

PEDOLOGICAL CHARACTERIZATION AND CLASSIFICATION OF THE SOILS IN ESAN NORTH EAST LOCAL GOVERNMENT AREA OF EDO STATE, NIGERIA

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ABSTRACT

This study was conducted to characterize the soils in Esan North East Local Government of Edo state, Nigeria. The methodology involved a rigid grid soil survey at a semi-detailed scale, which produced eight (8) mapping units; each mapping unit was represented by a pedon. The pedons were described sampled appropriately, and analysed for some routine properties. Means of pH ranged from 4.49- 6.09; organic carbon ranged from 0.52 gkg⁻¹ - 8.2 gkg⁻¹; Sand fraction ranged from 570 gkg⁻¹ - 808 gkg⁻¹; Silt fraction varied from 17.50 gkg⁻¹ - 134 gkg⁻¹ and Clay fraction had values ranging from 164.00 gkg⁻¹ - 392.00 gkg⁻¹ across the pedons. Pedologically, all the pedons had ochric epipedon; pedons 1,3,4,5,6 and 8 had argillic and kandic endopedons; pedons 2 and 7 had cambic endo-pedons. Results of soil classification revealed that the study area had two soil orders; Alfisols and Inceptisols, using USDA soil taxonomy; and two reference soil groups; Lixisols and Cambisols, using WRB.

Keywords: pedology, characterization, classification, USDA, WRB

INTRODUCTION

Soil is the most basic natural resource that determines the ultimate suitability and sustainability of any agricultural system. Due to the shift of emphasis to precision farming in Nigeria to meet food requirement of a rapidly growing population, investigations on properties of soils has become absolutely necessary. Soil characteristics are intrinsic properties conferred largely by parent materials (insitu or transported) as modified by agents of weathering (Imadojemu *et al.*, 2018). Soil characterization involves the description and recording of observable soil morphological, physical and chemical properties which are often linked to laboratory measurements to aid soil classification (Soil survey staff, 2010).

Complete soil characterization for classification purposes requires that all horizons of a standard soil profile or pedon be analysed; this act has been referred to as pedological soil characterization by some Soil scientists (Ejikeme *et al.*, 2021; Dismas *et al.*, 2019). Pedological characterization requires that apart from

considering the properties of soils in a given area, the pedogenic processes prevalent in a given soil should be observed. Information on such processes aid in proper classification and management of soils.

In recent times, the need for indepth information on the soils of a particular area, especially in developing countries like Nigeria, is continually increasing as most governmental policies are focused more on food security (Okoboh *et al.*, 2016). Such soil information can only be acquired through a systematic study of soil characteristics. Results from such study give a clear understanding of the origin of soils, morphology, classification and spatial distribution of soils of the area in question (Msanya *et al.*, 2003; 2016). Soil characterization information assists researchers and land users in assessing potentials and limitations of soils for different land uses which forms the basis for formulating appropriate management strategies targeted at specific management problems to improve crop production as well as soil and water conservation.

Esan North East Local Government Area is one that has become competitive for Urban development and expanding facilities, although a good portion still depends on farming as their source of livelihood. Variations existing in the properties of soils formed from the different parent materials in this local government have not been studied. Hence land use in this area has been based on mere discretion from local experience. The only solution is to institute rational soil-use that is, to use each soil in a way that best suits its characteristics and programme its management for minimal deterioration. Accurate soil information on Esan North East local government area would assist in taking soil management decisions that will enhance sustainable land use and provide useful information for agricultural enterprise. Thus, a study of this nature would provide necessary information on soil properties which would subsequently aid in allocation of land appropriate uses in the LGA. Therefore, this study was conducted to morphologically describe, characterize some physical and chemical properties, and classify the soils of Esan North East LGA according to internationally acceptable standards.

MATERIALS AND METHODS

Esan North East Local Government Area (LGA) is one of the 18 LGAs in Edo state. It lies within Longitudes 06°15'E and

06°30'E; and Latitudes 06°40'N and 06°55'N. The LGA occupies a land area of about 34,293.1ha (342.93 square kilometers), and is made up of two major towns: Uromi and Uzea. The site is bordered by [Atani](#) by [Ubiaja](#), [Ebhoiyi](#) by [Igueben](#), [Ivue](#) and [Obeidu](#) by [Irrua](#), [Uzea](#) by [Afemai](#), [Amendokhian](#) by [Ugboha](#) with towns in all its surroundings.

The site is located in the Rainforest belt and is characterized by a tropical climate with an annual average rainfall amount of 1540 mm and mean annual temperature of 31°C (Weppa, Farms weather station). The rainy season is from April to October, while the dry season starts in early November and ends by March. The rainfall pattern is bimodal with peaks in July and August. However, there is a short spell in mid August which is accompanied by few thunder storms.

According to the geological map of Nigeria, the soils of Esan North East were formed from three major parent materials: IMSH (clay, shale with lime stone) Imo shale formation of the Eocene tertiary formation; BASH (clay, claystone and shale), mainly from Bende Amaki formation of the EOCENE Tertiary formation; and LSR (Lignite, claystone and clay) from lignite formation of the Oligocene Miocene tertiary formation.

The topography is a terrace with a slope range of 32 - 186 m (in Uzea) and 391 – 460 m (in Uromi).

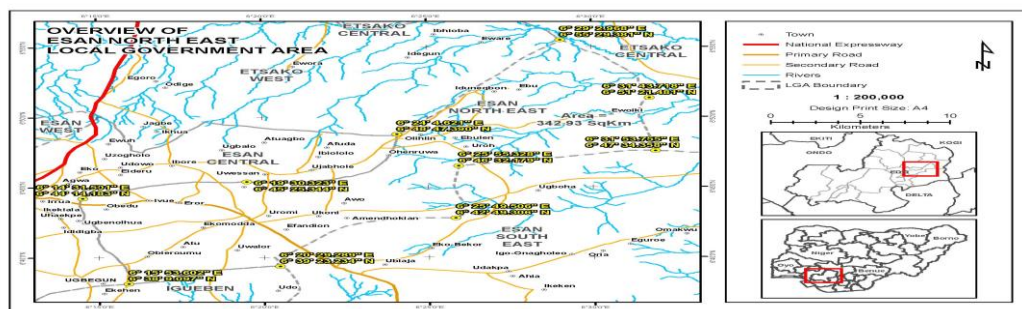


Fig.1: Location map of Esan North East LGA
Source: Edo GIS Office, 2020

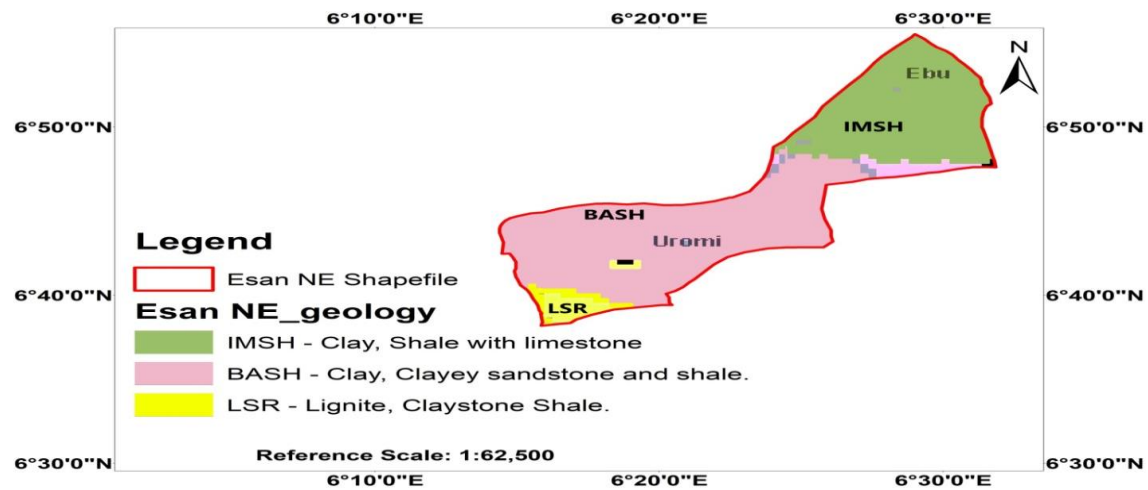


Fig.2: Geological Map of Esan North East LGA. Source: Geological map of Nigeria – an extract

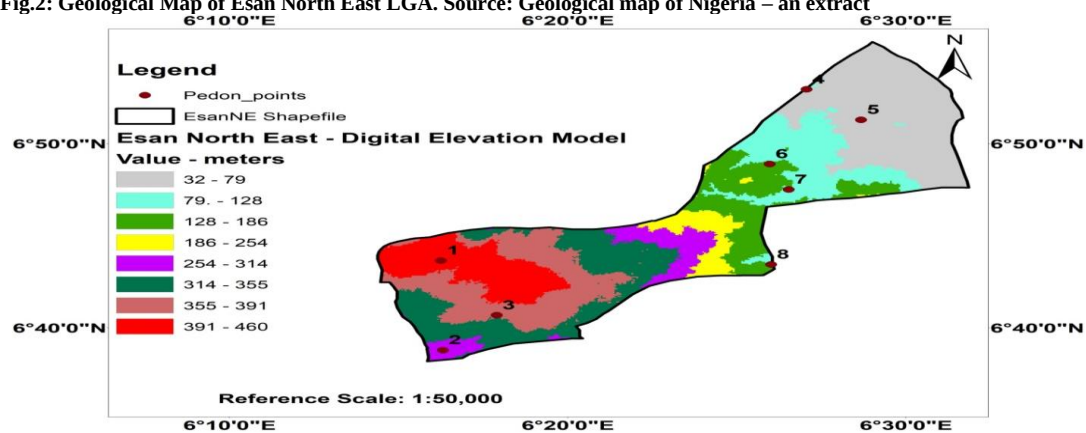


Fig. 3: Digital Elevation Model of Esan North East LGA. Source: Shuttle Radar Topographic Mission (SRTM)

(Bremner, 1996). Exchangeable Acidity was determined by titration method (Anderson and Ingram, 1993). Organic Carbon was determined by wet oxidation method (Page, 1982). Effective Cation Exchange Capacity (ECEC) was obtained by the summation of Exchangeable Bases and Exchangeable Acidity (Tan, 1996). Base Saturation was calculated by dividing the sum of Exchangeable Bases (Na, K, Ca and Mg) by the ECEC and multiplying the quotient by 100.

Statistical Analysis

Descriptive analysis for soil data generated was done using the 8.1 version of Genstat. Variability of soil properties of horizons within pedons was determined using coefficient of variation, which was ranked according to the procedure of Wilding *et al.* (1994), where

CV <15% = Low variation

15% $\geq$ CV $\leq$ 35% = Moderate variation

CV > 35% = High variation

Soil Map

Based on the field and laboratory results, a soil map was produced at a scale of 1: 1,500.

Soil Classification

Based on morphological, physical and chemical properties, the soils of the identified mapping units were classified according to USDA soil taxonomy (Soil Survey Staff, 2014) and World Reference Base for Soil Resources (IUSS, 2015)

RESULTS AND DISCUSSION

Characterization of the soils of Esan North East local government area of Edo state was done on the eight (8) mapping units in the study area. Soil types in the study area are largely influenced by the activities of soil forming factors; among which the dominant ones are topography as expressed in slope, parent material and climate (rainfall and temperature). As shown in table 1, the study area had colours ranging from red to yellowish brown (2.5YR, 5YR, to 7.5YR); variations in soil colour could be associated with drainage, parent material

and environmental factors (such as rainfall, humidity and temperature) (Osujike *et al.*, 2018), though organic matter content may be responsible for the brownish colour of surface horizons in all the pedons (Okunsebor and Umweni, 2021). Textural class for pedons 1, 7 and 8 was light in surface horizons (Sand-Loamy sand) but medium (Sandy loam) in pedons 2,3,4,5 and 6; while that of sub-surface horizons varied from medium to heavy (except for pedons 7 and 8), which suggests a moderate rate of leaching in the study area.

Structure of pedons at surface horizon for most of the pedons was very fine sub-angular blocky except for pedon 8 (single grain crumb) while subsurface horizons for all the pedons had medium sub-angular blocky structure; sub-angular blocky structured soils are prone to erosion. Root abundance for surface horizons was few in pedon 5, many in pedon 7, common in pedons 1 and 3, and ranged from few to many in pedons 2, 4, 6 and 8 while for sub surface horizons, it was few in pedons 2, 3, 4, 6, 7 and 8; ranged from few to common in pedon 1 and nil in pedon 5. Variations in root abundance may be associated with soil type and plant species present in the mapping units.

Sand fraction was highest among particle size fractions with means ranging from 570 gkg⁻¹ - 808 gkg⁻¹ and had variation (11.10 gkg⁻¹ - 29.30 gkg⁻¹) ranging from low (pedons 7 and 8) to medium (pedons 1, 2, 3, 4, 5 and 6) which confirms the heterogeneity of parent material in the study area. Silt fraction had the least values with means ranging from 17.50 gkg⁻¹ - 134 gkg⁻¹ and variation (13.6 gkg⁻¹ - 73.90 gkg⁻¹) ranging from low (pedon 8) – medium (pedons 2, 4 5) – high (pedons 1,3,6 and 7). Ahukaemere *et al.* (2017) opined that low silt fraction could be attributed to high degree of weathering in soils. Clay fraction had means ranging from 164.00 gkg⁻¹ - 392.00 gkg⁻¹ and high variation throughout the study area, which

could be attributed to argilluviation and the fact that the soils are medium textured (Udoh *et al.*, 2008; Ahukaemere *et al.*, 2017). Soil pH varied from extremely acidic to slightly; a condition that is expected in udic moisture regime. It was observed that LSR was most acidic (extremely acid - strongly acid) when compared with IMSH (extremely acid - moderately acid) and BASH (extremely acid – neutral). Coefficient of variation for soil pH ranged from medium in pedon 1 to low in all other pedons; indicating the homogeneity of all the horizons in terms of pH. Organic carbon content was highest in surface horizons and decreased with increase in depth; coefficient of variation ranged from high to medium. Generally, organic carbon was low ($< 4\%$) in all the pedons according to the ratings of FDALR, (1985). Nitrogen values were below the critical limit of 0.15% (FMANR, 1999; Chude, 2011), which indicates nitrogen deficiency. Available Phosphorus was above the critical limit ($< 6, < 5$) in pedon 6 but was below critical limit in pedons 1, 2, 3, 4, 5, 7 and 8 except for surface horizons. Exchangeable bases (Ca, Mg, Na, K) were generally moderate when compared with their critical levels (Ca - 4 cmolkg^{-1} , Mg - 0.5 cmolkg^{-1} , Na and K – 0.2 cmolkg^{-1} (FAO, 1976; Chude *et al.*, 2011) and their coefficients of variation varied from low to high across the pedons; suggesting a high degree of leaching, as evident in the pH of the soils. Exchangeable acidity (H and Al) varied from medium to high across the pedons. The ECEC had variations ranging from low to medium across pedons; and was below the critical level (12 cmolkg^{-1}) regarded to be suitable for crop production (FAO, 1976; Esu, 1991; Ekong and Uduak, 2015).

Tabel 1: Some Morphological Properties of The Study Area

PEDON ID	Horizon Design	Depth(cm)	Colour(moist)	Texture	Roots Abundance	Structure	Boundary form
1	A _p	0-11	2.5YR3/2	Loamy Sand	Very fine common	Very fine Single grain crumb	Smooth-Clear
	Bt	11-30	2.5YR4/6	Sandy clay Loam	Very fine common	Fine Sub-Angular blocky	Smooth-Gradual
	Bth	30-67	2.5YR5/6	Sandy clay	Very fine few	Medium/coarse Sub-Angular blocky	Smooth-Diffuse
	Bt ₂	67-108	2.5YR5/6	Sandy clay	-	Medium/coarse Sub-Angular blocky	Smooth-Diffuse
	Bt ₃	108-144	2.5YR5/8	Sandy clay	-	Medium Sub-Angular blocky	Smooth-Diffuse
	Bt ₄	144-180	2.5YR5/8	Sandy clay	-	Fine Sub-Angular blocky	
2	A _p	0-16	2.5YR3/2	Sandy Loam	Fine many	Very fine Sub-Angular blocky	Smooth-Clear
	AB	16-63	2.5YR4/6	Sandy clay	Medium few/coarse very few	Fine/Medium Sub-Angular blocky	Smooth-Diffuse
	Bw1	63-113	2.5YR4/8	Sandy clay	Coarse very few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bw2	113-176	2.5YR4/8	Sandy clay	Fine very few	Fine Sub-Angular blocky	-
3	A	0-12	2.5YR3/2	Sandy Loam	Medium common	Very Fine Sub-Angular blocky	Smooth-Clear
	BA	12-40	2.5YR4/4	Sandy Loam	Medium common	Very Fine Sub-Angular blocky	Smooth-Diffuse
	Bt1	40-90	2.5YR4/8	Clay	Fine- few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt2h	90-141	2.5YR4/8	Sandy clay	Fine- very few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt3h	141-177	2.5YR4/8	Clay	-	Medium Sub-Angular blocky	-

4	A _p	0-18	7.5YR3/2	Lomy Sand	Fine many	Very Fine Sub-Angular blocky	Smooth-Clear
	A	18-45	5YR4/3	Sand	Medium many	Very Fine Sub-Angular blocky	Smooth-clear
	AB	45-67	5YR4/6	Clay	Medium few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bth	67-105	5YR5/6	Clay	Fine few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bthc	105-145	5YR5/6	Clay	Fine few	Fine Sub-Angular blocky	-
5	Ap	0-10	7.5YR3/2	Sandy Loam	Fine many/Coarse few	Very fine Single grain crumb	Smooth-diffuse
	A	10-21	7.5YR5/4	Sandy Loam	Fine many/Coarse few	Fine Sub-Angular blocky	Smooth-clear
	Bt1hc	21-63	7.5YR5/6	Clay	Very fine-very few	Fine massive granular	Smooth-diffuse
	Bt2c	63-140	7.5YR5/6	Sandy Clay	-	Fine massive granular	-
	Ap	0-24	7.5YR3/2	Loamy Sand	Fine many/Medium coarse	Very Fine Sub-Angular blocky	Smooth-clear
6	A	24-37	7.5YR4/3	Sandy loam	Fine common	Very Fine Sub-Angular blocky	Smooth-clear
	AB	37-68	7.5YR4/6	Loamy Sand	Fine few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt	68-120	2.5YR4/6	Sandy Clay	Fine very few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt2h	120-160	2.5YR4/8	Sandy Clay	-	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt3	160-190	2.5YR5/6	Sandy Clay	-	Fine Sub-Angular blocky	-

7	A _p	0-10	5YR3/2	Loamy Sand	Fine many	Very Fine Sub-Angular blocky	Smooth-Clear
	A	10-32	2.5YR4/4	Sandy Loam	Fine many	Very Fine Sub-Angular blocky	Smooth-Diffuse
	Bw ₁	32-80	2.5YR4/6	Sandy Clay Loam	Fine few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bw ₂	80-137	2.5YR4/6	Sandy Clay Loam	Medium few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bw _{3h}	137-192	2.5YR4/6	Sandy Clay Loam		Fine Sub-Angular blocky	
8	A _p	0-17	5YR3/3	Sand	Medium many	Very fine Single grain crumb	Smooth-Clear
	A	17-48	5YR5/6	Sand/Loamy Sand	Medium common/fine many	Very fine Single grain crumb /Fine Sub-Angular blocky	Smooth-Diffuse
	AB	48-98	5YR6/6	Loamy Sand	Fine few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt	98-133	5YR6/6	Sandy clay loam	Fine few	Fine Sub-Angular blocky	Smooth-Diffuse
	Bth	133-182	5YR6/6	Sandy clay loam	Very Fine few	Fine Sub-Angular blocky	-

TABLE 2: Some Physical and Chemical Properties of the Study Area

PEDON ID	Horizon Depth (cm)	Horizon ID	pH H ₂ O	EC μS/cm	Org. C	O.M	N	Av. P	Ca	Mg	Na	K	Al	H	ECE C (Soil)	CEC	ECEC (CLAY)	BS(%)	Sand	Silt	Clay	Textural Class
<div><div>← gkg⁻¹ →</div><div>mgkg⁻¹</div><div>← cmolk⁻¹ →</div><div>← gkg⁻¹ →</div></div>																						
1	0-11	Ap	4.75	13.00	12.30	21.10	2.97	13.26	4.14	1.03	0.67	0.16	0.00	0.80	6.46	10.72	49.69	88.19	840.00	30.00	130.00	LS
	11-30	Bt1	6.06	10.00	4.90	8.40	1.20	4.45	3.65	0.96	0.70	0.22	0.00	0.60	6.13	18.14	23.57	89.76	690.00	50.00	260.00	SC L

2	30-67	Bt2h	4.34	05.00	5.90	10.10	1.40	4.31	4.17	0.93	0.70	0.14	0.00	0.80	6.74	26.54	13.76	88.19	500.00	10.00	490.00	SC
	67-108	Bt3	4.86	04.00	4.10	7.10	1.00	2.03	3.04	0.89	0.61	0.14	0.00	1.20	5.88	25.40	11.76	79.52	490.00	10.00	500.00	SC
	108-144	Bt4	4.38	05.00	2.30	3.90	0.60	4.84	2.84	0.90	0.63	0.13	0.00	0.80	5.30	25.28	10.82	84.92	490.00	20.00	490.00	SC
	144-180	Bt5	6.60	02.00	1.60	2.80	0.40	4.60	2.53	0.90	0.65	0.22	0.00	0.80	5.10	24.56	10.63	84.34	510.00	10.00	480.00	SC
		Mean	5.16	6.5.00	0.52	1.18	0.13	5.56	3.40	0.94	0.66	0.17	0.00	0.83	7.010	21.80	20.50	85.80	587.00	21.70	392.00	
		Cv	18.2	63.60	74.00	80.40	72.6	69.80	20.40	5.70	0.56	24.50	23.00	23.60	10.80	28.20	79.90	4.30	24.90	73.90	40.30	
		Ranking	MV	HV	HV	HV	HV	HV	MV	LV	LV	LV	MV	MV	LV	MV	HV	LV	MV	HV	HV	
			06.64651°N, 006.27185°E; 294 m ASL																			
	0-16	Ap	4.76	19.00	3.20	5.50	0.08	12.87	7.67	1.04	0.69	0.19	0.00	0.80	10.39	9.60	59.06	92.30	810.00	20.00	170.00	SL
	16-63	AB	4.44	8.00	5.90	10.15	0.14	2.42	4.84	0.96	0.67	0.16	0.00	0.60	7.23	22.52	17.68	91.77	570.00	20.00	410.00	SC
	63-113	Bw1	4.15	8.00	3.20	5.50	0.09	2.73	4.04	0.89	0.82	0.56	0.00	0.40	6.71	27.10	13.69	94.35	470.00	10.00	520.00	SC
	113-176	Bw2	4.62	7.00	3.00	5.20	0.73	2.96	2.38	0.86	0.87	0.54	0.00	0.60	5.25	21.54	56.72	88.59	570.00	20.00	410.00	SC
		Mean	4.49	10.50	0.38	0.66	0.26	5.20	4.7	0.94	0.76	0.36	0.00	0.60	7.40	20.20	37.00	92.60			378.00	
		Cv	5.90	54.20	36.20	35.80	120.90	97.00	46.70	8.40	12.80	59.90	27.20	27.20	29.20	37.00	66.40	3.30	605.00	17.50	39.10	
		Ranking	LV	HV	HV	HV	HV	HV	HV	LV	LV	HV	MV	MV	MV	HV	HV	LV	23.90	28.60	0	
3			06.67810°N , 006.29832°E; 359 m ASL																			
	0-12	A	4.85	28.00	9.20	15.82	0.22	23.23	4.25	1.01	0.74	0.18	0.00	1.0	7.18	12.16	39.94	86.13	780	40	180	SL
	12-40	BA	4.04	6.00	0.90	1.53	0.02	4.99	2.62	0.76	0.67	0.14	0.00	2.6	6.79	9.80	41.00	53.81	800	10	190	SL
	40-90	Bt1	4.68	6.00	2.30	3.95	0.06	3.12	2.68	0.76	0.69	0.16	0.00	2.6	7.90	27.30	14.91	54.38	450	20	530	C
	90-141	Bt2h	4.52	5.00	5.10	8.77	0.12	3.43	2.87	0.81	0.79	0.21	0.00	2.2	6.88	26.26	16.06	59.37	470	40	490	SC
	141-177	Bt3h	4.90	5.00	9.00	15.48	0.22	2.96	2.65	0.77	0.70	0.22	0.00	0.4	4.74	29.60	8.92	91.63	450	20	530	C
		Mean	4.60	10.00	2.10	3.70	0.13	7.60	3.01	0.82	0.62	0.28	0.00	1.76	6.70	21.00	24.20	69.10	590.00	26.00	384.00	
4		CV	7.50	100.70	178.70	178.50	71.30	116.90	23.20	13.00	36.90	85.40	23.00	57.00	17.60	44.20	62.60	26.50	31.00	51.60	47.50	
		Ranking	LV	HV	HV	HV	HV	HV	MV	LV	HV	HV	LV	HV	MV	HV	HV	MV	MV	HV	HV	
			06.88249°N, 006.45096°E; 74 m ASL																			
	0-18	Ap	5.24	13.00	3.20	5.50	0.09	13.34	4.46	0.92	0.77	0.21	0.00	0.40	6.75	6.60	61.36	94.12	730	160	110	SL
	18-45	A	4.63	16.00	2.40	4.13	0.06	4.37	3.63	0.93	0.80	0.25	0.00	0.40	6.01	8.82	37.56	93.41	710	130	160	SL

5	45-67	AB	4.16	5.00	3.40	5.85	0.08	3.74	3.71	1.01	0.70	0.18	0.00	1.14	6.80	7.66	20.61	82.37	530	140	330	SL
	67-105	Bth	4.47	7.00	5.20	8.94	0.13	2.81	3.49	0.91	0.69	0.18	0.00	0.6	5.87	22.28	14.32	53.37	430	160	410	L
	105-145	Bthc	4.40	4.00	1.73	2.98	0.42	1.87	3.79	0.90	0.74	0.17	0.00	0.4	5.60	26.96	14.31	93.38	450	130	420	C
		Mean	4.58	9.00	1.19	5.50	0.16	5.20	3.82	0.93	0.20	0.74	0.00	0.59	6.21	14.50	29.60	83.30	570.00	134.00	286.00	
		CV	8.90	58.30	41.00	41.00	96.00	88.70	9.90	4.70	16.50	6.30	54.5	54.50	8.70	65.30	67.90	20.90	24.90	13.60	50.10	
		Ranking	LV	HV	HV	HV	HV	HV	LV	LV	MV	LV	HV	HV	LV	HV	HV	MV	MV	LV	HV	
	06.85489°N, 006.47786°E; 60 m ASL																					
	0-10	Ap	5.53	28.00	13.1	22.50	0.32	105.85	9.01	1.06	0.70	0.21	0.00	0.60	11.58	13.00	68.12	94.78	760	70	170	SL
	10-21	A	4.53	9.00	5.80	9.90	0.76	10.14	3.89	0.95	0.78	0.36	0.00	0.40	6.37	9.66	37.47	93.77	740	90	170	SL
	21-63	Bt1hc	4.83	12.00	8.60	14.80	0.21	8.58	4.18	1.02	0.77	0.25	1.40	0.60	10.22	28.96	19.65	60.38	420	60	520	C
6	63-140	Bt2c	5.07	4.00	5.40	9.30	0.13	4.52	4.54	1.04	0.79	0.83	0.00	0.40	7.15	20.86	18.82	94.42	510	110	380	SC
		Mean	4.99	13.20	8.20	14.10	0.35	32.0	5.40	1.01	0.41	0.76	0.35	0.50	8.80	18.10	36.00	85.80	608.00	82.00	310.00	
		CV	8.70	78.30	43.10	43.20	79.20	152.20	44.70	4.70	69.20	5.40	200.00	23.10	28.00	47.60	64.00	19.80	27.80	26.90	55.30	
		Ranking	LV	HV	HV	HV	HV	HV	HV	LV	HV	LV	HV	HV	MV	HV	HV	MV	MV	MV	HV	
	06.81487°N, 006.43285°E; 148 m ASL																					
	0-24	Ap	6.08	3.00	2.40	4.10	0.06	57.25	7.36	1.00	0.70	0.19	0.00	0.60	9.85	8.32	65.87	93.88	830	20	150	SL
	24-37	A	5.92	7.00	1.40	2.40	0.01	17.47	3.82	0.84	0.73	0.22	0.00	0.60	6.21	4.98	69.00	90.34	870	40	90	LS
	37-68	AB	5.42	13.00	2.30	3.90	0.06	9.20	3.23	0.82	0.78	0.34	0.00	0.4	5.57	7.28	42.87	92.80	830	40	130	SL
	68-120	Bt1	5.07	13.00	1.10	1.90	0.03	13.49	3.35	0.84	0.71	0.21	0.00	0.4	5.51	20.88	13.44	92.70	570	20	410	SC
	120-160	Bt2h	5.40	5.00	2.40	4.10	0.06	11.06	3.68	0.83	0.70	0.15	1.40	0.60	5.96	20.32	15.28	89.97	590	20	390	SC
7	160-190	Bt3	5.24	5.00	1.40	2.40	0.03	5.54	3.97	0.86	0.78	0.19	0.00	0.40	6.00	26.32	11.76	93.35	470	20	510	SC
		Mean	5.52	7.70	1.83	3.13	0.04	19.00	4.24	0.87	0.22	0.73	0.23	0.50	6.52	14.70	36.00	92.70	740.00	26.70	280.00	
		CV	7.10	56.40	32.50	32.10	51.30	100.80	36.70	7.80	30.00	5.20	244.90	21.90	25.40	60.50	73.30	1.80	22.70	38.70	63.40	
		Ranking	LV	HV	MV	MV	HV	HV	HV	LV	MV	LV	HV	MV	MV	HV	HV	LV	MV	HV	HV	
	06.79178°N, 006.44225°E; 112 m ASL																					
	0-10	Ap	6.18	39.00	4.7	8.10	0.11	17.94	7.73	1.01	0.75	0.19	0.00	0.40	10.08	7.12	91.64	95.99	830.00	60.00	110.00	LS
	10-32	A	6.07	18.00	2.70	4.60	0.06	6.01	4.26	0.90	0.69	0.16	0.00	0.60	6.61	10.42	37.79	90.97	770.00	40.00	190.00	SL
	32-80	Bw1	5.99	6.00	0.20	0.30	0.02	3.04	4.73	0.91	0.79	0.41	0.00	0.40	7.23	13.56	26.78	94.51	720.00	10.00	270.00	SC
																					L	

	80-137	Bw2	6.10	5.00	0.60	1.00	0.01	2.03	4.89	0.90	0.70	0.17	0.00	0.40	7.06	16.70	21.39	94.28	650.00	20.00	330.00	SC L
		Mean	6.09	15.00	3.40	5.90	0.08	6.50	5.22	0.93	0.25	0.74	0.00	0.40	7.50	13.50	40.00	94.60	722.00	32.00	246.00	
		CV	1.10	96.00	103.90	104.60	101.90	100.00	27.20	5.1	44.40	6.10	35.40	35.40	19.10	36.60	75.50	2.40	11.10	60.10	38.70	
		Ranking	LV	HV	HV	HV	HV	HV	MV	LV	HV	LV	MV	MV	MV	HV	HV	LV	LV	HV	HV	
8	0-10	Ap	5.95	18.00	06.72400°N, 006.43356°E; 132 m ASL					8.90	15.30	0.22	25.97	4.75	0.96	0.67	0.17	0.00	0.40	6.94	8.06	69.4
	10-32	A	5.45	7.00	3.20	5.50	0.08	5.77	3.61	0.82	0.65	0.16	0.00	0.60	5.84	8.60	38.93	89.78	870.00	30.00	50.00	S
	32-80	AB	5.31	5.00	1.10	1.90	0.03	6.01	3.32	0.79	0.66	0.13	0.00	1.20	6.09	10.50	29.00	80.33	850.00	40.00	100.00	LS
	80-137	Bt	5.15	2.00	0.70	1.20	0.02	5.54	3.19	0.76	0.69	0.16	0.00	1.80	6.60	15.24	22.00	72.74	690.00	10.00	300.00	SC L
	137-182	Bth	5.30	2.00	15.90	27.30	0.39	5.30	3.07	0.77	0.69	0.14	0.00	2.00	7.68	18.96	28.44	60.85	710.00	20.00	270.00	SC L
		Mean	5.43	6.80	6.00	10.20	0.15	9.70	3.59	0.82	0.15	0.67	0.00	1.20	6.63	12.30	37.60	79.60	808.00	26.00	164.00	
		CV	5.70	97.20	108.20	108.10	106.10	93.50	19.00	9.90	10.80	2.70	58.90	58.90	11.00	38.20	50.10	16.80	12.60	43.90	68.80	
		Ranking	LV	HV	HV	HV	HV	HV	MV	LV	LV	LV	HV	HV	LV	HV	HV	MV	LV	LV	HV	

Soil Classification

The soils were classified pedologically, according to USDA soil taxonomy (Soil Survey Staff, 2014) and WRB (IUSS, 2015).

Pedologically, all the pedons had an ochric epipedon, as suggested by the light colour and thickness of their surface horizon. Clay movement and accumulation was clearly demonstrated by particle size data of pedons 1, 3, 4, 5, 6 and 8; this suggests the presence of clay coatings in their horizons and signifies the presence of an argillic or a kandic horizon. Argillic and kandic horizons were established in the pedons (pedons 1,3,4,5,6 and 8) because they met the following requirements: coarser surface textured horizons over vertically continuous subsurface horizons; ECEC(CLAY) value of 12 cmol^{-1} clay or more in surface horizons and ECEC(CLAY) value less than 12 cmol^{-1} clay or more in subsurface horizons; an Organic matter content that decreased regularly down the profile and clay content increase with depth (an indication of clay illuviation) (Soil Survey Staff, 2014); these in addition to the requirement of a base saturation (by sum of cations) greater than 35% at the appropriate depth qualified the pedons as Alfisols at Order level. They qualified as Udalf at suborder level because of the presence of a deep soil moisture control depth that is not dry for 90 consecutive days (Udic moisture regime). The pedons were classified as Kandiodalfs at Great Group level because they satisfied the conditions of no lithic, paralithic or petroferic contact within 150 cm of the mineral soil surface and have an ECEC (CLAY) value less than 12 cmol^{-1} clay in their kandic horizons. This is in line with the findings of Imadojemu *et al.* (2018) who established the presence of an udic moisture regime and a Kandic endopedon in the soils of Edo state. At subgroup level, pedon 1 was classified as Rhodic Kandiodalf, because it has, throughout the profile a hue of 2.5YR and a colour value

of 3; this is in agreement with findings of Okusami *et al.* (1997). This corresponded to Rhodic Nudiargic Lixisols (Nitric, Vertic) in WRB (IUSS, 2015). Pedon 3 qualified as Typic kandiodalfs because it had properties that were central to the Great group (Kandiodalfs), which correlated with Rhodic Lixisols (Differentic, Nitric) in WRB. Pedon 4 was classified as Plinthic Kandiodalfs because it had 5 percent or more (by volume) plinthite in one horizon within 150 cm of the mineral soil surface; this corresponded to Nudiargic Skeletic Lixisols (Vertic) in WRB. Pedon 5 was classified as Plinthic Kandiodalf because of the presence of redox depletion within 75 cm; and more than 5% by volume of plinthite in two horizons within 150cm of the mineral soil. It correlated with Skeletic Lixisols (Loamic) in WRB. Pedon 6 qualified as Grossarenic Kandiodalfs because it had a textural class (fine-earth fraction) of loamy fine sand and sandy loam throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 100 cm or more; It (pedon 6) qualified as Nudiargic Lixisols (Arenic) in WRB. Pedon 8 was classified as Arenic Kandiodalfs due to the presence of a textural class (fine-earth fraction) of sand and loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm; it correlated with Rhodic Lixisols Arenic in WRB.

Pedons 2 and 7 qualified as the order Inceptisols because of the presence of a Cambic B horizon (Soil Survey Staff, 2014). This confirms the findings of Okunsebor and Umweni (2021), who classified similar soil order in soils of Edo state. They qualified as Udepts at sub order level because of the presence of an Udic moisture regime (the predominant moisture regime for soils of humid climate). They qualified as Eutrudepts at the great group level because they have a base saturation (by NH_4OAc) of 60% or more in one or more horizons at a depth

between 25 and 75 cm from the mineral soil surface. At sub group level, pedon 2 qualified as Ruptic-Alfic Eutrudepts because it had a Cambic B horizon that include 10 – 50% (by volume) illuvial part that otherwise meet the requirements for an argillic or Kandic horizon; the pedon was classified as Eutric, Rhodic Cambisols (Loamic) in WRB. Pedon 7 qualified as Typic Eutrudept because it had properties central to the great group (Eutrudepts) and correlated with Rhodic Eutric Cambisols (Arenic). This agrees with the findings of Agbogun (2021), who classified similar soils in Edo state.

Table 3: Summary of Classification for all the Pedons

Pedon	USDA	WRB	Area Coverage (Ha)	Percentage (%)
1	Rhodic Kandiuudalf,	Rhodic Nudiargic Lixisols (Nitric, Vetic)	3,795.40	11.09
2	Ruptic-Alfic Eutrudepts	Eutric, Rhodic Cambisols (Loamic)	1,928.96	5.64
3	Typic kandiuudalfs	Rhodic Lixisols (Differentic, Nitic)	10,170.91	29.72
4	Plinthic Kandiuudalfs	Nudiargic Skeletic Lixisols (Vertic)	4,590.31	13.41
5	Plinthaquic Kandiuudalf	Skeletic Lixisols (Loamic)	2,574.02	7.52
6	Grossarenic Kandiuudalfs	Nudiargic Lixisols (Arenic)	3,695.07	10.80
7	Typic Eutrudept	Rhodic Eutric Cambisols (Arenic)	5,919	17.29
8	Arenic Kandiuudalfs	Rhodic Lixisols Arenic	1,547.12	4.52

USDA and WRB systems of soil taxonomy established the presence of argillic (argic in WRB), Kandic and Cambic endo-pedons in the respective pedons described in the study area. This relationship between both systems of classification is an indication that even though their criteria for placing soils in a particular category are not similar; for instance, the soil Reference soil group in WRB is equivalent to the Great-group category in USDA soil taxonomy, their final classification reveal same information about the soil properties.

CONCLUSION

This study showed that there are two soil orders; Alfisols (77.06% of the study area) and Inceptisols (22.93% of the study area) according to USDA soil taxonomy, and two reference soil groups; Lixisols (77.06% of the study area) and Cambisols (22.93% of the study area) in Esan North East Local area.

Morphologically, all the pedons had an ochric epipedon; pedons 1, 3, 4, 5, 6 and had both argillic and kandic endopedons, while pedons 2 and 7 had a cambic endopedon. Statistical data revealed that means of Sand fraction ranged from 570 gkg⁻¹ - 808 gkg⁻¹ ; Silt fraction ranged from 17.50 gkg⁻¹ - 134 gkg⁻¹ and Clay fraction ranged from 164.00 gkg⁻¹ - 392.00 gkg⁻¹ across the pedons; an indication of active argilluviation in the study area. Even though USDA soil taxonomy and WRB systems of soil classification do not consider similar criteria in their taxonomic procedure, application of both taxonomic systems would provide balanced soil information for a study of this nature on tropical soils. However, due to limitation in availability of weather data especially in remote areas of third world countries like Nigeria, the WRB system of soil taxonomy would be preferred.

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