PROPERTIES AND CLASSIFICATION OF SOILS DEVELOPED UNDER TWO CONTRASTING PARENT MATERIALS IN SOUTH EAST NIGERIA.

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ABSTRACT
The study was carried out to characterize and classify soils derived from two different parent materials (coastal plain sand and sand stone) in South east Nigeria. The areas were reconnoitered using footpaths and following free survey method, auger investigations were carried out on the two delineated mapping units designated as coastal plain sands (CP) and sandstone (SS). Three representative pedons were established in each mapping unit. The pedons were described for morphological attributes and samples collected from genetic horizons were analyzed for physical and chemical properties. Result revealed sandy loam underlain by sandy clay loam and sandy clay. The soils of CP were strongly acid (5.6) whereas those of SS were moderately acidic (5.0). Bulk density values of both parent materials were within the optimum level (1.06-1.64 gcm^{-3}) for crop production. Average Available phosphorus content (8.73 for CP and 16.55mgkg^{-1} for SS), exchangeable cations (0.74 cmolkg^{-1} and 1.51 cmolkg^{-1} for SS), exchangeable acidity (1.05 cmolkg^{-1} for CP and 1.53cmolkg^{-1} for SS), CEC (9.32 cmolkg^{-1} for CP and 8.12 cmolkg^{-1} for SS) were generally low for both parent materials while base saturation (80.2%) was high for SS parent material and low (31.7%) for CP parent material. Total nitrogen was high for CP (2.10 gkg^{-1}) and moderate for SS (0.70 gkg^{-1} parent material. Following the USDA soil taxonomy, the soils of CP parent material were classified as Typic Hapludult, Rhodic Paleudult and Oxyaquic Paleudult with WRB appropriate correlation as Haplic Acrisol, Rhodic acrisol and Histic Acrisol while SS parent material were classified as Typic Hapludalf and Arenic Hapludalf (USDA) with WRB correlation as Haplic and Arenic Luvisols. Liming, application of organic and inorganic materials and adoption of appropriate management practices are recommended strategies to improve agricultural activity in the study areas.
Keywords- Properties, classification, coastal plain sands, sandstone,

INTRODUCTION
Soil is the most important basic natural resource that determines the ultimate sustainability of any agricultural system. It varies in its physical, chemical, morphological and mineralogical characteristics especially where topography is a major factor controlling most of its surface processes (Esu, 2004). Afu, *et al.* (2017) reported variability in soil properties as a function of landforms, geomorphic elements, soil forming factors and soil management whereas, Obi and Udoh (2011) attributed the major changes in soil properties to pedogenesis occurring within a certain period of time depending on the parent material, climate, topography and vegetation of the region (Obi, 2015).
Parent materials have great influence on soil productivity and their ability to retain nutrients as indicated by their cation exchange capacity (CEC). Different parent materials affect the morphology and chemistry of soils under the same conditions, such as topography and vegetation in all geographical regions particularly in the tropics. Jenny, (1980) have stated that changes in physical, chemical and morphological properties of the soil are basically related to parent materials and that a soil landscape pattern often reflects the original parent material. Variations in soils could consequent upon different lithological formation of soil. It is therefore necessary to understand the nature, behaviour and distribution of various soils and the different parent materials that made up the soil and this can only be possible with the separate study, characterization and subsequent classification of the soils (Osujieke, 2017).
Soil characterization has been reported as the major building block for classification and for better understanding of the environment (Akamigbo, 2012; Akpan-Idiok *et. al*., 2013). Esu (2008), reported that one of the strategies for achieving food security as well as sustainable environment remains studying the soil resources in details through the processes of soil characterization and land evaluation for various land utilization types. The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use (Chikezie *et al.*, 2009). A soil surveyor characterizes the soils in a given area, classifies the soils according to a standard system of classification, maps out the soils and makes predictions about the behaviour of the soils (Brady and Weil, 2002).
Soils of South east Nigeria have been generally under intensive cropping but the soils are selected by farmers for different crops based on different criteria. For instance, Oti *et al.* (2013) noted that farmers in Mbaise, South east Nigeria, use sight and touch to determine the properties of the soils for cropping. They also noted that recommendation of agronomic practices especially in Ebonyi and Imo states, are often made to the farmers without due consideration or information on the specific soil management options such as fertilizer rate/frequency and types, tillage operations and herbicide application.

Therefore, this study was undertaken to characterize and classify the soils of two contrasting parent materials in South eastern Nigeria to facilitate transfer of knowledge, enhance utilization and ameliorate the productive constraints of the soils to farmers, researchers and stake holders in the area.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carried out in Ahiazu - Mbaise of Imo State, Nigeria (5º 14' –5º 41' N and 7º 08' –7º48' E) and Nguzu - Edda of Ebonyi State, Nigeria (5º 45' –5º 50' N and 7º 49' –7º 54' E) {Figure 1}. Imo and Ebonyi states have typical rainforest vegetation in South-east agro-ecological zone of Nigeria and farming is their major socioeconomic activities (*IITA, 1996*). The general climate is humid tropical, having distinct rainy season that begins from April to October and dry season from November to March. The mean annual rainfall is 2200 mm and annual relative humidity is about 75 %. The average minimum and maximum temperatures are about 22ºC and 30ºC respectively for Imo and Ebonyi states (Oti *et al.*, 2013).

The soils of Ahiazu-Mbaise are underlain by coastal plain sands while that of Nguzu-Edda are false bedded sandstone (Akamigbo, 2012; Nwadike and Nweke, 2017).

2.2 Field work

The study area was reconnoitered using footpaths and following free survey method. Auger investigations were carried out on the two delineated mapping units designated as coastal plain sands (CP) and sand stone (SS). Three representative pedons were established in each mapping unit. Each pedon was demarcated into horizons and described for morphological attributes according to the FAO guidelines (FAO, 2006). Disturbed and undisturbed (core) soil samples were collected from identified horizons and analyzed for their physical and chemical properties. All sample points were geo-referenced using a hand-held (*Garmin etrex*) Global Positioning System (GPS) receiver (Figure 1).

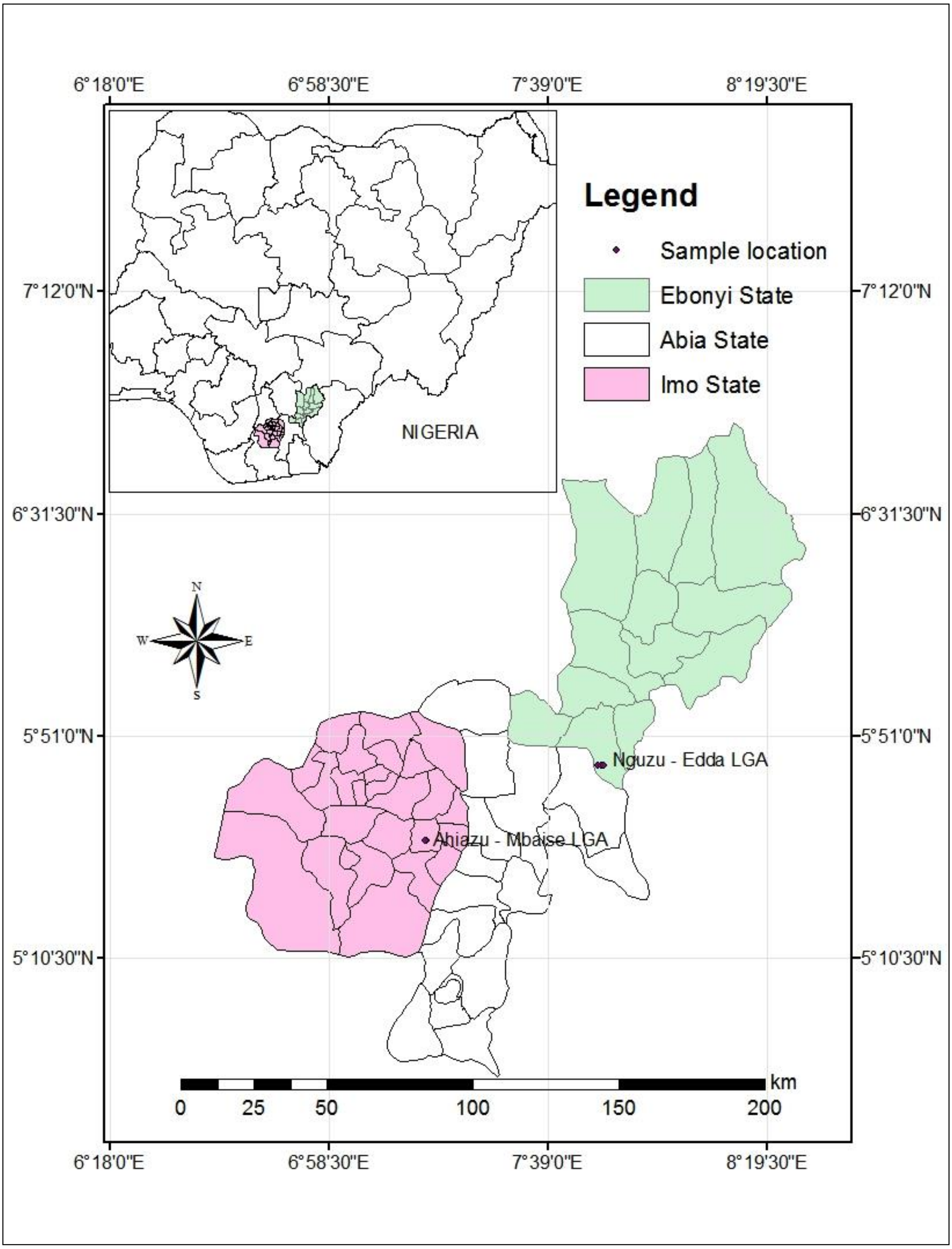

Fig. 1: Map of the study areas showing sample locations

2.3 Soil analysis

The disturbed soil samples collected were air-dried under laboratory conditions and sieved through a-2 mm wire mesh sieve. The fine earth fractions (< 2 mm) were subjected to routine soil analyses using standard procedures described by Udo *et al*., (2009). Particle size distribution was determined by Bouyocous method using sodium hexametaphosphate as dispersant and selenium tablets as catalysts (Gee and Or 2002).

Undisturbed soil core samples were oven-dried at 105ºC to a constant weight and bulk density was calculated using the formulae: $bd = m \div v$ …………… 1

Where: bd = bulk density (gcm^{-3}), m = mass of oven dry soil (g), v = volume of core sampler {$v = \pi r^2 h$} {where r and h are radius (m^2) and height (m) of the core sampler}.

Soil pH was measured potentiometrically in a soil: water suspension (ratio 1:2.5) using a glass electrode pH meter (Thomas, 1996). Organic carbon was determined (from the soil passed through 0.5 mm sieves) by the dichromate wet oxidation method (Udo, *et al*., 2006). Total nitrogen was determined on soil (through 0.5 mm sieve) by the regular mico-Kjeldahl method described by Bremner (1996). Available phosphorus was extracted with Bray number II solution of HF and HCl and the P in the extract was determined spectrophotometrically. The cation exchange capacity (CEC) was determined by the summation method (buffered at pH 8.2) in which all exchangeable cations including exchange acidity (Al^{3+} and H^+). The exchangeable bases were extracted by saturating the soil with neutral 1N KCl. Ca^{2-}, Mg^{2+}, Na^+ and K^+ displaced by $NH4^+$ were measured by Atomic Absorption Spectrometer (AAS) (Udo, *et al*., 2006). Exchangeable acidity was extracted with 1N KCl and estimated in the extract by titration (Udo, *et al*., 2006). The cation exchange capacity was determined titrimetrically using Ammonium acetate (IN NH_4OA_C) method. (Jackson 1958). Base saturation was obtained by expressing the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, and K^+) as percentages of the effective cation exchange capacity:

$$\% BS = \frac{TEB}{ECEC} \times 100 \ldots\ldots\ldots\ldots\ldots 3$$

2.4. Soil classification

Based on the morphological, physical and chemical properties obtained, the soils were classified following the USDA Soil Taxonomy System (Soil Survey Staff, 2014) and were correlated with World Reference Base for soil resources (WRB, 2014).

3.0 RESULTS AND DISCUSSION

3.1 Morphological characteristics

Under moist conditions, the soils of coastal plain sands mapping unit (CP/A, B and C) had very dark reddish brown (2.5YR2/3 to brownish black (7.5YR2/3) surface soils over reddish brown (2.5YR4/6) sub surface colour (Table 1). Soils of CP/C were characterized with few fine faint to few medium distinct (2.5YR5/6) bright brown mottles. The brownish black colour of the top soils could signify high organic matter accumulation at the top soil thereby conferring high fertility of the soils (Essoka 2014). While Soils of sandstone mapping unit (SS/A, B and C) had dark gray (5YR4/1) to light gray (5YR4/8) surface colours over reddish yellow (5YR6/8) to Pinkish gray (7.5YR5/6) sub surface colours. The reddish colours indicated that the soils are highly weathered. The drainage condition, parent material and physiographic position may have influenced the soil colour matrix of the mapping units studied, the effect of colour variation also further agrees with the findings of (Esu *et al.*,2008; Oti and Mbe, 2020), indicating evidence of gleization. This mottling might be due to the oxidation and reduction of iron and or manganese coupled with their removal and translocation in the soil unit. This observation agrees with the findings of Nsor *et al.*, (2016) who also encountered similar mottles in his studies in wetland soils of Umuecheala Ngwa, South East Nigeria. The structure of the soils in coastal plain soil mapping unit had weak fine granular structure occurring over moderate medium sub angular blocky structure at the sub surface soils while sandstone parent material had moderate fine granular structure occurring over moderate medium sub angular blocky structure. Nwaoba and Adesemuyi (2020) also encountered similar structures in their suitability studies of coastal plain soils of Ndegwu Owerri area of Imo state, South Eastern Nigeria. The consistence (moist) of coastal plain sand soils units indicated very friable surface soils over firm to very firm sub surface soils while soils of sandstone parent materials indicated a loose to friable surface soils over firm sub surface soils. Nsor *et al*., (2016) encountered similar morphological characteristics in coastal plain soils on a toposequence around Ohiya Autonomous community, south Eastern Nigeria. Oti and Mbe (2020) encountered similar characteristics in their study of Characterization and Management of soils of Amangwu – Edda, Ebonyi State for sustainable rice production. The texture of the soils of coastal plain sand parent material indicated a sand loam to sandy clay loam surface texture and sandy clay to clay sub surface texture while sandstones parent material had sandy loam surface textures and sandy clay to sandy clay loam subsurface textures. The soils were well drained to poorly drained coastal plain sand parent material as ground water was encountered at depth of 94cm (CP/C). The soils of sandstone parent materials were deep (148cm and 112cm, respectively) to moderately deep as concretions were encountered at the depth of 98cm (SS/C). Nwaoba and Lekwa (2016) also encountered deep and well drained soils in coastal plain soils in South-east Nigeria. The horizon boundary in all the pedons in both parent materials studied indicated clear, wavy horizons over gradual wavy sub soil horizons.

Table 1: Morphological properties of the soil units

Profile	Horizon	Depth	Colour (moist)	Mottles	Concretion	Texture	Structure	Consistence	Boundary
CP 1	Ap	0-18	7.5YR 2/2	Absent	Absent	SL	1fg	fr	cw
	AB	18-45	5YR 4/8	Absent	Absent	SL	2mg	fr	gw
	Bt1	45-98	2.5YR 4/6	Absent	Absent	SC	2msbk	fm	gw
	Bt2	98-112	2.5YR 4/8	Absent	Absent	SC	2msbk	fm	
2	Ap	0-24	2.5YR 2/3	Absent	Absent	SL	1fg	vfr	gw
	AB	24-75	2.5YR 4/6	Absent	Absent	SCL	1mg	fr	gw
	Bt	75-112	2.5YR 4/6	Absent	Absent	CL	2fsbk	fm	gw
	BC	112-158	2.5YR 5/8	Absent	Absent	SC	2msbk	fm	
3	Ap	0-20	2.5YR 2/3	Absent	Absent	SCL	2msbk	Vfr	cw
	AB	20-38	2.5YR 3/3	Absent	Absent	CL	1mg	fr	gw
	Bg1	38-77	2.5YR 3/6	bright brown	Absent	C	2msbk	fm	gw
	Bg2	77-94	2.5YR 4/4	bright brown	Absent	C	3msbk	vf	
SS 1	Ap	0-18	5YR 4/1	Absent	Absent	SL	fr	fr	cw
	AB	18-49	2.5YR 7/2	Absent	Absent	SL	fr	fr	
	Bt	49-98	2.5 YR 5/8	Absent	Absent	SCL	Vfr	fm	gw
	BC	98-102	5 YR 6/8	Absent	Absent	SC	fm	fm	
2	Ap	0-31	2.5YR 3/2	Absent	Absent	SL	vfr	vfr	gw
	B	31-73	7.5YR 5/3	Absent	Absent	SL	fr	fr	gw
	Bt	73-112	7.5YR 5/6	Absent	Absent	SCL	fm	fm	
3	Ap	0-21	10YR 2/2	Absent	Absent	SL	vfr	fr	cw
	Btc	21-58	2.5YR 4/2	Absent	few	SL	fr	fr	gw
	BC	58-98	5YR 5/3	Absent	Abundant	SL	m	fr	

Key: Texture: LS= loamy sandy, SL= sandy loam, SC= sandy clay, SCL sandy clay loam, CL= clay loam, C= clay ***Consistence***: vfr= very friable, fr= friable, fm= firm, vf= very firm, ***Structure***: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, g= granular, sbk= sub angular blocky, msbk= medium sub angular blocky, ***Boundary***: c= clear, w=wavy, g=gradual

3.2 Physical Characteristics

The sand content was observed to dominate silt and clay contents in both parent materials (Table 2). Clay contents generally increased down the profile suggesting clay illuviation while sand content decreased down the profile. This could be due to their coastal plain sand and sandstone parent materials as reported by Lekwa, 2002. The bulk density values ranged from 1.48gcm^{-3} to 1.70 gcm^{-3} and 1.61 gcm^{-3} to 1.81 gcm^{-3} for surface and sub-surface soils of coastal plain sand parent material while the sandstone parent material ranged from 1.31gcm^{-3} to 1.61 gcm^{-3} for surface and 1.64 gcm^{-3} to 1.94 gcm^{-3} for sub-surface soils. These values of the coastal plain sand parent material were lower than the critical value for root penetration (1.75 – 1.80 gcm^{-3}) (Soil Survey Staff, 2003). Least bulk density values were recorded in the surface horizons with corresponding high organic matter revealing the influence of organic matter on soil compaction. The low bulk density showed that the soils were not compacted (Lekwa, 2002). For sandstone parent material, the subsurface soils have values that were above the critical value for root penetration contrary to the values for the surface soils, this could be attributed to soil compaction at the root zone primarily from topographic effect (Oti and Mbe, 2020).

The total porosity was high to very high for all the soil units (Coastal plain sands and sanstone parent materials). This is consistent with the findings of Ojanuga *et al.* (2003) who studied wetland soils of Nigeria. With the total porosity of about 50 %, the loamy and sandy loam soils may have high moisture retention for crop plants. Total porosity showed that there is no risk of compaction on the soils since the total porosity from 0-40 cm is greater than 40 %. According to Harod (1975) when total porosity is less than 40 %, it shows excess strength indicative of likely risk of compaction and poor aeration.

Table 2: Physical properties of the study area

Profile	Horizon	Depth(cm)	Clay (%)	Silt (%)	Sand (%)	Textural class	Bulk Density (gcm^{-3})	Total porosity (%)
			COASTAL PLAIN SANDS					
CP 1	Ap	0-18	13	13	74	SL	1.57	59
	AB	18-45	21	16	63	SL	1.61	39
	Bt1	45-98	29	11	48	SC	1.70	36
	Bt2	98-102	41	20	51	SC	1.74	32
2	Ap	0-24	16	22	62	SL	1.48	43
	AB	24-75	38	19	43	SLC	1.67	38
	Bt	75-112	45	20	35	CL	1.72	31
	BC	112-158	46	20	34	SCL	1.81	29
3	Ap	0-20	36	06	60	SCL	1.69	34
	AB1	20-38	49	05	46	CL	1.70	33
	Bg1	38-77	59	08	33	C	1.75	31
	Bg2	77-94	58	11	31	C	1.79	30
			SAND STONE					
SS 1	Ap	0-18	10.8	16.4	72.8	SL	1.31	49
	Bt1	18-49	14.8	14.4	70.8	SL	1.64	38
	Bt2	49-98	24.8	15.4	59.8	SCL	1.91	25
	BtC	98-142	42.8	5.4	51.8	SC	1.94	64
2	Ap	0-24	11.8	12.4	75.8	SL	1.64	38
	B	24-75	13.8	9.4	76.8	SL	1.69	34
	Bt	75-112	28.8	7.4	63.8	SCL	1.91	25
3	Ap	0-21	12.8	11.4	75.8	SL	1.61	39
	Btc	21-58	18.8	9.4	71.8	SL	1.64	38
	BC	58-98	14.8	9.4	75.8	SL	1.74	33

Key: C: Clay; SC: Sandy clay; CL: Clay loam; LS: Loamy Sand; SL: Sandy Loam; SCL: Sandy Clay Loam

3.3 Chemical Characteristics

The soil pH averaged 5.0 in the coastal plain sand parent material. These values were rated strongly acid while in sandstone parent material the pH averaged 5.6. These values were rated moderately acidic. The acidic nature of the soils generally may be due to high intensity of rainfall in the area. Enwezor *et al.,* (1989) stated that leaching of Ca and Mg is responsible for development of acidity. The values of total Nitrogen for coastal plain sand parent material was rated high averaging 2.10 gkg^{-1} (Enwezor *et al.,* 1989) whereas sandstone parent material was rated low averaging 0.70 gkg^{-1} This could be attributed to the high intensity of agricultural activities such as continuous cultivation of field and rapid turnover (mineralization) of organic substrates derived from crop residue (Nsor and Okonkwo, 2014). The organic carbon content generally decreased with depth, high in epipedons and low for the subsoils of both parent materials based on organic carbon rating of the Southeastern Nigerian soils by Enwezor *et al*. (1989). This is evidence of organic material incorporation into the soils. The low values of organic carbon in the subsoils would encourage a rapid leaching of cations into the subsoils from the surface. Thus, the soils are low in CEC (averaging 9.32 $cmolkg^{-1}$ for coastal plain soils and 8.12 $cmolkg^{-1}$ for sandstone parent materials). Brady and Weil (1999) pointed out that the cation exchange capacity (CEC) of most soils increases with pH; thus at very low pH values, the CEC is also generally low. The values for available phosphorous were moderately low (8.73 $mgkg^{-1}$) for coastal plain sand parent material and Sandstone parent material (16.55 $mgkg^{-1}$). This observation agreed with Chikezie *et al.,* (2009) who observed that most Nigerian soils are moderately low in phosphorus partly due to the existence of parent rocks low in phosphorus but complicated by high phosphate fixing capacity of the soil. Considering the critical value for phosphorus, the soils may require phosphate fertilizer application for a sustainable crop yield. The values for exchangeable cations for coastal plain sand parent materials were very low for Na (0.08 $cmolkg^{-1}$); K (0.18 $cmolkg^{-1}$); Mg (1.25 $cmolkg^{-1}$) and Ca (1.45 $cmolkg^{-1}$). For the, sandstone parent material, the exchangeable cations were very low for Na (0.08 $cmolkg^{-1}$); K was very low to moderate (0.29 $cmolkg^{-1}$); Mg was moderate (1.35 $cmolkg^{-1}$) and Ca was low (4.3 $cmolkg^{-1}$) in all the soil units. The exchangeable acidity of the coastal plain soil units averaged (0.67 $cmolkg^{-1}$) Al^{3-}, (1.42 $cmolkg^{-1}$) H^- while sandstone soil units averaged (1.53$cmolkg^{-1}$) H^- (0.44 $cmolkg^{-1}$) Al^{3-}. These observations are similar to the findings of Nsor *et al.,* (2016) around Ohiya community South Eastern Nigeria who attributed low exchangeable bases to high leaching arising from the coarse textured nature of the soil. Base saturation for coastal plain sands parent material was rated low in all the pedons averaging (31.7%). This observation agreed to the findings of Nwaoba and Lekwa, 2016; Chukwu and Ifenkwe, 2012 and Nsor *et al.*, 2016 that low base saturation of south eastern soils could be as a result of absence of soluble forms of basic cations in the soil reaction. On the contrary, base saturation averaged 80.2% for sand stone parent material which is rated very high (Enwezor *et al*., 1989). The high base status showed that the soils had high native fertility, which is confirmed by the luxuriant growth of the vegetation of the soil. This agreed with the findings of Igomu and Idoga, (2017) and Oti and Mbe, (2020).

Table 3: Chemical properties of the soil

Profile	Horizon	Depth	pH	H^+	Al^{3+}	OC	TN	Ca^{+2}	Mg^{+2}	K^+	Na^+	CEC	BS	Av. P
		(cm)	H_2O	$cmolkg^{-1}$		g/kg	gkg^{-1}			$cmolkg^{-1}$			%	$mgkg^{-1}$
CP 1	Ap	0-18	5.40	1.60	0.85	4.50	1.90	1.50	1.00	0.15	0.11	9.30	29.70	8.80
	AB	18-45	4.60	1.75	0.99	2.60	1.60	1.10	0.90	0.11	0.07	7.50	29.10	7.24
	Bt1	45-98	4.50	0.62	1.05	2.10	0.80	1.60	2.00	0.25	0.06	11.40	34.30	6.12
	Bt2	98-102	4.70	1.70	0.95	2.30	1.30	1.00	1.20	0.19	0.05	8.10	30.10	6.44
2	Ap	0-24	5.50	1.40	0.65	10.2	3.10	1.30	1.00	0.14	0.08	7.50	33.60	6.65
	AB	24-75	5.10	1.35	0.70	6.50	2.15	1.10	0.70	0.10	0.05	6.50	30.00	6.11
	Bt	75-112	4.90	1.50	0.50	6.00	1.00	0.90	0.90	0.16	0.06	8.00	25.30	7.50
	BC	112-158	4.90	1.80	1.00	3.40	1.20	1.50	1.20	0. 20	0.06	8.50	34.80	4.61
3	AP	0-20	5.60	1.65	0.40	14.2	3.30	2.00	1.80	0.25	0.26	11.00	39.20	10.5
	AB	29-38	5.40	1.30	0.25	12.0	2.10	1.70	0.80	0.18	0.20	13.00	22.20	11.8
	Bg1	38-77	5.20	1.30	0.45	9.00	0.60	1.80	1.20	0.14	0.30	10.50	32.80	13.7
	Bg2	77-98	5.10	1.35	0.40	5.10	0.30	1.80	1.50	0.11	0.30	10.50	32.80	15.3
SS 1	Ap	0-18	5.80	1.38	0.42	18.40	1.60	5.00	2.00	0.40	0.33	9.12	84.86	20.50
	AB	18-49	5.90	1.30	0.31	16.90	1.30	5.30	1.80	0.38	0.29	9.07	85.66	17.80
	Bt1	49-98	5.80	1.72	0.64	5.90	0.50	4.00	0.80	0.20	0.16	6.88	75.00	14.20
	Bt2	98-142	5.50	1.78	0.66	2.40	0.20	3.60	0.60	0.11	0.08	6.17	71.15	12.60
2	Ap	0-24	6.40	0.92	0.24	15.30	1.50	5.50	1.80	0.42	0.35	8.99	89.76	19.80
	B	24-75	5.60	1.86	0.48	4.00	0.60	4.60	1.20	0.39	0.26	8.31	77.61	15.60
	Bt	73-112	5.70	1.86	0.46	1.20	0.10	4.00	0.60	0.19	0.10	6.75	72.44	11.00
3	AP	0-21	6.20	1.04	0.38	13.00	1.40	5.80	2.10	0.42	0.33	9.68	89.25	21.40
	Btc	21-58	5.80	1.76	0.44	6.70	0.60	5.10	1.20	0.37	0.25	8.69	79.73	18.70
	BC	58-98	5.30	1.88	0.46	5.10	0.20	4.30	0.80	0.16	0.11	7.25	74.04	13.90

Key: Av.P= Available Phosphorus, K= Potassium, Na= Sodium, M= Magnesium, Ca= Calcium, CEC= Cation Exchange Capacity, H^+= Hydrogen ion, Al^{3+}= Aluminium ion, EA= Exchangeable acidity, Al.Sat=Aluminium saturation N=Nitrogen, OM= Organic Matter, BS= Base Saturation.

3.4 Taxonomic classification of the soil units

For Coastal plain sand parent material, Soil unit CP/A was classified as Ultisol (Table 4) because of the argillic or kandic B horizon with low base saturation (less than 35%). It was placed on the suborder-Udults because within the soil moisture control section (20-60cm depth), the soils are not dry within 90 cumulative days (soil survey staff, 2013). Thus, they have Udic moisture regime. It also met the requirement of the great group Paleudults because it does not have densic or lithic contact within 150cm of the mineral soil surface and with increasing depth, it does not have a clay decrease of 20% or more from the maximum clay content. It was further classified as Typic Paleudult because it does not meet up with the requirements of other Paleudults. The world reference Base (WRB) correlation of the soil unit is Haplic Acrisol. Soil unit CP/B was classified as ultisol because of argillic horizon with base saturation less than 35%. It was also placed on the suborder-Udults because they have udic moisture regime. It was classified as Paleudults at the great group because it does not have a clay decrease of 20% or more from the maximum clay content. It was further classified as Rhodic Paleudults at the sub group because the upper 75cm of the argillic hroizon has a hue of 2.5YR, redder and a moist value of 3. The world Reference Base for soil resources (WRB) equivalent is Rhodic Acrisol. The soils of soil unit CP/C have base saturation less than 35% and possessed kandic and argillic subsurface diagnostic horizons, hence they are placed under the Ultisol soil order (soil survey staff, 2013). Their occurrences under udic soil moisture regime qualify them as Udults at the sub order level. At the great group level, it was also classified as Palendults because it does not have densic or lithic contact within 150cm of the mineral soil surface and with increasing depth it does not have a clay decrease of 20% or more from the maximum clay content. Soil unit CP/C was further classified as Oxyaquic Pleudults because it is saturated with water in one or more layers within 100cm of the mineral soil surface for 20 or more consecutive days. The world Reference Base for soil Resources (WRB) equivalent is Histic Acrisol. For sandstone parent materials, Soil unit SS/A was classified as Alfisol because of the presence of argillic horizon and the high base saturation (greater than 35%). It was placed on the suborder-Udalfs because within the soil moisture control section (20-60cm depth), the soils are not dry within 90 cumulative days (soil survey staff, 2013). Thus, they have udic moisture regime. It also met the requirement of the great group paleudalfs because it does not have densic or lithic contact within 150cm of the mineral soil surface and with increasing depth, it does not have a clay decrease of 20% or more from the maximum clay content. It was further classified as Typic paleudalf because it does not meet up with the requirements of other paleudalfs. The world reference Base (WRB) correlation of the soil unit is Haplic luvisol. Soil unit SS/B was classified as Alfisol because of argillic horizon with base saturation greater than 35%. It was also placed on the suborder-Udalfs because they have udic moisture regime. It was classified as Paleudalf at the great group because it does not have a clay decrease of 20% or more from the maximum clay content. It was further classified as Arenic Paleudalfs at the sub group because of their possession of sandy particle throughout the entire profile. The world Reference Base for soil resources (WRB) equivalent is Arenic luvisol. The soils of soil unit SS/C have base saturation more than 35% and possessed kandic and argillic subsurface diagnostic horizons, hence they are placed under the Alfisol soil order (soil survey staff, 2013). Their occurrences under udic soil moisture regime qualify them as udalfs at the sub order level. At the great group level, it was also classified as Paleudalfs because it does not have densic or lithic contact within 150cm of the mineral soil surface and with increasing depth it does not have a clay decrease of 20% or more from the maximum clay content. Soil unit UG/C was further classified as Arenic Paleudalf also because of their possession of sandy particle throughout the entire profile. The world Reference Base for soil Resources (WRB) equivalent is Arenic luvisol.

Table 4: Taxonomic classification of the soil units

Soil Units	USDA Soil taxonomy	World Reference Base (WRB)
CP/A	Typic Paleudult	Haplic Acrisol
CP/B	Rhodic Paleudult	Rhodic Acrisol
CP/C	Oxyaquic Paleudult	Histic Acrisol
SS/A	Typic Paleudalf	Haplic Luvisol
SS/B	Arenic paleudalf	Arenic Luvisol
SS/C	Arenic Paleudalf	Arenic Luvisol

CONCLUSION AND RECOMMENDATION

Results of the soils of coastal plain sand parent material and sandstone parent material of Ahiazu-Mbaise and Nguzu-Edda respectively studied showed that the soil reaction (pH) was strongly acidic (pH 5.0) for Coastal plain soils and moderately acidic (pH 5.6) for Sandstone parent material. Available phosphorus content, Exchangeable cations, Exchangeable acidity, Organic carbon, Cation Exchange Capacity (CEC) were generally low for both parent materials while Base saturation was high for Sandstone, low for Coastal plain sand parent materials and Total nitrogen was high for soils derived from coastal plain sands and moderate for sandstone. Liming can reduce the acidity of the soils, use of organic and inorganic manure and adoption of appropriate management practices like avoidance of bush burning and practicing crop rotation can also help to improve the soil nutrients in the study areas.

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