PROPERTIES AND CLASSIFICATION OF SOILS ON A TOPOSEQUENCE IN OVIM, ISIUKWUATO, SOUTH EAST NIGERIA.

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ABSTRACT
A study was carried out to characterize, classify and recommend management procedures for soils on a toposequence in Ovim, Isiukwuato, southeast Nigeria. A stratified random sampling technique based on topograghic attributes of the terrain was used to identify/stratify the toposequence into upper, middle, lower slopes and valley bottom. Four profile pits namely OV/A, OV/B, OV/C and OV/D were excavated, one on each of upper slope, middle slope, lower slope and valley bottom respectively. The pits were dug, characterized and samples taken to the laboratory for physical and chemical analysis. The results of the soil characterization indicated that soils of soil units OV/A and OV/B were deep (182 cm and 180 cm) and well drained while Soil units OV/C and OV/D were deep (165cm) and moderately deep (85cm) but imperfectly and poorly drained respectively. Soils of three slopes namely OV/A, OV/B and OV/D occurred on level or nearly level while ON/C occurred on a gently or undulating physiography. Soil unit OV/A had reddish black (5YR 4/1) surface colour over Reddish (10 R 4/6) sub surface colour. Soil unit OV/B had dark reddish brown (2.5 YR 2/4) to reddish Brown (2.5 YR 4/4) surface colours over reddish (10 R 4/8) sub surface colour while soil unit (OV/C) had dark grey (5 YR 4/1) to weak red (10 YR 4/4) surface soils over reddish brown (2.5 YR 4/4) to reddish (10 R 4/6) sub surface soils and OV/D had very pale brown surface (10YR 8/4) to brown subsurface soils (7.5 YR 5/4). The soils were strongly to moderately acidic (pH 5.3-5.9) with high base saturation (71.05 - 85.16 The organic matter contents were high for epipedons and low (< 2.0 %) for the subsoils. Thus, the soils were low in ECEC averaging (6.26 cmolkg^{-1}, 6.89 cmolkg^{-1}, 7.65 cmolkg^{-1} and 6.55 cmolkg^{-1}), available P (12.55 mgkg^{-1}, 12.88 mgkg^{-1}, 5.75 mgkg^{-1} and 12.40 mgkg^{-1}) and total N. (0.09 gkg^{-1}, 0.06 gkg^{-1}, 0.07 gkg^{-1} and 0.08 gkg^{-1}), for soil units OV/A, OV/B, OV/C and OV/D respectively. It was concluded that high acidic nature of the area can be reduced by liming. At the valley bottom, pore drainage may affect crop production except for moisture loving crops like swamp rice, sugarcane etc. The crest may have enhanced erosion at the middle slope and subsequent deposition at the valley bottom.

INTRODUCTION

Soils are anisotropic in nature (Adegbite *et al.*, 2019). And its variability has posed a major constraint for sustainable production of crops (Ubuoh *et al.*, 2020). Therefore, the need to study soils on different landscape positions for sustainable nutrient management can never be overemphasized. Topography is one of the major soil forming factors that influences the way soils develop. It affects runoff, drainage, soil temperature, soil erosion, soil depth, and thus soil formation.

Adjacent soils that show differing profile characteristics reflecting the influence of local topography are called toposequence. As a general rule, soil profile on the convex upper slope in a toposequence are more shallow and have less distinct sub surface horizons than soils at lower slope. As such, variations in most soil properties could be closely related to their landscape position (Surwase *et al.*, 2023; Nwaoba *et al.*, 2025)

The differences in soil properties as a result of slope position are associated to degree of detachment, transportation and deposition of soil materials. As such, different soil properties encountered along landscapes will influence plant production, litter production, and decomposition patterns, all of which will affect the soil's carbon and nitrogen content (Wakene and Heluf, 2004). Also, Landscape position has been found to be substantially linked with clay content and depth distribution, sand content, and pH.

Since, soils have a wide range of morphological, physical, chemical, and biological characteristics. Their characterization and classification are very important to get information of the soils. Soil characterization is a scientific way of gathering soil information that allows recognizing the physical, chemical and mineralogical properties of the soils (Sharu *et al.*, 2013). It is a major building block for understanding the soil environment. Furthermore, soil characterization records allow for the ideal classification of the soil to serve as a basis for a more detailed assessment of the soil (Onyekanne *et al.*, 2012). Soil classification is vital to reflect real diversity of soils to make decisions about adequate or sustainable land use. It also aids in the organization of our knowledge and the transfer of experience and technology from one location to another (Nwaoba and Lekwa, 2016: Nwaoba *et al.*, 2024).

Sharu *et al.* (2013) reported that coupling of soil characterization and classification provides a powerful resource for benefit of mankind especially in the area of food security and environmental sustainability while Lekwa *et al*. (2004) reiterated that soil characterization provides the basic information necessary to create functional soil classification schemes and assess soil fertility in order to unravel some unique soil problems in an ecosystem.

Understanding soil properties and their variation along a toposequence is important for their sustainable utilization and proper management systems on soils. Ezeaku and Iwuanyanwu (2013), worked on degradation rates of soil fertility as influenced by topography in southeastern Nigeria and noted that lower slope soils require greater management requirements. Also, (Osujieke, 2017) noted that soil properties such as Organic matter, Available P, total N and CEC increases with depth. As such, the variation of soil properties on a toposequence should be monitored and quantified to understand the effects of land use and management systems on soils.

The current shortage of food and increasing demand for food in the rapidly expanding population necessitate that soils on topographic positions be brought under intensive agricultural land use. As a result, most farmers in Ovim area have resorted to intensive cultivation of slope land and indiscriminate use of mineral fertilizers which has caused deterioration due to erosion and fertility depletion and also posing more risk to fragile soils. Hence this work is to describe the morphology of the soils of the toposequence, determine their physical and chemical properties, classify them using USDA soil taxonomy and World Reference Base systems of classification for proper management decisions.

Keyeords: Anisotropic, Management, Properties, Toposequence, Classification, Characterization

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Location

The study was carried out at Ovim, Isiukwuato LGA, Abia State, South Eastern Nigeria. The study area (toposequence) located between Latitudes 5^o40^I N 6^o30^I N and Longitudes 7^o 20^I E 7^o 35^I E. The area is underlain mainly by lower coal measures. The L.G.A is a typical rainforest vegetation in south-eastern agro-ecological zone of Nigeria (*IITA, 1996*).

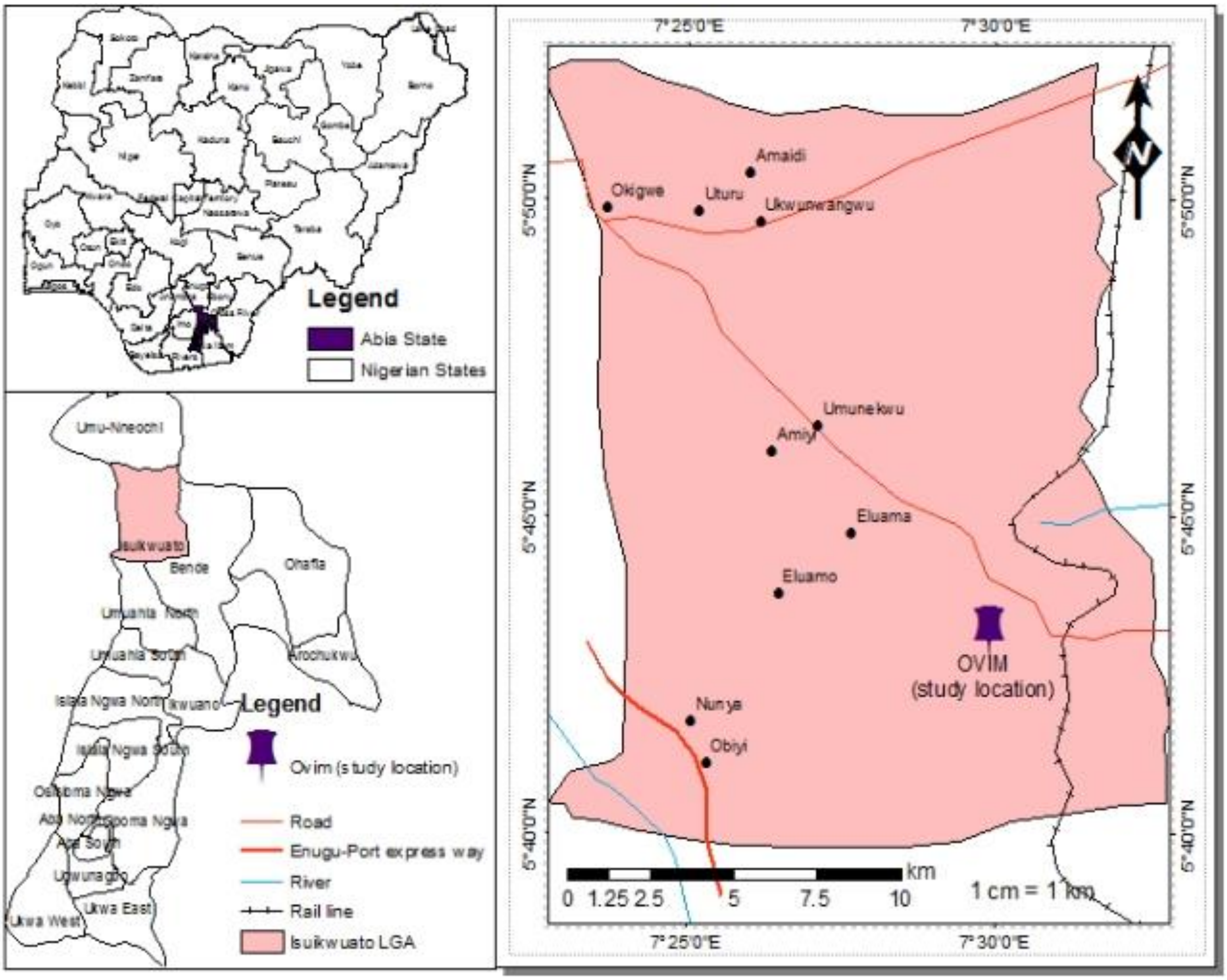

Figure 1: Location map of the study area

Climate

The general climate is sub-humid tropical, having distinct rainy season that begins from April to October and dry season from November to March. The total annual rainfall is 2200 mm, the mean annual temperature is about 31 ºC and the annual relative humidity is about 75 %. The average minimum and maximum temperatures are about 22 ºC and 30 ºC, respectively (Ndukwu *et al.,* 2012).

Relief and Geology

The relief is moderately to strongly sloping (4-7 %). The geology of Ovim is lower coal measures (Federal Department of Agricultural Land Resources, 1990). The area records the deposition of fluvio-deltaic sediments which consists mainly of clastic rocks (claystones, shales, siltstones, sandstones, conglomerates) interstratified with the beds of coal. Coal was discovered in the Mamu Formation (formerly called the 'Lower Coal Measures') of the Anambra Sedimentary Basin of south-eastern Nigeria (Ndukwu *et al*., 2012).

Land Use

The major land use of the area is agriculture. Cultivation of arable crops which includes Cassava (*Manihot spp*.), sweet potato (*Ipomea batatas*), Yam (*Dioscorea spp*.), Maize (*Zea mays*), Cocoyam (*Colocasia esculentus*). Also, Palm trees, Native pear (*Dacryodes edulis*), Mango (*Magnifera indica*), Orange, Grape, Lemon (*Citrus spp*.) etc are grown. Melon and garden vegetables which include fluted pumpkin (*Telferia occidentalis*), Pepper (*Capsicum spp*.) are the vegetable crops grown in Olokoro.

Vegetation

The vegetation of the study area is essentially secondary forest (Ndukwu *et al.,* 2013). Fallowing had continued to be the principal management practice to restore soil productivity in the area. The grasses found in the study area are Spear grass (*Imperata cylindrica*), Guiness grass (*Panicum maximum*), Elephant grass (*Pennisetum purpureum*) while weeds include Siam weed (*Chromolena* odorata), Calapo (*Calapogonium* spp.) and Stubborn grass (*Sida* acuta). Cashew trees, Palm trees, Native pear (*Dacryodes edulis*), Mango (*Magnifera indica*), Orange, Grape.

Field Work

A stratified random sampling technique based on topograghic attributes of the terrain was adopted for use in the study. The toposequence was stratified into upper slope, middle slope, lower slope and valley bottom. Four profile pits were excavated, one on each at the upper, middle, lower and valley bottom slopes. A hand held geographic positioning system (GPS) was used to determine the coordinates of the toposequence. The representative soil profiles designated as OV/A, OV/B, OV/C and OV/D for the four slopes respectively were described and horizons were designed in-situ according the guidelines of FAO (2014). Soil samples were collected from the identifiable horizons of the profile pits in each of the topographic units for physical and chemical analysis.

Laboratory studies

The following soil physical and chemical properties were determined following appropriate procedures;

Particle size distribution: This was determined by Bouyoucous Hydrometer method according to the procedure of Gee and Or (2002) where sodium hexametaphosphate (calgon) solution was used as a dispersing agent.

Bulk density: Bulk density was determined by core sampler method according to the procedure of Grossman and Reinsch (2002).

Bulk Density = $\frac{Mass\ of\ oven\ dry\ soil}{Volume\ of\ core\ sampler}$

It was expressed in g/cm^3 (Brady and Weil, 2002)

Total porosity: This was calculated from the result of bulk density and particle density.

$\frac{Db}{Dp} \times \frac{100}{1}$ Where P = Porosity Db = Bulk density (gcm^{-3}) Dp = Particle density (assumed to be 2.65g/cm^3)

Soil reaction (pH): This was measured in a suspension as soil/water ratio of 1:2:5 and 1:1 soil for H_2O and in KCl respectively. Standardization of pH meter was done using buffer solutions of pH 7.0 (water) and 4.0 (in KCl) and determined using glass electrode pH meter as described by Thomas (1996). **Organic carbon:** This was determined by the wet oxidation procedure (Nelson and Sommers, 1982). **Total nitrogen:** This was determined using the modified micro kjeldahl method according to the procedure of Bremner (1996). **Available phosphorus:** This was done using the molybdenum blue color Bray II method (Olsen and Sommers, 1982). In which P was extracted by adding 40.0ML of 0.5N$NaHCO_3$ as extracting solution, including a method of blank and standard quality control samples.

Exchangeable basic cations: This was determined with Ammonium Acetate (NH_4OAc) leachate of the soil (Thomas, 1996). Exchangeable calcium and magnesium was determined by the EDTA (Ethylene diamine tetra-acetic Acid) titration method where Ca and Mg indicator (EBT) complex were dissociated by titrating with standard EDTA solution. While exchangeable sodium and potassium was determined by flame photometer method.

Exchangeable acidity (Al + H): This was determined by titration as described by (Mclean, 1996). It was extracted with one normal potassium chloride solution. The exchangeable hydrogen was obtained by subtracting exchangeable aluminum from the exchangeable acidity. Exchangeable acidity (Al + H) - Exchangeable Al =Exchangeable H.

Effective cation exchange capacity (ECEC): This was derived by the summation of the total exchangeable bases (TEB) and exchangeable acidity (TEA) (Brady and Weil, 2002).

Percentage base saturation (%BS): This was calculated as

$\%BS = \frac{TEB}{ECEC} \times \frac{100}{1}$ Where % BS = Percentage base saturation, TEB = Total exchangeable basic cations, ECEC = Effective Cation Exchange Capacity.

Soil Classification: Based on the results obtained from the laboratory analyses and field morphological properties, the soils were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2014) guidelines and side by side correlation with World Reference Base (WRB).

RESULTS AND DISCUSSION

Morphological Characteristics

The morphological characteristics of the soils is presented in table 2.

Under moist conditions, soil unit OV/A had reddish black (5YR 4/1) surface colour over Reddish (10 R 4/6) sub surface colour (Table 2)

Soil unit OV/B had dark reddish brown (2.5 YR 2/4) to reddish Brown (2.5 YR 4/4) surface colours over reddish (10 R 4/8) sub surface colour. Soils colour at soil unit (OV/C) had dark grey (5 YR 4/1) to weak red (10 YR 4/4) surface soils over reddish brown (2.5 YR 4/4) to reddish (10 R 4/6) sub surface soils while soil unit OV/D had very pale brown (10YR 8/4) to brown (7.5 YR 5/4). This agreed with the findings of Obi (2018) in her study of wetland soils in Abia state agricultural zone south Eastern, Nigeria. Mottles were observed both at the top of soil unit OV/D and sub soils of OV/C and OV/D. It ranged from few faint yellow (10YR 8/6) to reddish yellow (7.5 YR 5/6) which is an evidence of gleization. The mottling could be attributed to cyclic oxidation reduction of iron compounds associated with fluctuation of water table that contains dissolved iron products. The soil colours observed in the study area are in conformity with the findings of Nsor *et al.,* 2016 who worked on topographic soils of Ohiya Autonomous community in Abia State, Nigeria.

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).

The texture of the soils of the study area indicated that soil unit OV/A had sandy loam surface and sub-surface texture, sandy loam to sandy clay loam surface and subsurface texture for soil unit OV/B. Soil unit OV/C had sandy loam surface and sandy loam to sandy clay loam sub-surface textures. Soil unit OV/D had sandy clay loam surface soils over sandy clay subsurface soils.

The structure of the soils in the study area indicated that Soil unit OV/A had moderate medium granular structure occurring over moderate medium sub angular blocky structure. Soil units OV/B and OV/C were characterized by moderate medium granular structure occurring over moderate medium sub angular blocky structures while for soil unit OV/D, the surface soils were characterized with moderate medium sub angular blocky structures and strong medium sub angular blocky structures at the subsurface soils. The consistence of soils unit OV/A indicated a loose (dry and moist), non-sticky to non-plastic (wet) surface soils over soft (dry), firm (moist), slightly sticky to non-plastic (wet) sub surface soils. Soil unit OV/B indicated a soft (dry), very friable (moist), non-sticky to non-plastic (wet) to soft (dry), friable (moist) and slightly sticky to slightly plastic (wet) surface soils over hard (dry), firm to very firm (moist), very sticky to very plastic subsurface soils. Soils of unit OV/C indicated a soft (dry), friable (moist), slightly-sticky to non-plastic (wet) surface soils over hard to very had (dry) firm to very firm (moist), slightly- sticky to plastic (wet) to sub surface soils while Soil unit OV/D was slightly sticky(wet), firm(moist) and slightly hard(dry) at the surface soils and very sticky(wet), firm(moist) and hard(dry) at the sub surface soils. This could be as a result of the clayey nature of the sub soils of OV/C and OV/D. Few fine pores were observed on the surface horizons and few medium and large pores were on the subsoils as water slowly drips from the pores through capillary action because of high water table. Obi (2018) made similar observation in her study of land capability and suitability studies in Okoko Item, Bende LGA, Abia state.

The consistence of soils unit OV/A indicated a loose (dry and moist), non-sticky to non- plastic (wet) surface soils over soft (dry), firm (moist), slightly sticky to non-plastic (wet) sub surface soils. Soil unit OV/B indicated a soft (dry), very friable (moist), non-sticky to non-plastic (wet) to soft (dry), friable (moist) and slightly sticky to slightly plastic (wet) surface soils over hard (dry), firm to very firm (moist), very sticky to very plastic subsurface soils.

Soils of unit OV/C indicated a soft (dry), friable (moist), slightly-sticky to non-plastic (wet) surface soils over hard to very had (dry) firm to very firm (moist), slightly- sticky to plastic (wet) to sub surface soils while soil unit OV/D indicated hard and firm (dry and moist), slightly sticky to slightly plastic (wet) consistence. Nsor *et al.*, (2016) also encountered similar morphological characteristics in soils on a toposequence around Ohiya Autonomous community, south Eastern Nigeria. The horizon boundary in all the pedons studied indicated clear wavy horizons over gradual wavy and clear smooth sub soil horizons.

Table 2: Morphological properties of the soil units

Horizon Designation	Horizon Thickness (cm)	Colour	Mottles	Texture	Consistence Dry	Moist	Wet	Structure	Horizon Boundary
OV/A									
AP	0-18	5YR 4/1; RB	None	SL	l	fr	ns-sp	2mg	cw
AB	18-59	2.5YR 4/4; RB	None	SL	s	fr	ns-p	2mg	gw
B	59-98	10R 4/6; R	None	SL	s	vfr	ns-np	3msbk	gw
BC	98-182	10 R 4/6; R	None	SL	s	f	s-vp	2msbk	
OV/B									
Ap	0-11	2.5YR 2/4; DRB	None	SL	s	vfr	ns-np	2mg	gw
AB	11-53	2.5YR 4/4; RB	None	SL	s	fr	ss-sp	2msbk	gw
B	53-92	2.5YR 4/6; R	None	SL	sh	f	ss-sp	2msbk	gw
Bt1	92- 121	10R 4/6; R	None	SCL	h	f	ss-sp	3msbk	gw
Bt2	121- 180	10R 4/8; R	None	SCL	h	vf	s-vp	2msbk	
OV/C									
Ap	0-12	5YR 4/1; DG	None	SL	l	fr	ss-np	2mg	cw
AB	12-58	10YR 4/4; WR	None	SL	s	fr	ns-sp	2mg	gw
Bt	58-93	2.5YR 4/4; RB	None	SCL	h	f	ss-sp	3msbk	gw
BCg	93-165	10R 4/6; R	2.5YR5/6fff; Bb	SL	vh	vf	vs-p	2msbk	
OV/D									
Apg	0-15	10Y R8/4 (PB)	10 YR 8/6 fff:Y	SCL	sh	fm	ss-sp	2msbk	cw
Btg	15-36	10YR 7/3 (VPB)	10YR 6/3 fmd: PB	SC	h	fm	ss-sp	2msbk	cs
BC	36-85	7.5 YR 5/4 (B)	7.5 YR 5/6 fff; RY	SC	h	fm	ss-sp	2msbk	

key

1. **Colour: RB= Reddish brown, DRB= Dark reddish brown, R= Red, DG= Dark Gray, WR=Weak Red, Bb= Brownish Black, VPB=Very Pale Brown, PB= Pale Brown,**
2. **Mottles: FFF= Few fine faint, Fmd= Few medium distinct.**
3. **Texture: SL= sandy loam, SCL sandy clay loam**
4. **Consistence: s= soft, sh= slightly hard, l= loose, h= hard, vh= very hard, vfr= very friable, fr= friable, f= firm, vh= very firm, ns-sp= non sticky-slightly plastic, ss-p= slightly sticky to plastic, ns-np= non sticky to non-plastic, ss-sp= slightly sticky to slightly plastic**
5. **Structure: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, g= granular, sbk= sub angular blocky, msbk= medium sub angular blocky**
6. **Boundary: gw=gradual wavy, cw = clear wavy, cs= clear smooth**

Physical Characteristics

The physical characteristics of the study area is shown in table 3

The sand content was observed to dominate silt and clay contents. 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 materials as reported by Nwaoba and Lekwa, 2016.

The bulk density values ranged from 1.53gcm^{-3} to 1.57 gcm^{-3}, 1.39gcm^{-3} to 1.53gcm^{-3}, 1.53 gcm^{-3} to 1.60 gcm^{-3} and 1.45 gcm^{-3} for surface soils but 1.78 gcm^{-1}, 1.75 gcm^{-1}, 1.68 gcm^{-1} and 1.67 gcm^{-3} for sub-surface soils of soil units OV/A, OV/B, OV/C and OV/D respectively. The subsurface soils have values very close to 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). Least bulk density values were recorded at the surface soils with corresponding high organic matter revealing the influence of organic matter on soil compaction (Nsor and Okonkwo, 2014).

Table 3: Physical Properties of the Soil Units

pedon	Horizon	Depth (cm)	Sand ←	Silt	Clay % →	TC	Bulk Density gcm^{-3}	Total Porosity %
OV/A (Upper Slope)	AP	0-18	75.20	11.8	13.0	SL	1.53	42.26
	AB	18-59	73.20	12.8	14.0	SL	1.57	40.75
	B	59-98	71.20	12.8	16.0	SL	1.78	32.45
	BC	98-182	71.20	12.8	16.0	SL	1.79	32.83
	Mean		72.70	12.50	14.75		1.66	37.07
OV/B (Middle Slope)	Ap	0-11	75.20	12.80	12.0	SL	1.39	47.54
	AB	11-53	71.20	12.80	16.0	SL	1.53	42.26
	B	53-92	70.20	11.80	18.0	SL	1.71	35.47
	Bt1	92- 121	63.20	11.80	25.0	SCL	1.75	33.96
	Bt2	121- 180	65.20	11.80	23.0	SCL	1.75	33.96
	Mean		69.00	12.20	18.80		1.63	38.64
OV/C (Lower Slope)	Ap	0-12	75.20	13.80	11.0	SL	1.53	42.26
	AB	12-58	70.20	15.80	14.0	SL	1.60	39.62
	Bt	58-93	67.20	12.80	20.0	SCL	1.61	39.24
	BCg	93-165	68.20	14.80	17.0	SL	1.68	36.60
	Mean		70.20	11.53	15.50		1.61	39.43
OV/D (Valley bottom)	Apg	0-15	50.00	26.00	24.00	SCL	1.45	45.28
	Btg	15-36	46.00	16.00	40.00	SC	1.57	40.75
	BC	36-85	44.00	16.00	38.00	SC	1.67	36.98
	Mean		46.60	58.00	34.00		1.56	41.01

Key: TC= Textural Class; SL= Sandy Loam; SCL= Sandy Clay Loam; CL= Clay Loam; SC= Sandy Clay

Chemical Characteristics

The chemical characteristics of the study area are presented in Table 4. The soil pH in the study area ranged from 4.30 – 5.70 averaging 5.45 in soil unit OV/A, 5.60 in OV/B, 5.75 in OV/C and 5.10 in soil unit OV/D. These values were rated strongly to moderately acidic. The acidic nature of the soils may be due to high intensity of rainfall in the area. Enwezor *et al.,* (1990) stated that leaching of Ca and Mg is responsible for development of acidity. The values of total Nitrogen in the study area ranged from 0.02 – 0.11 gkg^{-1}, averaging 0.09 gkg^{-1}, 0.06 gkg^{-1}, 0.07 gkg^{-1} and 0.08 gkg^{-1} for soil units OV/A, OV/B, OV/C and OV/D respectively. The values were rated low to moderately low. 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 contents are high for epipedons and low (<2.0 %) for the subsoils based on organic carbon rating of the South-eastern Nigerian soils by Enwezor *et al.* (1990). This is evidence of organic material incorporation into the soils. In all soil units, the values of organic carbon content decreased with soil depth below the critical level. 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 ECEC (<12.04 cmol kg^{-1}) and low in available P and total N. According to Chikezie *et al.* (2009), the environment of eastern Nigeria is characterized by high temperature and relative humidity conditions that favour rapid decomposition and mineralization of organic matter.

Therefore, organic matter content has to be substantially increased through effective crop residue management. The available phosphorus varied from 5.75 mgkg^{-1} to 12.88 mgkg^{-1}. The values were low to moderately low. 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 exchangeable cations were very low for Na (0.17 – 0.29 cmolkg^{-1}); K was very low to moderate (0.15–
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0.26 cmolkg^{-1}); Mg was low to moderate (0.80 – 2.40 cmolkg^{-1}) and Ca was low (2.60 – 4.80 cmolkg^{-1}) in all the soil units. 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. The exchangeable acidity of the soil units averaged (0.97 cmolkg^{-1}) H^- (0.50 cmolkg^{-1}) Al^{3-} for soil unit OV/A, (0.92 cmolkg^{-1}) H^- and (0.49 cmolkg^{-1}) Al^{3-} for soil unit OV/B, (0.62 cmolkg^{-1}) H^-, (0.48 cmolkg^{-1}) Al^{3-} for soil unit OV/C and (1.16 cmolkg^{-1}) H^- (0.47 cmolkg^{-1}) Al^{3-} for soil unit OV/D

TABLE 4: Chemical Properties of the soil Units

pedon	Horizon	Depth (cm)	pH H$_2$0	pH KCL	Total N (%)	OC (%)	OM (%)	TEA	EA cmol/kg H$^+$	EA cmol/kg Al^{3+}	Avail P. mgkg^{-1}	Exchangeable cation Ca (cmolkg^{-1})	Mg	Na	K	ECEC	BS %
OV/A (Upper Slope)	AP	0-24	5.50	4.60	0.11	1.11	1.91	1.48	0.99	0.49	14.80	3.20	1.80	0.25	0.27	7.00	78.86
	AB	24-53	5.70	4.60	0.10	1.08	1.86	1.38	0.90	0.48	15.30	3.80	1.80	0.26	0.28	7.51	81.62
	B	53-85	5.20	4.30	0.06	0.67	1.15	1.52	1.00	0.52	10.30	2.60	0.80	0.18	0.18	5.28	71.21
	BC	85-150	5.40	4.20	0.06	0.62	1.07	1.52	1.00	0.52	9.80	2.60	0.80	0.16	0.17	5.25	71.05
	MEAN		5.45	4.43	0.09	0.87	1.23	1.48	0.97	0.50	12.55	3.05	0.40	0.21	0.23	6.26	75.69
OV/B (Middle Slope)	Ap	0-11	6.00	5.40	0.12	1.38	2.38	1.28	0.84	0.44	15.80	4.80	2.20	0.28	0.29	8.86	85.55
	AB	11-53	5.80	5.20	0.08	0.88	1.52	1.36	0.90	0.46	15.40	3.80	2.00	0.27	0.28	7.71	82.36
	B	53-92	5.50	4.60	0.05	0.55	0.95	1.44	0.94	0.50	12.60	3.00	1.80	0.20	0.21	6.65	78.34
	Bt1	92- 121	5.30	4.40	0.02	0.23	0.40	1.48	0.96	0.52	10.50	2.80	1.20	0.15	0.18	5.81	74.53
	Bt2	121- 180	5.40	4.10	0.02	0.21	0.36	1.48	0.96	0.52	10.10	2.60	1.00	0.15	0.17	5.40	72.59
	MEAN		5.60	5.93	0.06	0.65	1.12	1.41	0.92	0.49	12.88	3.40	1.64	0.21	0.23	6.89	78.67
OV/C (Lower Slope)	Ap	0-12	5.70	5.20	0.12	1.30	2.24	1.42	0.94	0.48	15.20	4.40	2.10	0.28	0.28	8.48	83.25
	AB	12-58	5.90	5.50	0.11	1.11	1.91	1.32	0.86	0.46	16.30	4.60	2.40	0.29	0.29	8.90	85.16
	Bt	58-93	5.80	5.20	0.05	0.28	0.48	1.36	1.92	0.46	13.60	3.00	1.80	0.21	0.22	6.58	79.33
	BCg	93-165	5.60	4.70	0.03	0.25	0.43	1.52	1.14	0.52	12.40	3.00	1.80	0.17	0.18	6.67	77.21
	MEAN		5.75	5.13	0.07	0.73	1.27	1.41	0.62	0.48	5.75	3.75	2.03	0.95	0.24	7.65	81.24
OV/D (Valley Bottom)	Apg	0-15	5.80	5.30	0.05	1.84	3.17	1.42	1.38	0.40	16.40	5.20	2.00	0.24	0.22	9.09	84.37
	Btg	15-36	5.20	4.10	0.04	0.57	0.98	1.52	1.04	0.48	11.60	3.10	1.40	0.11	0.10	6.24	75.64
	BC	36-85	4.30	3.90	0.04	0.57	0.98	1.60	1.06	0.54	9.20	2.00	0.60	0.06	0.06	4.33	63.04
	Mean		5.10	4.40	0.08	0.99	1.71	1.51	1.16	0.47	12.40	3.43	1.33	0.14	0.13	6.55	74.35

Key

O.C= Organic carbon, O.M= Organic matter, N= Nitrogen, TEA= Total Exchangeable Acidity, EA-= Exchangeable Acidity, P= Phosphorus, ECEC= Effective Cation Exchange Capacity, BS= Base Saturation

TAXONOMIC CLASSIFICATION OF THE SOIL UNITS

The summarized taxonomic classification of the soil units correlated with world Reference Base (WRB) for soil resources is shown in table 5.

Soil unit OV/A (upper slope) was classified as Alfisol because of the presence of argillic horizon and the high base saturation (greater than 50%). 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 Hapludalfs and sub group Typic Hapludalfs because it does not meet any other requirement of udalfs. The world reference Base (WRB) correlation of the soil unit is Dystric luvisols.

Soil unit OV/B (middle slope) was classified as Alfisol because of argillic horizon with base saturation greater than 50%. 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 up to a depth of 50cm of the profile. The world Reference Base for soil resources (WRB) equivalent is Arenic luvisol.

The soils of soil unit OV/C (lower slope) have base saturation more than 50% and possessed kandic and argillic subsurface diagnostic horizons, hence they are placed under the Alfisol soil order (soil survey staff, 2013). Their occurrence under udic soil moisture regime qualify them as udalfs at the sub order level. At the great group level, it was also classified as kandiudalfs because it posseses a kandic horizon and 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 kandiudalfs also because of their possession of sandy particle up to 50% of the soil profile. The world Reference Base for soil Resources (WRB) equivalent is Arenic luvisol.

Soil unit OV/D (Valley bottom) was classified as Alfisol because of the presence of argillic horizon and the high base saturation (greater than 50%). Their occurrence under udic moisture regime qualify them as udalfs.

They have clay distribution in which the percentage of clay did not decrease much from its maximum amount within a depth of 150cm from the mineral soil surface and no fragipan, therefore are classified at the great group level as Paleudalfs. This Paleudalfs have in layers within 75cm of the mineral soil surface, redox depletions, accompanied by redox concentrations (mottles), and aquic conditions for some time in normal years, they are therefore classified at the subgroup level as Aquic Paleudalfs. The WRB equivalent of these soils is Haplic Luvisols.

Table 5: Summarized Classification of Soil units

Soil units	Soil Taxonomy (USDA)	Soil Legend (WRB)
OV/A	Typic Hapludalfs	Dystric Luvisols
OV/B	Arenic Paleudalfs	Arenic Luvisols
OV/C	Arenic Kandiudalfs	Arenic Luvisols
OV/D	Aquic Paleudalfs	Haplic Luvisols

CONCLUSION AND RECOMMENDATIONS

Characterization and classification of soils on a toposequence help to determine the most effective ways of conserving them and the most appropriate land use the soils can be subjected. It also reduces mis-management and degradation by users. Such mismanagement ranges from

conventional tillage along the slope, erosion and fertility depletion. The toposequence studied in Ovim Isiukuato, south Eastern Nigeria revealed that the soils were highly weathered belonging to Alfisols. Also that the properties, agricultural potentials as well as management varied from crest to valley bottom.

The major constraints of the soils were low fertility status and high acidity These constraints varied along the toposequence. The high acidic nature of the area can be reduced by liming. At the valley bottom, pore drainage may affect crop production except for moisture loving crops like swamp rice, sugarcane etc. The crest may have enhanced erosion at the middle slope and subsequent deposition at the valley bottom. This information is needed for proper management and soil amendment practices amidst continuous cropping or usage of the land at the various slopes. Further study of the area is also recommended especially soil landscape microbial type and population so as to give a sound recommendation of biological amendment practices like compost application.

REFERENCES

Adegbite, A.K., Okafor, M.E., Adekiya, A.O., Alori, E.T. and Adebiyi, O.T.V. (2019). Characterization and Classification of Soils of a Toposequence in a Derived Savannah Ecological Zone of Nigeria. The Open Agricultural Journal. Vol.13 pp.44-50

Brady, N.C. and Weil (2002). The Nature and Properties of Soils.13th edition. Pearson Education. India.

Bremner, J. M (1996). Total Nitrogen. In: Sparks, D.L. (Ed.). Methods of Soil Analysis. Part 3. Chemical methods. Book Series 5. *American Society of Agronomy and Soil Science*

Society of America, Madison, Wisconsin, pp. 1085-1121.

Buol, S.W., Hole F.D. and Mecracken R.J (1980). Soil Genesis and classification, 2nd ed: lowa State Univ. Press 40 pp.

Chikezie, A., Eswaran, H., Asawalam, D.O., and Ano, A.O. (2009). Characterization of the benchmark soils of contrasting parent materials in Abia State, South-eastern Nigeria. *Global J. of Pure and Applied Sciences* 16(1) 23-29.

Enwezor, W. O., Udo, E. J., Usoroh, N. J., Ayotede, K. A., Adepetu, J. A., Chude, V. O. and Udegbe C. I. (1990). Fertilizer Use and Management Practices for Crops in Nigeria Series, 2: 63-64.

Esu, I.E, Akpan-Idiok, A. U. and Eyong, M.O. (2008). Characterization and Classification of soils along a typical Hillslope in Afikpo Area of Ebonyi State Nigeria. *Nigerian Journal of Soil Science*, 23(2):217-232.

Ezeaku, P.I., and Iwuanyanwu, F.C. (2013). Degradation rates of soil chemical fertility as influenced by topography in southeastern Nigeria. J Environm Sci. Toxicol Food Technol 6(6): 39-49.

Gee, G.W. and Or, D. (2002). Particle Size Analysis. In: Dane, J.H. And G.C. Top (eds) Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. Am. Book Series No.5. ASA and SSSA Maidson. Wl. pg 255-293.

Grossman, R.B., Ranches, T.G. (2002). Bulk density and linear extensibility. In: Dane, J.H., Topp, G.C. (eds). Methods of soil analysis part 4: Physical methods. Soil Science Society American Book series No. 5, ASA and SSSA, Madison. WI, pp. 201-228.

Igomu I. E and Idoga, S. (2017). Evaluation of soils for cowpea (Vigna Unguiculata) production: A case study of siwes farms of University of Agriculture, Makurdi. *International Journal of plant and soil.* 15 (3): 1-8.

Lekwa, M.U., B.O. Anene and G. Lekwa, (2004) Chemical and morphological soil characteristics in drainage toposequence in southeastern Nigeria. Proceedings of the 28th Annual Conference of the Soil Science Society of Nigeria, November 4-7, 2003, Umudike, Abia State, pp: 316-322.w

Nsor, M.E. and Okonkwo, E.I. (2014). A characterization and Classification of a Toposequence on a Shale-Sandstone Parent Material in Cross River State, Nigeria. *Journal of sustainable Agriculture and Environment.* 15(2):217-231.

Nsor, M.E., Oji, C. H., Nwaoba, O.W and Uzoma, K. C. (2016). Properties, Classification and agricultural potentials of soils on a toposequence around Ohiya Autonomous community, Umuahia, south eastern Nigeria. *Journal of the sci. of Agric., food tech. and the Environ*. 15:42-50.

Nwaoba, O. W and Lekwa, G. (2016) Characterization and Classification of soils of Ndegwu, Owerri West LGA, Imo state, Nigeria. Soil Science Society of Nigeria Conference, Calabar (UNICAL, 2016)

Nwaoba, O.W., Adesemuyi, E.A and Osondu, C.C. (2025). Land Suitability Appraisal for Sweet Potato (*Ipomea batatas*) cultivation on a Toposequence at Ovim Isiukwuato, South East Nigeria. *Taraba Journal of Agricultural Research (TAJAR).* Volume 13 (2) 58-70.

Nwaoba, O.W., Onwuka, O. and Iroha, J.N. (2024). Morphology, Classification and Suitabilbity Evaluation of soils for groundnut cultivation in Owerri south East Nigeria. *Journal of Agripreneurship and sustainable Development (JASD)*. Vol.7(4)2024

Osujieke, N. O. (2017). Characterization and classification of soils of two toposequences formed over different parent materials in Imo state, Nigeria, *International Journal of Agriculture and Rural Development.* Volume 20 (1): 72-84.

Oti, N.N, and Mbe, J.O (2020). Characterization and Management of soils of Amangwu – Edda, Ebonyi State for sustainable rice production. *Nig. Agricultural Journal* Vol. 51(2): 460-470.

Oyekanne, C. F., Akamigbo, F. O., Nnaji, G. U., (2012). Characterization and Classification of soils of Ideato North local government area. *Nigerian Journal of Soil Science* 22 (1): 11-17.

Sharu, M.B., M. Yakubu, S.S. Noma and A.I. Tsafe, (2013). Characterization and classification of soils on an agricultural landscape in dingyadi district, Sokoto State, Nigeria. *Nig. J. Basic Applied Sci*., 21: 137-147.

Surwase, S. A., Singh, S.K., Reddy, G.P.O., Kadu, P.R., Mohekar, D.S., Naitam, K.R., Konde, N.M., Aage, A. B., Desmukh, P.S. (2023). Characterization and classification of soils in a toposequence of the semi-arid Basaltic landscape of Western India. *International Journal of Plant & Soil Science.* Volume 35, Issue 19, Page 876-887. Article no. IJPSS.103882 ISSN: 2320-7035.

Ubuoh, E. A, Onwughara, I. J, Ogbonna, P. C. (2020). Soil Physicochemical characteristics along gulley gradients in the selected humid tropical agro- ecological environments in Abia, South Eastern Nigeria. *Journal of erosion and environ. Degradation*. ISSN: 115- 1943.

Wakene, N. and Heluf, G. (2004). The impact of different land use systems on soil quality of western Ethiopia Alfisols. International Research on Food Security: Natural

Resource Management and Rural Poverty Reduction through Research for Development and Transformation. Deutcher TropentageBerlin 5-7 October 2004. pp. 1-7.