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CHARACTERIZATION AND MANAGEMENT OF SOILS DERIVED FROM SHALE IN SOUTHEASTERN NIGERIA FOR SUSTAINABLE CASSAVA PRODUCTION

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ABSTRACT
Cassava is of considerable importance to sub – Saharan Africa, especially Nigeria. It is an important source of carbohydrate and energy. It is of economic importance to Nigerians. Therefore, a Pedological study was conducted in soils of Ishiagu Ebonyi State South East Nigeria to characterize and assess their potentials for sustainable cassava production thereby gives management options for yield increase. A total of 500 ha of land was surveyed using the rigid grid format. Three mapping units were delineated based on similarities and differences observed in the morphological properties from the augered points and profile pits were dug in the identified mapping units. The Pits were sampled according to genetic horizons and taken to laboratory for analyses. From the analytical results the characteristics of the soils ranged as follows: soil texture, Sandy clay loam to Clay, pH, 4.6 to 5.2 Organic C, 0.19 to 2.68 %, total N, 0.01 to 0.34 %, available P, 1.40 to 5.43 mg kg^{-1} CEC, 6.19 to 13.70 cmol (+) kg^{-1} Base saturation, 20.60 to 50.70 % and available Fe, 12.00 to 52.80 mg kg^{-1}. For the soils to sustain cassava production, the fertility of the soils needs to be improved upon.

Keywords:* *Cassava, Characterization, Management, Production, and Soils

Introduction

The relatively scarcity of land for arable crops production, pasture for livestock and for other uses, as a result of increase in population, calls for land use accuracy. Therefore, in order to help the end users of land for crop production and other uses, the soils must be characterized. Soil characterization plays a very important role as a part of rationale cropping system in the value chain crop production. Characterization evaluates, describes and estimates the qualities and potentials of a particular soil for the production of a given crop. This implies that soil characterization is necessary as a first step to land use planning. This will enhance judicious and maximum utilization of any available piece of land, without jeopardizing the prospect of future generation. Characterization of soils is helpful in the appraisal of soil productivity (Mbagwu *et al.*, 1988). In order to properly evaluate a soil and make recommendations for utilitarian purposes, soils occupying any particular landscape must be properly characterized. This helps to organize our knowledge, facilitate the transfer of experience and technology from one place to another and helps to compare properties among soils (Esu, 2004). Onyekwere (2015) quoting Eswaran (1977) highlighted the benefits of soil characterization as follows; data generation of soil properties, correction of soil classification, and basis for detailed land evaluation, soil correlation purposes and development of soil property inter-relationships to guide soil properties prediction. According to him, other notable benefits are also determination of levels of elements which may be toxic or deficient, delineating soils which may require various levels of investment for their economic utilization, and evaluate the changes induced by management practices and thereby determine optional types of management for increased crop yield.

Cassava (*Manihot esculanta*) plays a major role in the economy of Nigeria, as it supplies more than half the calorie intake of her inhabitants (Abam *et a*l., 2006). The country is the largest producer in the world, with an annual production rate of 54 million metric tons (FAO, 2016). It has diverse uses; it is principally used as human food, where it provides the major source of dietary energy for well over 200 million people in Africa (Dorosh, 1988). As food it can be processed into gari, fufu, farinhnade, mandioca, flour, chips and starch (Onwueme, 1978). Cassava chips, pellets and leaves are important in animal feed industry. Cassava starch is used in glucose, textiles and confectionery industries, as well as in food industry. It is a major source of cash

income for household, as it generates cash income for the large number of household in comparison with other staple crops, thereby contributing to poverty alleviation (FMANR, 1997).
The annual production rate of this important economic commodity crop by Nigeria as stated earlier is not as a result of its yield per unit area in farmers' field compared to yield obtained from countries like Brazil, China and Thailand. The production rate is due to large expanse of land subjected to its production. Presently, it has been observed that cassava yield in farmers's field in Nigeria is less than 9 t ha^{-1}. This is as a result of some factors which include inherent poor soil fertility, pest and disease, use of unimproved cassava varieties and weed infestation. Among all these the most important factor is inherent soil fertility. To get a meaningful yield of cassava from farmers' field, the soil fertility needs to be managed to improve the soil resource base. Soil fertility management has resulted to increase in cassava root yield in experimental fields. For soil fertility management to be meaningful for cassava production in farmers' field, the soil must be properly characterized and assessed to ascertain its potentials for the production of cassava, thereby ascertaining some remediation options for yield improvement if needed.

Based on the importance of cassava and its recurrent low yield in farmers' field there is need for an increase in cassava yield per unit area in Nigeria. The first step in achieving this is to chararactrize and assess the potentials of soils in the available piece of land grown to cassava and identify soil fertility management system that will increase plant nutrients availability and restore soil resource base for yield increase. Adoption of soil management options that will guarantee high productivity basically depends on the nature and properties of the soil, which can be done through characterization. However, for cassava farmers in Ishiagu Ebonyi State, South East Nigeria to record an increase from the present yields, characterization of the soils under cassava cultivation is necessary, this will enable their proper use and development of management technology for an increase in its production. Therefore, the objective of this work was to assess the morphological, physical and chemical properties of the soils and further evaluate them for sustainable cassava production and give possible management measures for an increase in yield.

Materials and Methods

Study Area

The study area is Ishiagu, Ebonyi State South East Nigeria Agro ecological Zone. Ebonyi State lies within Latitude 5^0 40^1 and 6^0 45' E and Longitude 7^0 30' N. The climate is characterized by distinct wet and dry seasons. The wet season lasts for about seven months (April through October), with a short break in the month of August. On the other hand the dry season stretches mainly from November through March. Peters and Ekwe-Ozor (1982) reported that a condition of great uniformity is experienced in the area throughout the year with a mean annual temperature range between 22 and 31^0C, mean annual rain fall range of 1,570 to 2,800 mm and relative humidity varying from 60 to 81 %. The vegetation consists of derived savannah. The underlying geology of the location consists of the tertiary Imo formation (shale). The area is under cassava production. The vast land is use for cassava production intercropped primarily with maize and egusi melon.

Pedological Studies

Five hundred hectares of land was demarcated with the aid of Global Positioning System (GPS). The overall micro-relief of the surveyed areas consisted of slightly undulating to gently sloping terrain of not more than 4 %, gradient, which was measured using a clinometer. A detailed soil survey using the rigid grid format was conducted, transverses were cut along a properly aligned base line at 100 m intervals while auger borings were made at 25 cm interval to a depth of 100 cm and morphological descriptions (colour, texture, consistency and inclusions) were made. Based on similarities and differences of the morphological properties, 3 different soil mapping units were delineated. Three profiles pits measuring 2.00 m x 1.00 m x 1.00 to 1.120 m, which were restricted to get to 2m depth because of impenetrable layers, were sited in each delineated soil unit, making a total sum of nine soil profile pits. The morphological characteristics of each profile pits was described, according to the guidelines for profile pit description outlined in Soil Survey Manual (Soil Survey Staff, 1993). The profile pits were cleaned and demarcated based on depths of genetic horizons. Soil samples were collected horizon by horizon starting from bottom to avoid contamination. Samples were taken to the Laboratory for physical and chemical analysis. All the soil samples collected were air dried, gently ground and sieved using a 2 mm sieve preparatory for laboratory analysis. Samples for total N. and organic C were passed through a 0.5 mm sieve. For purpose of reporting, a representative profile pit was selected from the three soil profile pits in each delineated mapping unit.

Laboratory analysis

Physical Properties

Soil particle size analysis was determined after dispersing 51.00 g of air – dried soil samples with 5 % sodium hexametaphosphate overnight that is the Boyoucous hydrometer method as contained in the method of soil analysis by International Soil Reference and Information Centre and Food and Agricultural Organization. **(**ISRIC and FAO, 2002).

Chemical Properties

The chemical properties of the soils were determined according to standard laboratory procedures as contained in the method of soil analysis by International Soil Reference and Information Centre and Food and Agricultural Organization. **(**ISRIC and FAO, 2002). Soil pH (H_2O) was determined in 1:1 soil/ distilled water suspensions using a glass electrode. Organic carbon was determined by Walkley and Black titration method, which involved soil organic matter oxidation with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4). Total nitrogen was determined by using the modified Macro - Kjeldahl method of digestion, distillation and titration. Available phosphorus was determined using Bray P -2 extract of Bray and Kurtz method, and measured calorimetrically. Exchangeable Ca, Mg, K and Na in soil samples were extracted with I N neutral ammonia acetate (NH_4OAc), K and Na were determined by flame photometry while Ca and Mg were by EDTA titration. The soil samples were treated with I N KCl to extract the exchangeable H^+ and Al^{3+}. The KCL extract was subsequently titrated with 0.05 N NaOH. The amount of base used was equivalent to the total acidity. Exchangeable bases were extracted using 1N potassium acetate (KOAc) saturation and neutral IN (NH_4OAC) displacement using 5 g of soil sample. The displaced potassium was determined on a flame photometer thus CEC was estimated as follows:

$$\text{CEC cmol (+) kg}^{-1} / \text{100g soil} = \text{cmol (+) kg}^{-1}\ \text{k/100g soil}$$

Effective Cation Exchange Capacity was calculated as the sum of the exchangeable bases and acidity. Percentage Base Saturation was calculated as the percentage of exchangeable bases divided by effective cation exchangeable capacity.

$$\frac{(K^1 + Na^1 + Ca^2 + Mg^2) \times 100}{ECEC}$$

Results and Discussion

Morphological Properties

The morphological characteristics of the studied mapping units are shown Table 1. The soil colour of the mapping units of the soils studied described under moist condition indicated that the colour ranged from red (2.5YR4/2) to brown (10 YR 5/3) at the Ap horizon and yellowish red (5YR 5/8) to dark yellowish brown (10 YR 4/4) at the sub-soils, with soils from mapping unit 2 show redoxmorphic features with colour value of 4 and chroma of 2 at the Ap horizon (Soil Survey Staff, 2014). The soil colour observed in the mapping units studied corroborates the findings of FDALR (1990) and Essoka and Esu (2001), who also worked on similar soils. The reddish colour exhibited by the mapping units showed that the soils are well oxidized, which is an indication that these soils are highly weathered (Essoka and Essoka, 2013) and the dominance of iron oxide in the pedogenic environment (Sen *et al*., 1997). It has been further reported by Senjobi, *et al*. (2013) that soil colour has been expressed also as the function of iron and organic matter, pH and type of clay mineral in the soil. Soil texture at the Ap horizons of mapping units of the soils studied ranged from sandy clay loam to clay loam, while the texture of the sub soils ranged from clay loam to clay. The sub – angular blocky structures encountered within the Bt horizons could be attributed to the pressure faces on soil matrix, due to integrated translocated clay, micro swelling and shrinkage, which induced the formation of medium and strong aggregates in soils (Chude and Chukwu, 2000) The soils were all matured based on the evidence of argillic horizons and lessivage in all the mapping units studied. The process of eluviation, lessivage and illuviation observed, however was responsible for high clay content at the Bt than Ap horizon in the mapping units (Chukwu, 1997). Soil structure at the Ap horizons of mapping units of soils of the study area ranged from weak fine sub angular blocky structure to moderate medium sub angular blocky structure, while the sub soils ranged from weak medium sub angular blocky to moderate medium sub angular blocky structure. Soil consistency at the Ap horizon of mapping units of soils of the study area is generally firm while the sub soils had similar consistency**.** The soils of the mapping units studied were deep ranging from 101 to 120 cm

Physical Properties

The physical properties of the mapping units studied are shown in Table 2. The sand fraction of the mapping units of the soils studied ranged from 8.00 to 50.8 %. There was no definite pattern of distribution with depth in all the mapping units. The Ap horizon had an average value of 44. 87 %. The silt fraction of the mapping units studied ranged from 13.20 to 23.40 %. There was no definite pattern of distribution with depth in all the mapping units. The upper horizon had a mean value of 19.67%. The clay fraction of the mapping units of the soils studied ranged from 28.80 to 70.80%. There was no definite pattern of distribution with depth in mapping units 1 and 2 but increased with depth in mapping unit 3. The Ap horizon had an average value of 35.47%. The irregular distribution of clay in relation to depth in the mapping units indicated that the soils were formed as a result of stratification process (Onyekwere *et. al.*, 2013). The high silt and clay content of the soils indicated that the soils have high native fertility and can retain soil nutrients (Onyekwere *et al*., 2011). The rather lower clay content in the Ap horizon over the subsurface horizon in all the mapping units could be attributed to the sorting of soil materials by biological and agricultural activities clay migration or surface erosion by run off or a combination of these (Malgwi *et al*., 2000). There is need to incorporate plant residues and other organic materials into the soil, to improve the aggregates quality of the soils as this will lead to an increase in the yield of cassava. The values of silt/clay ratio of the mapping units of the soils studied ranged from 0.18 to 0.71. There was no definite pattern of distribution with depth in all the mapping units, with the Ap horizon having a mean value of 0.58. The mapping units are young soils derived from young parent materials with high degree of weathering. Asmoa (1983) reported that soils with silt/clay ratio less than 0.25 indicates low degree of weathering, It can be further observed that most of the primary minerals have been transformed into clay – size secondary minerals in some of the horizons with silt / clay ratio less than 0.50 in the soils The textural classification of the Ap horizon in all the mapping units studied ranged from sandy clay loam to clay. Generally the textual classification of these soils agrees with optimum criterion of light medium loam sandy soil (Onyekwere *et al*.,2009) required for unhindered anchorage and bulking of roots and tubers including cassava and for easy harvest apart from mapping unit 3.

Chemical properties of the soils

The results of the mapping units studied are shown in Table 3. The soil reaction expressed as pH (H_2O) for the soils studied were strongly acidic, with a range of 4.5 to 5.1. There was no definite pattern of changes in pH down the depth and in all the mapping units studied, with the Ap horizons having an average pH value of 5.1 . The pH values of these soils indicated that they are included among the excessively leached acid latosols with low to medium humus found in areas of rainfall approximately 2200 to over 5000mm per annum in hot lowland (Udoh *et al*., 2013). There is need to incorporate organic materials in the soils, to reduce the soil acidity. According to Onyekwere *et al*. (2012) addition of organic fertilizer to soil reduces soil acidity, because organic fertilizer has some liming effect to the soil. The organic carbon content of the soils studied varied from very low to moderate that is from 1.90 to 26.80 gkg^{-1}, the values decreased down the depth in all the mapping units studied apart from mapping unit 3. The values of the Ap horizons ranged from 21.40 to 26.80 gkg^{-1}, with an average value of 23.40 gkg^{-1}. The low organic carbon content in some of the mapping units studied can be attributed to any or all of the following, inadequate supply of organic litter, bush burning, long dry season and intensive mineralization during the rainy season (Dogie *et al*., 2008). Maintenance of a satisfactory organic matter status is essential to the production of most of the nitrogen and half of the phosphorus taken up by unfertilized crops (Von Uxekull 1986), including cassava. The total N content of soils of the mapping units studied ranged from low to high (0.10 to 3.40 gkg^{-1}) and the values decreased down the depth. All the mapping units had high total N content at the Ap horizon, with mapping unit 1, having the least value while mapping unit 3 had the highest value. The total N content of the Ap horizon in all the mapping units exceeded the critical level of 1.50 gkg^{-1} established for soils (Senjobi, *et al*., 2013). The available P content of the soils studied was low and ranged from 1.40 to 5.43 mg kg^{-1}, apart from mapping unit 1 that did not maintain any particular pattern of distribution with depth, values of the other mapping units decreased down the depth. All the mapping units are poor in available P content at the upper horizons, with mapping unit 1 having the highest value, while mapping unit 2 had the lowest value.

The value obtained from Ap horizon in all the mapping units were below the critical limit of 8.0 mg kg^{-1} P established for crops in South East Nigeria including cassava (FPDD, 1989) and the critical level of 15 mg kg^{-1} P recommended by Thomas and Peaslee (1973) cited by Onyekwere *et al.* (2009). The low value of available P as observed in the mapping units studied could be attributed to interaction of P and other soil constituents and due to low phosphate potentials of the parent rocks (Onyekwere 2004). This result showed that there will be positive response in yield upon application of phosphorus fertilizer in all the mapping units for the production of cassava. The exchangeable Ca, content of soils of the mapping units studied ranged from low to low that is from 0.68 to 2.80 cmol (+) kg^{-1} with the values of the Ap horizon ranging from 0.68 to 2.13 cmol (+) kg^{-1} with a mean value of 1.77 cmol (+) kg^{-1}. The exchangeable Mg content of soils of the mapping units studied ranged from low to moderate (0.29 to 1.83 cmol (+) kg^{-1}). The values of the Ap horizon were low and ranged from 0.67 to 0.83 cmol (+) kg^{-1}, with a mean value of 0.76 cmol (+) kg^{-1} . The exchangeable K content of the soils studied ranged from low to high (0.05 to 0.77 cmol (+) kg^{-1}) and the values decreased with depth only in mapping unit 2, whereas the remaining mapping units did not maintain any definite pattern of distribution with depth. All the mapping units were well endowed with exchangeable K at the Ap horizon, with mapping unit 1 having the least value, while mapping unit 3 had the highest value. The exchangeable Na content of the mapping units studied ranged from very low to low (0.05 to 0.14 cmol (+) kg^{-1}), with the values of the Ap horizon ranging from 0.09 to 0.14 cmol (+) kg^{-1} having a mean value of 0.11 cmol (+) kg^{-1}. The low level of exchangeable bases in the soils studied is as a result of soil loss through soil erosion Mbagwu (1988) reported that soil loss through soil erosion had resulted in the deficiencies of exchangeable bases in soil.

Conclusion

The work involved pedological examination and assessment of the potentials of Ishiagu, South East Nigeria soils for sustainable cassava production. The soils are deep, matured and highly weathered. The soils are strongly acidic, low to high in total N, low to moderate in exchangeable K and low in available P. The soil texture is favorable for production of cassava especially mapping units 1 and 2. Three mapping units were identified, and are all suitable for cassava production. For sustainable cassava production in the identified mapping units to be achieved, the following recommendations are made: Application of organic manure to reduce the soil acidity in all the mapping units, application of 20 kg/ha Urea , 20 kg/ha SSP and 40 kg/ha MOP in mapping units 1 and 3 and application of 20 kg/ha urea, 20 kg/ha SSP and 75 kg/ha MOP in mapping unit 2.

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Table 1: Field Morphological Properties of Mapping units studied

Horizon	Depth (cm)	Matrix Colour	Texture	Structure	Consistency (Moist)	Boundary	Other Feature
		Mapping unit 1					
Ap	0-12	Yellowish red (5YR4/6)	SCL	2msbk	frm	Gw	m2rts
Bt1	12-45	Yellowish red (5YR 5/8)	C	1msbk	frm	Gw	m2rts
Bt2	45-95	Red (2.5YR 5/8)	C	2msbk	frm	Gw	f2rts
BC	95-115	Red (2.5YR5/8)	C	2msbk	frm	-	m2rts
		Mapping unit 2					
Ap	0-15	Red (2.5YR 4/2)	SCL	2msbk	frm	Gw	m1rts
Bt1	15-36	Red (2.5YR 4/6)	C	2msbk	vfrm	Gw	m1rts
Bt2	36-68	Red (2.5YR 3/8)	C	2msbk	frn	Gw	f1rts
Bt3	68-98	Red (2.5YR3/6)	C	2msbk	frm	Gw	f1rts
BC	98-120	Red (2.5YR4/6)	C	2msbk	frm	-	f1rts
		Mapping unit 3					
Ap	0-18	Brown (10YR5/3)	CL	1fsbk	frm	Gw	m1rts
AB	18-40	Darkyellowish brown (10YR 4/4)	C	2msbk	frm	Gw	m1rts
Bt	40-62	Darkyellowish brown(10 YR 4/4)	C	1fsbk	frm	Gw	m1rts
BC	62-101	Darkyellowish brown(10 YR 4/4)	CL	1msbk	frm	-	f1rts

Short hand Notation and Meaning for Table 4.2

Boundary: a = abrupt, b = broken, c = clear, d = diffuses, s = smooth, w = wavy, I = irregular. When a dash (-) is present the property is not recorded. Structure: sbk = sub angular blockly, sg = single grained, c = coarse, cr = crumb, f = fine, m = medium, l = weak, 2 = moderate, 3 = strong. Consistency: Sfm = slightly firm, frm = firm, vfr = very friable, fr = friable. Texture: s = sand, SCL = sandy clay loam, Sl = sandy loam, LS = loamy sandy.Other Features: rts = roots, m = many, c = common, f = few, 1= fine, 2 = medium, 3 = coarse,

Table 2: Physical Properties of the Mapping units studied

Horizon	Depth	Particle Sand	Size (%) Silt	Clay	Clay + Silt (%)	Silt/Clay Ratio	Textural Class
			Mapping unit	**1**			
Ap	0-12	48.00	19.20	32.80	52.00	0.59	SCL
Bt1	12-45	23..80	15.40	60.80	76.20	0.25	C
Bt2	45-95	8.00	21.20	70.80	92.00	0.30	C
BC	95-115	17..20	22.00	60.80	82.80	0.36	C
			Mapping unit	**2**			
Ap	0-15	50.80	20.40	28.80	49.20	0.71	SCL
Bt1	15-36	15.00	19.60	70.00	89.60	0.28	C
Bt2	36-68	9.60	13.20	72.20	85.40	0.18	C
Bt3	68-98	9.00	20.20	70.80	91.00	0.29	C
BC	98-120	9.40	22.60	68.00	90.60	0.33	C
			Mapping unit	**3**			
Ap	0-18	36.80	23.40	39.80	63.20	0.59	CL
AB	18-40	35.80	19.40	44.80	64.20	0.43	C
Bt	40-62	27.00	16.20	56.80	73.00	0.29	C
BC	62-101	39.40	20.80	39.80	60.60	0.52	CL

Table 3: Chemical Properties of the Mapping units studied

Horizon	Depth (cm)	pH (H_2O)	OC (gkg^{-1})	TN (gkg^{-1})	Avail P ($mgkg^{-1}$)	Exch Ca	Mg	Bases K (cmol (+)Kg^{-1})	Na	Exch. Acidity	CEC NH_4OAC	ECEC	Base Sat (%)
				Mapping unit I									
Ap	0-12	5.0	21.4	2.80	5.43	2.13	0.67	0.30	0.09	3.10	8.67	6.29	50.70
Bt1	12-45	4.8	9.30	1.40	1.40	0.96	1.26	0.05	0.05	4.00	7.97	6.32	36.70
Bt2	45-95	5.0	3.00	0.20	3.68	1.35	0.87	0.06	0.05	3.50	7.85	5.83	40.00
BC	95-115	5.1	1.90	0.20	2.28	1.74	1.54	0.06	0.08	2.10	7.66	5.52	62.00
				Mapping unit 2									
AP	0-15	4.8	22.1	3.10	5.08	0.68	0.82	0.45	0.11	2.30	6.19	4.36	47.20
Bt1	15-36	4.8	7.50	1.40	3.15	0.96	0.68	0.08	0.09	3.10	7.98	4.91	36.90
Bt2	36-68	5.2	3.90	4.00	3.33	1.16	0.87	0.06	0.09	2.70	7.00	4.88	44.70
Bt3	68-98	4.7	2.40	0.30	1.75	0.77	1.49	0.05	0.08	2.70	7.35	4.09	34.00
BC	98-120	4.6	2.30	0.10	1.30	0.19	1.26	0.05	0.10	4.70	9.15	6.30	25.00
				Mapping unit 3									
Ap	0-18	4.6	26.80	3.40	5.08	2.80	0.80	0.77	0.14	5.5	13.70	10.01	45.1
AB	18-40	4.5	12.30	2.70	5.08	1.54	0.29	0.18	0.10	6.3	11.12	8.41	25.1
Bt	40-62	4.7	7.40	0.80	3.15	1.16	1.83	0.24	0.10	6.1	11.03	9.43	35.3
BC	62-101	4.7	7.50	0.10	2.63	1.11	0.72	0.28	0.12	8.6	13.96	10.83	20.6