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Morphological and Physico-Chemical Properties of Soils Formed from Diverse Parent Materials in Cross River State, Nigeria.

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Abstract: *Morphological features and Physico-Chemical Properties of twenty surface soils derived from five varied parent materials in Cross Rivers Sate, Nigeria were evaluated in relation to probable constraints to increase crop yields. Four replicate soil samples were collected from the top 15cm depth of each parent material for laboratory analyses using standard methods. Results showed that the colour notations, structure and texture of the soils were similar within Same Parent materials but varied widely across the locations. The particle size distribution showed that shale derived soils are finer in texture than those of other parent materials. Chemically, the soils are low in Plant nutrient elements and the reaction is acidic with pH values ranging from 4.1 to 5.8 units. Results also showed that shale and basaltic rock derived soils are more endowed with organic carbon, total nitrogen and exchangeable bases than the soils derived from coastal plain sand, basement complex rocks and sandstone. There was positive and highly significant correlation among the soil properties. In order to improve the productive capacity of these soils to obtain high cropyields, remedial measures aimed at correcting the deficiencies will include liming to increase pH levels to near neutral and providing optimal levels of Nitrogen, Phosphorus and basic cations through organic manure combine with inorganic fertilization.*

Keywords: *morphology, physico-chemical Properties, soils, plant materials.*

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I. Introduction

Esu (2010) defined parent material as the material from which soil is presumed to have been derived. It is also defined as the unconsolidated, chemically weathered mineral or organic matter from which the A and B horizons (Solum) of soils may have developed by pedogenic processes (Brady and Weil 2008). The effects of the other factors of soil formation such as climate (temperature and precipitation) coming Organisms (Plants and animals), relief (topography) and time are considered to be uniform in the study area. The only variable under consideration is the soil parent material.

The influence of parent materials on soil has been studied in several parts of the world and various observations highlighted. Irmak *et al* (2007) studied the soils of the Arid region of Turkey and observed that different parent materials affect the morphology and chemistry of soils under the same agro-ecological conditions. Brewer (1954) reported the important role of parent material in determining both the chemical and physical properties of soils. He concluded from his research that pedologistare not concerned with the age or geological relationships of rocks, but with those physical and chemical characteristics which affect soil formation. Westin (1976) observed that parent material of the soils in South Dakota, USA, has significant influence on potassium and phosphorus contents of the soils they studied. Robenhorst (1982) also found that, Mg^{2+} – rich soil in Maryland, USA, resulted from Mg^{2+} - rich parent material. Akamigbo and Asadu (1983) observed a significant relationship between parent material and most important properties of soil such as colour, texture, reaction, exchangeable bases, total acidity, soil depth, profile drainage and gravel content. Ojanuga and Awujooba (1981) opined that exchangeable cations, CEC and clay contents are related to the kind of soil parent material in Jos plateau, northern Nigeria.

Natural resources including soils cannot be properly managed without proper understanding of their characteristics (Idoga*et al* 2005). The soils of Cross River State are formed from different parent materials whose influence on soil properties must be studied in order to enhance their efficient agricultural use and management. Although studies on soil properties have been conducted in Cross River State, the scope was limited to few sample locations (Esu, *et al* 2015). In view of the above this study aims to evaluate the morphological and physico-chemical properties of the soils of Cross River State and assess their relationship due to varying parent materials, with a view to suggesting appropriate corrective measures to enhance crop production

II. Materials and methods

Description of Study Area

The study was conducted in soils representative of five (5) parent materials namely coastal plain sands (calabar), shale (Odukpani), basement complex rocks (Akamkpa), sandstone (Obubra) and basaltic rocks (Ikom) in central and southern agro-ecological zone of Cross River State. The area lies between (Latitude O5^{o} 32^{1} and O4^{o}27^{1} north and Longitude O7^{o} 15^{1} and O9^{o} 28^{1} south). The climate of the area is hot humid tropical and characterized by two seasons, the rainy which last from April to October and a dry period which lasts from November to March. Average rainfall amounts in this State Vary from 2000 mm to 3500 mm, while temperature and relative humidity vary from 22^{o}C to 33^{o}C and 81 to 96 respectively. Soil temperature regime of the area encourages cropping throughout the year provided there is sufficient water. Vegetation of the area is predominantly rainforest with extensive bush re-growth. Land use for agricultural production in the area is extensive and is the traditional low external input production systems. The major food crops grown in the state include cassava, yam, maize, cocoyam plantain and bananas, rice and assorted vegetables. The soil locations were chosen on the basis of the land use survey report of Cross River State (Bulktrade, 1989). None of the sampled locations had any known history of previous chemical fertilization.

Soil Sampling and Analysis

Four replicate soil samples (Approximate, one Kg) collected from a 50 x 50 cm dimension area at 15 cm soil depth of each parent material were used for the study. In the laboratory, the soil samples were air-dried and ground using mortar and pestle and passed through 2- mm diameter sieve to remove materials greater than 2mm and preserved for routine soil analysis using standard methods. Particle size distribution was determined according to the procedure of Gee and Or (2002). Bulk density was determined using core sample method described by Grossman and Reinsch (2002). Soil pH was determined on a soil: **w**ater suspension in a ratio of 1:2.5 using the pH meter (thomas1996). Organic carbon was determined in two-gram soil sample (Passed through O.5 mm sieve) by as outlined by Nelson and Sommers, (1996) and converted to organic matter by multiplying by a factor of 1.724. Total nitrogen was determined on samples (also passed through O.5mm diameter sieves) by the regular macro Kjeldahl Method as described by Bremner and Malveney, (1996). Available P was extracted using Bray and Kurtz (1945) extractants (Bray P-1 and P-2), and P in the extracts was determined using the molybdenum blue colour method of Murphy and Riley (1962). The exchangeable bases were extracted by saturating the soils with neutral IM NH_4OAc (Thomas, 1982) and the exchangeable bases Ca^+, Mg^+, Na^+, and K^+ displaced by NH_4^+, while potassium and sodium were determined by flame photometry, calcium and magnesium were determined by Atomic Absorption spectrophotometer (IITA, 1979). Exchange acidity (H^++ $A1^{+3}$) was extracted with IN KC1 and estimated in the extract by titration. Effective cation exchange capacity (ECEC) was determined by calculation while base saturation was obtained by expressing the sum of exchangeable Ca^+, Mg^+, Na^+, and K^+ as percentage of effective cation exchange capacity. Percentage aluminum saturation was calculated using the formula (Anderson and Ingram, (1993).

III. Results and Discussion

The morphological characteristics of soils in the study area are presented in Table 1. The soils are grouped on the basis of parent materials. The soils derived from coastal plain sands, Shales and Basement complex rocks (BCR) were characterized by dark brown 7.5 YR ¾ to reddish brown 2.5 YR 4/4 surface soils. The soils derived from sandstone parent materials had dark reddish brown (5 YR 3/3) to reddish brown (2.5 YR 4/4) moist surface soil colours. Soils of basaltic rocks (BAR) origin in the study area were characterized by dark reddish brown (5 YR 3/3) to yellowish red (5 YR 4/6) moist surface soil colours. Generally, the soils exhibited a weak crumb to coarse sub-angular blocky structure and granular. In terms of consistence, the soils were generally friable in dry conditions and weakly friable in moist conditions. There were no signs of mottling in the soils indicating fairly to well-draining conditions conforming with the assertions of Amalu, (2016). There were some visible evidence of freshly decomposing and decomposed leaves and roots in the soils. Values of particle size distribution as they relate to the various parent materials are presented in Table 2. Sand separate had the highest mean value of 699.0 g/kg in sandstone (SS) and lowest mean value of 590.3 g/kg in basement complex rocks (BCR); and generally in the order of sandstone > coastal plain sand > basaltic rocks > shale > basement complex rocks. The trend in silt content was however different with the highest mean value of 147.8 g/kg obtained for basement complex rocks and the least mean value of 88.0 g/kg for shale. The distribution pattern for clay fraction differed from the trend observed for sand and silt. Bulk density values varied widely in all the soils studied, ranging from mean value of 1.41 gcm^{-3} in sandstone to mean value of 1.52 gcm^{-3} in basaltic rocks. These bulk density values are within the range of 1.0 to 1.7g cm-^{3} by wild (1993) as ideal for agronomic activities for most mineral soils and permit easy penetration of most adventitious roots (Amalu,2016), except for soils derived from shale soils in other parent materials had silt/ clay ratio less than unity, indicating moderate to highly weathered soils vulnerable to destruction and may be difficult for mechanized farming involving heavy earth moving implements.

Chemically the soils are low in plant nutrients and the reaction is acidic (Table 3). The soils had pH values ranging from 4.1 in coastal plain sand to 5.8 units in shale, indicating that the soils were generally strongly to moderately acid and likely to be high in exchangeable hydrogen and aluminum ions and deficient in some basic cations especially calcium and magnesium (Chude*et al* 2004). These conditions occur due to excessive leaching of exchangeable bases and their replacement with exchange acidity especially under the high rainfall conditions of the study areas. The range of values of organic carbon varied widely among the soils. For coastal plain sands and sandstone the ranges were similar being from 4.4 to 11.2 g/kg and 4.1 to 10.7 g/kg, respectively. Organic carbon content were generally high on the surface soils derived from Shale with mean value of 13.0 g/kg. These values are comparable to those of the basaltic rocks. The content of organic carbon in the studied soils were considered very poor when matched with the critical levels of organic carbon (very low when less than 0.4g/kg), medium when it is 4.0 -10.0g/kg and high when it is greater than 10g/kg as established for organic carbon in tropical soils (Udo et. al., 2009). In comparison with the critical limit of 20.0 g/kg organic matter established for acid upland soils of southern Nigeria (FPDD, 1990), The soils, classified generally in the ultisol order of soil taxonomy (Enwezor et al, 1990), are low in organic matter.

The mean content of total N was 1.7 g/kg and 1.6 g/kg respectively for Shale and Basalt. The values were lower in the coastal plain sands, Basement Complex Rocks and Sandstone, being 1.2, 1.3 and 1.1g/kg respectively. These soils can generally be considered as having low total N content. For New Zealand soils, Blackmore et al, (1972) considered 0.3% N as critical level. However, going by Enwezor*et al* (1990) criterion for soil fertility classification with respect to total N, the soils of Cross River State fall between low and medium class having mean total N generally less than 0.2% (2g/kg) on the surface soils. The C/N ratio were generally low ranging from mean values of 6.1 to 7.6 in coastal plain sands and shale respectively. The carbon to nitrogen ratios obtained from the entire soils varied from 3.7 to 11.2, indicating net mineralization or increase in mineral nitrogen level. The release of nutrients by soils is influenced by the carbon to nitrogen (C/N) ratio. When the carbon to nitrogen ratio is below 25, application of low rate of nitrogen will accelerate mineralization (Agbede, 2009). The carbon to nitrogen ratios are of importance for the survival of microbial life which in turn performs virtually all the mineral transformations in soils. Generally when the carbon to nitrogen ratio is greater than 25, net immobilization occurs, but at ratios less than 25 net mineralization is expected (Agbede, 2009); indicating that in the present soils net mineralization would occur to the advantage of most crops. From the results obtained, it would appear that the level of mineralization of organic nitrogen would be higher in the soils irrespective of the parent material from which they were formed, since C/N ratios greater than 25 could lead to immobilization or non-release of nitrates on decomposition of organic matter.

The relative abundance of the exchangeable basic cation content of the surface soils was similar in all the soil groups, the abundance being, in the decreasing order of calcium, magnesium, potassium and sodium except in soils of the sandstone (SS) and coastal plain sands (CPS) where sodium (Na) was slightly higher than potassium (K), indicating the very low levels of potassium (K) in these soils. Content of exchangeable calcium were very low. Calcium mean values which ranged from 2.1 and 2.8 cmol/kg in sandstone and shale respectively were far below the critical (5.0 cmol/kg) reported by Taylor and Pohlen (1970) for similar tropical soils of New Zealand. Regardless of the soil type or parent material, all the above values of calcium were adjudged only low to marginal, based on the established critical level of 5.0 cmol/kg (Landon, 1991), below which most crops would respond to calcium application in whatever form it is applied. The poor calcium endowment is rather very surprising, as periswamy*et al* (1983) had earlier reported high values of 4.2 to 5.2 cmol/kg calcium for soils of southeastern Nigeria. Exchangeable magnesium content in the selected soils varied widely from mean value of 1.3 cmol/kg in coastal plain sands to 2.5 cmol/kg in shale. In tropical soils, critical ranges of magnesium values have been established as low when values are less than 1.5, moderate when they are 1.5 to 3.0 and high when they are greater than 3.0 cmol/kg (Landon, 1991), elsewhere higher values have been reported as critical for similar group of soils (lombin and Fayemi, 1976 and Taylor and Pohlen, 1970), all indicating clearly that the studied soils were low to moderately endowed with exchangeable magnesium, and that responses to applied magnesium would sooner or later appear in the soils. The exchangeable potassium status of the present soils could be considered low when compared with lower and upper critical levels of 0.2 and 0.4cmol/kg established by Enwezor*et al* (1990). However the soils of Shale and Basaltic rocks had potassium mean values of 0.24 and 0.21cmol/kg respectively, which were either at the critical limit of 0.2cmol/kg soil exchangeable K recommended for soils of south-eastern Nigeria (FPDD, 1989) or below it. The exchangeable K values of some of the soils were considered to be high when compared with the values of 0.07cmol/kg and 0.12cmol/kg determined earlier by Unamba-Opara (1985) and Iren and Amalu (2012) for similar soils in Imo and Cross River States respectively. Exchangeable potassium values of most of the soils were also considered to be low, below the critical level of 0.16 to 0.25 cmol/kg as established by Adeoye and Agbola (1985) in soils of coastal Plain Sand, basement complex rocks and Sandstone. Mean sodium values were between 0.07 and 0.14 cmol/kg at Odukpani soils derived from shale and Obubra soils derived from sandstones and were higher than the critical level of 0.02 cmol/kg sodium in soils as reported by Amalu, (1998). The above values certainly would not constitute a problem for growth and development of most crops, particularly, as the exchangeable sodium percentage saturation of the exchange complex (mean values 0.7 to 1.4) hardly reached the generally accepted 15%, at which deleterious effects begin for most crops. According to Amalu 2016), most soils contain sufficient sodium for crop growth and responses to sodium fertilizers are confined to crops with definite sodium requirements such as sugar beet and Marigolds.

The combined concentrations of Hydrogen and Aluminum ions – exchangeable acidity levels were variable and moderate in the soil with mean percent Aluminum saturation of the exchange complex being generally less than 30% (11.8 to 22.8%). Percentage Aluminum saturation value greater than 30% may affect sensitive crops (Amalu, 2016), while over 60% could bring about aluminum toxicity (Amalu, 2016). Ambergor (2006) indicated that a concentration of aluminum ion greater than one (>1 cmol/kg) in the soil solution could lead to aluminium toxicity. Exchangeable acidity (H^+ and Al^{+3}) rained among the soils with mean values in the exchange complex range from 4.3 at Odukpani Shale to 7.7 cmol/kg at Calabar coastal plain sand, of the two, however, hydrogen ions rather than aluminum ions dominated the exchange acidity largely in agreement with reports of Amalu (1998) that H^+ rather than Al^{3+} dominates in majority of soils with pH less than 5 units. Although hydrogen ions were rather higher than the aluminum ions in values, the ultimate influence of exchange acidity to the acidity of tropical soils had been attributed to presence of aluminum ions (Fageria*et al*, 1988). Aluminum saturation percentage were low to moderate (range 7.9 to 23.6%) in the soils, indicating unlikelihood of aluminum toxicity to most crops grown in these soils. For soils formed from coastal plain sand sandstone, the total exchangeable bases (TEB) were low in comparison with the level of exchangeable acidity, resulting in low base saturation of the soils. The low base saturation is an indication of the acidity problems that would be encountered in the soils. Although the base saturation ranged from 28.8 to 59.6%, it was low in most of the soils with values remaining below 44%. Only soils formed in shale and basaltic rocks had values above 51%. Effective cation exchange capacity (ECEC) was generally low for the soils except in those of basaltic rocks, sand stone and coastal plain sands where values averaged 10, 10.2 and 11.4 cmol/kg respectively. In tropical soils, critical ranges of ECEC values have been established as low when values are less than 10.0, medium when they are 10 –20 and high when they are greater than 20 cmol/kg (Landon, 1991). ECEC values were low, below 15 cmol/kg reported by Udo et al (2009) as the critical level of ECEC in tropical soils. The correlations in (table 4) shows the relationships among the soil properties. Sand was negatively and significantly correlated with silt (r = - 0.567**), clay (r = - 0.899***) and organic carbon (r = -0.611**). This result indicates that there was a strong inverse relationship between sand and silt, clay and organic carbon, suggesting that an increase in sand leads to decrease in silt, clay and organic carbon and this is not in harmony with sustainable crop production since clay minerals play important role in soil fertility status of a given location. Clay correlated positively highly significantly with organic carbon (r = 0.771***) indicating that clay is not only a source but that there is a synergy between clay and organic carbon in relation to the fertility status of the soils. Exchangeable calcium was positively and significantly correlated with Bray P 1 (r = 0.626**) and P 2 (r = 0.632**). Organic carbon also correlated positively and significantly with Bray P 1 (r = 0.491*).

IV. Conclusion

The results of the study showed that the general properties of the soils vary appreciably reflecting the nature of the parent materials, the morphological features of the soils differed in terms of colour, texture, structure and consistency due to varied parent materials. Also the physic-chemical properties of the soils varied remarkably. The Particle size distribution showed that shale-derived soils are finer in texture than those of other parent materials. Soils formed from shale and basaltic rocks are more endowed with exchangeable basic cations whereas those on coastal plain sands, basement complex rocks and sandstones parent materials appear low and deficient in nutrient content.

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Table 1: Morphological Properties Of Representative Soils Of Varying Parent Materials.

Sample number (Replicates)	Soil Colour (Mussel)	Soil Structure	Presence of Mottles	Presence of organic Matter and Roots	Soil Consistency (Dry)	Soil Consistency (Moist)
Coastal Plain Sands (CPS) – Calabar						
1	(2.5YR 4/4) Reddish Brown	Granular	None	Abundant	Friable	Loose
2	(7.5YR 3/4) Dark Brown	Granular	None	Abundant	Friable	Loose
3	(7.5YR 3/4) Dark Brown	Subangular blocky	None	Low	Friable	Firm
4	(7.5YR 3/4) Dark Brown	Weak, Coarse, granular	None	Medium	Friable	Loose
Shales (SH) – Odukpani						
1	(2.5YR 4/4)Reddish Brown	Gravelly granular	None	Abundant	Friable	Loose
2	(7.5YR 3/2) Dark Brown	Weak crumbs		Abundant	Friable, Non sticky	Loose
3	(7.5YR 3/4) Dark Brown	Weak crumbs	None	Abundant	Friable	
4	(7.5YR 3/4) Dark Brown	Gravelly granular	None	Abundant	Friable	Loose
Basement Complex (BCR) – Akamkpa						

1	(2.5YR 4/4) Reddish Brown	Gravelly	None	Abundant	Friable	Loose
2	(7.5YR 3/2) Dark Brown	Sub angular blocky	None	Abundant	Friable	Loose
3	(7.5YR 3/2) Dark Brown	Sub angular blocky	None	Abundant	Friable	Loose
4	(7.5YR 3/2) Dark Brown	Coarse Sub angular blocky	None	Medium	Firm Sticky, Slightly Plastic	Loose
1	(5YR 3/3) Dark Reddish Brown	Gravelly granular	None	Abundant	Friable	Loose
2	(2.5YR 4/4) Reddish Brown	Weak, coarse, granular	None	Medium	Friable, non sticky, non plastic	
3	(5YR 3/3) Dark Reddish Brown	Weak, coarse, granular	None	Low	Friable, non sticky, non plastic	
4	(2.5YR 4/4) Reddish Brown	Gravelly, granular	None	Abundant	Friable	Loose
Basalt (BAR) – Ikom						
1	(5YR 3/3) Dark Reddish Brown	Crumbly S	None	Abundant	Friable	Loose
2	(5YR 3/4) Dark Reddish Brown	Gravelly		Abundant	Friable	Loose
3	(5YR 3/4) Dark Reddish Brown	Sub angular blocky	None	Medium	Friable	Loose
4	(5YR 4/6) Yellowish red	Sub angular blocky	None	Medium	Friable	Loose

Table 2: Physical Properties Of Representative Upland Soils Of Varying Parent Materials.

Sample number (Replicates)	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Texture	Bulk Density (gcm^{-3})	Silt/Clay Ratio
Coastal Plain Sands (CPS) – Calabar						
1	463.0	117.0	420.0	Sandy Clay	1.41	0.3
2	813.0	67.0	120.0	Loamy Sand	1.50	0.6
3	728.0	124.0	148.0	Loamy Sand	1.51	0.8
4	754.0	138.0	108.0	Loamy Sand	1.43	1.2
Mean	**689.5**	**111.5**	**199.0**		**1.46**	**0.7**
Shales (SH) – Odukpani						
5	606.0	147.0	247.0	Sandy Clay Loam	1.64	0.5
6	763.0	34.0	203.0	Sandy Clay Loam	1.49	0.2
7	683.0	34.0	283.0	Sandy Clay Loam	1.37	0.1
8	423.0	137.0	440.0	Sandy Clay	1.38	3.0
Mean	**618.75**	**88**	**293.25**		**1.47**	**1.0**
BasementComplex (BCR) – Akamkpa						
9	586.0	34.0	380.0	Sandy Clay	1.42	0.1
10	716.0	87.0	197.0	Sandy Loam	1.59	0.4
11	553.0	223.0	224.0	Sandy ClayLoam	1.40	0.9
12	506.0	247.0	247.0	Sandy Clay Loam	1.30	1.0
Mean	**590.25**	**147.75**	**262.0**		**1.43**	**0.6**
Sand Stones (SS) – Obubra						
13	403.0	157.0	440.0	Sandy Clay	1.4	0.4
14	806.0	44.0	150.0	Loamy Sand	1.53	0.3
15	753.0	97.0	150.0	Loamy Sand	1.36	0.6
16	834.0	98.0	68.0	Loamy Sand	1.35	1.4
Mean	**699.0**	**99.0**	**202.0**		**1.41**	**0.7**
Basalt (BAR) – Ikom						
17	566.0	134.0	300.0	Sandy Clay Loam	1.59	0.4
18	693.0	97.0	210.0	Sand Clay Loam	1.63	0.5
19	733.0	57.0	210.0	Sand Clay Loam	1.45	0.3
20	676.0	104.0	220.0	Sand Clay Loam	1.39	0.5
Mean	**667.0**	**98.0**	**235.0**		**1.52**	**0.4**

Table: 3 Mean Values and Ranges Of Some Chemical Properties Of Selected Upland Soils of Cross River State.

Parent Material/ Location	pH (H_2O)	pH (Kcl)	Org. Carbon (g/kg)	Total N (g/kg)	C/N Ratio	Exchangeable Cations (cmol/kg) Ca^{2+}	Mg^2	K^+	H^+ (cmol/kg)	Al^{+3}	Ex. Acidity	TEB	ECEC	BS (%)
CPS– Calabar	5.1	4.2	7.3	1.2	6.1	2.2	1.3	0.10	5.1	2.6	7.7	3.7	11.4	32.5
SH – Odukpani	5.7	4.8	13.0	1.7	7.6	2.8	2.5	0.24	3.0	1.3	4.3	5.6	9.9	57.0
BCR-Akamkpa	5.3	4.4	8.7	1.3	6.7	2.3	1.6	0.15	4.0	1.7	5.7	4.2	9.8	43.0
SS Obubra	5.2	4.3	7.1	1.1	6.5	2.1	1.4	0.13	5.2	1.2	6.4	3.8	10.2	37.3
BAR	5.6	4.7	10.1	1.6	6.3	2.6	2.2	0.21	3.3	1.6	4.9	5.1	10.0	51.0

CPS - Coastal Plain Sands, SH - Shales, BCR - Basement Complex Rocks, SS -Sandstones and BAR - BasalticRocks

Table 4: Pearson' Correlation Coefficient Among Some Soil Properties

Bray-2-P	Sand	Silt	Clay	pH	Org.C	Ca	Ex.Al	ECEC	Bray-1-P	Bray-2-P
Sand	1.000									
Silt	-0.567**	1.000								
Clay	0.899***	0.150	1.000							
pH	-0.051	-0.033	0.079	1.000						
Org.C	-0.611**	-0.071	0.771***	0.492*	1.000					
Ca	-0.105	0.217	0.010	0.508*	0.310	1.000				
Ex.Al	-0.209	0.156	0.168	-0.445*	0.028	-0.134	1.000			
ECEC	0.081	0.068	-0.135	-0.313	-0.176	0.074	0.641**	1.000		
Bray-1-P	0.002	-0.254	0.132	0.776***	0.491*	0.626**	-0.264	-0.195	1.000	
Bray-2-P	-0.035	-0.201	0.149	0.651**	0.425	0.632**	-0.213	-0.119	0.950***	1.000

Level of significance: *P = 0.05, **P = 0.01, ***P = 0.001. Ca = calcium, Ex.Al = exchangeable aluminum, ECEC = effective cation exchange capacity, Bray-1-P = bray 1 available phosphorus, bray -2 –P = bray 2 available phosphorus

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