate in the upper and middle slopes. Though exchangeable acidity values were high (above 1cmol/kg) across depths, slope and location (Nahmud et al., 2019), all pH values were above 5.5 (critical level), below which acidity problem is potential. One should, therefore, expect no soil acidity problem in these soils. The exchangeable bases and acidity variability results are probably a reflection of differences in the source of parent materials and possibly the degree of hydromorphism. However, the physical properties of the soils were less variable than the chemical properties, as previously reported by Amuyou et al. (2013) and Mahmud et al. (2019).

Table 3: Variability of some physical and chemical Properties of Odoni Soils

Soil Properties	ODN1				ODN2				ODN3			
	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)
pH (H_2O)	5.33-6.48	5.90	0.37	6.19a	5.38-6.70	6.06	0.46	7.55a	5.67-6.62	6.17	0.32	5.22a
pH ($CaCl_2$)	5.17-5.72	5.35	0.84	3.41a	5.18-6.19	5.39	0.33	2.98a	5.18-5.70	5.38	0.16	2.98a
Org. C (%)	0.01-1.07	0.52	0.93	75.58c	0.20-2.13	0.93	0.63	68.00c	0.31-2.33	1.04	0.73	71.40c
Total N (%)	0.01-0.05	0.04	0.02	52.91c	0.03-0.21	0.08	0.06	70.75c	0.03-0.20	0.09	0.06	68.20c
C/N ratio	10-21	13.50	4.72	34.96c	5-15	11.38	3.16	27.77b	10-12	11.13	0.84	7.51a
Avail P (mg/kg)	3-15	10.13	4.16	41.07c	2 – 16	8.38	6.59	78634c	1 – 22	9.88	8.39	84.92c
Ca^{2+}	0.72-1.25	0.76	0.04	24.85b	0.70-0.83	0.76	0.04	5.25a	0.69-1.95	1.06	0.43	40.79c
Mg^{2+}	0.15-0.99	0.59	0.24	41.27c	0.28-0.89	0.55	0.24	69.94c	0.32-0.92	0.51	0.20	40.04c
K^+	0.17-1.12	0.47	0.30	63.42c	0.10-0.82	0.35	0.24	62.44c	0.18-2.13	0.88	0.61	69.49c
Na^+	0.03-0.09	0.08	0.02	27.60b	0.05-0.08	0.07	0.01	13.23a	0.04-0.13	0.08	0.03	32.15b
TEB (cmol/kg)	1.07-2.99	2.06	0.60	29.25b	1.47-2.02	1.77	0.18	10.19a	1.36-4.34	2.52	0.94	37.33c
Acidity (cmol/kg)	1.10-2.80	1.95	0.52	26.72b	1.50-6.20	2.51	1.56	62.18c	1.60-3.40	2.20	0.57	25.73b
Exch. Al(cmol/kg)	0.70-1.80	1.21	0.39	32.51b	0.70-3.60	1.53	0.94	61.70c	0.80-2.00	1.33	0.37	28.85b
ECEC(cmol/kg)	2.47-4.75	4.01	0.71	17.59c	2.97-8.06	4.28	1.61	37.61c	3.66-6.84	4.72	1.08	22.85b
BS (%)	41-73	61.88	9.28	15.00b	23-59	44.29	11.38	25.70b	37-68	52.38	10.82	20.66b
Al (%)	17-45	30.50	9.07	29.74b	20-45	33.50	8.98	26.81b	16-41	28.50	7.73	27.12b
Sand (%)	22-41	18.63	4.41	23.66b	21-48	44.38	10.54	23.75b	19-33	24.13	4.70	19.50b
Silt (%)	52-65	63.38	7.37	11.62a	38-60	50.85	8.82	17.34b	53-65	54.88	6.98	12.72a
Clay (%)	6-18	18.00	8.60	47.97c	12-19	14.28	2.36	16.52b	12-29	21.00	5.59	26.57b
Silt/clay ratio	2.9-8.8	4.96	1.82	36.3c	2.7-4.4	3.56	0.68	19.03b	1.7-5.4	2.86	1.22	42.59c

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 4: Variability of some physical and chemical Properties of Odi Soils

Soil Properties	ODI1				ODI2				ODI3			
	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)	Range	Ẋ	SD	CV (%)
pH (H2O)	5.60-6.40	6.04	0.31	5.05 a	5.70-6.10	5.99	0.15	2.43a	5.67-6.30	6.00	0.19	3.23a
pH ($CaCl_2$)	5.07-5.55	5.29	0.14	2.62a	4.78-5.47	5.24	0.26	4.87a	5.11-5.40	5.28	0.11	1.99a
Org. C (%)	0.11-0.95	0.45	0.57	124.42c	0.11-1.58	0.45	0.56	124.62c	0.38-5.25	1.01	1.74	172.95c
Total N (%)	0.01-0.04	0.04	0.05	125.50c	0.01-0.14	0.04	0.05	125.50c	0.02-0.45	0.08	0.15	187.32c
C /N ratio	6-28	16.38	7.91	48.29c	10-17	11.83	5.04	22.32b		13.38	4.37	32.66b
Avail P (mg/kg)	6-19	11.38	4.37	38.40c	6-19	11.83	5.04	42.60c	2-21	8.75	5.80	66.29c
Ca^{2+}	0.63-0.77	0.72	0.05	6.73a	0.44-1.13	0.76	0.22	28.91b	0.65-0.85	0.76	0.06	8.52a
Mg^{2+}	0.23-1.26	0.51	0.34	67.25c	0.22-1.12	0.60	0.36	59.66c	0.02-0.87	0.31	0.29	95.10c
K^+	0.11-1.51	0.71	0.54	76.73c	0.10-1.44	0.71	0.43	60.87c	0.11-0.73	0.39	0.23	60.29c
Na^+	0.03-0.07	0.06	0.02	31.43b	0.06-0.08	0.07	0.01	11.13a	0.04-0.08	0.07	0.01	18.12b
TEB (cmol/kg)	1.14-2.96	1.99	0.67	33.58b	1.48-3.77	2.14	0.82	38.19c	0.82-2.25	1.52	0.44	28.72b
Acidity (cmol/kg)	1.50-2.50	1.81	0.32	17.54b	0.90-2.70	1.97	0.64	32.59b	1.80-5.00	2.50	1.06	42.56c
Exch. Al(cmol/kg)	0.80-1.20	0.95	0.20	21.05b	0.40-1.40	1.03	0.40	39.01c	0.90-3.00	1.34	0.73	54.33c
ECEC(cmol/kg)	2.74-4.56	3.81	0.71	18.58b	2.38-5.87	4.11	1.17	28.51b	3.22-5.82	4.02	0.86	21.35b
BS (%)	36-65	51.38	4.78	18.83b	42-64	52.17	9.43	18.08b	14-51	39.38	12.05	30.60b
Al (%)	20-34	25.38	9.38	18.26b	17-30	24.50	5.09	20.78b	20-51	31.88	9.69	30.40b
Sand (%)	11-41	27.25	10.33	18.79b	15-42	30.83	10.88	35.31c	15-37	24.25	8.07	33.26b
Silt (%)	41-67	56.50	27.25	37.92c	45-69	55.00	9.12	16.58b	53-65	61.38	4.72	7.69a
Clay (%)	12-22	16.25	1.26	34.05b	11-18	14.17	2.56	18.09b	8-20	14.38	3.93	27.31b
Silt/clay ratio	2.20-4.10	3.18	0.62	19.33b	2.70-5.55	3.29	1.18	30.42b	2.50-9.00	4.48	2.17	48.51c

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.

5.0. Conclusions

Nun River plain soils' physical and chemical properties showed varying degrees of variability, chemical properties being more variable. Variability, to a great extent, reflected the degree and the pattern of flooding, the source of parent materials and the degree of hydromorphism. Mixed parent materials of different origins and seasonal inundation by the flood water and dryness 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 and need to be addressed.

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