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Variability in Selected Soil Physico-chemical Properties of Five Soils Formed on Different Parent Materials in Southeastern Nigeria

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Abstract: Different soil individuals require different land use and management practices for optimum performance and yield. This is only possible if there is adequate information on the physico-chemical properties of the soil type in question. Too frequently, farmers and other land users in the Southeastern Nigeria have treated or handled the soils of this sub region in a similar manner, wrongly believing that all the soils are the same. This wrong notion and approach has often led to seriously low return on investment, both for agricultural production and other land use types. Studies were carried out in 2001 and 2002 on five representative profiles derived from five different parent materials, namely basement complex rock, sandstone, basalt, shale and coastal plain sands, to provide information on the physico-chemical properties of the soils derived from the various parent materials. Samples were collected from the genetic horizons of the modal profiles and then subjected to routine analysis and for iron and aluminum contents. The results showed that the soils differ in their physico-chemical properties and these differences have very significant soil management implications. The information provided will hopefully lead to a more profitable and sustainable manner of exploiting the soil resources by the various land users.

Key words: Variability, physico-chemical properties, soils, parent materials, Southeastern Nigeria.

INTRODUCTION

Different soils have varying potential to support different land use types[4]. The productivity of a soil depends largely on its physico-chemical properties. These properties are as a result of the interaction among the five soil forming factors, namely, parent material, living organism, climate, relief and time[6].

Where the relative influence of these factors differs, this will give rise to different kinds of soils, with different productivity potential. Therefore in order to derive the maximum benefit from a soil, it is necessary to know its physical and chemical properties. Such information will enable the user to manage the soil resources in such a way to derive maximum yield and performance from the land. For example, planting a particular kind of crop in a soil that does not possess the necessary requirements for that crop will result in poor yield.

Too often both commercial and resource-poor farmers in Southeastern Nigeria have incurred huge losses of their investment due to poor crop yield resulting from low fertility status of the soils. Several studies have been carried out on some aspects of the soils of different parts of Southeastern Nigeria. Juungerius[13] and Floyd[8] studied the red clayey soils derived from tertiary basalt around Ikom and Obubra areas of the present Cross River State, Nigeria. Eshett *et al.* [5] also studied some wetland soil profiles in Southeastern Nigeria and were able to identify several minerals including Lepidocrocite and gibbsite. However, a comprehensive work on the soils of this sub-region is yet to be done with respect to finding out more properties of these soils to satisfy the needs of a larger spectrum of resource users. Especially to supply the information needed on the properties of the soils in order to facilitate planning and their management for enhanced agricultural productivity. Food shortage is a prevalent problem in the Southeastern part of Nigeria which is known for its rapid population growth rate, and this problem need urgent solution.

Most farmers in Southeastern Nigeria have regarded the soils to be the same in every respect simply because they are all in the same geographical location. The present study is intended to show that these soils indeed differ from one another despite their geographical proximity. Also, it intends to provide information on the physical and chemical properties of the soils derived from the various parent materials. It is hoped that such information will enable potential users to appreciate the individuality of the various soil types in the sub-region, so that they can use them appropriately to derive maximum productivity.

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MATERIALS AND METHODS

This study was carried out in 2001 and 2002 in five locations situated within latitude 5^0 29′ and 6^0 45′ North and longitudes 7^0 02′ and 8^0 45′ East. The natural vegetations range from forest to savannah. Annual rainfall ranges from 2000-3000 mm with four months of dry season and eight months of rainy season. Average minimum and maximum temperature are 25 and 30^{0}C, respectively.

With augerings and minipits, modal profile pits were located, dug, and described according to FAO[7], Quideline for Soil Profile Description; on each of the five different parent materials. In all, twenty-three soil samples were collected from the genetic horizons of the profile pits.

The profiles in Ogoja, Obubra and Ikom are formed on basement complex, sandstone and basalt, respectively. The profiles in Odajie and Eziobodo are formed from shale and coastal plain sand, respectively[5].

The soil samples were air-dried under shade for three days and then ground with mortar and pestle. The ground samples were then sieved through a 2 mm sieve. The sieved samples were then subjected to routine physical and chemical analysis for the various soil parameters.

Mechanical analysis was carried out using hydrometer method[2]. pH in water/soil mixture was determined using the pH meter. The soil: water ratio was 1:2.5. pH in soil/KCl mixture at the ratio of 1:2.5 was taken using Beckman Zeromatic pH meter. The soil/water and soil/KCl mixtures were equilibrated for 30 minutes before taking the pH reading. Delta (Δ) pH was obtained by subtracting pH (H_2O) from pH (KCl). The soil organic carbon content was determined by wet oxidation, using an acid dichromate method as outlined in Okalebo *et al.,*[20]. Total nitrogen was analysed using the modified wet acid oxidation procedure as outlined in Okalebo *et al.*[20]. Available phosphorus was extracted by the Bray No. 1 method as described by Bray and Kurtz[3] and then determined using AA2 auto-analyser.

Exchangeable cations, namely, Calcium, Magnesium, potassium and sodium were estimated by the neutral ammonium acetate procedure[11]. Calcium and magnesium were determined by the Ethylene diamine-tetra-acetic acid (EDTA) method while sodium and potassium were determined by flame photometer. Exchangeable acidity was determined by extracting 5g portion of the soil with 1N KCl solution. Aliquot of the extract was then titrated with 1N NaOH[1]. Effective cation exchange capacity (ECEC) was obtained by the summation of the exchangeable bases and exchangeable acidity[14,18]. Percentage base saturation was computed by dividing the total exchangeable cations by ECEC and then the quotient was multiplied by 100.

Sesquioxide content: Total free iron and aluminum oxides were determined by Dithionite-citrate bicarbonate (DCB) method[17]. Amorphous iron and aluminum oxides were determined by the oxalate extraction procedure[16]. In all, the extracts iron and aluminum were determined colorimetrically using the O-phenanthroline method[12] and the modified aluminon method for aluminum[10].

RESULTS AND DISCUSSION

The physical properties of the soils are shown in Table 1. The profile depths differed from one soil to another. The solum thickness, A-B horizons were in the decreasing order of magnitude as follows: Soils developed on coastal sand > soils developed on basalt > soils developed on basement complex rock > soils developed on sandstone > soils developed on shale. Hence the ability of those soils to support deep-rooted crops is most likely to follow the order of decreasing solum thickness.

In texture, the soils also showed dissimilarities. Soils developed on basalt exhibit the finest texture, sandy clay loam to clay. This was followed by soils derived from sandstone, which ranged from sandy loam to sandy clay loam. The soils derived from coastal plain sand are the coarsest of all the soils ranging from loamy sand to sand. The texture was almost similar for soils developed on basement complex rock and shale; it ranged from loamy sand to sandy clay loam. The silt / (silt +clay) ratio is used to indicate the relative abundance of clay in the fraction: The lower the ratio the more abundant clay is relative to silt. This also has management significance depending on the crop or land use type that is being proposed.

Table 2 shows the chemical properties of the soils. All the soils were acidic, but some were more acidic than the others. The pH (H_2O) values ranged from 4.30 to 6.90. Soils formed from coastal plain sand were the most acidic, with pH (H_2O) values ranging from 4.95-5.20. This is followed by soils derived from basalt and shale in that order. Soils derived from sandstone exhibited pH (H_2O) values close to neutrality. This was followed by soils derived from basement complex rock.

The soils also differed in the value of Δ pH. Delta pH indicates the presence of excess negative charge in the exchange complex[9] and the negative delta pH would suggest a predominance of a highly silicated clay mineralized suite and juvenile stage of weathering[9,15]. Soils derived from basement complex rock had the greatest negative delta pH.

The soils differed in the amount of organic carbon and total nitrogen. The organic carbon content of the

Table 1: Physical properties of the Southeastern Nigeria soils studied

Horizon	Depth (cm)	Mechanical composition of soil (g kg-1)			Silt/(Silt+Clay)	Textural Class
		Clay	Silt	Sand		
	Profile No. 1 on Basement complex rock in Ogoja					
A1	0-15	90.00	70.00	84.00	0.44	Loamy sand
A2	15-26	120.00	70.00	81.00	0.37	Loamy sand
B1	26-58	200.00	60.00	71.00	0.23	Sandy loam
B21t	58-100	300.00	80.00	62.00	0.21	Sandy clay loam
B22t	100-139	320.00	70.00	61.00	0.18	Sandy clay loam
C	139-200	380.00	80.00	54.00	0.17	Sandy clay loam
	Profile No. 2 on Sand stone in Obubra					
Ap	0-21	180.00	200.00	620.00	0.53	Sandy loam
Bg1	21-43	240.00	200.00	560.00	0.45	Sandy loam
Bg2	43-80	280.00	160.00	540.00	0.36	Sandy loam
Bg3	80-138	300.00	160.00	560.00	0.35	Sandy clay loam
Cg	138-160	320.00	160.00	540.00	0.33	Sandy clay loam
	Profile No. 3 on Basalt in Ikom					
A1	0-7	400.00	200.00	400.00	0.33	Sandy clay loam
B1		480.00	160.00	360.00	0.25	Sandy clay loam
B2	35-96	580.00	50.00	370.00	0.08	Clay
B3	96-148	620.00	50.00	330.00	0.07	Clay
	Profile No. 4 on Shale in Odajie					
Ap	0-15	100.00	50.00	85.00	0.33	Loamy sand
B1gh	15-50	120.00	80.00	80.00	0.40	Loamy sand
B2gh	50-120	360.00	120.00	52.00	0.25	Sandy clay loam
	Profile No. 5 on Coastal Plains sand in Eziobodo					
Ap	0-20	40.00	30.00	930.00	0.43	Sand
A2	20-40	60.00	30.00	910.00	0.33	Sand
B1	40-90	100.00	20.00	970.00	0.17	Loamy sand
B2	90-135	130.00	20.00	850.00	0.13	Loamy sand
B3	135-200	150.00	20.00	830.00	0.12	Loamy sand

Table 2: Chemical properties of the Southeastern soils studied.

Horizon	Depth (cm)	pH (1:2.5) H_2O	1N KCL	Δ pH	Organic C (%)	Total N (%)	C:N ratio	Available P (mg kg^{-1})	Exchangeable cations ($cmol\ kg^{-1}$) * Ca	Mg	K	Na	Ex. Acidity (cmol kg^{-1})	ECEC (cmol kg^{-1})	**Base sat. (g kg^{-1})
Profile No. 1 on Basement Complex rock in Ogoja															
A1	0-15	6.40	4.70	-1.70	1.47	0.10	14.70	18.48	7.44	1.44	0.25	0.23	0.30	9.66	970.00
A2	15-26	6.20	4.85	-1.35	0.74	0.06	12.33	10.78	4.88	1.36	0.18	0.17	0.20	6.79	970.00
B1	26-58	5.90	4.70	-1.20	0.48	0.05	9.00	3.85	5.36	0.56	0.19	0.20	0.30	6.61	960.00
B21t	58-100	6.10	5.00	-1.10	0.28	0.04	6.50	2.31	6.32	1.04	0.22	0.21	0.20	7.89	980.00
B22t	100-139	5.90	4.70	-1.20	0.22	0.03	7.33	2.31	7.20	1.36	0.16	0.21	0.30	9.23	970.00
C	139-200	6.30	4.75	-1.55	0.19	0.03	6.33	2.30	4.96	0.56	0.18	0.17	0.20	6.07	970.00
Profile No. 2 on Sandstone in Obubra															
Ap	0-21	6.90	6.50	-0.40	1.76	0.30	5.87	6.93	13.20	0.96	0.40	0.38	0.30	15.24	980.00
Bg1	21-43	6.65	5.90	-0.75	0.38	0.08	4.75	3.85	16.80	0.24	0.23	0.24	0.20	17.71	990.00

Table 2: Continue

Bg2	43-80	6.50	5.60	-0.90	0.32	0.05	6.40	2.31	15.52	0.88	0.27	0.26	0.30	17.63	980.00
Bg3	80-138	6.60	5.60	-1.00	0.32	0.03	10.67	10.01	15.52	0.48	0.16	0.23	0.20	16.59	990.00
Cg	138-160	6.60	5.60	-1.00	0.40	0.05	25.00	17.71	22.88	1.28	0.22	0.27	0.40	25.05	980.00
Profile No. 3 on Basalt in Ikom															
A1	0-7	5.50	5.00	-0.50	2.46	0.35	7.03	16.16	11.84	0.64	0.30	0.28	0.35	13.39	970.00
B1	seven-35	5.15	4.70	-0.35	1.22	0.20	6.10	5.39	7.36	0.72	0.14	0.17	0.35	8.74	960.00
B2	35-96	5.50	4.60	-0.40	0.61	0.18	3.39	10.78	6.08	1.44	0.09	0.15	0.30	8.06	960.00
B3	96-148	5.20	4.90	-0.30	0.29	0.13	2.24	24.64	7.52	0.56	0.27	0.29	0.60	9.18	940.00
Profile No. 4 on Shale in Odajie															
Ag	0-15	5.40	5.00	-0.40	1.44	0.10	14.40	1.54	7.20	0.80	0.26	0.21	0.30	8.77	970.00
B1gh	15-50	5.30	4.80	-0.50	1.02	0.08	12.50	7.70	5.92	1.28	0.24	0.21	0.25	7.90	970.00
B2gh	50-120	5.20	4.50	-0.70	0.26	0.04	6.50	0.72	7.04	1.28	0.20	0.15	0.35	9.02	960.00
Profile No. 5 on Coastal sand in Eziobodo															
Ap	0-20	4.95	4.25	-0.70	0.76	0.07	10.86	2.80	0.16	0.08	0.04	0.15	1.10	1.53	280.00
A2	20-40	5.00	4.20	-0.80	0.64	0.04	16.00	3.50	0.32	0.08	0.02	0.28	1.10	1.79	390.00
B1	40-90	5.05	4.54	-0.06	0.16	0.04	4.00	0.70	0.32	0.24	0.03	0.27	1.30	2.16	400.00
B2	90-135	5.20	4.55	-0.65	0.12	0.04	3.00	0.07	0.32	0.08	0.01	0.07	1.20	1.68	290.00
B3	135-200	5.16	4.45	-0.70	0.04	0.03	1.13	0.07	0.24	0.08	0.01	0.04	1.20	1.58	240.00

*Ex. Acidity - Exchangeable acidity
**Base sat. - Base saturation

Table 3: The distribution of various iron and aluminium expressed as Fe_2O_3 and Al_2O_3 respectively in selected Southeastern Nigerian soils.

Horizon	Depth (cm)	Iron (%)			Aluminium (%)	
		Free Fe	Oxalate Fe	*Active ratio	Free Al	Oxalate Al
	Profile No. 1 on Basement complex rock in Ogoja					
A1	0-15	0.13	0.01	0.08	0.02	0.01
A2	15-26	0.55	0.13	0.24	0.03	0.02
B1	26-58	0.59	0.04	0.07	0.40	0.05
B21t	58-100	0.82	0.04	0.05	0.03	0.01
B22t	100-139	0.17	0.01	0.10	0.30	0.05
C	139-200	0.84	0.06	0.07	0.40	0.08
	Profile No. 2 on Sand stone in Obubra					
Ap	0-21	0.11	0.06	0.45	0.10	0.02
Bg1	21-43	0.67	0.05	0.07	0.03	0.01
Bg2	43-80	0.42	0.05	0.12	0.02	0.01
Bg3	80-138	0.42	0.34	0.81	0.02	0.01
Cg	138-160	0.82	0.24	0.29	0.03	0.02
	Profile No. 3 on Basalt in Ikom					
A1	0-7	0.84	0.71	0.86	0.33	0.08
B1		0.61	0.18	0.30	0.90	0.14
B2	35-96	0.50	0.44	0.88	1.40	0.19
B3	96-148	0.82	0.07	0.09	0.10	0.01
	Profile No. 4 on Shale in Odajie					
Ap	0-15	1.20	0.67	0.56	0.06	0.05
B1gh	15-50	0.78	0.47	0.53	0.04	0.03
B2gh	50-120	1.20	0.28	0.23	0.06	0.04

Table 3: Continue

	Profile No. 5 on Coastal Plains sand in Eziobodo					
Ap	0-20	0.81	0.01	0.01	0.01	0.05
A2	20-40	1.34	0.02	0.01	0.14	0.02
B1	40-90	1.27	0.01	0.01	0.03	0.03
B2	90-135	1.29	0.02	0.01	0.10	0.07
B3	135-200	1.17	0.01	0.01	0.10	0.01
Mean		0.78	0.17	0.25	0.21	0.05

*Active ratio = $\frac{\text{Oxalate } Fe_2O_3}{\text{Total } Fe_2O_3}$

A horizons of the soils showed in the decreasing order of abundance as follows: soils on basalt > soils on basement complex rock > soils on sandstone > soils on shale > soils on coastal sand. In the A horizon, the total nitrogen showed in the following decreasing order of abundance in the various soils: Soils derived from sandstone > soils on basalt > soils on basement complex rock > soils on coastal sand.

The available P contents differed among the various soil samples. It was highest in soils derived from basalt, followed by soils derived from basement complex, sandstone, shale and coastal sand in a decreasing order of magnitude.

Differences were also observed in the amount of cation exchange capacities of the various soils. To the depth of about 120 cm the cation exchange capacities of the various soils ranked in the decreasing order of: Soils on sandstone > soils on basalt > soils on basement complex rock > soils on shale > soils on coastal sand. Hence the capacities of the various soils to hold plant nutrients differ from one another.

In terms of base saturation, the soils on basement complex rock, sandstone, basalt and shale had high values, each above 950 g kg^{-1}, with the soils on sandstone recording the highest. The soils on coastal sand had a low base saturation, with a value of 320 g kg^{-1}.

Table 3 shows the mean and range of extractable iron and aluminum. The soils differ in the contents of extractable iron and aluminum. They differ in the amount of sesquioxides they contain, which is a pointer to the fact that the parent materials from which the soils have been derived have undergone different degree of weathering. The sesquioxides are very useful parameters in the measurement of rate of chemical weathering. Total chemical analysis is the most reliable method of determining the amount of chemical weathering that has taken place in a rock[19]. This allowed the comparison of the data of the fresh rock with that of the weathered rock. From this, the relative change that has taken place becomes very obvious. One of the compounds usually analysed for are sesquioxides, and these are used for the calculation of one of the molar ratios (i.e. % oxide divided by the molecular weight), which research studies have shown to be reliable indices of weathering[19]. One of the commonly used molar ratios is silica: sesquioxide (SiO_2: Al_2O_3 +Fe_2O_3).

As a rule, these ratios decrease with weathering, that is, the lower the ratio, the higher the degree of weathering. Since the content of sesquioxide differed in amount in the various soils, it can be assumed that the ratio of chemical weathering of the five parent materials differed and that they have undergone different degrees of weathering. This in turn suggests that amounts of nutrients or products of weathering differed among the various soils.

Conclusion: The results have shown that the various soils differ not only in parent material but also in many important physical and chemical properties. Therefore, their potential to support various types of land use are expected to differ. This means that if their productivity must be enhanced and these maximised differences should be appreciated and taken into consideration in the planning and management of the various potential use types.

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