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Characterization and Classification of Soils on Topographic Units in Amainyi-Nta, Ihitte/Uboma Local Government Area of Imo State

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ABSTRACT

Efforts towards achieving food security will be fruitless without understanding the dynamics of soils and as well as classifying them, since soil is the major medium for plant growth. Thus, this research aimed at characterizing and classifying the soils along the toposequence of Amainyi-nta in Ihitte/Uboma Local Government Area of Imo State. The pedons were sited along the toposequece with one soil profile pit representing each topographic position. The soil profile pits were examined and sampled for laboratory analyses of the physical and chemical properties. The morphological examination of the soil profiles revealed various shades of brownish soil colour. The bulk density values did not exceed 1.63 g/cm^3. The soils' total porosity values ranged from 39.10 to 70.09. Argillic horizons were expressed by sandy clay loam and sandy clay dominance in the subsurface horizons. The soils were low in organic carbon and total nitrogen. The soil pH values ranged from 4.73 to 6.50 while the maximum cation exchange capacity value obtained was 7.21 in the surface soil of AMA 1. AMA 1 and AMA 2 were classified as Typic Paleudults while AMA 3 was classified as Aquic Arenic Paleudults. One of the best management options of these soils is to plant acid-tolerant crops to minimize cost of production through liming.

Keywords: *Ultisols, Characterization, Classification, Topsequence, Argillic horizon, Porosity*

INTRODUCTION

Soil characterization and classification are essential components of soil science. Through the process of characterization and classification, the varying soil properties can be well understood. Also, their behavior and potential uses can be articulated (Brady and Weil, 2002). Characterization is achieved through analyzing the soils morphological, physical and chemical properties of the soils. Furthermore, classification is achieved through categorizing the soils into distinct groups. The information derived from characterization and classification of soils can facilitate informed decision in agriculture, ecology, and environmental management (Soil Survey Staff, 2014). Toposequence is a sequence of soils that differ in their characteristics due to variations in topography, while other factors such as climate, parent material, and vegetation remain relatively constant (Akamigbo, 2010). This concept is important in understanding how relief influences soil water movements, soil erosion and soil aeration. Toposequences offer valuable insights into the complex relationships between topography/relief, soil characteristics and the ecosystem processes. By understanding the relationships between the above mentioned factors, researchers, farmers, environmentalists and land managers can develop more effective strategies for sustainable land use, soil conservation as well as ecological restoration. In the field of agriculture, Ajoagu *et al*. (2024) highlighted that understanding toposequences can help optimize agricultural productivity by identifying areas with suitable soil characteristics for specific crops. Thus, this research objective was to characterize and classify the soils along toposequence of Amainyi-nta in Ihitte/Uboma Local Government Area of Imo State, Nigeria.

METHODOLOGY

Description of Study area

Ihitte/Uboma Local Government Area lies within latitudes 4°45'N and 7°15N and Longitude 6°50'E and 7°25 and is located in Imo state, Nigeria. The climate of the area is typical of tropical humid region with annual rainfall varying from 1990 to 2200 mm, a mean annual temperature of above 20°C and an average annual relative humidity of 75% (Ukabiala and Obazi, 2022). The soils of the area are formed from the Tertiary Coastal Plain Sands (Ukabiala *et al., 2016*). The area is strongly undulating in most part, with depressions to streams. The original rain forest in the area has been deforested, so the vegetation is that of the secondary bush. The cropping system practiced in the area includes the rotational bush fallow and mixed cropping.

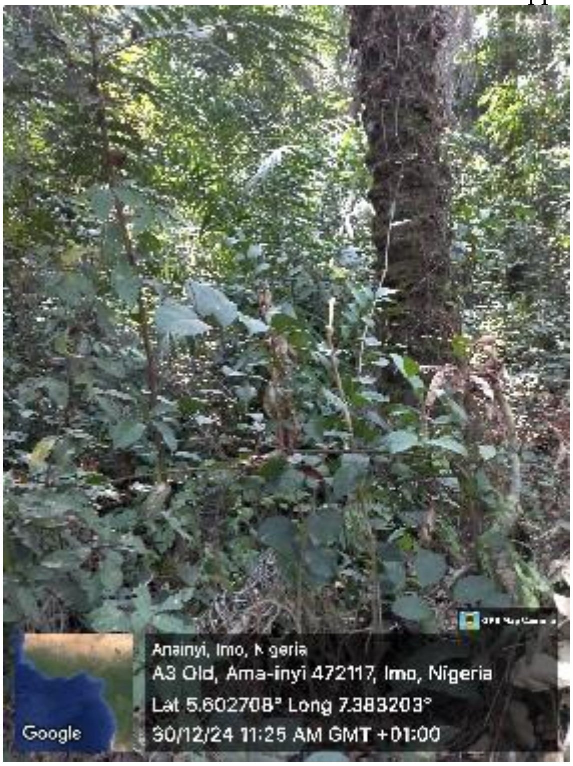

Plate 1: The Vegetation of the surveyed land

Data Collection

The sampling adopted a transet survey technique as outlined by Osujieke et al. (2016). In this method, three slope positions were identified following the physiography. The slope positions were denoted as Upper Slope (AMA 1), Middle Slope (AMA 2) and Lower Slope (AMA 3). One profile pit was dug in each unit to represent the pedon. Each profile pit was dug to the depth 200 cm, unless where water table was encountered at 35 cm in AMA 3. Each pedon was described morphologically following the United States Department of Agriculture (USDA) standards Schoeneberger *et al*. (2012). Pedogenic soil horizons were identified in each pedon, and samples taken. The disturbed and undisturbed soil samples taken were taken to the soil science laboratory for the determination of selected physical and chemical properties.

Soil physical properties determination

The particle size distribution (PSD) < 2 mm was determined using Bouyoucos Hydrometer method. Sodium hydroxide was used as dispersant (Ukabiala, 2022). The textural classes were read out from the USDA soil textural triangle, while Bulk density was determined by the method described by Landon (1981).

$$Soil\ bulk\ density = \frac{\text{Oven dry weight of soil}}{\text{Volume of soil}}$$ -----*Equation 1*

Soil porosity was calculated with the values of the bulk density using the method outlined by Brady and Weil (2002).

$$\text{Soil total porosity (\%)} = 100 - \frac{Bulk\ density}{Particle\ density}\ x\ 100$$ ---*Equation 2*

Soil chemical characteristics

Soil pH was determined in water and 1N KCl solution using a soil solution ratio of 1:2.5 with the aid of a glass electrode pH meter (McLean, 1982). Organic carbon was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982). Total nitrogen was estimated by the macro-kjeldahl digestion method (Bremmer and Mulvaney, 1982). Available phosphorus was obtained using Bray II bicarbonate extraction method (Olsen and Sommers, 1982), using 0.03 N ammonium fluoride with 0.1N HCl. The phosphorus in the extract was determined with a photo-electric colorimeter. Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N NH_4OAc (pH 7.0) using 1:10 soil solution ratio. Potassium and sodium in the extract were determined with Flame Photometer while Ca and Mg were determined by atomic absorption spectrophotometry (Thomas, 1982).

The titration method, as outlined in Selected Methods for soil and plant analysis (Thomas, 1982) was used in the determination of the exchangeable acidity. The samples were extracted with 1N KCl solution and the extract titrated with 0.05 NaOH to a permanent pink end point using phenophthalen indicator. Total exchangeable bases (TEB) were obtained by the summation of the exchangeable bases (Na, K, Ca and Mg) (Rhoades, 1982). The cation exchange capacity of the soils was determined with 1N NH_4OAc, pH 7.0 (Rhoades, 1982).

The percentage base saturation will be derived by dividing the total exchangeable bases (Ca, Mg, K and Na) by the CEC obtained and multiplying by 100 (Rhoades, 1982).

$$PBS = \frac{Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}}{CEC} \times \frac{100}{1}$$ *Equation 3*

The classification of soils was achieved using the Soil Taxonomy of the USDA (Soil Survey Staff, 2014).

RESULTS AND DISCUSSION

Plates 2, 3 and 4 show the soil profiles of the three pedons (AMA 1, AMA 2 and AMA 3). The morphological, physical and chemical characteristics of the soils of AMA 1, AMA 2 and AMA 3 are presented in Tables 1, 2 and 3 respectively.

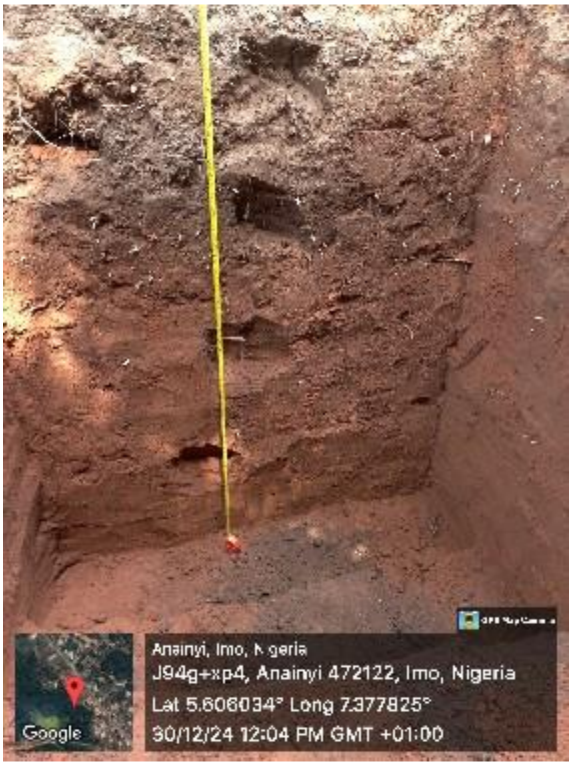

Plate 2: AMA 1

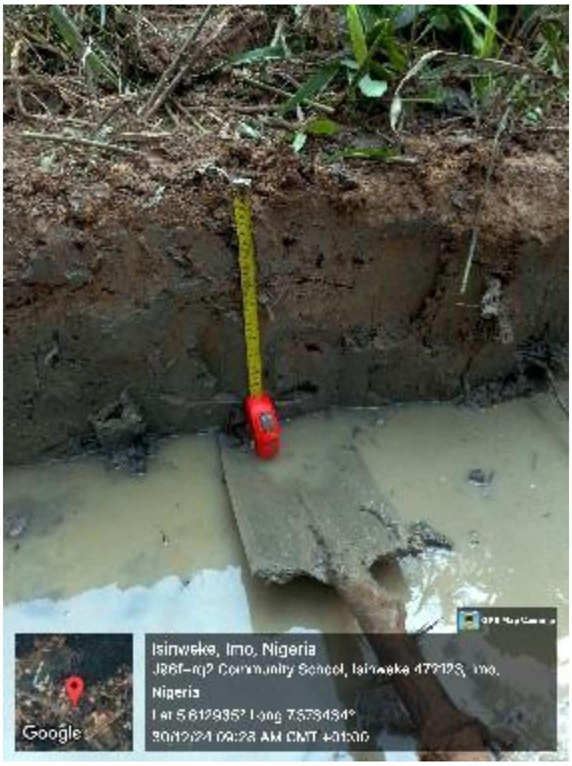

Plate 3: AMA 2

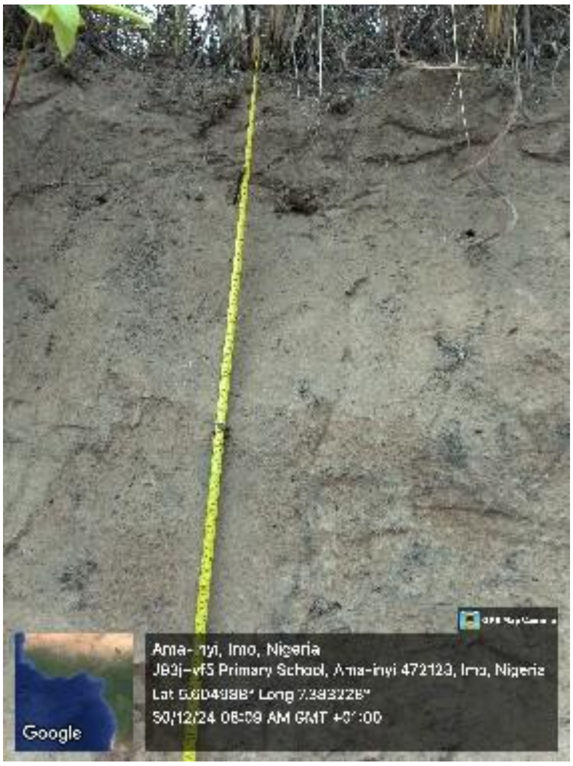

Plate 4: AMA 3

Table 1: Morphological properties of soils of Amainyi-nta Toposequence

Pedon	Horizon depth (cm)	Horizon designation	Matrix Colour		Texture	Structure	Consistence		Boundary	Pores	Roots	Others
			Notation	Name			Wet	Moist				
AMA 1	0-18	Ap1	2.5Y4/4	Very dark grayish brown	sl	25g	nsnp	fr	aw	cfi	cfi	-
	18-42	Ap2	2.5Y4/4	Olive brown	sl	15c	nsnp	fr	cw	cfi	cfime	-
	42-85	Bt_1	2.5Y3/3	Dark olive brown	sl	25sbk	sssp	f	cs	fme	ffime	Ants
	85-140	Bt_2	10YR5/8	Yellowish brown	scl	36sbk	sssp	vf	ds	ffi	ffi	-
	140-200	Bt_3	7.5YR5/8	Strong brown	scl	26sbk	sp	f				
AMA 2	0-20	Ap1	2.5Y3/3	Dark olive brown	ls	24g	nsnp	l	cw	ffi	cfi	-
	20-59	Ap2	2.5Y4/4	Olive brown	sl	36c	sssp	vf	gs	ffi	cfi	-
	59-131	Bt_2	10YR5/8	Yellowish brown	scl	36sbk	sssp	vf	ds	fvfi	cfi	-
	131-200	Bt_2	7.5YR5/8	Strong brown	sc	36sbk	sssp					
AMA 3	0-16	Apg	2.5Y5/6	Light olive brown	cl	15c	sssp	fr	cw	cfi	mfico	-
	16-35	Cg	2.5Y6/6	Olive yellow	c	14c	sp	fr	gs	ffi	cfi	Water Table

Structure: 1=weak, 2= moderate, 3= strong, 4= fine, 5= medium, 6= coarse, c= crumb, g= granular, sbk= subangular, abk= angular blocky, s= single grain
Texture: l= loam, s= sand, c= clay, si= silt, cl= clay loam, sl= sandy loam, scl= sandy clay loam, sc= sandy clay, g= gravelly, v= very, e= extremely, st= stony
Consistency: sp= sticky and plastic, sssp= slightly sticky and slightly plastic, nsnp= non sticky and non plastic, l= loose, vfr= very friable, fr= friable, f= firm, v=very firm. **Pores and Roots:** f= few, v= very, m= many, c=common, fi= fine, me= medium, co= coarse
Boundary: a= abrupt, c= clear, g= gradual, d= diffuse, s= smooth, w= wavy, i= irregular

Table 2: Selected physical properties of Amainyi-nta Toposequence

Pedon	Depth (cm)	Horizon designation	Bulk Density (g/cm^3)	Moisture Content (%)	Porosity (%)	Sand	Silt	Clay	Textural class
							(g /kg)		
AMA 1	0-18	Ap1	1.26	4.05	53.50	67.52	13.26	19.22	sl
	18-42	Ap2	1.49	3.02	44.20	65.88	15.89	18.23	sl
	42-89	Bt_1	1.54	5.95	42.10	66.87	13.15	19.98	sl
	89-140	Bt_2	1.63	7.25	39.50	62.67	6.22	31.11	scl
	140-200	Bt_3	1.50	7.30	44.60	55.67	11.00	33.33	scl
AMA 2	0-20	Ap1	1.46	3.55	45.00	75.33	9.66	15.01	ls
	20-59	Ap1	1.62	3.49	39.10	68.88	13.11	18.01	sl
	59-131	Bt_1	1.31	5.49	51.43	55.62	12.26	32.12	scl
	131-200	Bt_2	1.54	3.72	42.11	52.11	2.67	45.22	sc
AMA 3	0-16	Apg	1.07	28.26	60.37	35.20	25.28	39.52	cl
	16-35	Cg	0.82	54.74	70.09	7.20	7.28	85.52	c

ls= loamy sand, sc= sandy clay, scl= sandy clay loam, sl= sandy loam

Table 3: Chemical properties of soils of Amainyi-nta Toposequence

Pedon/ Coordinate	Depth (cm)	Horizon designation	pH (H_2O)	OC (%)	OM (%)	TN (%)	C:N	Av. P (mg/kg)	Exchangeable cations (cmol/ kg) Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Exchangeable Acidity	CEC	BS (%)
AMA 1	0-18	Ap1	5.04	0.89	1.55	0.20	4.45	14.91	3.70	1.44	0.06	0.37	1.64	7.21	77.2
	18-42	Ap2	4.95	0.88	1.51	0.20	4.45	12.26	3.30	1.30	0.08	0.40	0.60	5.68	89.4
	42-89	Bt_1	4.83	0.60	1.03	0.19	3.16	13.71	2.40	0.96	0.05	0.41	0.60	4.42	86.4
	89-140	Bt_2	4.80	0.91	1.55	0.17	5.35	10.40	1.89	0.88	0.03	0.37	0.84	4.01	79.05
	140-200	Bt_3	4.78	0.24	0.41	0.15	1.60	9.66	1.50	0.83	0.03	0.35	1.00	3.71	73.04
AMA 2	0-20	Ap1	4.90	1.19	2.06	0.21	5.66	11.90	2.05	0.77	0.15	0.38	0.60	3.95	84.81
	20-59	Ap1	4.90	0.40	0.69	0.18	2.22	12.11	1.95	0.67	0.08	0.41	0.52	3.63	85.67
	59-131	Bt_1	5.02	0.20	0.34	0.16	1.25	10.36	1.55	0.58	0.06	0.41	0.50	3.1	83.87
	131-200	Bt_2	4.73	0.30	0.52	0.15	2.00	9.46	1.38	0.47	0.20	0.90	0.76	3.71	79.51
AMA 3	0-16	Apg	6.50	1.40	2.41	0.23	6.08	14.11	2.20	0.94	0.11	0.42	0.56	4.23	86.76
	16-35	Cg	6.40	0.88	1.51	0.19	4.63	8.82	2.15	0.90	0.03	0.57	0.68	4.33	84.3

OC= Organic carbon, OM = Organic Matter, TN= Total Nitrogen, Av. P= Available Phosphorus, Ca^{2+}= Exchangeable Calcium, Mg^{2+}= Exchangeable Magnesium, K^{+}= Exchangeable Potassium, Na^{+}= Exchangeable Sodium, Al^{3+}= Exchangeable Aluminium, CEC = Cation Exchange Capacity, BS = Base Saturation

Morphological Characteristics of the Soils

The matrix colour showed notations which are interpreted as various shades of brownish soil colour. Olive yellow colour is an indication of wetness of the layer. The surface soils of AMA 1, AMA 2 and AMA 3 have sandy loam, loamy sand and clay loam soil textures which are as the result of varying proportions of the sand silt and clay mineral particles. The presence of dominance of sandy clay loam, sandy clay and clay textures in subsurface layers are clear indications of illuviation or in-situ clay formations in the sub-layer horizons (Brady and Weil, 2002). The dominant structure in the surface soils are granular and crumb, while the subsurface horizons are characterized by subangular blocky structure with exception in AMA 3. The surface soils of AMA 1 and AMA 2 are non-sticky and non-plastic in consistence due to low clay content while the subsurface layers are slightly sticky and slightly plastic, which could be attributed to the clay content down the profiles. The abrupt and clear wavy boundaries of the soils may be attributed to the variations in organic matter accumulations of the soils that were distinct. The roots and pores were fine and course in some layer. There was presence ant activities observed at the depth of 42-85 of AMA 1, while water table was encountered 16-35 cm of AMA 3.

Physical Characteristics of the Soils

The bulk density values decrease irregularly down the soil profile. Soils of AMA 3 had very low bulk density in the Cg horizon (0.82 g/cm^3) which may be due to textural variation at this depth. The moisture contents of the soils were low, with highest values of 28.26 and 54.74 % which are measured in the Apg and Cg horizons of AMA 3. The sampling period was December which was during dry season. Nevertheless, the AMA 3 pedon occurred in the lower slope with fluctuating water table 35 cm of soil depth. The total porosity values were significantly higher in AMA 3. This may attributed to the high clay content of this soil as shown by the textural classes of clay loam and clay in the surface and subsurface horizons of this pedon (Table 2). Soils with high clay content have high porosity because of the tiny size of clay particles and the way they are packed together. It has been reported that small particles create numerous micro-pores, resulting in a larger total pore space compared to soil with larger particles like sand (Ukabiala, 2022). The averagely moderate soil porosity values of AMA 1 and AMA 2 shows that these soils can conduct water, air and nutrients into it. Reynolds et al. (2002) reported that pore-size distribution provides the ability to soil to store root zone water and air necessary for plant growth.

Chemical Characteristics of the Soils

The soil pH of the soils ranged from 4.73 in AMA 2 to 6.50 in AMA 3. The low soil pH values in AMA 1 and AMA 2 may be as a result of leaching of non-acid cations in the their developed soil profile, and accumulation and activity of hydrogen ions in the soil profiles. The near neutral soil pH values obtained in AMA 3 would mean that the pedon will not suffer phosphorus fixation problems. The organic carbon content, organic matter and total nitrogen in all the pedons were low to moderate owing to the fact that these soils occur in high rainfall and sunshine area with high leaching and mineralization of the these elements. The phosphorus levels were low to moderate and decreased irregularly down the profiles. The higher phosphorus contents in the surface soils may be due to the higher accumulation of organic matter in the soil surface layers. Again, Sharpley *et al.* (2013) opined that certain soils with high organic matter or clay content, can retain more phosphorus. The exchangeable calcium, magnesium, potassium and sodium in the soils were low. In AMA 1 and AMA 2, the low contents of the exchangeable cations are in consistent with the strongly acidic nature of the soils. The soils of AMA1, AMA 2 and AMA 3 have low cation exchange capacity measures. The implication of low CEC in soils is that nutrients are leached easily, thus more frequent fertilization might be necessary. The base saturation values are moderate to high. In the soils of AMA 3 the high base saturation ensures balance fertilization in maintaining optimal nutrients ratios. Also, it will often affect nutrient availability and microbial activity (Hazelton and Murphy, 2018).

Classification of the Soils

Pedons AMA 1, AMA 2 and AMA 3 are broadly classified as Ultisols in the Order level of the USDA Soil Taxonomy. This is following the fact that there is presence of argillic horizons and udic soil moisture regime. The chemical properties in Table 3 shows clearly that the release of bases by weathering in these pedons is equal to or less than the removal by leaching, with few centimetres of accumulation of bases. Also, the base saturation decreased with increasing depth (Table 3). These pedons occurs on Pleistocene/older surfaces. From Table 3, it deduced that the argillic horizons are calcium-deficient.

At the Suborder level of USDA Classification, the three pedons are classified as Udults, being freely drained soils and relatively humus poor. The pedons are have also udic moisture regime, meaning that they receive well distributed rainfall. Also, the argillic horizons have yellowish brown colours (Table 1).

At the Greatgoup level of USDA Soil Classification system, the three pedons are placed as Paleudults, having met the following criteria;

They are deep (>150 cm in depth)

They are freely drained

They have thick argillic horizons (Table 1)

They d not have fragipan within 150 cm o the mineral soil surface

AMA 1 and AMA 2 are further classified as Typic Paleudults at the Subgroup level of USDA classification, having no cracks within 125 cm of the mineral soil surface. The AMA 3 is placed as Aquic Arenic Paleudults due to mainly the groundwater that fluctuates within 75 cm of the soil surface.

Management of the Soils

The best management of the soils of AMA 1, AMA 2 and AMA 3 will involve practices that can improve the soil pH and organic matter levels of the soils. The colours of the soils (Table 1) shows typifies low organic matter and fast rate of nutrient mineralization and depletion. When the soil pH and organic matter are enhanced, the cation exchange capacity of the soils will improve, thus increasing the fertility of the soils. AMA 3 can actively be used in the production of vegetables like Garden egg (*Solanum aethiopicum*), Ugu (*Telferia occidentalis*), Amaranth (*Amaranthus spp*), Okra (*Abelmoschus esculestus*), etc., with less fertilization. Nevertheless, other crops that are climatically suitable can be also cultivated in AMA 3 with good drainage system in place. Researchers have suggested that the basic approach to optimizing the use of Ultisols include the use of plants that are adapted to acid soil constraints to maximize the use of fertilizers and lime needed to produce about 80% of their maximum yield, and to take advantage of favourable attributes o acid infertile Ultisols (Sarkar and Singh, 2018).

CONCLUSION

This research was centered on the characteristics and classification of soils of a toposequence in Amainyinta in Ihitte/Uboma Local Government Area of Imo state, Nigeria. The findings revealed that the morphological properties can support improvement approached to boost the fertility of the soils. Thus, the soils are sandy loam and loamy sand in the surface horizon which can support good infiltration and water holding capacity. The total porosity values measured are adequate while the bulk density values did not show compaction of the soils. The soil pH values varied between strongly acid and slightly acid. The soil carbon and nitrogen contents are low. The low CEC shows the low available forms of the exchangeable cations. Hence, the three pedons, AMA 1, AMA 2 and AMA 3 are classified as Ultisols.

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