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PROPERTIES OF SOILS OF DIFFERENT LITHOLOGY IN THE HUMID TROPICS OF SOUTHEASTERN NIGERIA

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ABSTRACT

This study evaluated the properties of soils developed on diverse parent materials in Ogoja Local Government Area. Five profile pits on five different parent materials were dug, morphologically delineated and described. The five parent materials were basement complex (BC), mudstone (MS), sandstone (SS), shalestone (SH) and limestone (LS). Morphologically, the soils were deep with varying color, structure, texture and consistency. The results of chemical analyses revealed that the soils have acid pH with means of 5.4, 5.4, 5.4, 5.3 and 5.4 in BC, MS, SS, SH and LS. Organic carbon was low (<15g/kg) across the parent materials while total N was slightly higher in MS, SS and LS with means of 0.04 g kg^{-1}, 0.10 g kg^{-1}, 0.04 g kg^{-1}, 0.10 g kg^{-1} and 0.20 g kg^{-1} in BC, MS, SS, SH and LS accordingly. Available P was low (<8mg/kg) across the parent materials with slightly higher value recorded in SH than in other parent materials. Calcium and sodium were the dominant and the least bases respectively with mean values of 3.2 cmol/kg, 3.93 cmol/kg, 3.65 cmol/kg, 3.3 cmol/kg and 3.95 cmol/kg and 0.25 cmol/kg, 0.10 cmol/kg, 0.08 cmol/kg, 0.08 cmol/kg, 0.08 cmol/kg in BC, MS, SS, SH and LS respectively. Exchangeable bases were higher in MS than other soils. Both Al^{3+} and H^{+} contributed at the same level to acidity of the soils. Correlation analysis showed that sand correlated negatively and significantly with clay (-0.81), OC (-0.41), TN (-0.42), and Al^{+++} (-0.78) and positively and significantly with pH (0.72), Ca^{2+} (0.7), Mg^{2+} (0.64), K^{+} (0.56), ECEC (0.71) and BS (0.70). Correlation between pH and exchangeable bases, available P (0.83), ECEC (0.9) and base saturation (0.83) was significant and positive. However, most properties had negative and non-significant correlation with each other.

KEYWORDS: Parent materials, acidity, exchangeable bases, correlation.

INTRODUCTION

It is projected that the world population would reach about 8.5 billion in 2030 (UNPD, 2015). This has created concern for many world economies including Nigeria. This increased population means that increased resources will be required for meeting food demands of the growing population. Food security is a first priority for the poor, especially people living in Sub-Sahara Africa (Afu *et al.,* 2019). Agriculture can however, help tremendously in providing most of these resources (food, feed, fiber etc.), thus ensuring food security. In Nigeria and Cross River State in particular, agriculture is the major source of livelihood for most of its populace, especially those living in the rural areas; it is the source of food and income. With this rapidly increasing population, there is need to intensify effort in meeting the increasing demand for food sustainably through crop production.

In view of ensuring sustainable crop production for the present and future generation, knowledge of our soil is inevitable. Soil is known to provide essential ecosystem services including but not limited to serving as a medium for plant growth, providing physical support to terrestrial plants, supplying fundamental resources (water, nutrients and oxygen), cycling nutrients, such as carbon and nitrogen, and regulating important gas fluxes between the subsurface and the atmosphere (Andrews *et al.,* 2004). The capacity of any soil in performing these functions or providing these services is inarguably determined by the type of parent material the soil developed. The capacity of a soil to bear load, subsist, supply nutrients and produce a given crop community maximally or poorly and its vulnerability to degradation and rate of weathering are all linked to parent materials. The soils of humid tropics have received over-whelming acceptance for agriculture and other uses. However, most farmers in Cross River State, especially those that

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are not conversant with soil pedogenetic processes often regard soils to be the same in all aspects especially when such soils are in the same geographical location (Afu *et al.,* 2017). It is against this backdrop that Afu *et al*., (2017) aptly stated that soils formed on different parent materials differ greatly in their physico-chemical properties. Irmak *et al*. (2007) also affirmed that soils in the same agro-ecological conditions can vary greatly due to differences in their parent materials.

Soils of Cross River State are developed from diverse parent materials. However, soils in Ogoja are exclusively developed on limestone, shale and sandstones and basement complex formation (Ofem *et al.,* 2020) and the area produces the highest agricultural crops in Cross River State. Thus, information on variations in soil properties within and across soil overlying different parent materials in Ogoja will enable potential users of the soils to appreciate the behavior of the soils and also enable farmers to rationally plan the development and use of the soils accordingly so as to put available agricultural lands to their best uses for sustainable food production. Now that emphasis is being tailored toward precision farming in Nigeria in order to meet up with food requirement of rapidly growing population, investigations on properties of soils on different parent materials and landscape positions is necessary (Afu *et al.,* 2021; John *et al.,* 2019).

Owing to the importance of soil in human existence, it has become imperative to take account of the variability of soil properties especially when intending to design a suitable soil management system to be used in selecting appropriate agronomic practices for such soils. This study aimed to assess the fertility and variability in physical and chemical properties of soil developed on different parent materials in Ogoja, Cross River State, Nigeria.

MATERIALS AND METHODS

Location of study

The study was conducted in Ogoja Local Government Area of Cross River State. The area has tropical climate and lies between Latitudes 6^0 25' and 6^0 36' N and Longitudes 8^0 30' and 9^0 00' E with elevation ranging from 2 m to 236 m (Fig. 1). The mean annual rainfall of the area ranges from 1718- 2190 mm with mean annual air temperatures and relative humidity of 27 ^{0}C and 87 %, respectively (Eshett *et al.,* 1990). The soils in the study area are formed from diverse parent materials including sedimentary rock (sandstone), shale, limestone, mudstone, basement complex (Eshett *et al.,* 1990). The vegetation of the study area consists of Guinea and Derived Savannah.

Soil sample collection

Soil samples were collected from five profiles dug on five identified parent materials; basement complex (BC), mudstone (MS), sandstone (SS), shalestone (SH) and limestone (LS) with the use of geological map of the study area (Fig. 1). The profiles were morphologically described and soil samples were collected from each pedogenic horizon properly labeled and transported to the laboratory.

Laboratory analysis

In the laboratory, the samples were air-dried at room temperature, crushed with pestle and sieved with 2 mm mesh sieve, bagged, and labeled for soil routine analysis. Particle size was determined by Bouyoucous hydrometer methods as outlined by Gee and Or (2002). pH was determined using the procedure reported by Udo *et al.* (2009) while organic carbon was determined by Walkley-Black wet oxidation method described as by Udo *et al.* (2009). Total nitrogen was determined using modified micro-kjeldhal method (Udo *et al.*, 2009) while available phosphorus was determined using Bray P-1 described by Srinkanth *et al.* (2013).

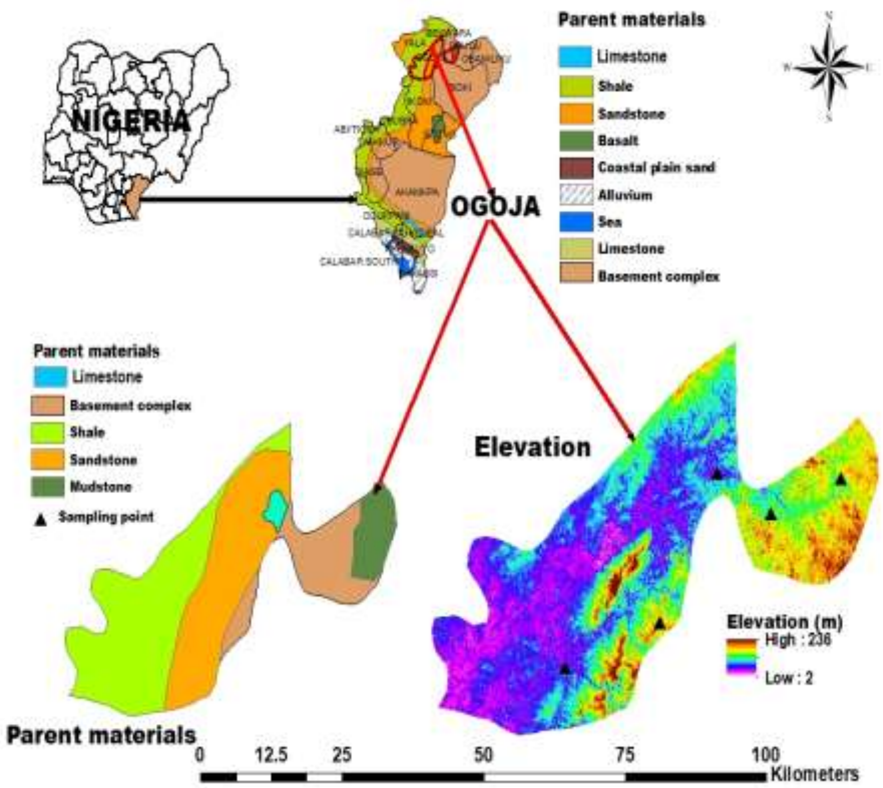

Fig. 1: Map of the study area showing different parent materials and sampling points

Exchangeable bases were determined by leaching the soil samples with 1ml neutral NH4OAc as the extractant solution. Calcium (Ca) and Mg were determined by the EDTA complexometric titration method while K and Na were determined by flame photometry using procedure outlined by Udo *et al.* (2009). Exchangeable acidity was determined by titration method described by Srinkanth *et al.* (2013). ECEC was obtained by summation method and base saturation obtained by expressing the exchangeable bases as percentage of the ECEC.

RESULTS AND DISCUSSION

Morphological properties

The morphological properties of the soils studied are presented in Table 1. All the profiles had distinctively A, B and C horizons with clay accumulation in B horizons. The depth to non-soil material or parent rock was variable in all the profiles of the parent materials and was 135 cm in basement complex (BC), 114 cm in limestone (LS), 145 cm in sandstone (SS), 120 cm shale stone (SH) and 78 cm mudstone (MS). All the soils have shallow Ap horizons, thicker B and C horizon and however generally deep. The color of the soil varied with parent materials. In basement complex, it varied from brown (10YR4/3) in Ap, Bt_1 and Bt_2 to yellowish brown (10YR4/4) in Cr horizon while in mudstone it varied from dark brown (7.5YR3/3) in Ap and Bt to yellowish brown (10YR5/6) in Cr horizon, from dark reddish brown (5YR3/3) in Ap horizon to red (2.5YR5/8) in Bt_1, Bt_2 and Cr horizons of limestone. Similarly, in sandstone, color ranged from very dark grey (10YR3/1) in Ap to strong brown (7.4YR4/6) in Cr horizon whereas in shale stone, the color ranged from dark brown (7.5YR3/3) in Ap through brown (7.5YR4/3) in Bt_1 and Bt_2 to yellowish brown (10YR5/6) in Cr horizon (Table 1). Basement complex, shale stone, sandstone and mudstone soils had sandy loam and sandy clay loam texture in surface and subsurface horizons accordingly while limestone soil had sandy loam and loamy sand textures in surface and subsurface horizons. The soils developed on basement complex and mudstone had sub angular blocky structure of different grades and classes while in limestone soil, Ap and Cr horizons had granular structure and Bt_1 and Bt_2 had crumb structure with different grades and classes (Table 1).

Table 1: Morphological properties of the studied soil

Parent materials	Horizon	Depth	Color	Texture	Structure	Consistency	Boundary	Inclusion
	AP	0-16	Brown (10YR4/3)	Sl	1mfsbk	Ssfr	Cs	Few common pores, few roots and rock fragments
BC	Bt_1	16-50	Brown (7.5YR4/4)	Scl	2mfsbk	Ssfr	Ci	Common pores, few roots and rock fragments
	Bt_2	50-84	Brown (75YR4/4)	Scl	1wfsbk	Sfr	Ci	Common pores, few roots and rock fragment were found.
	Cr	84-135	Yellowish brown(10YR144)	Scl	2mfsbk	Ssfr	Gi	Few common pores, few roots, rock fragments, decomposed leaves and termite were found.
MS	Ap	0-13	Dark brown (7.5YR3/3)	Sl	2mfsbk	Ssfrl	Cw	Common pores, few roots and termites and ant, few rock fragments were also found.
	Bt_1	13-44	Dark brown (10YR3/3)	Scl	1trfcr	Ssfr	Ci	Common few pores, roots, insects and few rock fragments were found.
	Cr	44-78	Yellowish brown (10YR5/6)	Scl	2mfsbk	Ssfr	Ci	Common pores, insect, rock fragment were found.
LS	Ap	0-21	Dark reddish brown(5YR3/3)	Sl	1mg	Sfr	Cs	Common pores, undecomposed leaves, rock fragments were found
	Bt_1	21-49	Red (2.5YR5/8)	Lc	2lfmcr	Sfr	Gi	Few root, common pores, rock fragments and termite were found.
	Bt_2	49-78	Red (2.5 YR5/8)	Lc	2fmcr	Sfr	Ci	Few roots, common pores, rock fragment and insects were found.
	Cr	78-114	Red (2.5YR5/8)	Lc	21mg	Ssfr	Ci	Common pores, few roots, rock fragment and insects were found.
SS	Ap	0-22	Very dark grey (10YR3/1)	Sl	2fg	Nsfrl	Cw	Common pores, few roots, rock fragments and insects were found.
	Bt_1	22-54	Dark grey (7.5YR4/4)	Scl	1fcr	Ssli	Cw	Common pores, few roots, rock fragments and insects were found
	Bt_2	54-105	Brown (7.5YR5/4)	Sc	1fcr	Ssfr	Gi	Common pores, few roots, rock fragments and insects were found.
	Cr	105-145	Strong brown (7.4YR4/6)	Lc	1fsbk	Ssl	Ci	Common few pores, common roots and rock fragments were found.
SH	Ap	0-12	Dark brown (7.5YR3/3)	Sl	1msbk	Ssfrl	Ci	Common pores, medium roots and rock fragments were found.
	Bt_1	12-31	Brown (7.5YR4/3)	Scl	1msbk	Ssfr	Gi	Common pores, medium roots, rock fragment were found.
	Bt_2	31-82	Strong brown (7.5YR5/6)	Scl	1fcr	Ssfr	Gi	Common pores, medium roots, rock fragment were found.
	Cr	82-120	Yellowish brown (10YR5/6)	Scl	1fcr	Ssfrl	Gi	Common pores, medium roots, rock fragment were found.

Texture: SC=Sandy clay; SL=Sandy loam; SCL=Sandy clay loam; CL=clay; S = sand: **Structure**: 1= weak, 2= moderate, f= fine m= medium; sbk= sub angular blocky cr= crumb g= granular **Consistency**; s= sticky ss= slightly sticky ns= non-sticky, fr= friable l= loose sh= slightly hard h= hard: **Boundary**, c= clear I=irregular w=wavy g= gradual d=diffused, BC = Basement complex, MS = Mudstone, SS = Sandstone, SH= Shalestone, LS = Limestone

Sandstone soil had structure varying from granular in the surface horizon to crumb and sub angular blocky in subsurface horizons while in shalestone, the surface horizon had sub angular blocky structure and the subsurface had crumb structure. Consistency of the soils was slightly sticky (wet) and friable and firm (moist) across all the parent materials except sandstone parent materials where the consistency was non sticky (wet) and friable (moist). Horizon boundaries in profiles of all the parent materials varied from gradual irregular in shalestone parent materials to clear irregular in mud stone and basement complex parent materials (Table 1).

Particle size distribution

The results of particle size distribution of the different soils presented in Table 2 show that basement complex had clay loam and sandy clay while sandstone had predominantly clayey and silty clayey texture, mud stone clayey texture while shalestone and lime stone had texture varying from clay to clay loam. Sand was higher in basement complex and limestone and ranged from 100 to 370 g kg^{-1}, 90 to 270 g kg^{-1}, 60 to 380 g kg^{-1}, 50 to 360 g kg^{-1}, 110 to 280 g kg^{-1} with mean values of 245 g kg^{-1}, 166.7 g kg^{-1}, 162.5 g kg^{-1}, 202.5 g kg^{-1} and 222.5 g kg^{-1} for BC, MS, SS, SH and LS. Similarly, silt ranged from 170 to 230 g kg^{-1}, 210 to 290 g kg^{-1}, 170 to 500 g kg^{-1}, 150 to 500 g kg^{-1}, 310 to 360 g kg^{-1} with mean values of 207.5 g kg^{-1}, 260 g kg^{-1}, 270 g kg^{-1}, 287.5 g kg^{-1} and 335 g kg^{-1} while clay ranged from 400 to 680 g kg^{-1}, 520 to 620 g kg^{-1}, 400 to 740 g kg^{-1}, 390 to 800 g kg^{-1}, 380 to 580 g kg^{-1} with mean values of 547.5 g kg^{-1}, 573 g kg^{-1}, 567.5 g kg^{-1}, 510 g kg^{-1} and 442.5 g kg^{-1} for BC, MS, SS, SH and LS soils correspondingly (Table 2). In related studies, Aki and Ediene (2018), Eyong and Akpa (2019), Afu *et al.* (2020) obtained contrary values for particle size distribution in sandstone parent materials in Cross River State. Abam and Orji (2019) also had contrary observations in similar study in the State.

However, similar distribution of soil separates was obtained for basement complex in Ogoja by Eshett *et al.* (1990). In the same vein, the results of basement complex agree with those reported by Olim *et al.* (2020) in the same parent material at Awi in Akamkpa Local Government of Cross River State. The increase of clay fraction with depth is perhaps due to the pedogenic process of illuviation and translocation of clays from the surface downward by argilluviation process (Esu *et al.,* 2014). Amalu and Isong (2018) obtained higher clay and silt content in their study and posited that soils with high percentages of clay and silt have high potentials for agricultural practices as they provide good aeration, high nutrient and moisture retention capacities. Higher levels of silt and clay recorded in this study therefore means higher fertility of the soils.

CHEMICAL PROPERTIES

Soil pH

The soils of all the parent materials are acid in reaction as shown in Table 2. The pH of the soils ranged from 5.0 to 5.9, 5.3 to 5.7, 5.1 to 5.7, 5.1 to 5.5, 5.1 to 6.1 with mean values of 5.4, 5.4, 5.4, 5.3, 5.4 for BC, MS, SS, SH and LS respectively. The pH values are higher in shale and sandstone than the mean values of 4.3 and 5.0 obtained in shale stone by Afu *et al.* (2020). The mean pH value (5.4) of basement complex obtained in this study is higher than 5.0 and 5.1 obtained in basement complex in Akamkpa by Olim *et al.* (2020). High acidic nature of the soils may be due to high rainfall in the area that leaches basic cation down the soil profile and high level of aluminum that undergoes hydrolysis releasing hydrogen ions into the soil that lower pH. Olim *et al.* (2019) attributed low pH in agricultural soils to leaching by high rain fall and the use of acid forming fertilizers in intensive cultivation. Afu *et al.* (2019) obtained similar pH value of 5.4 and 5.7 in surface and sub-surface soils of basement complex and opined that low pH causes deficiency of basic cations in soils. The pH values obtained in this study are higher than those reported for sandstone and basaltic soils by Donatus *et al.* (2018) but similar to those reported by Abam and Orji (2019) in similar area. Afu *et al.* (2019) obtained similar pH values in sandstone. However, the pH values obtained were within the tolerant range of 5.5-6.5 for the growth and performance of arable crops (Enwezor *et al*., 1990; Landon, 1991).

Soil organic carbon

Soil organic carbon had means of 0.56 gkg^{-1}, 1.16 gkg^{-1}, 0.57 gkg^{-1}, 1.16 gkg^{-1}, 2.3 gkg^{-1} for basement complex, mudstone, sandstone, shale stone and limestone soils, accordingly. These values show that organic carbon was low across the parent materials (Landon, 1991), and lower in values when compared to the values of 13 gkg^{-1}, 8.7 gkg^{-1} and 7.1 gkg^{-1} recorded in shalestone, basement complex and sandstone by Abam and Orji (2019). Organic carbon generally decreased with depth in all the profiles. Low level of organic carbon may be due to rapid organic matter weathering in the tropics, bush burning in the area and intensive utilization of the soils for agricultural crop production with short fallowing period for soil recuperation and regeneration of botanical biodiversity. These soils will be low in CEC due to their low organic content as Nwachukwu *et al* (2021) defined soil organic matter as a complex and heterogeneous mixture of organic substances that provide much of the CEC and water holding capacity of soils. Different observation was also made on organic carbon by Akpan-Idiok *et al.* (2016) who reported moderate values of organic carbon for similar soils in Cross River State.

Total Nitrogen

Total nitrogen was slightly higher in mudstone, sandstone and limestone, however they are generally rated low in all the parent materials (Landon, 1991) and had mean values of 0.04 gkg^{-1}, 0.10 gkg^{-1}, 0.04 gkg^{-1}, 0.10 gkg^{-1}, and 0.20 gkg^{-1} for BC, MS, SS, SH and LS soils correspondingly. The low level of nitrogen in the area may have been due to volatilization caused by high temperature and bush burning in the area leaching by high rainfall, crop removal and also may not be something different from the low organic carbon content of the soils. Foth (2006) stated that nitrogen is the nutrient that is absorbed by plant from the soil in the greatest quantity and is the most limited nutrient for food production. This therefore means that for sustainable crop production practices addition of nitrogen to the soil is inevitable as crop production continually mines nitrogen from the soil. The values of total nitrogen obtained in this study are in disagreement with those obtained in similar study by Abam and Orji (2019) in soil of diverse parent materials in Cross River State but within the range obtained in basement complex in the same location by Afu *et al* (2019).

Available Phosphorus

Available P was low (<8mg/kg) (Landon, 1991) and had mean values of 2.56 $mgkg^{-1}$, 13.12 $mgkg^{-1}$, 3.44 $mgkg^{-1}$, 3.66 $mgkg^{-1}$ and 4.62 $mgkg^{-1}$ in BC, MS, SS, SH and LS respectively. However, available P was higher in mudstone than in other parent materials. Higher P values obtained in mudstone disagree with the study of Osujieke *et al* (2017) who recorded higher P values in sandstone soils than in other parent materials in Imo State. However, in a similar study Afu *et al.* (2020) made similar observation as they obtained higher P in Shale stone than in sandstone. Higher values of P obtained in mudstone may be due to higher content of P bearing mineral/apatite in mudstone. Low level of available P may have been caused by its fixation by Al ions in the soils. Aluminum ion, hydroxides and oxides of metals are the major cause of P fixation in acid soils.

Table 2: Chemical properties of the studied soil in relation to parent materials

Profile	Horizon Depth	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	TC	pH (H_2O)	OC ←	TN (gkg^{-1}) →	AV.P	Ca^{2+} ←	Mg^{2+}	K^+	Na^+ Cmol/kg →	Al^{+3}	H^+	ECEC	BS (%)
BC	0-16	100	220	680	CL	5.9	0.99	0.08	4.25	4.6	2.4	0.12	0.09	0.00	1.04	8.25	87
	16-50	330	170	500	SC	5.1	0.62	0.05	2.00	2.2	1.0	0.10	0.08	1.56	0.56	5.50	61
	50-84	370	230	400	SC	5.0	0.38	0.02	2.25	2.6	2.4	0.10	0.07	2.36	0.88	8.32	62
	84-135	180	210	610	C	5.5	0.26	0.01	1.75	3.4	2.4	0.10	0.08	0.52	2.00	8.50	70
MS	0-13	90	290	620	C	5.7	1.66	0.14	30.37	5.2	2.8	0.11	0.09	0.56	0.84	9.60	85
	13-44	140	280	580	C	5.3	1.19	0.1	6.62	3.2	1.2	0.12	0.10	0.48	0.44	5.54	83
	44-78	270	210	520	SC	5.3	0.62	0.05	2.37	3.6	2.4	0.12	0.10	0.28	0..6	7.10	88
SS	0-22	70	190	740	C	5.7	0.99	0.08	3.00	4.2	1.6	0.11	0.08	0.36	0.64	6.99	86
	22-54	140	170	690	C	5.5	0.50	0.04	5.75	3.6	0.8	0.11	0.09	1.68	0.8	7.08	65
	54-105	380	220	400	SC	5.2	0.48	0.03	2.00	3.0	2.2	0.10	0.08	4.00	1.24	10.62	51
	105-145	60	500	440	SiC	5.1	0.32	0.02	3.00	3.8	1.2	0.08	0.07	0.36	0.72	6.44	83
SH	0-12	60	500	440	SiC	5.5	2.71	0.23	4.75	4.2	1.0	0.09	0.07	0.36	0.72	6.44	83
	12-31	50	150	800	C	5.3	1.04	0.09	3.00	2.8	2.4	0.10	0.08	0.52	0.82	6.72	80
	31-82	360	250	390	CL	5.1	0.54	0.04	3.25	2.6	1.8	0.10	0.09	1.48	0.36	6.43	71
	82-120	340	250	410	CL	5.3	0.36	0.02	3.62	3.6	2.0	0.08	0.06	1.04	0.76	7.54	76
LS	0-21	110	310	580	C	6.1	3.49	0.31	8.62	6.6	2.4	0.14	0.11	0.36	0.64	10.25	90
	21-49	280	310	410	CL	5.1	2.01	0.17	2.00	2.8	1.6	0.08	0.07	2.08	1.92	8.55	53
	49-78	260	360	380	CL	5.1	1.66	0.14	3.87	3.4	2.2	0.11	0.08	1.08	0.72	7.59	76
	78-114	240	360	400	CL	5.1	2.03	0.17	4.00	3.0	2.4	0.08	0.06	2.58	2.06	10.18	54
BC	**Min**	**100**	**170**	**400**		**5.0**	**0.26**	**0.01**	**1.75**	**2.2**	**1.0**	**0.10**	**0.07**	**0.00**	**0.36**	**8.25**	**61**
	Max	**370**	**230**	**680**		**5.9**	**0.99**	**0.08**	**4.25**	**4.6**	**2.4**	**0.12**	**0.69**	**2.36**	**2.00**	**8.50**	**87**

	Mean	245	207.5	547.5	5.4	0.56	0.04	2.56	3.2	2.05	0.11	0.25	1.11	1.12	8.39	70
MS	Min	90	210	520	5.3	0.62	0.05	2.37	3.2	1.2	0.11	0.09	0.28	0.44	5.54	83
	Max	270	290	620	5.7	1.66	0.14	30.37	5.2	2.8	0.12	0.10	0.56	0.84	9.60	88
	Mean	166.7	260	573	5.4	1.16	0.10	13.12	3.93	2.2	0.12	0.10	0.33	0.63	7.41	85
SS	Min	60	170	400	5.1	0.32	0.02	2.00	3.0	0.8	0.08	0.09	0.36	0.72	6.44	51
	Max	380	500	740	5.7	0.99	0.08	5.75	4.2	2.2	0.11	0.09	4.0	1.24	10.62	83
	Mean	162.5	270	567.5	5.4	0.57	0.04	3.44	3.65	1.45	0.10	0.08	1.6	0.87	7.65	70.5
SH	Min	50	150	390	5.1	0.36	0.02	3.00	2.6	1.0	0.08	0.06	0.36	0.36	6.43	71
	Max	360	500	800	5.5	2.71	0.23	4.75	4.2	2.4	0.10	0.09	1.48	0.82	7.54	83
	Mean	202.5	287.5	510	5.3	1.16	0.10	3.66	3.3	1.8	0.09	0.08	0.84	0.67	6.78	77.5
LS	Min	110	310	380	5.1	1.66	0.14	2.00	2.8	1.6	0.08	0.06	0.36	0.64	7.59	53
	Max	280	360	580	6.1	3.49	0.31	8.62	6.6	2.4	0.14	0.11	2.58	2.06	10.25	90
	Mean	222.5	335	442.5	5.4	2.30	0.20	4.62	3.95	2.15	0.10	0.08	1.52	1.36	9.14	68.3

Key: BC = Basement complex, MS = Mudstone, SS = Sandstone, SH= Shalestone, LS = Limestone, TC=Textural class, CL= Clay Loam, SC = Sandy Clay, C= Clay, SiC = Silty Clay

Exchangeable Bases

Calcium and magnesium were higher in mudstone and limestone than in other parent materials but abundance of the bases across the soils was in the order of Ca > Mg >K > Na. Calcium, potassium and sodium were low in the soils while magnesium was moderate (Landon, 1991). Calcium had mean values of 3.2 $cmol^{+}kg^{-1}$, 3.93 $cmol^{+}kg^{-1}$, 3.65 $cmol^{+}kg^{-1}$, 3.3 $cmol^{+}kg^{-1}$, and 3.95 $cmol^{+}kg^{-1}$ while magnesium had means of 2.05 $cmol^{+}kg^{-1}$, 2.2 $cmol^{+}kg^{-1}$, 1.45 $cmol^{+}kg^{-1}$, 1.8 $cmol^{+}kg^{-1}$, 2.15 $cmol^{+}kg^{-1}$ in BC, MS, SS, SH and LS soils accordingly. Similarly, potassium had mean values of 0.11 $cmol^{+}kg^{-1}$, 0.12 $cmol^{+}kg^{-1}$, 0.10 $cmol^{+}kg^{-1}$, 0.09 $cmol^{+}kg^{-1}$, 0.10 $cmol^{+}kg^{-1}$ while sodium had average values of 0.25 $cmol^{+}kg^{-1}$, 0.10 $cmol^{+}kg^{-1}$, 0.08 $cmol^{+}kg^{-1}$, 0.08 $cmol^{+}kg^{-1}$, 0.08 $cmol^{+}kg^{-1}$ for BC, MS, SS, SH and LS respectively.

Exchangeable Aluminum

Aluminum had average values of 1.11 $cmol^{+}kg^{-1}$, 0.33 $cmol^{+}kg^{-1}$, 1.6 $cmol^{+}kg^{-1}$, 0.84 $cmol^{+}kg^{-1}$, 1.52 $cmol^{+}kg^{-1}$ while hydrogen had means of 1.12 $cmol^{+}kg^{-1}$, 0.63 $cmol^{+}kg^{-1}$, 0.87 $cmol^{+}kg^{-1}$, 0.67 $cmol^{+}kg^{-1}$, 1.36 $cmol^{+}kg^{-1}$ in BC, MS, SS, SH and LS soils respectively. These values show that both Al^{3+} and H^{+} contributed at the same level to acidity. However, higher values of Al^{3+} recorded in limestone, basement complex and sandstone may result in toxicity of aluminum in the soils according to Ambergo (2006) who opined that concentration of Al^{3+} > 1cmol/kg in soil solution can lead to its toxicity.

Effective Cation Exchange Capacity (ECEC)and Base Saturation (BS**)**

ECEC had mean values of 8.39 $cmol^{+}kg^{-1}$, 7.41 $cmol^{+}kg^{-1}$, 7.65 $cmol^{+}kg^{-1}$, 6.78 $cmol^{+}kg^{-1}$, 9.14 $cmol^{+}kg^{-1}$ while base saturation had averages of 70 %, 85 %, 70.5 %, 77.5 %, 68.3 % for BC, MS, SS, SH and LS soils accordingly. The ECEC of the soil is low Landon (1991). Low ECEC of the soil may be due to the advance stage of weathering of the soils. The soils may be dominated by low activity clay such as kaolinite and oxides and hydroxides of metals as Eshett *et al* (1990) in their study in Ogoja reported preponderance of kaolinite and oxides and hydroxides of metals in the soils.

Relationship between selected physicochemical properties in the studied soils

The correlation matrix of properties of the soils studied is presented in Figure 2. Sand correlated negatively and significantly with clay (-0.81), OC (-0.41), TN (-0.42), and Al^{+++} (-0.78) which means that increase in sand contents would lead to a decrease in these soil properties and positively and significantly with pH (0.72), Ca(0.7), Mg (0.64), K (0.56), ECEC (0.71) and BS (0.70). Similarly, this means that increase in sand content results in increased levels of pH, CA, Mg, K, ECEC and BS. In a related study, Abam and Orji (2019) obtained significant and inverse relationship between sand and clay, sand and organic matter. The correlation between silt and most of the properties was negative and not significant except the significant and positive correlation of silt with organic carbon (0.81) and total N (0.79) while correlation between clay and other properties was negative and not significant except for the positive and significant correlation with Al^{+++} (0.63).Clay also correlated positively and non-significantly with available P which is contrary to the observation of Amhakian and Osemwota (2012). Calcium, magnesium potassium and sodium had significant and positive correlation with ECEC and base saturation accordingly (Fig 2). Most of the properties had negative and non-significant correlations with each other. However, correlation between pH and exchangeable bases, available P (0.83), ECEC (0.9) and base saturation (0.83) was significant and positive.

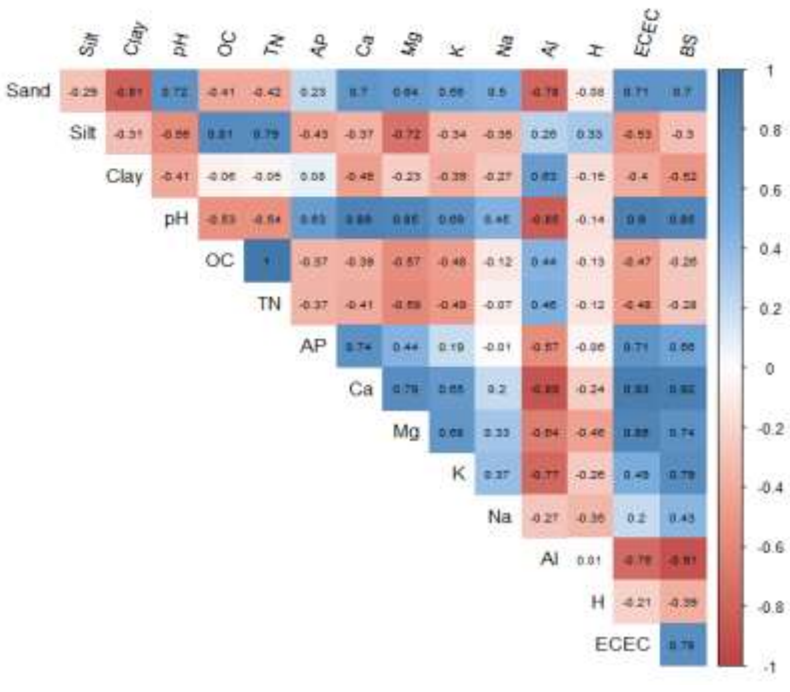

Fig 2: Relationship among soil physicochemical properties in the studied soils

CONCLUSION

The result of this study revealed that parent material has great influence on soil properties. The soils are morphologically and chemically different in most of their properties. All the soils were strongly acidic in reaction, low in organic carbon with highest and the least value obtained in limestone and basement complex soils respectively, rated low in total N with slightly higher values obtained in mudstone, limestone and sandstone than in other parent materials. Available P was also rated low in all the soils with highly variable values obtained showing highest value for P in mudstone. All the soils were low in ECEC which is the major cause of low to moderate basic cations in the soils. A critical look at the results shows that mudstone, shale stone and limestone soil are relatively more fertile than basement complex and sandstone soils. With these variations in properties, different management practices must be adopted for sustainable production of the soils. However, liming is required in all the soils to raise the pH as all the soils are strongly acidic while practices that increase soil organic matter, total nitrogen and soil buffering capacity should be carried out.

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