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CHARACTERIZATION AND CLASSIFICATION OF SOILS ALONG A TOPOSEQUENCE IN AN AGRICULTURAL EXTENSION VILLAGE IN NIGERIA

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Abstract: Characterization and classification of soils is necessary for deep understanding of soil properties and better decision making on soil resources. It is in this vein that the soils of Federal University Oye-Ekiti Extension Village were characterized and classified. Soil profile pits were dug, described, and sampled at the upper, middle, and lower slopes (pedons 1 to 4). The soils are medium to very deep (90-170cm). The dominant hue is 7.5YR. The texture is loamy sand at the surface, sandy loam, and sandy clay loam at subsurface of pedons 1 and 2, sand, loamy sand, and sandy loam at pedons 3 and 4. The soil pH is slightly acidic, and the soils were low in total nitrogen (0.10 to 0.17% at the surface) and cation exchange capacity (1.34 to 2.65cmolkg^{-1}). Pedon 1 is Arenic Hapludalfs/Chromic Differentic Lixisols, pedon 2 is Psammentric Hapludalfs/Haplic Arenic Lixisols, pedon 3 is AquicUdipsamments/Chromic Novic Arenosols and pedon 4 as Oxyaquic Udipsamments/Chromic Novic Arenosols. Good management practices to improve the capability of the soils for crops are recommended.

Keywords: characterization, soil, taxonomy, classification, sandy.

INTRODUCTION

The properties of soils are a reflection of factors of soil formation, the influence of these factors on soil is distinct but has interdependent effects on soil, and the combine effect of all factors of soil formation gives rise to distinct soil types. The knowledge of soil properties is very useful in determining soil characteristics, classification, quality, and productivity (Bamikole *et al.*, 2020). Proper soil resource management for food security and a sustainable environment is quite appropriate and deserves great attention considering the rapidly increasing pressure on our soil due largely to population increase and intensive agricultural production. Nuga *et al*. (2006) stated that farmers are beginning to crop on marginal lands including farming on slopes in many tropical countries.

Characterization and classification of soils is a very important task that is necessary for an in-depth understanding of soil properties and better decision making on soil resources. Soils in most landscapes form the foundation for many ecological processes such as biogeochemical cycling, the distribution of plant communities, and, ultimately, the location of human activities. Soils are usually characterized using relevant physical, chemical, and morphological properties inherent in them (Idoga *et al.*, 2005).

An increase in pressure, on the agricultural sector as a result of a higher population that requires more production of food (food security) on a very small acre or hectare of land, constitutes a serious problem in the agricultural sector, therefore an increasing demand for information on soils as a means to produce food is required (Fasina *et al*., 2007). As it is well known planting of crops is basically done in rural areas, where by efficiency of the production must be high to increase profit when correlated with the inflow and outflow of money in the production, whereby, low capital to high income was pronounced.

The low knowledge of the information of the soils in terms of classification and characterization will lead to poor decisions on land utilization and management which could cause very low production per unit area of land used for cropping. Local farmers need to surpass the stage of farming by trial and error by knowing the characteristics, potentials, and limitations of a land in other to get maximum productivity and efficiency from such land. Therefore this study is to contribute to information on soils of the study area to farmers and other soil workers. The objectives of this study are to evaluate the morphological and physico-chemical properties and classify the soils of Federal University Oye-Ekiti, Extension village, Itapaji-Ekiti, Nigeria.

MATERIALS AND METHODS

Description of the study area

The research was conducted at the Federal University Oye-Ekiti Extension village, Itapaji, near Iyemero-Itapaji dam, Ekiti State, Nigeria. It lies on a Latitude of N 7°57'39.27924" and a Longitude of E 5°28'16.00896" with an Altitude of 443 m above sea level (MSL). The area is of dry upland tropical rainforest type with distinct wet and dry seasons. The dry season comes up between November and March while the wet season prevails between April and October. The annual rainfall is 1,375mm/annum. The average annual temperature is 29.8°C and the average relative humidity of 88% (WeatherBase, 2021). The

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location consists of the upper, middle, and lower slopes and is bounded by a river. Part of the area is under fallow while some parts are cultivated by tenant farmers. Crops cultivated include yam, rice, cassava, leafy and fruit vegetables. The area belongs to the basement complex geology of Nigeria.

Soil sampling

A reconnaissance visit was carried out before the commencement of field operations and four topographic positions were identified. The soil profile was dug within the representative portions of each position. The positions were geo-referenced with a Garmin GPS device, after which a description of each soil profile was done in situ according to the guidelines of soil description (FAO, 2006). The color, structure, consistency, mottles, drainage, and horizon boundary were determined on the field. Soil samples were collected from all the horizons in each of the soil profiles, packaged, and labeled for laboratory analysis.

Laboratory Methods

The samples collected from each soil profile were air-dried and then gently crushed by using a mortar and pestle which will later sieved through a 2mm mesh. The sieved samples were used for the analysis of the following physicochemical properties: particle size distribution by Gavlack *et al.* (2005), soil pH by Sumner and Miller (1996), organic carbon using the Walkley-Black method as described by Nelson and Summers (1982), organic matter calculated by Kiflu and Beyene (2013), total nitrogen determined by using Kjeldahl method Bremner (1996), available phosphorus by Bray's method (Kuo, 1996), exchangeable cations (K, Na, Ca, and Mg) and exchangeable acidity by Thomas (1982), effective cation exchange capacity (ECEC), cation exchange capacity and percentage base saturation by IITA (1979), and micronutrients (iron, copper, zinc and copper) by the methods of Agbenin (1995).

Statistical analysis

Analysis of variance was used to evaluate variation between the soil pedons. The Pedons were considered as treatments and the horizons as the replicate, where significant differences were observed, and the means were separated with the Duncan Multiple Range Test. The statistical analyses were carried out at a 95% confidence level with Statistix version 21 statistical packages.

Soil classification

The pedons were classified with the USDA soil taxonomy and FAO/UNESCO world reference base for soil resources.

Land capability classification

The land capability classification ratings were obtained by matching the land capability system of Klingebiel and Montgomery (1961) and USDA (2017) with climatic data and soil characteristics of the pedons.

RESULTS AND DISCUSSION

Soil morphological properties

The morphological properties of soils at different pedons are presented in Table 1. The soil depth is from 90 to 170cm; they are medium to very deep soils. The shallowest is Pedon 2, which is restricted by a hardpan at 90cm. Generally, there will be no restriction to the rooting activities of most crops in the soils. The relationship between soil depth and rooting activity has been established by Odunze (2006) and Senjobi and Ogunkunle (2011). The dominant color is 7.5YR in most of the pedons, 5YR, and 2.5YR in some other parts of the surface and subsurface horizons of the pedons. The brown color at the surface soils indicates braunification while yellowish red to red colors at the subsoils indicate the presence and accumulation of iron in the soils. This result is in agreement with the findings of Babalola *et al.* (2021) in soils developed on granitic parent rock in Ekiti State.

The pedons are dominated by crumbs structure; this can be attributed to the sandy nature of the soil and crop cultivation activities (Orimoloye *et al.*, 2019). Pedons 1 and 3 had a sub-angular blocky structure at the subsurface horizon; this could be attributed to the increase in clay content of the pedons. In terms of consistency, the soils are non-sticky and non-plastic at the surface in pedons 1 to 3, and slightly sticky and non-plastic in pedon 4, this could also be a result of the sandy nature of the pedon. However, the consistency indicated that it will be easy to till the soils of the location.

There are roots in the surface horizon and most of the sub-surface horizons. There is no restriction to root penetration in the soils. Concretions are present in pedons 3 and 4 some of the pedons indicated accumulation and aggregations of iron and manganese oxides resulting in plinthization. There are erosion channels at the upper slope this could be due to the exposure of the area to cultivation activities and removal of vegetation than the other parts (Nur *et al.*, 2020) and topographic position which can encourage run-off.

Soil physicochemical properties

The results of the physicochemical properties of the pedons studied are presented in Tables 2, 3, and 4. Generally, the texture of the surface soil is Loamy sand, while the sub-surface horizons were sandy loam and sandy clay loam at pedons 1 and 2 and sand, loamy sand, and sandy loam at pedons 3 and 4.

Table 1.

Soil morphological properties of the pedons

Horizon Designation	Depth (cm)	Color (Moist)	Mottles	Drainage	Slope (%)	Structure	Consistency Wet	Consistency Moist	Texture	Concretion	Root	Boundary	Other features
A	0-20	7.5YR 2.5/2	absent	good	0 – 2	2,F, Cr	Fr	ns-np	S	absent	cc	a, s	Erosional channels
Bt_1	20-45	7.5YR 4/3	absent	good		1,C, Cr	L	ns-np	LS	absent	cm	g, w	-
Bt_2	45-85	5YR 4/4	absent	good		2,C. Sbk	Fr	ss-sp	SL	absent	cf	a, s	-
C	85-120	7.5YR 5/4	absent	good		3,M, Sbk	Fm	ss-sp	SL	absent	-	-	-
A	0-30	2.5YR 3/1	absent	good	0 – 2	1,F, Cr	Fr	ns-np	S	absent	cm	c, w	-
Bt_1	30-50	7.5YR 4/3	absent	good		1,F, Cr	Fr	ss-sp	LS	absent	cf	d, w	-
Bt_2	50-90	7.5YR 4/4	absent	good		2,F, Cr	Fm	ss-sp	LS	absent	ff	-	Hardpan
A_1	0-26	7.5YR 3/2	absent	good	0 – 2	1,F, Cr	Fr	ns-np	LS	absent	cc	c, s	-
A_2	26-35	2.5YR 4/1	absent	good		1,F, Cr	Fr	ns-np	LS	absent	cm	c, s	-
Bt_1	35-63	7.5YR 6/2	absent	good		1,F, Sbk	L	ns-np	LS	few	cf	c, s	-
Bt_2	63-90	7.5YR 7/1	absent	poor		2,M, Cr	Fm	ss-np	SCL	abundant	ff	c, s	-
C	90-170	7.5YR 6/2	absent	poor		2,M, Cr	Fm	ss-np	SCL	abundant	-	-	-
A	0-20	5YR 3/1	absent	good	0-2	2,F, Cr	Fr	ss-np	LS	absent	cc	c, s	-
Bt_1	20-34	7.5YR 3/2	absent	good		1,F, Cr	Fr	ss-np	LS	absent	cm	a, s	-
Bt_2	34-55	7.5YR 4/2	absent	poor		1,C, Cr	Fr	ss-sp	SL	few	ff	c, w	-
C	55-160	7.5YR 6/3	absent	poor		2,M, Cr	Fr	ss-sp	SL	Abundant	None	-	-

Structure: 1 = Weak, 2 = Moderate, 3 = Strong, M = Medium, C = Coarse, F = Fine, Cr = Crumb, Sbk = Sub-angular blocky, G= granular
Consistency: s = soft, l = loose, sh = slightly hard, h = hard, vh = very hard, fr = friable, fm= firm, vfm = very firm, ns-np = non-sticky-non plastic, ss-sp = slightly sticky-slightly plastic, s-p = sticky-plastic.
Roots: cc = common coarse, cm = common medium, fm = few medium, cf = common fine, ff = few fine
Boundary: a = abrupt, c = clear, g = gradual, w = wavy, s = smooth, h = sharp, d = diffusion

Table 2.

Physico-chemical properties of the soils in the study site

Depth (cm)	pH (H_2O)	pH ($CaCl_2$)	OC	OM	Clay	Sand	Silt	Textural Class	Total N (%)	Avail. P ($mgkg^{-1}$)	K	Na	Ca
			(%)								($cmolkg^{-1}$)		
PEDON 1 – UPPER SLOPE 7°57'34.0"N 5°28'13.9"E, 487m													
0-20	5.6	5.1	2.04	3.52	6.88	85.64	7.48	LS	0.17	5.24	0.172	0.022	1.40
20-45	5.8	5.2	1.12	1.93	8.88	83.64	7.48	LS	0.14	4.35	0.256	0.022	1.05
45-85	6.0	5.5	0.69	1.20	18.88	75.64	5.48	SL	0.10	2.71	1.026	0.035	1.05
85-120	6.2	5.7	0.81	1.40	22.88	69.64	7.48	SCL	0.07	4.39	0.718	0.030	1.15
PEDON 2 – MIDDLE SLOPE 7°57'40.9"N 5°28'15.7"E, 471m													
0-30	6.2	5.7	1.08	1.86	4.88	85.64	9.48	LS	0.11	6.88	0.195	0.026	1.10
30-50	6.2	5.6	0.73	1.26	6.88	85.64	7.48	LS	0.08	2.71	0.090	0.030	1.10
50-90	4.3	4.0	0.69	1.20	12.88	81.64	5.48	SL	0.04	3.37	0.059	0.026	0.80
PEDON 3 – LOWER SLOPE 7°57'47.4"N 5°28'19.9"E,425m													
0-26	5.5	5.0	1.35	2.33	4.88	83.64	11.48	LS	0.10	3.91	0.051	0.022	1.40
26-35	5.6	5.2	0.89	1.53	4.88	85.64	9.48	LS	0.07	2.93	0.033	0.026	1.15
35-63	6.1	5.4	0.58	1.00	4.88	89.64	5.48	S	0.04	2.57	0.023	0.022	0.95
63-90	6.2	5.4	0.23	0.40	6.88	89.64	3.48	S	0.03	2.04	0.031	0.004	0.80
90-170	6.1	5.7	0.35	0.60	8.88	79.64	11.48	LS	0.01	1.73	0.036	0.030	0.65
PEDON 4 – LOWER SLOPE 7°57'50.0"N 5°28'21.3"E,425m													
0-20	6.2	5.6	1.89	3.26	6.88	83.64	9.48	LS	0.10	4.04	0.126	0.022	1.65
20-34	5.9	5.7	0.69	1.20	10.88	79.64	9.48	SL	0.04	1.55	0.113	0.026	1.50
34-55	5.9	5.4	0.66	1.13	10.88	81.64	7.48	LS	0.03	2.31	0.103	0.026	1.45
55-100	6.1	5.7	0.77	1.33	14.88	77.64	7.48	SL	0.13	1.38	0.085	0.030	1.20

OC = Organic carbon, OM = Organic matter, S= Sand, SL = Sandy Loam, LS = Loamy sand, and SCL = Sandy Clay Loam.

Table 3.

Physico-chemical properties of the soils in the study site

Depth	Mg	Exch. Al^{3+}	Exch. H^{+}	CEC	ECEC	Base Saturation	Cu	Fe	Mn	Zn
(cm)			($cmolkg^{-1}$)			(%)		(mg/kg)		
PEDON 1 – UPPER SLOPE 7°57'34.0"N 5°28'13.9"E, 487m										
0-20	0.70	0.12	0.64	2.29	3.05	75.11	0.41	6.92	12.06	4.27
20-45	0.55	0.08	0.20	1.88	2.16	87.03	3.33	10.43	10.31	4.12
45-85	0.45	0.10	0.70	2.56	3.36	76.19	0.64	6.50	4.25	5.41
85-120	0.65	0.12	0.32	2.55	2.99	85.28	0.54	5.95	4.26	4.70
PEDON 2 – MIDDLE SLOPE 7°57'40.9"N 5°28'15.7"E, 471m										
0-30	0.55	0.14	1.14	1.87	3.15	59.38	1.49	5.77	17.06	5.82
30-50	0.30	0.12	0.24	1.52	1.88	80.85	0.24	5.17	8.95	3.15
50-90	0.45	0.76	0.84	1.34	2.94	45.49	0.69	7.00	11.33	3.11
PEDON 3 – LOWER SLOPE 7°57'47.4"N 5°28'19.9"E,425m										
0-26	0.80	0.20	0.40	2.27	2.87	79.12	0.78	58.73	1.56	4.49
26-35	0.70	0.10	0.54	1.91	2.55	74.90	0.85	31.78	1.01	3.31
35-63	0.70	0.48	0.24	1.69	2.41	70.18	0.94	12.62	1.42	2.93
63-90	0.65	0.58	1.18	1.49	3.25	45.76	0.89	15.08	0.78	3.79
90-170	0.65	0.02	0.62	1.37	2.01	68.10	1.31	12.56	1.17	4.18
PEDON 4 – LOWER SLOPE 7°57'50.0"N 5°28'21.3"E,425m										
0-20	0.85	0.26	0.86	2.65	3.77	70.27	1.00	11.97	10.68	3.58
20-34	0.70	0.20	1.04	2.34	3.58	65.35	1.22	18.75	4.09	3.22
34-55	0.60	0.20	0.32	2.18	2.70	80.73	1.14	13.77	3.62	2.72
55-100	0.45	0.16	0.52	1.77	2.45	72.19	1.17	22.71	4.65	4.24

Exch. = Exchangeable, CEC = Cation exchange capacity, and ECEC = Effective cation exchange capacity.

Table 4.

Mean Separation of the Soil Properties

Soil properties	Pedon 1 (US)	Pedon 2 (MS)	Pedon 3 (LS)	Pedon 4 (LS)
pH (H_2O)	5.9000^{a}	5.5667^{a}	5.9000^{a}	6.0250^{a}
pH ($CaCl_2$)	5.3750^{a}	5.1000^{a}	5.3400^{a}	5.6000^{a}
OC	1.1650^{a}	0.8333^{a}	0.6800^{a}	1.0025^{a}
OM	2.0125^{a}	1.4400^{a}	1.1720^{a}	1.7300^{a}
Clay	14.380^{a}	8.2133^{ab}	6.0800^{b}	10.880^{ab}
Sand	78.640^{b}	84.307^{ab}	85.640^{a}	80.640^{ab}
Silt	6.9800^{a}	7.4800^{a}	8.2800^{a}	8.4800^{a}
Total nitrogen	0.1200^{a}	0.767^{ab}	0.0500^{b}	0.750^{ab}
Available P	4.1725^{a}	4.3200^{a}	2.6360^{a}	2.3200^{a}
K	0.5430^{a}	0.1147^{b}	0.0348^{b}	0.1068^{b}
Na	0.0273^{a}	0.0273^{a}	0.0208^{a}	0.0260^{a}
Ca	1.1625^{ab}	1.0000^{b}	0.9900^{b}	1.4500^{a}
Mg	0.5875^{ab}	0.4333^{b}	0.7000^{a}	0.650^{a}
Exch. Al^{3+}	0.1050^{a}	0.3400^{a}	0.2760 ^{a}	1.4500^{a}
Exch. H^{+}	0.4650^{a}	0.7400a	0.5960^{a}	0.6850a
CEC	2.3200^{a}	1.5767^{c}	1.7460^{bc}	2.2350^{ab}
ECEC	2.8900^{a}	2.6567^{a}	2.6180^{a}	3.1250^{a}
BS	80.903^{a}	61.907^{b}	67.612^{ab}	72.135^{ab}
Cu	1.2300^{a}	0.8067^{a}	0.9540^{a}	1.1325^{a}
Fe	7.4500^{b}	5.9800^{b}	26.154^{a}	16.800^{ab}
Mn	7.7200^{ab}	12.447^{a}	1.1880^{c}	5.7600^{bc}
Zn	4.6250^{a}	4.0267^{a}	3.7400^{a}	3.4400^{a}

US = Upper slope, MS = Middle slope, LS = Lower slope, OC = Organic carbon, OM = Organic matter, Exch. = Exchangeable, CEC = Cation exchange capacity and ECEC = Effective cation exchange capacity. This means that different alphabets in the rows are significantly different at a 5% probability level according to DMRT.

The sand fraction ranges from 69.64 to 89.64%. Pedon 1 and 2 decrease in percentage sand with an increase in soil depth. The pattern of distribution of sand can be attributed to the degree of weathering of the parent material (Babalola *et al.,* 2021). There was a significant difference (p<0.05) in mean, pedon 3 is significantly higher. The clay fraction increases with an increase in soil depth for the entire pedons studied. This is attributed to the elluviation and illuviation of clay particles along the horizons (Malgwi, 2001). The increase in clay is higher in pedons 1 and 2 and there is a significant difference (p<0.05) between the pedons with pedon 1 having a significantly higher value. There was a decrease in the percentage of silt from the upper slope to the lower slope; from Pedon 1 to Pedon 3 and 4, this comes to a place as a result of the movement of silt content from the upper slope to the lower slope due to the presence of erosion on the upper slope (Maniyunda *et al.*, 2014). There was no significant difference in the pedons.

The soils at the surface are slightly acidic (5.5 to 6.2) (Lawal *et al.*, 2012). Many crops will grow within this range (Brady and Weil, 1999). Pedon 1 and 3 have lower pH in water and 0.01N CaCl on the surface, this may be due to the presence of organic matter on the surface as the area has more trees and shrubs compared to grasses. For all the pedons, the pH in 0.01N CaCl is lesser than the pH in water, this indicates that on their colloids there is a net negative charge. A pH change in 0.01N CaCl and water that is positive, zero small negative indicates a soil dominated by variable charge minerals. (Jimoh, 2015). The soils in this studied area can be said to contain or are dominated by variable charge minerals. There is no significant difference among the pedons.

The surface of the examined pedons has a higher amount of organic matter than the subsurface, which could be owing to the immobilization of organic matter down the profile as a result of clay that increases down the profile (Shobayo, 2010). All of the pedons have low soil organic carbon levels, which could be due to continual tillage and exposure to sun radiation (Haddaway *et al.*, 2017). There is no significant difference among the entire pedons at ($p<0.05$). The organic matter at the surface of the overall pedons is higher than the sub-soils, and this is due to the immobility of organic matter down the profile, which causes it to accumulate at the surface. The organic matter in the study area is generally low, which could as a result of deforestation, continuous farming without allowing fallow, and continual tilling which enhance rapid mineralization of organic matter (Shobayo, 2010). There was no significant difference among the pedons at ($p<0.05$). The total nitrogen is low for all the pedons. It is lower than the critical level of 0.20% set for Nigeria soils (Sharu *et al.*,2013). There was a significant difference between the pedons. The available phosphorus (AP) ranges from 1.38 to 6.88 mg kg^{-1}. With increasing soil depth, the AP values diminish. The pedons have the highest values at their surface, but the level is extremely low, which could be attributed to the limited return of phosphorus to the soil following crop harvesting, particularly after harvesting heavy feeder crops. (Raji *et al.*, 1996).

The sequence of concentration of the exchangeable cations revealed that calcium (Ca) had the highest value. A similar sequence was observed by Kehinde *et al.* (2019). The values are generally low in the pedons and can be attributed to plant uptake and leaching (Odunze, 2006; Singh *et al.*, 2013). There was a significant difference between the pedons, there are higher values in the lower slope. The trend of distribution of exchangeable magnesium (Mg) followed the Ca. The Mg ranges from 0.30 to 0.85cmolkg^{-1}. Down the profile, the concentration of exchangeable Mg reduces. This may be as a result of parent rock or crop cultivation which leads to the accumulation of Mg on the surface of the soil, (Gransee, 2013). The soils in this studied area have a good range of exchangeable Mg and there was a significant difference between the pedons ($p<0.05$). Pedons at the lower slope had significantly higher values ($p<0.05$).

Exchangeable potassium (K) ranges from 0.0023 to 1.0250cmolkg^{-1}. There was an increase in the concentration of exchangeable K in Pedon 1 20-54 cm soil depth; it could be a result of the leaching of the element from the upper horizon as pointed out by (Jalali, 2009). Shobayo (2010) also reported a similar trend of distribution for soils in the basement complex geology of Nigeria. There was a significant difference between the pedons ($p<0.05$). Exchangeable sodium (Na) ranges from 0.004 to 0.034 cmolkg^{-1}. The surface has lesser exchangeable Na compared to the sub-surface of the profile, which could be a result of leaching. An increase in Na in the soil basically affects soil structure (Babalola *et al.*, 2011). There was no significant difference between the pedons ($p<0.05$).

The exchangeable Al in all horizons of the entire pedons is less than 1.0 cmol/kg soil and it ranges from 0.02 to 0.76 cmolkg^{-1}. There was an irregular pattern of exchangeable Al in the soil. The exchangeable H in the pedons ranges from 0.20 to 1.18 cmol/kg. There was no significant difference between the pedons for exchangeable Al and H. The cation exchange capacity (CEC) of the soils is generally low, it ranged from 1.37 to 2.65 cmolkg^{-1}. The low CEC is a common feature in the tropics and has been attributed to low-activity clay (Tan, 2000; Babalola *et al.*, 2021). There was a significant difference between the pedons ($p<0.05$) but Pedon 1 had significantly higher values. The range of ECEC was from 1.88 to 3.77cmolkg^{-1}. The progression along the profile is similar to that of CEC although. There was no significant difference between the pedons.

The micronutrients studied are as follows: copper (Cu), Iron (Fe), manganese (Mn), and Zinc (Zn). Fe values vary from 5.17 to 58.73 mg kg-1; the values are higher than the critical values of 3.0 to 4.5 mg kg^{-1} set by Sillanpa (1982) for tropical soils. Parent materials and weathering have been reported to influence the concentration of Fe in tropical soils (Babalola *et al.*, 2021). There was a significant difference ($p<0.05$) between the pedons. The pedons at the lower slopes had significantly higher values than others. Mn values vary from 0.78 to 17.06 mg kg^{-1}. The critical value of Mn set for Nigerian soils is 1 mg kg^{-1} for the lower limit and 5 mg kg^{-1} for the higher limit (Esu, 1991). Mn is high at the surface of all pedons except for pedon 3 which is low. The Mn decreases with an increase in soil depth, a similar pattern of distribution was reported by Shobayo (2010) and Babalola *et al.* (2021). There was a significant difference between the pedons and Pedon 2 was significantly higher than the other ($p<0.05$). Zn ranges from 2.72 to 5.82 mg kg^{-1}. The surface horizon layer is higher than the subsurface and this could be due to the leaching of micronutrients down the soil profile. There was no significant difference ($p<0.05$) between the pedons. Cu ranges from 0.24 to 3.33 mg kg^{-1}. Cu is lower at the surface compared to the sub-surface horizons in all the pedons except in Pedon 2 where the reverse is the case. The lower content of Cu at the surface in most of the pedons could be due to the downward accumulation (leaching)of Cu down the profile (Odunze *et al.*, 2009). There was no significant difference in Cu content between the pedons.

Soil classification

The pedons were classified according to the USDA soil taxonomy (Soil Survey Staff, 2014) and correlated with the FAO/UNESCO legend of the world reference Base (FAO, 2014) (Table 5).

USDA Soil Taxonomy system

Clay increases down the depth in Pedon 1 and 2. The trend indicates the presence of argillic horizons, these along with base saturation above 35% made the pedons to be classified in soil order Alfisols. The Udic moisture regime (the dry period of the soil is less than 6 months) made the soils be placed into sub-order Udalfs. They were further placed into the great group Hapludalfs because they exhibited properties unique to Udalfs. In the sub-group category, Pedon 1 is Arenic Hapludalfs as a result of the loamy sand texture throughout the layer extending from the mineral soil surface to the top of the argillic horizon at a depth of around 50cm. Pedon 2 is Psammentric Hapludaffs as a result of the sandy nature throughout the entire argillic horizon.

Pedon 3 and 4 were classified as Entisols at the sub-order level because they did not have a distinct diagnostic horizon. They were classified as Psamments at sub-order level as a result of the prominent loamy fine sand and coarse horizon layers. In the great group, they were placed into Udipsamments as a result of the Udic moisture regime. At the sub-group level pedon3 was classified as Aquic Udipsamments due to the argic condition and chroma of 2 within 100cm of the mineral soil surface while Pedon 4 was classified as Oxyaguic Udipsamments as a result of saturation by water within 100cm of the mineral soil surface.

Table 5.

Summary of classification of pedons

Pedon	USDA	WRB
1.	Arenic Hapludalfs	Chronic Diffentic Lixisol
2.	Psammentic Hapludalfs	Haplic Arenic Lixisols
3.	AquicUdipsamments	Chromic Novic Arenosols
4.	Oxyaguic Udipsamments	Chromic Novic Arenosols

USDA – United States Department for Agriculture
WRB – World Reference Base

FAO/UNESCO soil map of the world legend and World Reference Base of Soil Resources

At the higher category, Pedon 1 and 2 were classified as Lixisols due to the presence of argillic horizon and base saturation that is higher than 35%. Pedon 3 and 4 were classified as Arenosols due to the loamy sand and coarse texture throughout the profile.

At the lower category, Pedon 1 is Chromic Differntic Lixisols as a result of the hue redder than 7.5YR within one of the horizons, pedon 2 is Haplic Arenic Lixisols due to loamy sand texture over a hard pan within 100cm of the mineral soil surface and Pedons 3 and 4 as Chronic Novic Arenosols due to hue that is less than 7.5YR in one of the horizons and coarse texture throughout the profile.

Land capability classification of the pedons

The land capability classification rating of the pedons in the study area is presented in Table 6. There were traces of erosion in pedon 1 and, it was rated in class II for erosion while all the other pedons are in class I. The erosion channels in pedon 1 can be attributed to the high position of the pedon in the landscape which could have occasioned runoff.

The land is gently sloppy and has a slope angle in the range of 0-2%, therefore, all the pedons were placed in class I for slope.

There was no flooding and the soils are well-drained, there is the likelihood that excess water that would have been retained on the landscape is usually drained to the nearby river and flowed into the Itapaji-Iyemero dam. The pedons were placed in class I for flooding and drainage.

The pedons were grouped into class one for rock outcrops and boulders because there were no rock outcrops and boulders.

The soil depth is 120, 170, and 100 cm in pedons 1, 3, and 4 respectively, they were all rated in class I while for pedon 2 the soil is 90 cm, it is thus rated in class II. The soils are generally deep and will support root penetration of most crops, however, there could be restrictions for the roots of deep feeder tree crops in Pedon 2 over the years.

Cation exchange capacity (CEC) was low; it is in the range of 1.58 to 2.32 cmol/kg, this suggested low nutrient reserves of the pedons, hence, occasioned pedons 1, 3, and 4 to be placed in suitability class VI and pedon 2 into class VII.

Surface texture which is in the range of Loamy sand was placed into class I. Precipitation is 1,375mm/annum and climate type is humid, for these characteristics, the pedons were placed in class I.

In the aggregate land capability ratings, all the soils were placed in classes lower than I. They were grouped as follows: pedon1 is $VIe^{1}s^{3}$, pedon 2 is $VIIs^{2,3}$, while pedon

3 and 4 are VIs[3]. According to Babalola *et al.* (2019), class VI has severe limitations that make them generally unsuited to cultivation therefore the use is limited mainly to pasture, range, forestland, or wildlife food and cover, and class VII has very severe limitations that make them unsuited to cultivation and restrict their use main grazing, forest land and wildlife,

Among the limiting factors, erosion and cation exchange capacity can be ameliorated with improved soil management practices and this could improve the ratings of pedon 1, 3, and 4 to class I and pedon 2 to class II.

Table 6.

Land capability classification system

Properties	Pedons			
	1 (Upper slope)	2 (Middle slope)	3 (Lower slope)	4 (Lower slope)
Erosion hazard (e)				
[1]Erosion	II	I	I	I
[2]Slope Angle (%)	I	I	I	I
Excess Water (w)				
[1]Drainage class	I	I	I	I
[2]Flooding	I	I	I	I
Soil Limitation (s)				
[1]Rock outcrop, stone, and Boulders	I	I	I	I
[2]Effective Soil depth (cm)	I	II	I	I
[3]CEC (cmol/kg)	VI	VII	VI	VI
[4]Surface Texture Class	I	I	I	I
Climate (c)				
[1]Effective precipitation (mm)	I	I	I	I
[2]Nature of Climate	I	I	I	I
Aggregate Capability	VI^{e1s3}	$VII^{s2,3}$	VI^{s3}	VI^{s3}

CONCLUSION

The soils are iron-rich, sandy, slightly acidic, low CEC, organic matter, and nitrogen with high base saturation. The upper slope (Pedon 1) and middle slope (Pedon 2) belong to the order Alfisols while the lower slope (Pedons 3 and 4) are Entisols. This study is a contribution to efforts towards the identification of the distribution of soil types in Nigeria and the compilation of soil types for the production of the National Soil Classification System.

To enhance the productivity of the soils to support a wide range of crops there will be a need for proper soil management techniques involving proper post-harvest handling of residues, incorporation of organic manure, minimal tillage, and incorporation of legumes in the cropping pattern of the location are suggested.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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