Characterization and classification of soils developed on coastal plain sands in Oruk-Anam, Akwa Ibom State

Ernest R. Ita, Ene E. Aki, Denis M. Olim, Fidelis V. Aberagi and Idongesit S. Umana
Department of Soil Science, Faculty of Agriculture, University of Calabar, Calabar
Corresponding Author's email: olimdenis001@gmail.com

Abstract

Soil characterization is critical in optimizing cocoa production, especially in Sub-Saharan Africa where growers are faced with low and fluctuating cocoa yields due to several challenges, prominent among which is soil nutrient management. This study characterized and classified soils formed from coastal plan sands for cocoa production in Oruk-Anam LGA, Akwa Ibom State. Using free soil survey method, the study area was delineated and four soil profile pits were dug. Soil samples were collected from diagnostic horizons, labeled and analyzed for physical and chemical properties. Findings revealed very dark gray (10YR 3/2) surface to dark brown (10YR 3/3) and yellowish brown (10YR 5/4) sub surface horizons. Surface texture ranged between loamy sand and sandy loam over sandy loam and sandy clay loam subsurface soils. Both the surface and subsurface soils showed low pH in water (4.95-4.98), indicating high acidity. Furthermore, total nitrogen was low, while available P was moderate. The results also indicated that all the exchangeable cations were all low. The clay minerals identified were quartz (85.2 %), kaolinite (13.6 %), anatase (0.3 %), magnetite (0.4 %) and goethite (0.4 %). The soils were classified as Ultisols and correlated with FAO-WRB as Acrisols. Liming, application of crop residues, the use of organic and organo-mineral fertilizers, biochar application could enhance proper soil management and aid in the removal of the current limitations.

Keywords: Characterization, classification, coastal plain sands

Introduction

Coastal plain sands soils otherwise known as acid sands soils are the predominant soils in Southern Nigeria. In Akwa Ibom State, the soils occupy 55 % of the land mass (Obi *et al*., 2020), and have been minimally used for crop production. The soils are inherently low in fertility and highly susceptible to degradation under poor management conditions. Soils formed from coastal plain sands parent material are highly leached, low in weatherable minerals, cation exchange capacity, organic matter, base saturation (Obi *et al*., 2020), dominantly sandy (Lekwa and Whiteside, 1986). Due to their sandy and porous nature, they are frequently leached (Enwezor *et al*., 1990) and easily lost to soil erosion (Udo *et al*., 2013).

The soils of coastal plain sands occupy large land area in Akwa Ibom State but are not intensively used for crop production due to their poor nutrient status. This situation coupled with poor soil management and land use options by farmers seem to threaten the economic fortunes and food system of the State. Reversing this current situation requires soil characterization which is prerequisite for effective soil management and utilization. It has been demonstrated that every 1% increase in agricultural yield translates into a 0.6–1.2% decrease in the numbers of absolute poor households in the world (Thirstle *et al*., 2001).

Soil characterization is the process of determining soil physical, chemical, biological and morphological properties. It ensures that soil is put to the most appropriate and sustainable use (Onyekanne *et al*., 2012). According to Esu (2004), it provides a powerful resource for the benefit of mankind especially in the area of environmental sustainability and food security. Characterizing soils is very critical for agricultural crop production especially cocoa since it identifies the level of deficits or surpluses of critical nutrient required for cocoa growth and yield that may constitute a constraint that requires site-specific restorative interventions (Wessel and Quist-Wessel, 2015). It helps to identify areas at risks of soil erosion and nutrients losses through leaching and runoff, and potential land uses, enabling informed decision-making for sustainable soil management (Sparks, 2003).By understanding soil properties, farmers can optimize crop selection, fertilizer application, and irrigation management, leading to improved crop yields and productivity (Carter and Gregorich, 2007).

When planning for establishment of agricultural plantation crop such as cocoa, soil characterization and classification can serve as insurance against poor yield. It has been reported by Kongor *et al*. (2017) and Liet *et al*. (2015) that soil nutrient constrain is the major factor responsible for poor cocoa yield or yield inconsistency. Using land without characterization to know its potentials for crop production has serious consequences on land use and constitutes a setback for achieving maximum yield to guarantee food security in countries with fast growing population like Nigeria (Oko-Oboh *et al*., 2016).

Despite huge occupation of landmass of Akwa Ibom State by coastal plain sands soils, to the best of our knowledge the soils have not been characterized to evaluate their potentials for cocoa production. This study was therefore designed to characterize and classify the soils developed on coastal plain sands for cocoa production in Oruk-Anam Local Government Area (LGA) of Akwa Ibom State, Nigeria. We hope that the outcome of this study will provide useful information on the limitations and potentials of coastal plain sands soils in Oruk-Anam LGA of Akwa Ibom State to guide in making useful recommendations to farmers on appropriate soil management techniques that should be adopted for increased cocoa production. The findings of this study will also be beneficial not only to farmers in the state who have interest in cocoa production but to farmers of other crops considering the wide coverage of coastal plain sands soils in the landscape of Akwa Ibom state.

Materials and Methods

Description of the study area

The study was conducted in four communities: Ikot Eka Ide, (4° 57' 22.7"N; 7° 44' 53.2E), Eka Nung Ikot (4° 56' 44.0"; 7° 45' 4.2E), Nung Ikot (4° 57' 45.1" N; 7° 45' 54.6"E), Ikot Udo Idem (4° 58' 35.1"N; 7° 45' 24.8E) in Oruk-Anam LGA, Akwa Ibom State (Fig.1). Based on Physiography, the landscape comprises low-lying plains and riverine areas with almost no portion exceeding 175 meters above sea level. The area has humid tropical climate, characterized by two seasons; the rainy and dry seasons. The mean annual rainfall ranges from 2200 – 4700mm, while mean annual temperature ranges of 27°C - 29°C and relative humidity ranged between 80-86 %. There is a period marked by 'little dry season' and occurring for about 2-4 weeks in August is referred to as August Break. This gives room to rainfall double maxima in June/July for the first maximum, and September for the second maximum.

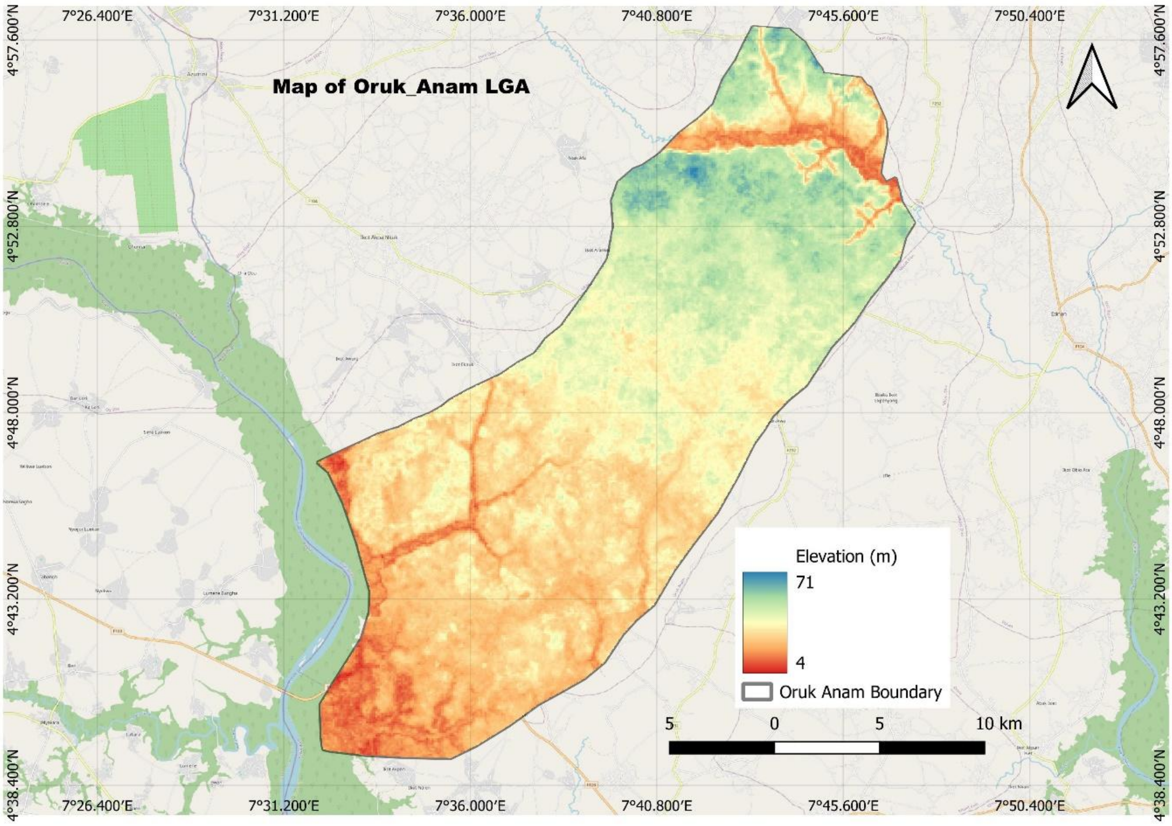

Fig. 1: Map of Akwa Ibom state showing the study area

Field Studies

Reconnaissance visit was made to the selected communities across Oruk Anam Local Government Area to sensitize the local stakeholders about the intended study. Free survey method (judgment sampling) was used to site the soil profile pits. One soil profile pit was sunk in each community making a total of four (4) profile pits for the study. The coordinates of each profile pits were recorded with the aid of the Global Positioning System (GPS). Environmental characteristics such as local relief, slope, drainage and morphological properties were described in the field and documented using the soil description sheet and field note book. A total of 16 soil samples were collected from delineated pedogenic horizons of the profiles from bottom to top order (to avoid contamination of samples by soils of the overlying horizons) to into properly labeled poly bags and conveyed to the laboratory. Soil samples for bulk density determination were collected by driving core cylinder rings of known volume into the soil based on the identified horizons in each profile in accordance with the procedures as outlined by Soil Survey Staff (2014).

Laboratory Analysis

Soil samples collected from profile pits were air-dried under laboratory conditions, and sieved through a 2-mm sieve. Fine-earth (< 2mm) separates were subjected to laboratory analyses. Particle size fractions were determined by mechanical analysis technique of Bouyocous (Gee and Or, 2002) using sodium hexa-metaphosphate as a dispersant. Soil pH was measured potentiometrically in a soil: water suspension (mixed at a ratio of 1:2.5 soil: water) using glass electrode pH meter following procedure described by Udo *et al*. (2009). Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black as outline in Nelson and Sommers (1996). Total nitrogen was determined by micro-Kjeldahl digestion method; available phosphorus (P) was extracted by Bray-1 method suitable for acid soils and the colour was developed in soil extract using ascorbic acid blue method (Kuo, 1996); exchangeable bases (Ca^+, Mg^+, Na^+, and K^+) were extracted by saturating soil with neutral 1*M* NH_4OAc (Thomas, 1982) and Ca and Mg in the extract was determined using atomic absorption spectrophotometer (AAS) while K and Na were determined by flame photometry; exchangeable acidity was determined by extracting the soil with 0.1*N* KCl solution and titrating the aliquot of the extract with 1*N* NaOH following the procedure outline by Udo *et al.* (2009). Cation exchange capacity (CEC) was determined by saturating the soil with normal neutral ammonium acetate solution. Base saturation was calculated as the sum of total exchangeable bases divided by NH4OAc cation exchange capacity and expressed as a percentage. For mineralogy of the soil, the soil samples were split, milled, scanned and prepared for XRD analysis using backloading preparation method. Ten percent internal standard (fluorite) was added and the samples micronized. The micronized material was analyzed with XRD utilizing a Malvern PANalytical Aeris Diffractometer with Pixcel detector and fixed slits with Fe filtered Co-Ka radiation. The phases were identified using X'Pert Highscore plus software. The XRD analysis was used to determine the crystalline mineral phases present in the sample. The abundance of each mineral phase (weight %) was determined by the Refinement method.

Results and Discussion

Morphological and physical properties of the studied soils

In Oruk-Anam, all the studied soils had the horizons sequence Ap-Bt1-Bt2 CB (Table 1). These horizon sequences are indicative of active movement of fine clay particles in suspension, away from the transition AB, BA, or BC horizons (eluviation) and accumulation in the Bt or Crt horizons in the process of argillation.

The accumulation of clay (argillation) covering horizon thickness of over 75 cm in almost all the studied soils and extending to the Crt horizons is an indication of intense weathering and prolonged pedogenesis in the coastal plain soils of Akwa Ibom State. In a related study in Abia state and southeast Nigeria, Nuga and Akinbola (2011) and Adesemuyi and Adekayode (2019) observed Ap-AB-Bt-BC horizon sequence without a C-horizon, whereas Akpan-Idiok and Ukwang (2012) and Akpan *et al*., (2017) reported clear Ap-Bt-C horizon sequence in the coastal plain soils of Calabar. These findings appear slightly different from the presentations in the current study and suggest differences in soil properties despite similarities in lithological properties. Such slight differences may be explained by differences in periods of deposition of coastal plain sands.

The surface soils of Oruk-Anam were characterized by very dark gray (10YR 3/2) to dark grayish brown (10YR 3/2) and very dark grayish brown (10YR 3/2), while the subsurface soils, were portrayed by dark brown (10YR 3/3) and yellowish Brown (10YR 5/4) to strong brown (7.5YR 4/6, 5/8) (Table 1). The surface soils had sandy loam and loamy sand textures while the subsurface soils varied from sandy loam to sandy clay loam in textures. The generally high values of the sand separate at all sampling locations reflect the coastal plain sands parent material of the soils (Ibia *et al.*,2009). Soils that are high in sand contents are prone to leaching and so are often impoverished and low in inherent soil fertility since sand has a small surface area for the adsorption and retention of exchangeable cations. Soils high in sand content often warm up easily and as such low in organic matter content because of rapid rate of organic matter mineralization at high temperature. Furthermore, soils high in sand content are often low in organic carbon due to their inability to protect organic matter from rapid decomposition compared to soils high in clay. Hence, such sand dominated soils as in the current study should be amended with organic materials like poultry droppings and compost. Akpan-Idiok and Ukwang (2012) reported values of sand above 70 % in the Calabar coastal plain soils, while high sand content was recorded in Abia state coastal plain soils with values decreasing from 88.00 % in the top-soil to 60.00 % in the sub-soil (Adesemuyi and Adekayode, 2019) and Akpan *et al*. (2017) obtained values that exceeded 70 % in the coastal plain soils of Calabar.

In the surface of the entire studied soils, soil structure ranged from weak medium granular and subangular blocky structures to moderate, fine, medium and coarse subangular blocky structures in the subsurface soils. However, occurrence of strong structural grade in the Cr (110-169 cm) horizon of Ikot Eka Ide was observed. This variation may have been caused by differences in organic matter content and stage of development between these soils. Soil consistence followed the trend of soil texture and structure closely as sand dominated soils are non-sticky (wet) and non-plastic (moist) in the surface soils. The subsurface soils that seem to have an accumulation of clay which ultimately bind coarse particles together were sticky to very sticky (wet) and friable to firm (moist). Friable soil consistence implies high permeability of water.

Particle size distribution and bulk density of the studied soil

The results of particle size distribution and bulk density of coastal plain sands soils in Oruk Anam are presented in Table 2. The results show that sand content ranged from 753 - 813 in the surface to 483 - 743 mgm^{-3}in the subsurface soils, with means of 783 and 602 mgm^{-3} respectively, while silt content with ranges of 80-130 and 50-220 mgm^{-3} in the surface and subsurface soils respectively. Meanwhile clay values were 112 and 262 mgm^{-3} and 97-127 and 187-347 mgm^{-3}as the means and ranges for the surface and subsurface soils, respectively. Furthermore, bulk density was low and ranged from 1.39 to 1.55 mgm^{-3}.

Chemical properties of the studied soil

The chemical properties of coastal plain sands soils of Oruk Anam LGA of Akwa Ibom State are given in Table 3. From the Table, it is seen that the soil pH (H_2O) values ranged from 4.7-5.1 and 4.7-5.2 for surface and subsurface soil with a mean of 4.95 in the surface soils 4.98 in the subsurface soils. Furthermore, for SOC, it ranged from 0.1 - 0.96 and 0.06-0.4 % in the surface and subsurface soils, with respective means of 0.50 and 0.24 %. However, TN ranged of 0.01 – 0.08 and mean of 0.04% were obtained in the surface soils and range of 0.01-0.03 and mean of 0.02% were obtained in the subsurface soils. For available phosphorus, it ranged from 3.2-26.2 mg/kg and 2.6 – 43.6 for the surface and subsurface soils, with a mean of 10.4 and 11.7mg/kg. Exchangeable Ca ranged from 0.8 – 2.4 and 1.0-2.8 cmol/kg for surface and subsurface soils with both maintaining a mean of 1.75 cmol/kg. These were all in line with investigation by Afu *et al.*(2024).Exchangeable Mg ranged from 0.4-1.0 with a mean of 0.75 $cmolkg^{-1}$ for surface soil and 0.2-1.0 $cmolkg^{-1}$ with mean of 0.585 $cmolkg^{-1}$ for subsurface soil. Mean exchangeable K was 0.08 and 0.09 $cmolkg^{-1}$ for surface and subsurface soils. Exchangeable Na ranged from 0.06-0.08 and 0.06 – 0.09 $cmolkg^{-1}$ in the surface and subsurface soils. Exchangeable acidity (Al^{3+})value obtained ranged from 0.00-0.88 and 0.4-1.12 $cmolkg^{-1}$ for surface and subsurface soil, while for exchangeable (H^+) it ranged from 0.96-2.0 and 0.44-2.64 $cmolkg^{-1}$ for surface are subsurface soil respectively. Values of CEC ranged from 12-16 $cmolkg^{-1}$ with mean of 14.2 $cmolkg^{-1}$ for surface soils while it ranged from 8-22.0 $cmolkg^{-1}$ with mean of 12.83 $cmolkg^{-1}$ for subsurface soil. The mean base saturation (NH_4OAc) was 19 and 21% for surface and subsurface soil and ranged from 10 – 24% and 9-36 % for surface and subsurface soils, respectively. The soils of the study area have strongly acidic pH and are rated low in all chemical properties according the rating of soil chemical properties by Landon (1991).

Table 1: Morphological properties of the studied soil

Horizon	Depth (cm)	Munsell colour (moist_)	Tex.	Structure	Consist.	Bound.	Other characteristics
Ikot Eka Ide, N04º 57' 22.7"; E007º 44' 53.2", 65m					Wet Moist		
Ap	0-18	Very Dark grey (10YR 3/2)	Sl	1mgr	Wnnp	Cs	common medium roots; ant activities
AB	18-52	Dark Brown (10YR3/3)	Sl	2f/m/c sbk	Ssvfr	Cs	fine, medium, many, pores, fine, medium roots, ants, worm cast activities observed
BC	52-110	Strong Brown (7.5YR4/6)	Scl	2f/m/c sbk	vs vfi	Cs	few thin at ped faces cutan few, fine roots, common fine pores
Cr	110-169	Strong brown (7.5YR5/8)	Scl	2/3f/msbk	vs vfi		few thin cutan at ped faces, many iron concretions
Eka Nung Ikot, N04º 56' 44.0"; E007º 45' 04.2", 69m							
Ap	0-15	Dark greyish Brown (10YR 3/2)	Ls	1f/mgr	Nsnp	Cs	common medium roots, Iron concretion, animal facal, termite hill, ant activities
AB	15-62	Dark Brown (10YR3/3)	Scl	2f/msbk	ss fi	Cs	fine, medium, many, pores, fine, medium roots, ants, worm cast activities observed
BC	62-100	Yellowish Brown (10YR5/4)	Scl	2m/c sbk	ss vfi	Cs	few thin at ped faces cutan few, fine roots, common fine pores; ant, worm cast observed
Cr	100-177	Yellowish brown (10YR5/8)	Scl	2f/m/c sbk	Vsvfi		few thin cutan at ped faces, many iron concretions
Nung Ikot, N04º 57' 45.1"; E007º 45' 54.6", 54m							
Ap	0-18	Very Dark greyish brown (10YR 3/2)	Ls	1mgr	ns np	Cs	common medium roots, Iron concretion, animal feacal, ant inclusion
AB	18-49	Dark Brown (7.5YR3/2)	Sl	2m/f/c sbk	ss fi	Cs	medium, many, pores, fine, medium roots, ants, worm cast activities observed
BC	49-95	Strong brown (7.5YR4/6)	Scl	2m/c sbk	s fr/fi	Cs	few thin at ped faces cutan few, fine roots, common fine pores
Ct	95-172	Strong brown (7.5YR5/8)	Sl	2m/c sbk	vs fr		few thin cutan at ped faces, many iron concretions
Ikot Udo Idem, N04º 58' 35.1"; E007º 45' 24.8", 54m							
Ap	0-17	Very Dark greyish brown (10YR 3/2)	Sl	1mgr	Nsnp	Cs	common medium roots
BC	17-58	Dark Brown (7.5YR3/4)	Scl	2m/f/c sbk	s fi	Cs	medium, many, pores, fine, medium roots, ants, worm cast activities observed
Bt	58-99	Yellowish red (5YR4/6)	Scl	2m/c sbk	s fr/fi	Cs	few thin at ped faces cutan few, fine roots, common fine pores; ant, worm cast observed
Ct	99-170	Yellowish red (5YR5/8)	Scl	2m/c sbk	vs vfi		few thin cutan at ped faces

Key: Text. = texture, l = loam, s = sand, c = clay ls=loamy sand, scl = sandy clay loam, sl = sandy loam; struc.= structure: 1,2 = weak, moderate, m, c = medium, coarse; gr, cr, sbk = granular, crumby and sub-angular blocky structure; consist.= consistence: ss = slightly sticky, fr = friable, fi = firm, v = very; bound.= boundary: cs = clear smooth, ASL: above sea level

Table 2: Soil physical properties across locations within Oruk Anam LGA

Location/ Horizon	Depth (cm)	Clay	Silt mgm-3	Sand	Textural Class	Bulk Density (mgm-3)
Eka Nnung Ikot						
Ap	0-15	127	80	793	LS	1.49
AB	15-62	247	110	643	SCL	1.39
BC	62-100	327	50	623	SCL	1.54
Cr	100-177	307	90	603	SCL	1.51
Ikot Eka Ide						
Ap	0-18	107	120	773	SL	1.45
AB	18-52	187	130	683	SL	1.43
BC	52-110	327	140	533	SCL	1.68
Cr	110-169	327	170	503	SCL	1.65
Ikot Udo Idem						
Ap	0-17	117	130	753	SL	1.56
AB	17-58	227	160	613	SCL	1.51
Bt	58-99	347	130	522	SCL	1.56
Ct	99-170	297	220	483	SCL	1.70
Nnung Ikot						
Ap	0-18	97	90	813	LS	1.47
AB	18-49	137	120	743	SL	1.45
BC	49-95	217	140	643	SCL	1.60
Ct	95-172	197	170	633	SL	1.58
Mean surface		112	105	783	SL	1.48
Range surface		97-127	80-130	753-813		1.45-1.56
Mean subsurface		262	135.8	602	SCL	1.55
Range subsurface		187-347	50-220	483-743		1.39-1.70

Mineralogy

The results of mineralogical analysis indicated that the soils of Oruk Anam are dominated by quartz with little percentage of some iron minerals. Figure 2 shows the X-ray diffractogram peaks of the identified clays identified. The clay minerals identified were quartz (85.2 %), kaolinite (13.6 %), anatase (0.3 %), magnetite (0.4 %) and goethite (0.4 %). The dominance of quartz in this study is line with the study of Ita and Esu (2013) who reported quartz range of 61.1 to 89.1 % in coastal plain sand soils of Akwa Ibom State and Jou (1981) who stated that Quartz is the major constituent of coastal plain sand parent material. Theoccurrence of kaolinite as the second dominant and the presence of metallic oxides in the soils may be an indication that the soils of the study are at advance stage of weathering. These observations are in agreement with previous works by Igwe (1991) and Osabor *et al*. (2009) who obtained kaolinite as the dominant mineral in coastal plain sand soils of south eastern Nigeria. Dominance of quartz and low activity clay like kaolinite and metallic oxides has negative implication in soil fertility since these minerals have very low CEC and highly resistance to weathering (Afu *et al.,* 2024).

Soil Classification

The summary of taxonomic classifications of the studied soils by the USDA Soil Taxonomic and World Reference Base for Soil Resources Systems is presented in Table 4. All the studied pedons had argillic horizons and base saturation by NH_4OAc (pH 7) of less than 50% below the upper boundary of the argillic horizon. The entire studied epipedons were either sandy loam or loamy sand textures. The soils show signs of active leaching as exchangeable bases appeared depleted in the soils, and therefore qualify as Ultisols in the soil order category.

The soils have Udic soil moisture regime and qualify as Udults in the suborder category of USDA Soil Taxonomy.

All the pedons have subsurface horizons with significant accumulation of clay that exceed 1.2 when compared with the overlying horizons with the clays being dominated by low activity clays kaolinite and having varying amounts of oxyhydroxides of Fe based on the x-ray diffraction analysis. The subsurface horizons were underlain by coarse loamy sand or sandy loam surface textures and have thicknesses that exceed 18 cm, found between the depths of 100-200 cm with texture finer than loamy very fine sand. Based on the criteria set by Soil Survey Staff (2022), the subsurface horizons qualify as kandic horizons. The soils therefore quality in the great group Kandiudult and Typic Kandiudult in the sub group category of USDA Soil Taxonomy and correlated with FAO-WRB as Acrisols.

Table 3: Chemical properties of the studied soil

Location/ Horizon	Horizon	Depth (cm)	pH			OC	TN	Avail. P	Ca	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	ECEC	CEC	CEC/clay
			H_2O	$CaCl_2$	KCl	%	%	mg/kg	←				cmol/kg			→	
Ikot Eka Ide																	
		0-18	5.00	4.50	4.20	0.10	0.01	8.37	2.40	1.00	0.09	0.08	0.74	2.00	6.31	15.0	125
		18-52	4.70	4.30	4.00	0.40	0.03	4.62	1.00	0.80	0.08	0.06	1.12	2.08	5.14	14.0	44.0
		52-110	4.80	4.40	4.10	0.40	0.03	11.25	1.40	0.60	0.09	0.06	0.56	2.64	5.35	8.00	39.0
		110-169	5.00	4.50	4.10	0.14	0.01	6.87	1.40	1.00	0.09	0.07	0.60	0.44	3.60	9.00	48.0
Eka Nung Ikot																	
		0-15	5.10	4.60	4.20	0.30	0.02	3.87	0.80	0.60	0.10	0.08	0.00	0.96	2.54	16.00	140
		15-62	5.00	4.50	4.20	0.06	0.01	4.75	2.80	1.00	0.09	0.07	0.80	0.56	5.32	11.00	74.0
		62-100	5.00	4.40	4.10	0.30	0.02	9.00	1.80	0.40	0.08	0.06	0.80	1.04	4.18	13.00	24.0
		100-177	4.90	4.40	4.10	0.16	0.01	3.12	1.20	0.20	0.08	0.07	0.88	0.56	2.99	15.00	27.0
Nnung Ikot																	
		0-18	4.70	4.30	4.00	0.64	0.05	26.25	2.00	0.40	0.07	0.06	0.60	1.60	4.73	12.00	119
		18-49	5.00	4.50	4.10	0.34	0.02	43.62	1.80	0.40	0.09	0.07	0.80	0.96	4.12	13.00	57.0
		49-95	5.20	4.60	4.20	0.16	0.01	31.25	3.00	0.40	0.11	0.09	0.88	0.96	5.44	12.00	63.0
		95-172	5.10	4.50	4.20	0.08	0.01	16.37	1.20	0.40	0.10	0.08	0.00	0.96	2.74	14.00	33.0
Ikot Udo Idem																	
		0-17	5.00	4.50	4.10	0.96	0.08	3.25	1.80	0.80	0.09	0.07	0.88	1.04	4.68	14.00	123
		17-58	5.20	4.70	4.20	0.40	0.03	3.12	2.60	0.40	0.10	0.08	0.40	1.44	5.02	13.00	94.0
		58-99	4.90	4.50	4.30	0.30	0.02	4.62	1.00	0.80	0.08	0.06	1.04	1.08	4.06	22.00	55.0
		99-170	5.00	4.50	4.20	0.16	0.01	2.62	1.80	0.60	0.10	0.08	0.76	1.52	4.86	10.00	71.0
Mean surface			4.95	4.47	4.12	0.50	0.04	10.43	1.75	0.70	0.08	0.07	0.55	1.40	4.56	14.25	130
Range surface			4.7-5.1	4.3-4.6	4.0-4.2	0.1-0.96	0.01-0.08	3.25-26.25	0.8-2.4	0.4-1.0	0.07-0.10	0.06-0.08	0.0-0.88	0.96-2.0	2.54-6.31	12-16	119-140
Mean subsurface			4.98	4.48	4.15	0.24	0.02	11.76	1.75	0.58	0.09	0.07	0.72	1.18	4.40	12.83	59.0
Range subsurface			4.7-5.2	4.3-4.7	4.-4.3	0.06-0.40	0.01-0.03	2.62-43.62	1.0-2.8	0.2-1.0	0.08-0.11	0.06-0.09	0.40-1.12	0.44-2.64	2.74-5.44	8.0-22.0	24-94

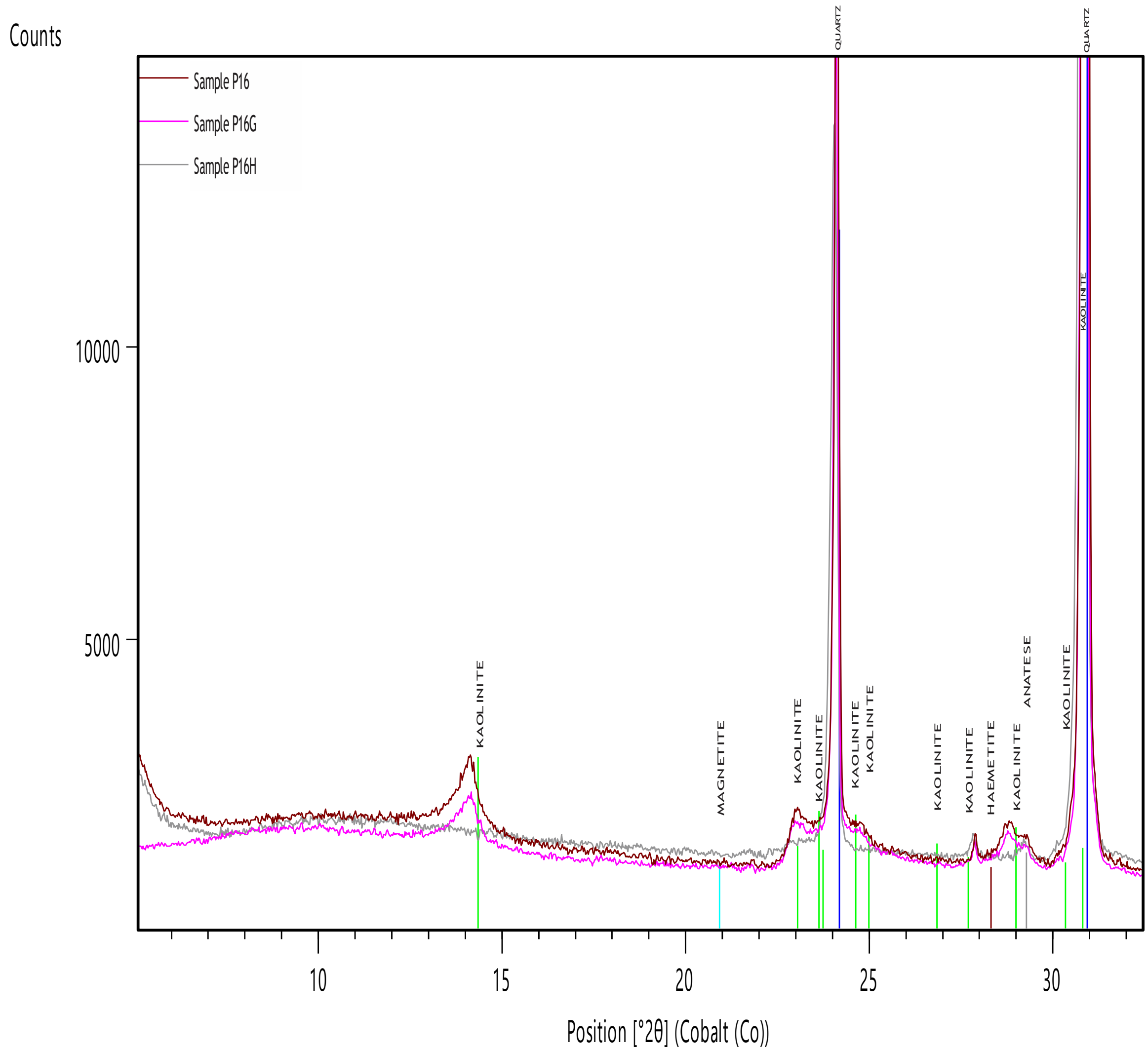

Figure 2: X-ray diffractogram of mineral phases identified in Oruk Anam LGA

Table 4: Summary of Taxonomic Soil Classification

Pedons	USDA System	WRB for soil resources
Ikot Eka Ide	Sandy, Mixed, Active, Isohyperthermic, Typic Kandiudult	Chromic Acrisol Loamic Cutanic Ochric
Eka Nnung Ikot	Sandy, Mixed, Active, Isohyperthermic, Typic Kandiudult	Haplic Acrisol Loamic Cutanic Ochric
Nnung Ikot	Sandy, Mixed, Active, Isohyperthermic, Typic Kandiudult	Chromic Acrisol Loamic Cutanic Ochric
Ikot Udo Idem	Sandy, Mixed, Superactive, Isohyperthermic, Typic Kandiudult	Chromic Acrisol Loamic Cutanic Ochric

Conclusion

The studied soils have characteristically low pH, organic carbon, total nitrogen, CEC, exchangeable bases and moderate available phosphorus with high sand content and have quartz and kaolinite as dominant clay minerals. The soils were classified as Ultisols and correlated with FAO-WRB as Acrisols. Low levels of most characteristics of the soils pose severe limitations to their capacity to support optimal cocoa production. To raise the productivity of these soils for optimum cropproduction and to sustain their productive potentials, integrated nutrient management involving the use of organic and inorganic nutrient sources, with regular soil testing to monitor nutrient balances should be adopted. Judicious use of lime to raise soil pH and enhance the availability of the deficient nutrients is also required with application of crop residues to ensure adequate soil conservation and water retention. The organic carbon content and retention of basic cations can be improved by the use of animal droppings, plant residues and compost. It will be possible to grow crops optimally in these soils and have maximum economic benefits when these recommended soil management practices are applied by farmers.

References

Adesemuyi, E. A. & Adekayode, F. O. (2019). Agricultural Potential of Soils Derived from Coastal Plain Sand for Oil Palm (*Elaeis guineensis*) Cultivation in Ikwuano Local Government Area, South Eastern Nigeria. *J. Sustain. Agric. Environ,* 17 (1): 1 - 18

Afu, S.M., Olim, D.M.&Asadu, C.L.A. (2024). Clay mineralogy and chemistry of selected soils in northern Cross River State, Nigeria. *Journal of Agriculture, Forestry and Environment.* 8(1):146-158

Akpan, J. F., Aki, E. E.& Isong, I. A. (2017). Comparative assessment of wetland and coastal plain soils in Calabar, Cross River State. *Global Journal of Agricultural Sciences.* 16, 17-30. DOI: http://dx.doi.org/10.4314/gjass.v16i1.3

Akpan-Idiok, A. U. & Ukwang, E. E. (2012). Characterization and Classification of Coastal Plain Soils in Calabar, Nigeria. *Journal of Agriculture, Biotechnology and Ecology*, 5(3), 19-33.

Carter, M. R., & Gregorich, E. G. (2007). Soil sampling and methods of analysis. CRC Press.

Enwezor, W. O., Ohiri, A.C., Opuwaribo, E.E.& Udo, J.E. (1990). Literature

Review on Soil Fertility Investigation in Nigeria, Federal Ministry of Agriculture and Natural Resources, Lagos.

Esu, I.E. (2004) Soil characterization and mapping for food security and sustainable environment in Nigeria. *In Proceeding of the 29th Annual Conference of Soil Science Society of Nigeria*. 10-17

Gee, G.W. & Or, D. (2002). Particle Size Analysis. In: Methods of Soil Analysis, Part 4, Physical Methods, Dane, J.H. and G.C. Topp (Eds.). ASA and SSSA, Madison, WI. 255-293.

Igwe, C. A., Akamigbo, F. O. R. & Mbagwu, J. S. C. (1999). Chemical and mineralogical properties of soils in southeastern Nigeria in relation to aggregate stability. *Geoderma*; 92 111-123.

Kongor, J.E., De Steur, H., Van de Walle, D., Gellynck, X., Afoakwa, E.O., Boeckx, P. and Dewettinck, K. (2017) Constraints for future cocoa production in Ghana. *Agrofor Syst*.

Kuo, S. (1996) Phosphorus. In: Sparks, D.L., Ed., Methods of Soil Analysis: Part 3, SSSA Book Series No. 5, SSSA and ASA, Madison, 869-919.

Lekwa, A.G. &Whiteside, E.P. (1986). Coastal plain soils of Southeastern Nigeria: I. Morphology classification, and genetic relationships. *Soil Science Society of America Journal,* 50(1): 154–160.

Li, T., Wang, H., Wang, J., Zhou, Z. &Zhou, J. (2015) Exploring the Potential of Phyllosilicate Minerals as \Potassium Fertilizers Using Sodium Tetraphenylboron and Intensive Cropping with Perennial Ryegrass. *Scientific Reports*, 5, Article No. 9249.

Nelson, O. W. & Sommers, L. E. (1996). Total Carbon, Organic Carbon and Organic Matter. In O. L. Sparks (ed). Methods of Soil Analysis Part 3, Chemical Methods. Soil Science Society of America Book Series Number 5. *American Society of Agronomy*, 961 – 1010.

Obi, J.C., Udoh, I.B. & Obi, I.C.(2020). Modelling soil properties from horizon depth functions and terrain attributes: An example with cation exchange capacity. *Eurasian J Soil Sci*2020, 9 (1) 10 - 17.

Oko-oboh, E., Senjobi, B.A., Agiboye, G.A., Oviasogie, P.O. & Awanlemhem, B.E. (2016). Suitability Assessment of Soils of NIFOR Sub-station Ohuso, Edo State for Oil Palm (*Elaeis guinensis*) and Coconut(*Cocos nucifera*) cultivation. *Nigerian Journal of Soil Science*, 14-20.

Onyekanne, C.F., Akamigbo, F.O.R., & Nnaji, G.U.(2012) Characterization and classification of soils of Ideato North Local Government Area. *Nigeria Journal of Soil Science*, 22(1):11-17.

Osabor, V.N., P.C. Okafor, K.A. Ibe &Ayi, A.A. (2009). Characterization of clays in Odukpani, Southeastern Nigeria. *Afr. J. Pure Applied Chem*. 3: 79-85.

Soil Survey Staff (2022). Keys to soil taxonomy. 13th edition. USDA natural resources conservation service. 401.

Soil Survey Staff (2022). Keys to soil taxonomy. 12th edition. USDA,Washington DC. 360

Sparks, D. L. (2003). Environmental soil chemistry. Academic Press

Thirtle C., Irz, X., Lin, L., Mckenzie-Hill,

V. and Wiggins, S.(2001) Relationship between changes in agricultural productivity and the incidence of poverty in developing countries. In: DFID Report No. 7946.

Thomas, G. W. (1982). Exchangeable cations In: Page A. L. *et al.* (eds). Methods of soil analysis. Part 2 Agron. Mongr. 9 (2nd edition),159-165.ASA and SSSA, Madison, Wisconsin, USA.

Udo, E. J., Ibia, T.O., Ogunwale, J.A., Ano, A.O & Esu, I.E. (2009). Manual of Soil, plant, and water Analysis .Sibon Books Publishers Ltd., Nigeria, 183.

Udoh, B.T., Ogunkunle,A.O., & Akpan, U.S.(2013). Fertility Capability Classification of Acid sands(soils) as influenced by parent materials in Akwa Ibom State, Nigeria. *Nigerian Journal of Soil Science,23(1), 56-66.*

Wessel, M. &Quist-Wessel, P.M.F. (2015). Cocoa production in West Africa, a review and analysis of recent developments NJAS - *Wageningen J. Life Sci*., 74–75, 1-7