Particle Size Distribution, Reactivity, Organic Matter and Exchange Properties of Soils from Different Parent Materials in Abia State, Southeastern Nigeria.

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Abstract- Soils derived from different parent materials (PM) exhibit variations in their properties. In AbiaState, soils formed from four contrasting PM were studied to provide information on the variations in their physico-chemical properties. The parent materials were shale (SH), alluvium (AL), coastal plain sands (CPS) and sandstone (SS). From each PM location, eight soil auger samples were randomly collected at 0-20 and 20-40 cm depths totaling 32 soil auger samples from all four PM. Standard procedurewas used in the laboratory analysis. SPSS version 20 package was used for statistical analysis. Analysis of variance (ANOVA) for a randomized complete block design was performed to evaluate the influence of PM on soil properties. Correlation analysis was used to determine relationship among soil properties. Soils derived from SH and AL contained more clay (520.00 and 386.00 g/kg, respectively) and less sand (277.00 and 449.50 g/kg, respectively) than the CPS- and SS- derived soils (82.50 and 235.00, respectively for clay and, 644.50 and 887.00 g/kg, respectively for sand). The SH and AL soils were strongly to moderately acidic (pH: 5.40-5.85) while CPS- and SS- derived soils were very strongly to strongly acidic (pH: 4.50-5.13). The acidity of these soils increased with depth. The organic matter (OM) contentsof the soils ranged from the lowest of 12.40g/kg in the SS-derived soil at 20-40 cm depth to the highest of 37.70g/kg in the SH-derived soil at 0-20 cm depth. However, soil derived from AL contained the overall highest of OM (35.40g/kg at topsoil +24.30 at subsoil). The exchange properties were higher in soils derived from SH and AL compared to CPS- and SS- derived soilsalthough, the exchange acidity (EA) was higher in the latter soils. Apart from EA which increased with soil depth, all the other exchange properties reduced. For the SH- and AL- derived soils, the sand fraction, more than silt and clay, correlated with pH, OM and the exchange properties whereas for the CPS- derived soil, clay correlated with these soil parameters. For the soil formed from SS, the sand and clay fractions correlated with the parameters better than the silt fraction. It is therefore recommended that practices which will maintain the OM status of the soils as well as reduce acidity of CPS- and SS- derived soils should be adopted. These practices may include mulching, cover cropping, minimum tillage, liming, etc.

Index Terms- Exchange properties, organic matter, parent material,pH, soil depth

I. INTRODUCTION

Soils generally contain the same components (mineral, organic, water and air) (Anon, 2001) but vary in their properties such as texture, organic matter content, pH, etc. (Effiong and Ibia, 2009; Randy and Thompson, 2006; Obasi, 2004). These variations are attributed to changes in soil forming factors and processes occurring in different parent materials under different climatic, topographic and biological conditions over time (Soil Survey Staff 1999;Jaiyeoba, 1996). The cultural and land use practices such as tillage systems, soil amendments, cropping sequences and systems, animal dungs and manures, as well as compaction from grazers or machinery could also be the causesof variations (Oguike and Mbagwu 2009, Hartemink 2003). The variability of soil chemical properties such as organic matter (OM), pH, base saturation, etc. are key factors that affect the health status of soils, thereby determining crop performance.

The type of parent material (PM) in an area determines the predominant mineral and particle sizes of the soil (Ahukaemere*et al*., 2016; Irmak *et al*., 2007) and thus confers certain characteristics on the soil which influence its general behavior and use. Typically, soils of Abia State fall within the broad ferralitic soils of the coastal plain sands (CPS) and escarpment (Abia State Government, 2012). Other soil types within the State include alluvial soils, soils from shale, coastal plain sands, sandstone and soils formed over basement complex (FPDD, 1990). Theirphysico - chemical characteristics are therefore a reflection of the varied nature of the underlying parent materials which determine the fertility status as well as the agronomic potentials of these soils.

The proper knowledge of the distribution of particle sizes, chemical properties and their variations according to parent materials in azone is imperative in the determination of the use to which soils of the area may be put (Amusan*et al*., 2006) as well as the management strategies to be adopted. Therefore the objective of this study wasto provide some basic information on the variation and distribution of some physico-chemical properties of soils formed fromfour parent materials in Abia State, Southeastern Nigeria.

II. MATERIALS AND METHODS

The physical environment and land use

The soils used for this study were collected from locations typical offour parent materials (PM) in Abia State. The parent materials were identified and mapped by the Federal Department

of Agriculture and Land Resources (FDALR, 2005) through a reconnaissance soil survey. The locations were atIbere (shale - SH), Owerrinta (alluvium - AL), Umudike (coastal plain sands - CPS) and Ohafia (sandstone - SS). The distances between locations ranged from 10km to 70km.

Abia State lies within latitudes 5° 25'to 5° 43' N and longitudes 7° 31' to 7° 52' E in Southeastern Nigeria. The climate is tropical with wet and dry seasons. Mean annual rainfall is 2250mm.The rainy season starts in early March and ends in late October while the dry season starts in November and ends in February. A short break in rainfall known as 'August break' is usually experienced in August and may last for about 14 days. Maximum and minimum temperatures are 31°C and 21°C, respectively (NRCRI, 2007). Throughout the year, insolation is high in the area. The area is geomorphologically low-lying, tropical rainforest withmoderately high plains and wooded savanna in some places. It has an average elevation ranging from 120 to 180 m above sea level (Abia State Government, 2012).

Farming is done at subsistence level with traditional tools like hoes and machetes. Food crop cultivation dominates the agricultural landscape. The conservation practices include shifting cultivation that involves a one- season cropping followed by a two to four years bush fallow period, multiple cropping, covercropping, mulching and organic manure application. Due to financial constraints of the resource- poor farmers, inorganic fertilizer application is rarely practiced.

Soil sampling

Atotal of 32 auger soil samples were collected at two depths (0-20 and 20-40cm) from the four PM locations. At Ibere, the sampling location was under a cocoa plantation where plant litter was continually returned to the soil. The sampling location at Owerrinta was a vegetable farm by the bank of Imo River interspersed with oil palm trees. TheUmudike sampling location was a cassava plot intercropped with cocoa yam while theOhafia location was a two- year grass fallow land. In each location, soil samples were randomly collected at four different spots. At each spot, six auger samples were randomly taken and bulked to form one composite sample.

Laboratory analysis

The composite soil samples were air dried, and sieved with a 2mm sieve and used for the determination of particle size distribution, soil pH, organic matter, exchangeable bases, and exchangeable acidity. Effective cation exchange capacity was calculated as the sum of the exchangeable bases and exchangeable acidity.

Particle size distribution was by Bouyoucos hydrometer method as outlined by Gee and Or (2002). Soil organic matter was by the method outlined by Nelson and Sommers(1996). Soil pH was determined using a pH meter in a 1:1 soil - water ratio (Hendershot*et al*., 1993). Exchangeable bases were determined by leaching the soil with neutral ammonium acetate (NH_4OA_C). From the leachate,Ca and Mg were determined using the EDTA titration method (Lanyon and Heald, 1984) while K and Na were by flame photometry (Kundsen*et al*., 1982).Exchangeable acidity (EA)was determined by 1N KCl extraction procedure as described by Thomas (1996).

Statistical analysis

Statistical package used for the analysis was SPSS version 20. Data generated were subjected to analysis of variance (ANOVA) for randomized complete block design (RCBD). Differences between means were detected by least significant difference at 5% probability level ($LSD_{0.05}$). Correlation was used to determine the relationship among soil properties under the four different parent materials.

III.   RESULTS AND DISCUSSION

Particle size distribution

The physico-chemical properties across the parent materials (PM) are shown in Table 1. The values of the particle size distribution indicated that the textural classes were clay at the two depths for shell-derived soil (SH), clay loam (0-20cm) and clay (20-40cm) for alluvium soil (AL) and sandy loam (0-20) and sandy clay loam (20-40cm) for coastal plainsand-derived soil (CPS). For the soil formed over sandstone (SS), the texture was sand (0-20cm) and loamy sand (20-40cm). These variations suggested direct relationship of texture with parent materials (Igwe, 1999).

Soil derived from SS contained more sand than the other soils with values of 887.00g/kg at 0-20cm and 852.00g/kg at 20-40cm depths while the soil formed over SH contained the least (277.00g/k at 0-20cm and 337.00g/kg at 20-40cm depths). At 0-20cm depth, the sand fraction was significantly (P≤0.05) different across the PM while at 20-40cm it was statistically different only in CPS- and SS- derived soils but similar in soils of SH and AL origins. For the silt fraction, soil formed from SH had the highest at both depths (203.00g/kg at 0-20cm and 337.00g/kg at 20-40cm). The decreasing order according to PM was SH>AL>CPS>SS. However silt contents were statistically similar in soils derived from SH, AL and CPS at both depths. With regard to clay fraction, significant (P≤0.05) variation was observed. Soil derived from SH had the highest values of 520.00 and 480.00g/kg at 0-20cm and 20-40cm depths, respectively. The clay fraction of the SH-derived soil was significantly (P≤0.05) higher than those of AL, CPS and SS soils at both depths whereas soil derived from SS had the lowest. Apart from the SH-derived soil where reduction in clay content with depth was observed, the other soils derived from AL, CPS and SS increased in clay content with depth. These results were in consonance with the observations of other researchers. Obasi (2004) reported similar results where sand contents of soils derived from SS and CPS were higher than those formed from SH. In the present study, observation of high clay and silt contents in the SH-derived soil corroborated the reports ofChikezie*et al*. (2009) andOguike and Henshaw (2013) that the clay and silt fractions of soils from SH were above 30 and 15%, respectively. The increase in finer particles with depth as observed in the AL, CPS and SS may be as a result of very high leaching and illuviation processes common in humid tropics (Mbagwu, 2003) due to high rainfall. Leaching was unlikely with respect to soil derived from SH due to their dense and poor subsurface drainage nature (Soil Survey Report, 2009) reflected in high clay content.

Table 1: Physico-chemical properties of soils formed from diverse parent materials in Abia State

Properties	Values									
	SH	AL	CPS	SS	LSD$_{0.05}$	SH	AL	CPS	SS	LSD$_{0.05}$
			0 – 20 cm					20 – 40cm		
Sand g/kg	277.00	449.50	704.50	887.00	127.20	337.00	384.50	644.50	852.00	61.00
Silt ::	203.00	164.50	143.00	30.50	75.90	188.00	172.00	120.50	43.00	75.30
Clay ::	520.00	386.00	152.50	82.50	39.60	480.00	433.50	235.00	105.00	52.20
pH (H$_2$O)	5 .85	5.68	5.13	4.78	0.27	5.50	5.40	4.73	4.50	0.20
OM (g/kg)	37.70	35.40	31.50	23.70	11.70	19.80	24.30	20.90	12.40	4.50
Ca (Cmol/kg)	13.10	10.55	3.98	2.90	1.57	8.80	6.20	2.85	2.05	0.52
Mg ::	6.38	5.05	2.45	1.60	2.15	4.95	3.55	1.55	1.00	0.44
K ::	0.23	0.22	0.15	0.09	0.02	0.20	0.20	0.12	0.08	0.59
Na ::	0.18	0.16	0.11	0.07	0.03	0.14	0.14	0.09	0.05	0.59
EA ::	0.32	0.41	1.19	1.70	0.13	0.50	0.57	1.78	2.09	0.29
ECEC	20.20	16.39	7.86	6.36	2.08	14.95	10.65	6.65	5.27	0.75

SH=shale, AL=alluvium, CPS=coastal plain sands, SS=sandstone, LSD$_{(0.05)}$= least significant difference at 0.05 level of confidence, OM=organic matter, Ca=calcium, Mg=magnesium, K=potassium, Na=sodium, EA=exchangeable acidity, ECEC=effective cation exchange capacity.

pH and organic matter

The result presented in Table 1 showed that pH and OM varied with the parent materials. Soils derived from SH and AL were lower in acidity and higher in OM than those formed from CPS and SS probablydue to the higher contents of finer particles such as clay and silt in the former than the latter. The high clay and OM contents buffer the soil against changes in pH. The soil formed from SS was the most acidic while SH- derived soil was the least acidic. At 0-20cm and 20-40cm depths, pH values ranged from 4.78 to 5.85 and 4.50 to 5.50, respectively. These values were considered very strongly acidic to moderately acidic in reaction (Enwezor*et al*., 1989). Some researchers had previously reported higher values of pH and OM in fine textured soils than in coarse ones (FAO, 2015; Adeleye*et al*.,2010). The pH of the soils from the various PM decreased with depth. Similar results where pH values of soils derived from SH, AL, CPS and SS decreased with depth had been reported (Obasi, 2004). The pH of soils derived from SH and AL were statistically similar at both depths but significantly (P≤0.05) different from those of CPS- and SS- derived soils which were also significantly (P≤0.05) different from each other. The higher pH observed in the soils derived from SH and AL compared to the CPS- and SS- derived soils was possibly due to reduced leaching intensity and mineral weathering occasioned by higher colloidal presence in the former soils. The higher contents of OM in the finer textured soils may have resulted to higher concentrations of exchangeable cations, reflected in the higher contents of Ca, Mg, K, capable of reducing acidity in these soils. The increase in exchangeable cations was probably a result of microbial decarboxylation of OM in these soils (Natsher and Schwetnmann, 1991) which may have resulted to an increase in ion exchange reaction (Dikinya and Mufwanzala, 2010) leading to the higher pHvalues in the soils formed from SH and AL. This observation affirmed the earlier findings of Onwu*et al*. (2014) that soils with high OM contents were less acidic than those with low OM. However, this observation disagreed with Obasi (2004) who reported that soils with higher OM contents had lower pH compared to soils with lower OM contents.

The organic matter (OM) contents of these soils varied, ranging from 12.4g/Kg in the soil formed from sand stone (20-40cm) to 37.7g/Kg in the SH-derived soil (0-20cm) (Table 1). The values were considered high with soil derived from AL containing the overall highest (35.40g/kg at topsoil +24.30 at subsoil). Across parent materials, OM decreased with depth. At both depths, the OM contents of the soils derived from SH, AL and CPS were statistically similar. However, the OM content of soil derived from SH was significantly (P≤0.05) higher than that of soil derived from SS. In this study, the higher OM contents of soils derived from SH, AL and CPS compared to SS-derived soil corroborated (Obasi, 2004) who made similar observation. With regard to the SH- and AL-derived soils, the higher OM contents observed could be attributed to their fine textures and probably poor aeration status (FAO, 2005). The fine clay-sized particles protected the associated OM against microbial decomposition (Yuan and Theng, 2012). Also, litter fall (Hirabuki, 1991) common in the SH environment and prolonged saturation and anaerobic conditions (Randy andThompson, 2006) in the AL environment may have contributed to the high OM

contents.Contrarily, in the coarse textured soils, the rapid decomposition of OM (FAO, 2005), annual burning of vegetation (Debano, 1990) by farmers in the area and high leaching potentials of sandy soils could also be responsible for the lower OM content in the SS- derived soil. The influence of PM on OM is derivable from their control of texture. This can be explained by the characteristics of the different sized particles. Sandy soils are well aerated, tending towards low moisture content which favours low OM contents. On the other hand, clayey soils are less aerated, higher in micro pores with tendency towards higher moisture retention and therefore, higher OM content. Some researchers had earlier reported coarse textured soils to be characteristically low in OM content (Oguike and Ndifreke, 2016, Myravarapu*et. al*., 2014;Onunkwo*et al*., 2013;Kaur*et al*., 2002).

Exchange properties

The variations in the exchange properties were controlled by the parent materials of the soils studied (Table 1). Soils derived from SH and AL contained higher concentrations of exchangeable bases and ECEC with a lower concentration of EA than soils derived from CPS and SS. Some researchers had previously shown that fine-textured soils contained higher concentrations of exchangeable bases and ECEC compared to soils with coarse textures (Soil Quality, 2016;Onunkwo*et al*, 2013;Filipek, 2011; Van Erp*et al*, 2001). A general decline of exchangeable bases with depth was observed. At the two depths, the exchangeable bases in the soils followed the descending order of SS<CPS<AL<SH.The exchangeable Ca in the soils were significantly (P≤0.05) different from each other at 20-40cm depth whereas at 0-20cm depth, it was statistically the same in soils derived from CPS and SS.Soil derived from SH had the highest concentration of exchangeable Mg while SS- derived soil had the lowest. The exchangeable Mg concentration at 0-20cm depth in SH- and AL- derived soils were statistically the same but significantly (P≤0.05) higher than those formed from CPS and SS which were as well statistically similar. At 20-40cm depth, Mg in the soils significantly (P≤0.05) differed from one another.Exchangeable K varied across the parent materials. The highest and the lowest values were observed in soils derived from SH and SS, respectively. However, at 0-20cm depth, K concentration in soils formed from SH and AL were statistically similar but differed significantly (P≤0.05) from CPS and SS soils which were also statistically different from each other. At 20-40cm depth, K concentrations in the soils were statistically similar.With regard to Na, the concentration at 0-20cm depth in soil derived from SH and AL were statistically the same but significantly (P≤0.05) higher than those of CPS and SS soils which were also significantly (P≤0.05) different. At 20-40cm depth, Na concentration in the soils was statistically the same.
Soils derived from CPS and SS were considered to be of low base status (Enwezor*et al*., 1989) while soils derived from SH and AL were of high base status. The high concentration of exchangeable bases in soils of SH and AL origins may be due to the high contents of colloidal materials such as clay and OM in these soils (Table 1) (Filipek, 2011). Across the depths, exchangeable acidity (EA) in soil derived from SH and AL were statistically the same but significantly (P≤0.05) lower than those

of CPS and SS soils which were significantly (P≤0.05) different (Table 1). The EA was observed to increase with depths. This observation was inconsistent with the report of Obasi (2004) who stated that the EA of soils derived from diverse PM reduced with depths. At both depths of 0-20 and 20-40cm, respectively, soils derived from SH held the highest amount of cations (20.20 and 14.95Cmolkg^{-1}) at the exchange complex while the SS soil held the lowest (6.36 and 5.27Cmolkg-1). However, at 0-20cm depth, ECEC of soils derived from CPS and SS were statistically similar but significantly (P≤0.05) lower than those of SH and AL soils which were significantly (P≤0.05) different from each other. At 20-40cm depth, ECEC of the soils were significantly (P≤0.05) different from one another. The lower values of ECEC observed in soils derived from CPS and SS compared to SH and AL soils were expected because sandy soils are known to have lower ECEC compared to clayey soils (Soil Quality, 2016). This may be as a result of the low aggregation due to the low concentration of basic cations (Mbagwu*et al*, 2004) common to sandy soils.

The results of this study, where values of ECEC were observed to be higher in the SH and AL soils than those of CPS and SS origins,confirmed that soils with high sand contents are usually low in ECEC (Mbagwu*et al*, 2004). However, this observation disagreed with Obasi (2004) who reported ECEC values in soils derived from SS to be higher than soils of SH and AL origins.

Correlation of soil physico-chemical properties

The correlations of the soil properties studied are shown in Tables 2 – 5. In the SH-derived soil (Table 2), sand fraction negatively correlated with the clay fraction,pH, OM and the exchange properties, and positively with EA. Therefore, the sand fraction reduced with increase in these soil properties but only increased with increase in EA. Silt fraction only correlated positively with OM and showed no significant correlation with the other soil properties. The clay fraction positively correlated only with Mg,and negatively with EA.

Table 2: Correlation matrix of soil physicochemical properties derived from Shale

	Sand	Silt	Clay	pH (H$_2$O)	OM (g/kg)	Ca	Mg	K	Na	EA	ECEC
	← g/kg →					← (Cmol/kg) →					
Sand (g/kg)	1										
Silt ,,	-.341	1									
Clay ,,	-.914**	-.069	1								
pH (H$_2$O)	-.846**	.460	.699	1							
OM ,,	-.821*	.709*	.565	.921**	1						
Ca (Cmol/kg)	-.802*	.549	.615	.876**	.933**	1					
Ng ,,	-.818*	.340	.722*	.851**	.867**	.954**	1				
K ,,	-.714*	.699	.457	.925**	.935**	.869**	.772*	1			
Na ,,	-.843**	.634	.621	.943**	.976**	.923**	.867**	.954**	1		
EA ,,	.924**	-.548	-.744*	-.915**	-.946**	-.937**	-.913**	-.897**	-.966**	1	
ECEC ,,	-.809*	.500	.643	.876**	.923**	.997**	.974**	.851**	.915**	-.937**	1

** Correlation is significant at 0.01 level (2-tailed).

* Correlation is significant at 0.05 level (2-tailed).

As shown in Table 2, sand fractioninfluenced pH, OM and the exchange properties more than they were influenced by clay and silt fractions. The soil pH was observed to correlate positively with these properties but was negatively correlated with EA. Generally, there was observable positive correlation among the soil properties but with EA always negatively correlating with the others.

For the AL-derived soil (Table 3), sand fraction negatively correlated with pH, OM and the exchange properties but positively correlated with EA. This indicated that EA increased with increase in sand fraction. This may be as a result of low basic cations attached to sand fractions. The silt fraction did not

show correlation with the soil properties studied and so did not influence them. Soil pH correlated with all the properties but not with Na and silt fraction. The OM correlated with the soil properties other than silt and clay fractions. The exchange properties were correlated,though they revealed negative correlation with EA.The clay fraction of the CPS-derived soil (Table 4) positively correlated with the soil properties but negatively with EA. Except for the sand fraction which correlated positively with Na, together with clay, they showed no correlation with the other properties. There was a general correlation of pH, OM and the exchange properties.

Table 3: Correlation matrix of soil physicochemical properties derived from Alluvium

	Sand	Silt	Clay	pH	OM	Ca	Mg	K	Na	EA	ECEC
	←	g/kg	→	(H$_2$O)	(g/kg)	←		Cmol/kg		→	
Sand (g/kg)	1										
Silt ,,	-.450	1									
Clay ,,	-.768*	-.226	1								
pH (H$_2$O)	.862**	-.176	.814*	1							
OM ,,	.765*	-.330	.598	.779*	1						
Ca (Cmol/kg)	.816*	-.114	.808*	.863**	.938**	1					
Ng ,,	.817*	-.095	.823*	.920**	.913**	.984**	1				
K ,,	.722*	-.044	.756*	.776*	.884**	.967**	.953**	1			
Na ,,	.429	.000	.467	.588	.749*	.803*	.801*	.904**	1		
EA ,,	-.893**	.268	-.782*	-.965**	-.891**	-.923**	-.941**	-.820*	-.610	1	
ECEC ,,	.813*	-.104	.812*	.876**	.933**	.999**	.991**	.969**	.811*	-.926**	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlation matrix of soil physicochemical properties derived from CPS

	Sand	Silt	Clay	pH	OM	Ca	Mg	K	Na	EA	ECEC
	←	g/kg	→	(H$_2$O)	(g/kg)	←		(Cmol/kg)		→	
Sand (g/kg)	1										
Silt ,,	-.577	1									
Clay ,,	-.687	-.198	1								
pH (H$_2$O)	.331	.429	.779*	1							
OM ,,	.702	-.019	.826*	.472	1						
Ca (Cmol/kg)	.527	.346	.940**	.918**	.769*	1					
Ng ,,	.353	.414	.792*	.739*	.698	.872**	1				
K ,,	.430	.401	.872**	.846**	.773*	.956**	.915**	1			
Na ,,	.818*	-.080	.910**	.776*	.674	.855**	.676	.754*	1		
EA ,,	-.573	-.290	-.946**	-.838**	-.808*	-.966**	-.834*	-.905**	-.820*	1	
ECEC ,,	.412	.412	-.861**	.859**	.717*	.950**	.970**	.965**	.776*	-.882**	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 5 revealed correlation among the propertiesof the soil derived from SS. The EA exhibited negative relationship with all the properties except in its relationship with silt which was positive. The sand fraction and Ca mostly correlated with all the other soil properties. The sand fraction decreased as the clay and silt fractions increased. The sand fraction also increased with increase in pH, OM and the exchange properties but decreased with increase in EA.

These correlations indicated that increasing OM content of soil will reflect in an increase in its base status. The results of the correlation analyses corroborated the observations of Adeleye*et al* (2010) and Grichs (1990) who reported that enhanced OM contents in soils increased their exchangeable bases. Reports had shown that the exchangeable bases of soils varied with the OM fractions (Oorts*et al*., 2003), soil texture (Van Erp*et al*, 2001) and soil pH (Katou, 2002). Perhaps, certain pedogenic and anthropogenic conditions (not investigated in this study) such as illuviation and soil erosion, respectively (Filipek, 2011, Favre *et al*., 2002), may also be sources of variation.

Table 5: Correlation matrix of soil physicochemical properties derived from Sandstones

	Sand	Silt	Clay	pH	OM	Ca	Mg	K	Na	EA	ECEC
	←	g/kg	→	(H₂O)	(g/kg)	←		(Cmol/kg)		→	
Sand (g/kg)	1										
Silt ,,	-.830*	1									
Clay ,,	-.934**	.575	1								
pH (H2O)	.788*	-.673	.724*	1							
P(Mg/kg)	.898**	-.674	.883**	.765*							
OM ,,	.743*	-.782*	.589	.718*	1						
Ca (Cmol/kg)	.989**	-.856**	.902**	.797*	.738*	1					
Ng ,,	.805*	-.520	.846**	.456	.375	.819*	1				
K ,	.808*	-.647	.770*	.870**	.662	.829*	.505	1			
Na ,,	.867**	-.845**	.730*	.891**	.768*	.909**	.574	.927**	1		
Ea ,,	-.979**	.773*	-.939**	-.810*	-.799*	-.963**	-.797*	-.781*	-.846**	1	
ECEC ,,	.910**	-.698	.886**	.611	.514	.932**	.965**	.675	.753*	-.879**	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Tables 2, 4 and 5 showed significant (P≤0.01; 0.05) negative relationship of EA with exchangeable bases in soils derived from SH, CPS and SS, while in soils derived from AL (Table 3), EA correlated negatively and significantly (P≤0.01) with Ca, Mg and K only. However, it showed no significant relationship with Na in soil derived from AL. These results indicated that increase in the basic cations reduced EA of these soils. The availability of Ca and Mg in soils had been reported to reduce EA by neutralizing Al in the soils (Mbagwu*et al*, 2004). Tables 2 to 5 showed a positive correlation between ECEC and OM as well as ECEC and exchangeable bases in the soils studied. In SH derived soil (*Table* 2) ECEC positively correlated significantly (P≤0.01) with OM as well as with exchangeable bases. Similar positive significant (P≤ 0.01) correlation in AL-derived soil was observed (Table 3). In soil derived from CPS, ECEC also positively correlated significantly (P≤0.01) with OM and exchangeable bases (Table 4) whereas Table 5 showed positive significant (P≤0.01, 0.05) correlation of ECEC only with Ca, Mg and Na for SS- derived soil. There was no significant correlation of ECEC with K though the relationship was positive. These results implied that the ECEC of the soils studied varied according to the OM content (Oorts*et al*., 2003), the concentration of exchangeable bases and soil texture (Van Erp*et al*., 2001).

IV.   CONCLUSION

The results from this study indicated that soils derived from SH and AL were less acidic with higher contents of OM, higher concentrations of basic cations, and ECEC compared to the soils of CPS and SS origins. These were attributed to the former's higher clay contents compared to the latter. The condition of lower clay and silt contents as well as higher sand content in soils of CPS and SS made them very prone to the leaching of basic cations, and thus more acidic. However, it is recommended that practices such as mulching, cover cropping, minimum tillage, etc. that will enhance OM contents of these soils should be adopted. These will stabilize soil aggregates and thus reduce leaching in CPS- and SS-derived soils while enhancing the properties of SH and AL soils for sustainable agriculture. Liming will be useful in checking the acidity problems of CPS and SS soils.

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