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Characterization and classification of soils of the Rivers State University Teaching and Research Farm, Port Harcourt, Southern Nigeria

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Abstract

This study was conducted to characterize and classify the soils of the Teaching and Research Farm, Rivers State University, Port Harcourt, covering 30 hectares of land area. A rigid grid soil survey method at a very detailed level (100 × 100) m² (1 ha) with two mapping units identified and delineated. Each of the mapping unit was represented by a soil profile described from the lowest end to the upper part of the profiles to avoid contamination. Soil samples were collected for laboratory analysis from the various horizons identified. The results obtained, indicated that the soils were of Inceptisols/ Cambisol order, Udepts at the suborder level, Eutrudepts Great group level and Typic Eutrudepts (subgroup level). Thus, the drainage, parent materials, climate (rainfall), and vegetation of the area along with the geologic material, formed from the sedimentary rocks that were weathered into coastal plain sands and buried under alluvium at various degrees at different locations in the study area, greatly affected the soils of Teaching and Research Farm, Rivers State University, Port Harcourt, which are primarily Inceptisols/ Cambisols.

INTRODUCTION

Soil characterization and classification is a land evaluation assessment process that helps to identify limiting qualities of soils and thus, provide a good basis to advise the farmers on appropriate land management practice to be adopted for optimum crop production (Peter et al., 2021). Soil characterization, classification and evaluation help in establishing a soil database for proper understanding of soil resources within our environment and for judicious uses of land resources (Peter and Umweni, 2021a). Proper soil characterization procedure provides the foundation for understanding and appreciating the soil, and further classification. To minimize damage to soils and its/their environment, there is a need for proper soil characterization and classification according to the proposed kind of use. This is because, soil characterization and classification provide key information on the performance of land resources (soils) for crop production on a sustainable bases (Peter and Umweni, 2020a); thus, the classification of soils is usually done based on soil properties described in terms of their various diagnostic horizons and identifiable properties that are measurable in situ (the field) (Peter and Umweni, 2020b). Lack of soil characterization becomes an obstacle to utilize the soil identified in an area based on its production potentials and adaptation of better management practice to increase soil productivity. Soil resource records through the description of soils (land resources) provide an insight into the capabilities and constraints of soils (Peter and Aaron, 2019). Generally, most lands in Nigeria are put to use without any form of land evaluation, and available land evaluation results are sometime not utilized. In farming, the risk is reduced by matching the requirement of land use to the land qualities, thereby

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predicting the potential of agricultural land (Peter and Umweni, 2021a). Every hectare of land should be used in accordance with its capability, suitability, and limitations by performing a land suitability evaluation, which entails interpreting soil survey data. The assessment and determination of the parent material from which the soils are formed, as well as the potential of such soils for agricultural production, engineering, urban development, pollution control, etc., are all aspects of soil characterization and classification, according to Peter and Umweni (2020a). Therefore, to maintain sustainable agriculture and land use planning, proper soil investigation needs to be embarked upon using the procedure for proper soil characterization and classification at both local, regional and, international level (Peter and Umweni, 2020b). Thus, the main objective of this research was to characterize and categorize soils of the Rivers State University Teaching and Research Farm, Port Harcourt, Southern Nigeria.

MATERIALS AND METHODS

The study area is the research farm belonging to the Faculty of Agriculture, Rivers State University, Port Harcourt, Nigeria. This land has been under intensive cultivation since the establishment of the University in 1979. It lies between latitude of 4°40'50"N and 4°51'40"N, and longitude of 6°57'30"E and 7°5' 0"E. It has a mean annual rainfall of 2000–3000 mm and mean annual temperature of 25–28°C (Peter and Aaron, 2019; Ikati and Peter, 2019); while the relative humidity varied between 70–85 %. A period of low precipitation (dry season) commonly called the harmattan period (late November to February) is also experienced in the study location. The vegetation of the study area, as described by Ikati and Peter (2019) and Peter and Aaron (2019), is that of the humid tropical ever green, but tremendously altered as a result of the continuous cropping system normally practiced in the area. The study area is underlain by the coastal plain sands and alluvium of marine deposits (Peter and Aaron, 2019).

Field study

The Teaching and Research Farm covering 30 hectares of land area was assessed using a detailed soil survey procedure. It was geo-referenced and digitized using Arc map software to form the proposed shape field of the study location. The digitized map was gridded using the rigid grid method (100 × 100) m² (1 ha) per sampling point. Thirty (30) auger soil sampling points were identified, and soil samples were collected at the depths of 0–30 cm, 30–60 cm, 60–90 cm and 90–120 cm. Soil samples were described in the field. Soil morphological properties were ascertained in situ using soil color, texture (by hand feeling), structure, drainage, presence or absence of mottles, concretions, and other morphological properties. Soils with identical properties were assembled to form mapping units. And from the grouping based on similarities, two

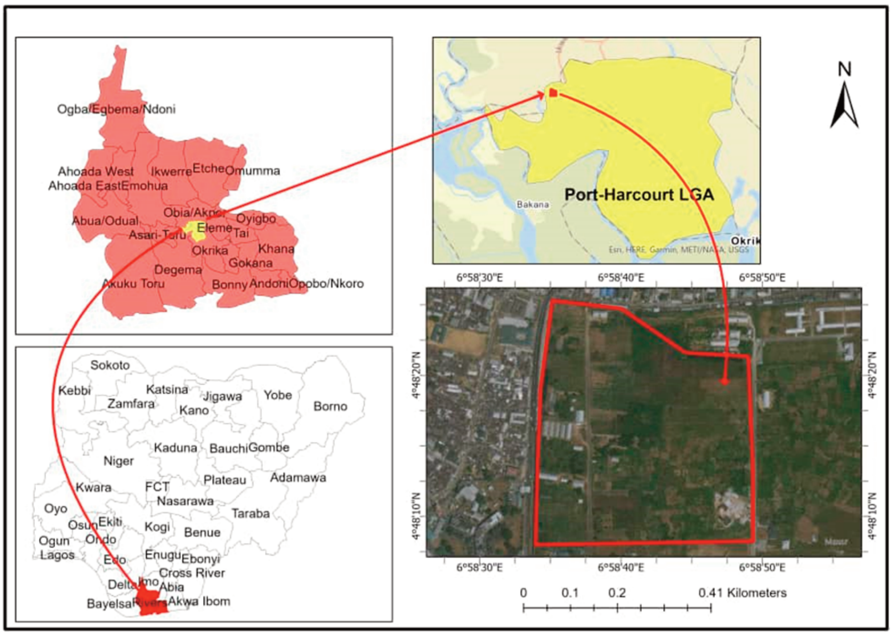

Figure 1. Map of the study area

mapping units were identified and delineated. Soil profiles pit (2m × 2m × 2m) was dug in each of the mapping unit (pedon) and described starting from the bottom to top according to (Peter et al., 2022a).

Laboratory analysis

Particle size distribution was determined by the hydrometer method described by Wang et al. (2022). Bulk density was determined using the clod method by Liu et al. (2020). Soil reaction (pH) determination was performed in 1:1 water ratio using a glass electrode pH meter (Zhou et al., 2022). Electrical conductivity was measured using an electrical conductivity meter; soil organic carbon was determined using method by He et al. (2022); while total nitrogen was calculated using the Macro Kjeldhal digestion method (Hicks et al., 2022). Available phosphorus was also determined using the method described by Lin et al. (2022). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) were all determined using the Ammonium acetate saturation method by Zhao et al. (2020). Effective Cation Exchange Capacity (ECEC) was calculated by adding total exchangeable bases and total exchangeable acidity, and Percentage Base Saturation was calculated by expressing the total exchangeable bases as a function of cation exchange capacity. Exchangeable acidity was determined using the EDTA Titration method (Zhao et al., 2020).

$$\%\ \text{Base Saturation} = \frac{\text{Total Exchangeable Bases}}{\text{CEC}} \times 100$$

Soil classification

Soils of the Teaching and Research Farm were classified using two conventional methods of the Soil Taxonomy of the USDA (2020); Marnard et al. (2020); Sina et al. (2021) and correlated with the World Reference Base for Soil Resources (Peter, 2018).

RESULTS AND DISCUSSION

Morphological properties of soils

Soil morphological properties of the study area are shown in Table 1. It was observed that soil depths of the both pedons were deep (200 cm). The various pedons showed different soil color matrix. Pedon 1 had soil color ranging from very dark greyish brown (10YR 3/2) in the Ap1-horizon to strong brown (7.5YR 4/6) (moist) in the Bt2-horizon, while in pedon 2, all the horizons had strong brown coloration (moist). The soils were well drained, and this accounted for observable changes in soil colors in the study location. This collaborates with the reports of Dumba and Peter (2020) and Peter and Umweni (2020b). The brownish coloration in most of the horizons was due to the

Table 1. Morphological properties of soils in the study area

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistency			Roots
					Moist		Wet	
Pedon 1								
Ap1	0–21	10YR 3/2 very dark grayish brown	sl	sbk	Friable	Sticky	Plastic	Abundant root
Ap2	21–34	10YR 3/8 strong brown	scl	bk	Friable	Sticky	Plastic	Abundant root
Ab	34–55	10YR 4/6 dark yellowish brown	scl	bk	Friable	Sticky	Plastic	Abundant root
Bt1	55–87	7.5YR 5/8 strong brown	scl	bk	Friable	Non sticky	Plastic	No root
Bt2	87–200	7.5YR 4/6 strong brown	scl	bk	Friable	Highly sticky	Plastic	No root
Pedon 2								
Ap	0–23	7.5YR 5/6 strong brown	ls	sbk	Friable	Sticky	Plastic	Less root
AB	23–80	7.5YR 4/6 strong brown	scl	bk	Friable	Non sticky	Plastic	Less root
Bt1	80–200	7.5YR 5/6 strong brown	scl	bk	Friable	Sticky	Plastic	No root

Remarks: sl = sandy loam, scl = sandy clay loam, ls = loamy sand, sbk = sub-angular block, bk= blocky.

presence of organic matter as the most influential coloring agent in the surface soils. This is also collaborated with the reports of Peter and Umweni (2020a), Peter et al. (2021), Peter et al. (2022a) and Peter et al. (2022b) who opined that soil dark coloration was due to the presence of organic matter at soil surface horizons. Again, the degree of pedogenic activities (illuviation and eluviation) in the soils also contributed to the color matrix of each pedon. Soil textural class for pedon 1 ranged from sandy loam at the surface level (Ap1) to sandy clay loam at the subsurface horizons (Bt2-horizon), and it varied from loamy sand to sandy clay loam in pedon 2. Soil textures in both pedons had sub-angular blocky to blocky structures, soil consistency was friable, sticky and plastic when moist depending on the depth, with root abundance at the soil surface region.

Soil physical properties

Table 2 presents the physical properties of soils in the study area. It shows that soils across the pedon are well drained as indicated by the colored. Sand fractions decreased from 832 g/kg to 692 g/kg with mean value of 748 g/kg down the profile depth (in pedon 1). Sand fractions in pedon 2 decreased from 852 g/kg to 692 g/kg with mean value of 752 g/kg. There were reductions in sand fraction down the profile with an increase at soil surface horizons. The increase in sand fractions at soil surface horizons could be attributed to erosion and eluviation of clay particles resulting into the sandy nature of the soils at the upper horizons. Silt fractions were 26 g/kg across the horizons in pedon 1, but ranged from 26 g/kg to 46 g/kg with a mean value of 32.2 g/kg in pedon 2. The clay fractions of the soils increased from 142 g/kg to 282 g/kg in pedon 1, while the clay fraction value in pedon 2 increased from 102 g/kg to 282 g/kg. It was also observed that clay fractions increased down the depth of the profile in all pedons. The eluviation-illuviation processes, as well as the geologic materials from which the soils were created, may be responsible for the rise in clay percentage along the depth of the profile. This concurs with the results of Peter and Umweni (2022b); Peter et al. (2021); Peter et al. (2022a); and Peter et al. (2022b). Soil bulk density values in the study area ranged from 1.59 to 1.89 g/cm^2 in pedon 1 and 1.63 to 2.09 g/cm^2 in pedon 2. The soil bulk density (1.75 –1.8 g/cm^2) of the study area was higher than critical limits for root restriction as reported by Key to Soil Taxonomy, Soil Survey Staff (2020). The increase could be attributed to the activities of farm machinery over time (Peter et al., 2022a).

Soil chemical properties

The soil chemical properties are as shown in Table 3. Electrical conductivity (EC) varied from 19.16–42.72 ds/cm^2 in pedon1 and 12.33–18.33 ds/cm^2 in pedon 2. Soil reaction (pH) in water (H_2O) ranged from strongly acidic to moderately acidic when compared to the rating by Peter and Umweni (2020b). Pedon 1 had soil pH (H_2O) that increased from 4.75 to 5.53; while pedon 2 had pH values ranging from 4.59 to 5.16. The acidic nature of the soils could be attributed to erosion and high rate of leaching in the soils as a result of the high rainfall (2000–3000 mm) experienced overtime within the study location. This is also in line with the finding of Peter et al. (2022). Soils of the study location had

Table 2. Physical properties of soils of the study area

Horizon	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	TC	Drainage	BD (g/cm^3)
Pedon 1							
AP1	0–21	832	26	142	sl	well drain	1.89
AP2	21–34	752	26	222	scl	well drain	1.63
Ab	34.55	752	26	222	scl	well drain	1.79
Bt1	55.87	712	26	262	scl	well drain	1.61
Bt2	87–200	692	26	282	scl	well drain	1.54
	Mean	748	26	226			1.69
Pedon 2							
AP	0–23	852	46	102	ls	well drain	2.09
Ab	23–80	712	26	262	scl	well drain	1.79
Bt1	80–200	692	26	282	scl	well drain	1.63
	Mean	752	32.6	215.4			1.84

Remarks: TC= Textural Class, BD = Bulk Density.

Table 3. Chemical properties of the soils in the study area

Horizon	Depth (cm)	EC (ds/cm)	pH (H_2O)	OC (g/kg)	TN	Av. P (mg/kg)	CEC Cmol/kg	Ca	Mg Cmol/kg	K	BS (%)
Pedon 1											
Ap1	0–21	42.70	5.41	0.66	0.07	48.59	6.10	4.6	0.6	0.11	87.68
Ap2	21–34	32.90	5.53	0.39	0.01	12.81	6.93	4.4	1.6	0.13	89.01
Ab	34–55	30.70	5.40	0.27	0.07	7.02	5.98	4.4	0.8	0.14	89.89
Bt1	55–87	53.60	5.45	0.31	0.07	17.54	5.73	3.2	2	0.21	94.69
Bt2	87–200	19.16	4.75	0.98	0.07	3.59	4.89	2.8	1.4	0.21	90.77
	Mean	35.81	5.31	0.52	0.056	17.91	5.93	3.88	1.28	0.16	90.41
Pedon 2											
Ap	0–23	12.33	4.65	0.43	0.14	2.29	5.52	1.8	2.2	0.08	75.13
Ab	23–80	18.33	5.16	0.39	0.07	24.56	4.20	3.8	1	0.08	93.01
Bt1	80–200	12.49	4.59	0.31	0.01	1.75	7.34	4.8	1	0.10	81.77
	Mean	14.38	4.80	1.13	0. 028	12.86	5.69	3.46	1.06	0.09	83.30

Remarks: EC: Electrical Conductivity, OC: Organic Carbon, Av. P: Available Phosphorus, CEC: Cation Exchange Capacity and TN: Total Nitrogen.

low organic carbon ranging from 0.27–0.98 g/kg in pedon 1 and pedon 2 recorded organic carbon level of 0.31–0.43 g/kg. It was observed that surface soils had more organic carbon than the subsurface soils. This could be attributed to deposition of organic materials on the surface soils leading to an increase in the organic carbon content at soil surface horizons. Total nitrogen ranged between 0.01–0.07 g/kg in pedon 1 and 0.01–0.14 g/kg in pedon 2. The values were rated very low when compared to available standard as reported by Peter and Aaron (2019). The available P level in both pedons ranged from 1.75–48.59 mg/kg. It was also observed that available P level was above the minimum critical level required for optimum crop productivity as stated by Peter et al. (2021). CEC varied from 4.89–6.92 cmol/kg in pedon 1 and 4.20–7.34 cmol/kg in pedon 2. CEC was moderate both in at surface soil levels but there was no increase with depth in pedon 1. This contradicted the finding of Magaji (2018), but there were increase in the CEC level with depth in pedon 2 conforming the report of Magaji (2018). The concentration of exchangeable bases in soils showed that calcium level was medium (2.8–4.6 cmol/kg and 1.8–4.8 cmol/kg) in both pedons; magnesium level was medium to high in both pedons (0.6–1.2 cmol/kg and 0.1–2.2 cmol/kg); while potassium level was low to medium in pedon 1 (0.11–0.21 cmol/kg) and low in pedon 2 (0.08–0.10 cmol/kg). The low to medium level of exchangeable bases (Ca, Mg and K) could be as a result of pedogenic process occurring in the soils (Peter and Umweni, 2020), the continuous cropping system, leaching, and the origin (parent materials from where the soils were formed) (Peter et al., 2022b). Pedon 1 and 2 had high percent base saturation (87.68–94.69 %).

Soil classification

The soils were categorized according to the latest criteria laid down in Key to Soil Taxonomy (USDA)/Soil Survey Staff (2020); Marnard et al. (2020); Sina et al. (2021); and World Reference Base for Soil Resources (Peter, 2018). Soil classification was done at Order, Suborder, Great group and Subgroup levels using some morphological, physical and, chemical properties of the soils. Pedons 1 and 2 showed the development of color and structural weak appearance of cambic B-horizons produced by soil forming factors and showed no evidence of accumulation of clay, iron oxide, aluminum oxide or organic matter in sub-soils. They also had no separate pedogenic diagnostic horizons, rather they have a cambic subsurface horizon and their base saturation was <50% (by NH_4OAc), thus classified as Inceptisols. Based on both soil temperature and udic moisture regimes as influenced by climate, they were placed under the Udepts suborder. Both Pedons 1 and 2 were eligible for the Eutrudepts Great group by having base saturation by NH_4OAc of 60% or more in one or more strata at a depth of 25 to 75 cm from the mineral soil surface. Due to their drainage patterns, lack of saturation in any layer within 100 cm of the mineral soil surface for 20 or more consecutive days or 30 or more days cumulatively in normal years, and lack of ochric, kandic, and/or argillic horizons with the regular reduction in soil organic carbon, Pedon 1 and 2 also belong to the Typic Dystrudept subgroup. Using World Reference Base (Peter, 2018), both pedons 1 and 2 correspond to Haplic Ferralic Cambisol.

CONCLUSIONS

The soils of the Teaching and Research Farm have been under intensive crop cultivation due to an increasing student population and urbanization pressure worldwide on land resources, also there is a need to increase crop cultivation to provide food for the teaming population. To achieve this task, it is imperative to obtain detailed and reliable information on the types of land resources (soils) in the area and their suitability. These soils of Teaching and Research Farm, Rivers State University are largely Inceptisols/ Cambisols and these soils could be sustained for reasonable agricultural productivity. However, they require careful management to ameliorate acidity and nutrient deficiencies.

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