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Soil mapping, classification and morphological characteristics of the University of Benin land

Okunsebor, F.E. and Umweni, A.S.

Department of Soil Science and Land Management, University of Benin, Nigeria.

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Corresponding Author's E-mail Address:
faith.okunsebor@uniben.edu 2348164980646

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ABSTRACT

This study was conducted to map, and classify the soils of University of Benin Teaching, Research and Integrated Farm site. Rigid grid soil survey method at an intensive scale was done on a 62-hectare land that produced seven mapping units. In each mapping unit, a representative pedon was sunk, described and sampled. Soil samples were analyzed using standard methods. Data generated were analyzed using descriptive statistics to determine their coefficient of variation. The result indicated that the soils were reddish when moist at different contrasting levels. Textural classes ranged from Loamy sand to Sandy Clay Loam while structure ranged from Single grain crumb to Sub-angular blocky. The pedons were well drained except for pedon 5, which had mottles at subsurface horizon. Means of Sand fraction ranged from ≤649 to ≥ 931 gkg^{-1}; Silt ranged from ≤13.2 to ≥ 47.7gkg^{-1} while Clay ranged from≤ 50 to ≥ 303 gkg^{-1} in all the pedons; clay fraction increased with increase in depth, forming argillic horizon in pedons 1,2 and 7. pH had means ranging from ≤4.23 to ≥5.28 and recorded low variation (≤ 3.6 to ≥ 13.0 %) in all the pedons. organic carbon had means ranging from ≤ 3.3 to ≥ 36.4 gkg^{-1}; CEC ranged from ≤ 4.85 to ≥ 16.4 cmolkg^{-1} while Base saturation ranged from ≤16.6 to ≥ 51%. Hence pedons 1, 2 and 7 were placed in the order Ultisols (Acrisols); pedons 3and 4 in Entisols (Arenosols) Pedon 4; Pedons 5and 6 in Inceptisols (Cambisols) according to USDA Soil Taxonomy and correlated with WRB.

1.0 Introduction

Soil mapping is the process of delineating natural bodies of soils, classifying and grouping the delineated soils into map units, and capturing soil property information for interpreting and depicting soil spatial distribution on a map (Esu et al., 2014). It involves locating and identifying the different types of soil that occur in an area, collecting information about their location, nature, properties and potential use, as well as recording this information in maps and other documents to show the spatial distribution of every soil type. University of Benin Farm land has not been mapped and classified according to internationally accepted standards hence, the benefit of this study.

The most fundamental step, commonly omitted, in our land use and management process is the ability to identify and classify the soils of our project area. The neglect of this has often led to the citing of most experiments on soils without accurate identities, thereby making the verification and benefits of the outcome of such experiments the exclusive preserve of the researcher (Okunsebor, 2014). The relevance of soil classification can be seen in the determination of the best possible use and management of soils (Osujike et al., 2018).

The coupling of soil characterization, Soil classification and soil mapping provides a powerful resource for the benefit of mankind especially in the area of food security and environmental sustainability (Sharu *et al.,* 2013). University of Benin is an academic institution saddled with the responsibility of providing relevant information that will rescue the agricultural sector, especially now that emphasis has been shifted to precision agriculture in order to meet up with the food demand of the rapidly growing population of Nigeria.

This study was done to classify the soils of the University of Benin Teaching, Research and Integrated Farm Site at both local and international standards (Soil Survey Staff, 2014) and WRB (IUSS, 2015) that will facilitate transfer of knowledge in the relevant field.

2.0. Materials and methods

2.1. Study area

This study was carried out at the University of Benin Teaching, Research and Integrated Farm site, Benin City. The site lies within Latitude 6°23'50"N and 6°24'20"N; and Longitude 5°37'50"E and 5°38'20"E defined by points PC1 to PC8, appropriately geo-referenced as in the attached Location map1, divided into parcels: A (29.1 ha) and B (33.1 ha).

The area is characterized by a tropical climate with an annual average rainfall amount of 1900mm, mean annual temperatures ranging from 23°C to 37°C and mean annual relative humidity ranging from 89% in the morning (10.00 am) to 75% in the evening (4 pm), recorded over a period of 18years (NIFOR, 2013). The site is situated at the Rainforest belt of

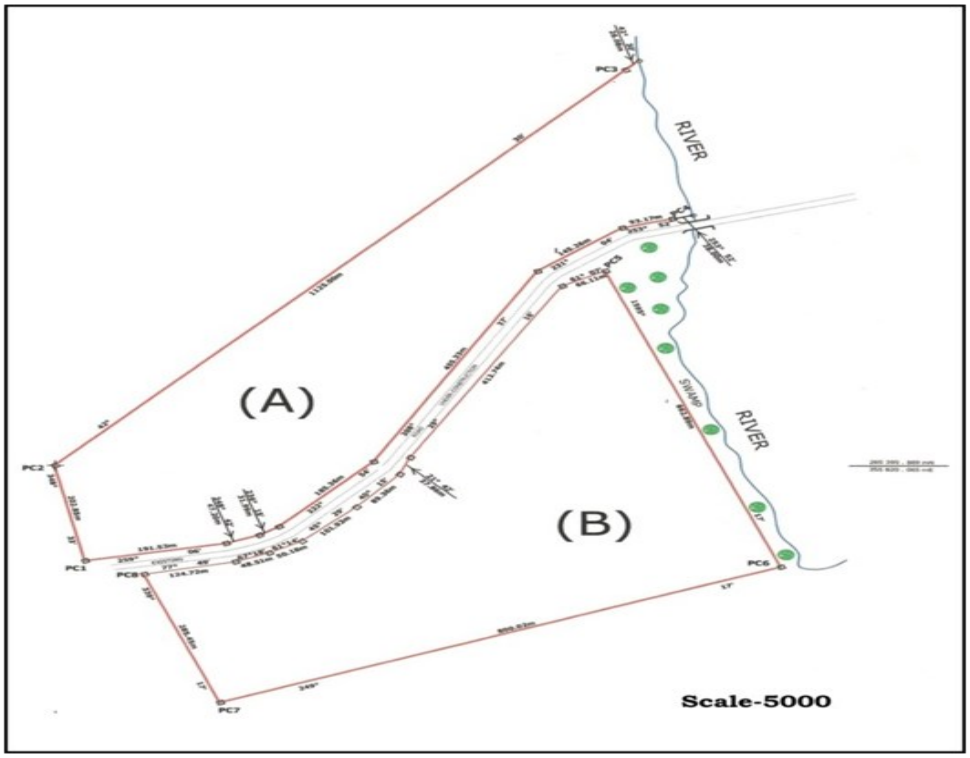

Fig 1: Location Map of a selected portion of the University of Benin Teaching, Research and Integrated Farm Site

the humid tropics (Illoba and Ekrakene, 2008) and southern ecological zone of Nigeria, with distinct dry and wet seasons (Molindo and Nwanchokor, 2010). The seasons correspond to the periods of dominance of the wet tropical continental air masses with seasonal distribution of rainfall following the direction of the Inter-Tropical Divergence (ITD) and vary almost proportionally with distance from the coast. The dry season begins 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. The soils are derived from recent coastal plain sands known as Benin formation (unconsolidated sands and sandy clay) and alluvial deposits (Umweni, 2007).

The topography of the site is as shown by the Topographical map created from SRTM (Shuttle Radar Topographic Mission (Fig. 2). It indicates that the site has a height differentia of 50 m

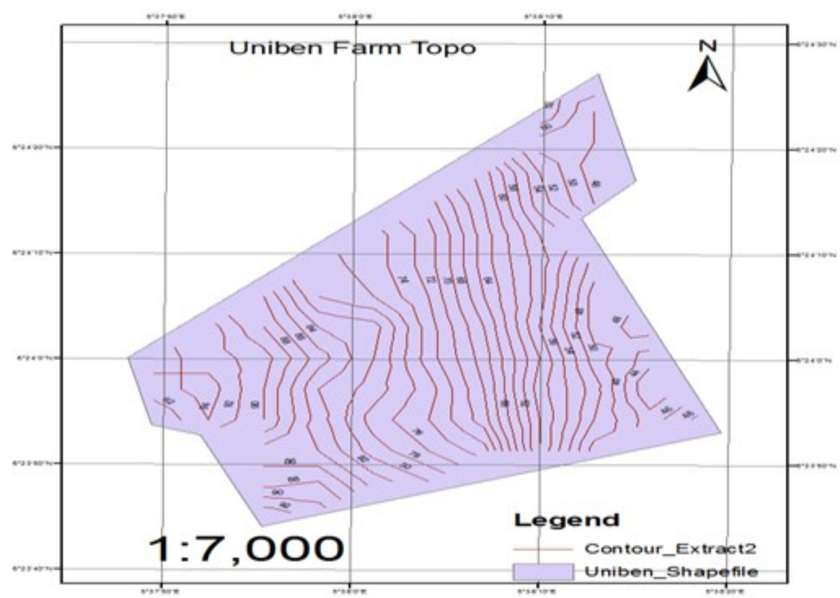

Fig. 2: Topographical-map created from SRTM (Shuttle Radar Topographic Mission) of a selected portion of the University of Benin Teaching, Research and Integrated Farm Site

within 1.5 km. Physiographic position is a terrace.

The vegetation is as shown in Fig. 3. It includes riparian forest along the river course; scattered trees of Rubber, Oil palm, Bamboo and Raffia palms; and some old and new farms cultivated to yam, cassava, fluted pumpkin, plantain, banana, pineapple.

A land survey map which served as the base map was produced by a team of land surveyors. Field survey was conducted in a selected area measuring 62 hectares using the rigid grid systematic survey method .Auger points were placed at 50m interval along the traverses, giving a total of 228. Auger points at depth intervals of 0-30cm, 30-60cm, 60-90cm and 90-120cm respectively. Auger samples were described morphologically on the field (soil colour, texture by feel, presence or absence of mottles, mottle colour and so). Areas with similar properties and characteristics such as topographical positions on the land scape and texture were grouped to produce the various soil mapping units. Seven mapping units were thus delineated. Pedons were dug at representative points in each mapping unit, described according to the guidelines of FAO (2006).

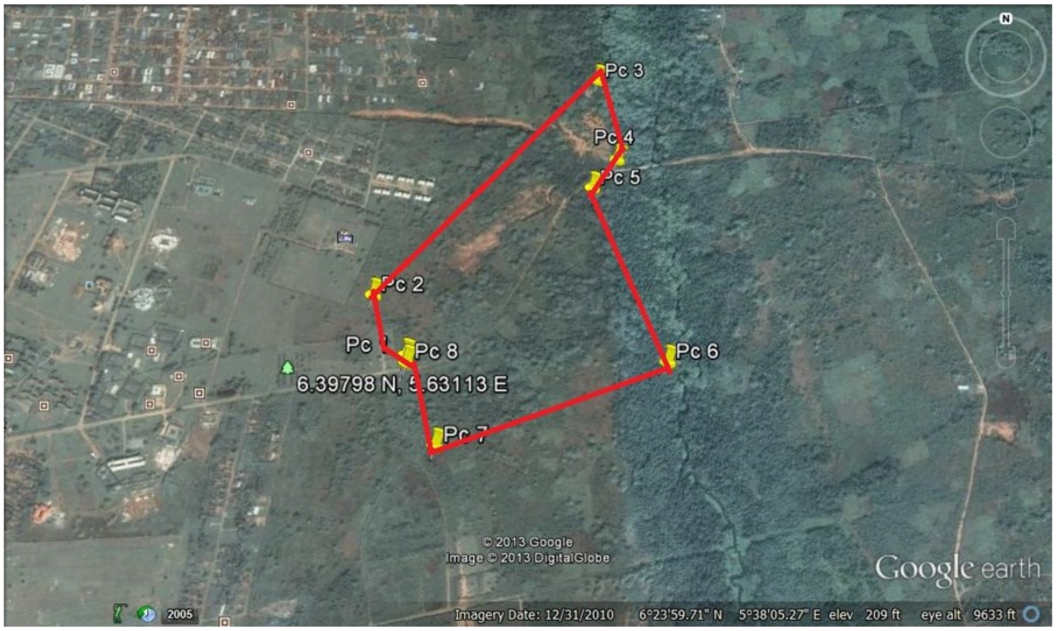

Fig. 3: Google imagery of a selected portion of the University of Benin Teaching, Research and Integrated Farm Site

2.2. Laboratory analysis

Soil samples collected from each horizon were air-dried and passed through a 2mm sieve.

The sieved samples were analysed for some physical and chemical properties. Particle size distribution was determined by the hydrometer method (Gee and Or, 2002) after the removal of organic matter content with hydrogen peroxide and dispersion with sodium hexametaphosphate (International Institute for Tropical Agriculture - IITA, 1979). Available P was determined by Bray-1 method (Olsen and Sommers, 1982). The pH was determined with glass electrode pH meter in soil: soil and water at ratio 1:1 (Maclean, 1982). Exchangeable Bases (Na, K, Ca and Mg) were extracted with neutral normal ammonium acetate (NH_4OAC at pH 7.0); Na and K were determined by flame photometer while Ca and Mg were determined by atomic absorption spectro photometer (Thomas, 1982). Total N was determined by Macro Kjedhal method (Bremner, 1996). Exchangeable Acidity was determined by titration method (Anderson and Ingram, 1993). Organic Carbon was determined by Walkley Black 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.

2.3 Soil map

Based on the field and laboratory results, a soil map was produced at a scale of 1:5000

2.4 Statistical analysis

Data generated by gen stat (version 8.1) statistical was used to determine variability of soil properties within pedons. Coefficient of variation (cv) was ranked according to the procedure of wilding *et al*., (1994) where cv < 15 % = low variation, cv ≥ 15 % ≤ 35 % = moderate variation, cv > 35 % = high variation.

2.5 Soil classification

Field and laboratory data were used to classify the soils using usda soil taxonomy (soil survey staff, 2014) and wrb (iuss working group, 2015).

3.0 RESULTS

3.1 Morphological properties

The result (Table 1) showed that all the horizons observed had colours which varied from 5YR3/2 (reddish brown), 2.5YR3/4 (dark reddish brown) to10R3/4 (dusky red) in Pedon 1; 5YR, 2.5/2, 2.5YR, 3/4 (dark reddish brown) to 2.5YR 4/6 (red) in pedon 2; 7.5YR, 3/1 (very dark grey colour), 5YR, 4/4 (reddish brown), to 7.5YR, 4/6 (yellowish red) in pedon 3; 2.5YR, 4/6 (red colour), 2.5YR, 4/6 (Red) to 10R, 4/6 to 10R, 3/4 (Dark red) in pedon 4; 10R, 4/6 (Red) to 10YR, 4/4 (dark yellowish brown colour -mottles) in pedon 5; 2.5YR, 4/6, 10R, 4/6 to 10R, 3/6 (Red) in pedon 6; 7.5YR, 3/3 (dark brown), 2.5YR, 3/4dark (reddish brown) to 2.5YR, 3/6 (dark red) in pedon 7. The varions in colour could be associated drainage, parent material and environmental factors (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. Textural class was light in surface horizons (Sand-Loamy sand except for pedon 5) and medium (Sandy loam-Sandy clay) in the sub-surface horizons (except for pedons 3and 4), which suggests high rate of leaching in the area. Structure of pedons at surface horizon for most of the pedons was single grain crumb except for pedons 5 and 6 (sub-angular blocky). Subsurface horizon for pedons 1,2,3,5,6 and 7 had sub-angular blocky structure while pedon 4 had single grain crumb. Root Abundance for surface horizon was many in pedons 1,2 and 7; common in pedons 4,5and 6 but few in pedon 3 while all the pedons had few roots in subsurface horizons except pedon 3 (which had many roots). Variation in root abundance may be associated with soil type and plant species present in the study area. Horizons of all the pedons were well drained except for subsurface horizon of pedon 5 which had mottles at the last layer.

3.2 Soil physical and chemical properties

Sand fraction of study area was highest among the particle size components, with means of 649, 725, 917, 931, 802, 829 and 723 gkg^{-1} for all the pedons. However, the pedons recorded low variations≤ 2.2 ≥ 15.5 gkg^{-1} which suggests homogeneity of the study area (osujieke *et al.*, 2018); this confirms uniformity of parent material in the study area (coastal plain sands). Silt fraction was generally low in all the pedons , with mean values ranging from≤ 13.2 ≥ 50 gkg^{-1}. The low silt content could be attributed to high degree of leaching. Silt variability was moderate in pedons 4 and 7 but high in all other pedons. Clay fraction ranged from ≤ 55 ≥ 303 gkg^{-1} and had variability ranging from moderate in pedons 2, 6 and 7 to high in pedons 1,3,4 and 5. Clay increased with increase in soil depth, suggesting the presence of an argillic horizon in the illuvial horizons of some of the pedons. ph of the pedons had low variabibiliy and ranged from extremely acidic (pedons 5,7), strongly acidic (pedons 1,2,4,6) to moderately acidic (pedon 3) with mean values ranging from ≤ 3.6 ≥ 5.2 the acidic nature of the soils could be attributed to the nature of parent material (coastal plain sands) and climatic condition of the study area. This agrees with the findings of ogunkunle (1983) who classified similar soils in nifor as acid sands due to low ph values and high degree of leaching in these soils . Weil and brady (2016) also opined that acidic ph can be attributed to acidic nature of parent material from which the soils were formed. Organic carbon had high variability in all the pedons (≤ 3.59 ≥ 61 %) except pedon 7 which had moderate variability (34.6%), with means ranging from ≤3.35 ≥ 36.4 gkg^{-1}. The exceptionally high organic carbon content of pedon 4 (34.6 gkg^{-1}) could be attributed to soil type (entisols) and slope position (valley bottom) of the soils. Organic carbon decreased irregularly with increase in depth in most of the pedons . Nitrogen was deficient in all the pedons according to the ratings of chude et al., (2011) with means ranging from ≤ 0.05 ≥ 0.63 gkg^{-1}. The low amount of nitrogen may be attributed to bush burning, crop harvest and degree of leaching in the study area. However variability was high in all the pedons. Nitrogen decreased with increase in depth. Available phosphorus had mean values of 5.2, 6.3, 15.0, 3.1, 8.5, 19 and 9.2 respectively. Variability of phosphorus ranged from high to medium ≤22.4% ≥ 139.6 % . This could be as a result of the acidic nature of the soils. Ano (2004) reported that acid soils have a high capacity of fixing phosphorus due to formation of insoluble al-p complex the result of exchangeable bases (table 2) showed that calcium was the only prominent basic cation in the study area. Sodium ranged from 0.24-0.37 $cmolkg^{-1}$, potassium content ranged from 0.01-0.27 $cmolkg^{-1}$, calcium ranged from 0.16-3.84 $cmolkg^{-1}$, magnesium ranged from 0.01 0-0.60 $cmolkg^{-1}$ in all the pedons. According to the ratings of landon (1991), potassium and magnessium were low, calcium was moderate, potassium ranged from low to moderate. The seeming low values of exchangeable bases further buttresses the fact that the degree of leaching is actually high as already suggested by the low ph values discussed above. Exchangeable acidity (hydrogen and aluminum) was low in all the pedons, which could be as a result of the low ph values of these soils and rate of leaching in the study area. Variability was high in pedons 2 and 5 (83.3%, 54.0%) but medium in other pedons (≤19% ≥2 8.5 %). Cation exchange capacity (cec) for all the pedons ranged from low to moderate with mean values ranging from ≤ 4.8 ≥ 16.4 gkg^{-1}. The low values could be attributed to climate and nature of parent material of the soils. Base saturation was less than 35% in pedons 1,2 and 7; strongly suggesting that they belong to the ultisol soil order of the usda soil taxonomy, but varied in other pedons. Ratio of eluvial to illuvial clay in pedons 1,2 and 7established the presence of argillic horizons in these pedons .

3.3 Taxonomic classification

Soil classification was done using USDA soil taxonomy and World Reference Base for soil Resources systems of soil classification. The soils were designated as pedons: 1,2,3,4,5,6 and 7. Pedons 1,2 and 7 had argillic horizon, udic moisture regime, iso-hyperthermic temperature and base saturation value less than 35% at the appropriate depth, which qualified them as Ultisols; pedons 3 and 4 had neither noticeable genetic horizons nor main morphological feature outside colour, thus they were classified as Entisols. Pedon 5 had shallow depth to water table as its main morphological feature; therefore it was classified as an Inceptisol. The main feature of pedon 6 was the presence of a cambic B horizon, thus, was also classified as an Inceptisol.

The udic moisture regime qualified pedons 1 and 2 as udults; the presence of kandic horizon in both pedons placed them as kandiudult at the great group level. They were classified as Rhodic kandiudult at sub-group level due to the nature of their colour (2.5YR, 5YR and 10R). At family level, Pedon 1 was classified as Fine loamy, Kaolinitic, Isohyperthermic, Rhodic Kandiudults because the area is characterized by an Isohyperthermic temperature regime, Loamy sand surface texture and Kaolinitic clay mineral class (Ogunkunle, 1983) under USDA soil taxonomy (Soil Survey Staff, 2014) and locally as Orlu series; they correlated as Nitic, Vetic Acrisols (Rhodic, Hyperdystric) in WRB (IUSS, 2015).

Pedons 3 and 4 were classified as Psamments at sub order level because they had less than 35% (by volume) rock fragments and a texture of Sand in all layers. At great group level, they qualified as udipsamment because they have an udic moisture regime; and Typic udipsamment at sub group level which is an indication that they do not possess a lithic contact, redox depletion, plaggen epipedon and are not saturated with water. At Family level, they qualified as Sandy Kaolinitic Isohyperthermic Typic Udipsamment under USDA soil taxonomy. Locally, Pedon 3 qualified as Ahiara series, while Pedon 4 qualified as Iweke series. This correlated as Protic Hypoluvic Arenosols (Eutric) in WRB for pedon 3; and Rubic Protic Arenosols (Eutric) in WRB for pedon 4.

Pedon 5 was classified as udept at sub order level, because of udic moisture regime. At great group level, it was classified as Dystrudept because it does not have a base saturation (by NH_4OAc) of 60% or more in one or more horizons at a depth between 25 and 75cm from the mineral soil surface. It was classified as Oxyaquic dystrudept at sub group level, because it is saturated with water in one or more layers within 100cm in normal years. At Family level, they qualified as Coarse Loamy Kaolinitic Isohyperthermic Oxyaquic Dystrudept under USDA soil taxonomy. Locally, they qualified as Kulfo series. This correlated as Stagnic Fluvic Cambisols (Oxyaquic, Dystric) in WRB.

Pedon 6 was classified as udept at sub order level, because of udic moisture regime. At great group level, it was classified as Dystrudept because it does not have a base saturation (by NH_4OAc) of 60% or more in one or more horizons at a depth

Table 1: Summary of morphological properties of the soils

Horizon	Depth(cm)	Colour(moist)	Texture	RootsAbundance	Structure	Boundary form
A_p	0-7	5YR3/2	Loamy Sand	Fine-Many	Very fine Single grain crumb	Smooth-Clear
BA	7-27	2.5YR3/4	Sandy Clay Loam	Fine-Common	Fine Sub-Angular blocky	Smooth-Gradual
Bt_1	27-66	2.5YR3/4	Sandy Clay Loam	Medium-Few	Fine Sub-Angular blocky	Smooth-Gradual
Bt_2	66-97	10R3/4	Sandy Clay	Medium-Very Few	Fine Sub-Angular blocky	Smooth-Gradual
Bt_3	97-143	10R3/4	Sandy Clay	Medium-Very Few	Fine Sub-Angular blocky	Smooth-Diffuse
Bt_4	143-185	10R3/4	Sandy Clay	Medium-Very Few	Fine Sub-Angular blocky	
A	0-13	5YR,2.5/2	Loamy Sand	Fine –Many	Fine or thin Single grain crumb	Smooth-Clear
Bt_1	13-49	2.5YR3/4	Sandy Clay Loam	Medium –Many	Fine or Thin Sub-Angular blocky	Smooth-Diffuse
Bth	49-80	2.5YR3/4	Sandy Clay Loam	Medium-Few	Fine or Thin Sub-Angular blocky	Smooth-Diffuse
Bt_2	80-120	2.5YR4/6	Sandy Clay Loam	Medium- Few	Medium Sub-Angular blocky	Smooth-Diffuse
Bt_3	120-171	2.5YR4/6	Sandy Clay Loam	Medium- Few	Medium Sub-Angular blocky	
A_p	0-14	7.5YR,3/1	Sand	Fine-Few	Very Fine-Single Massive Grain	Smooth-Clear
BA	14-31	5YR,4/4	Sand	Fine-Very Few	Fine-Single Massive Grain	Smooth-Clear
B_1	31-85	7.5YR,4/6	Sand	Fine-Very Few	Fine-Single Massive Grain	Smooth-Diffuse
B2	85-118	5YR,4/6	Sand	Medium-Very Few	Very Fine-Sub-Angular Blocky	Smooth-Gradual
B3	118-156	5YR,4/6	Sand	Medium-Very Few	Very Fine-Sub-Angular Blocky	
A_p	0-27	2.5YR,4/6	Loamy Sand	Fine-Common	Medium-Single Grain Crumb	Smooth-Clear
B_1	27-62	2.5YR,4/6	Sand	Fine- Few	Coarse-Single Grain Crumb	Smooth-Clear
B_2	62-120	2.5YR,4/6	Sand	Fine- Few	Coarse-Single Grain Crumb	Smooth-Clear
B_3	120-142	10R,4/6	Sand	Fine- Few	Coarse-Single Grain Crumb	Smooth-Clear
B_4	142-160	10R,3/4	Sand	Fine- Few	Coarse-Single Grain Crumb	
A_p	0-7	10R,4/6	Sandy Clay Loam	Fine-Common	Medium-Sub-Angular Blocky	Smooth-Clear
B	7-56	10R,4/6	Sand	Fine- Few	Coarse-Single Grain Crumb	Smooth-Clear
Bw_1	56-99	10R,4/6	Sandy Loam	Fine- Few	Medium-Sub-Angular Blocky	Smooth-Clear
Bw_2	99-117	10R,4/6 10YR4/4	Sandy Clay Loam	Fine- Few	Medium-Sub-Angular Blocky	
A_P	0-8	2.5YR,3/3	Sand	Fine-Common	Very Fine-Sub-Angular Blocky	Smooth-Gradual
BA	8-28	2.5YR,3/4	Loamy Sand	Fine- Many	Very Fine-Sub-Angular-Blocky	Smooth-Gradual
Bw_1	28-61	2.5YR,3/6	Sandy Loam	Fine- Many	Fine-Sub-Angular Blocky	Smooth-Clear
Bw_2	61-105	2.5YR,3/6	Sandy Loam	Medium- Few	Medium-Sub-Angular Blocky	Smooth-Diffuse
Bw_3	105-144	10R,3/6	Sandy Loam	Medium- Few	Medium-Sub-Angular Blocky	Smooth-Diffuse
Bw_4	144-170	10R,3/6	Sandy Clay Loam	Medium- Few	Medium-Sub-Angular Blocky	
A	0-13	7.5YR,3/2	Loamy Sand	Medium-Many	Very Fine-Single Grain Crumb	Smooth-Clear
BA	13-31	2.5YR,3/4	Sandy Clay Loam	Medium- Few	Very Fine-Sub-Angular Blocky	Smooth-Clear
Bt_1	31-66	2.5YR,3/2	Sandy Clay Loam	Medium- Few	Very Fine-Sub-Angular Blocky	Smooth-Clear
Bt_2	66-100	2.5YR,3/6	Sandy Clay Loam	Medium- Few	Fine-Sub-Angular Blocky	Smooth-Clear
Bt_3	100-145	2.5YR,3/6	Sandy Clay Loam	Medium- Very Few	Fine-Sub-Angular Blocky	Smooth-Clear
Bt_4	145-179	2.5YR,3/6	Sandy Clay Loam	Medium- Very Few	Fine-Sub-Angular Blocky	

Table 2: Some physical and chemical properties of the soils

Horizon	Depth	pH	EC	Org.C	N	P	Na	K	Ca	Mg	E.A.	CEC	ECEC (soil)	ECEC (clay)	BS	Clay	Silt	Sand
	cm	H_20	$\mu S/cm$	gkg^{-1}	gkg^{-1}	$mgkg^{-1}$					$Cmolkg^{-1}$				(%)		gkg^{-1}	
A_p	0-7	5.00	15.88	12.90	0.70	11.20	0.25	0.13	3.04	0.10	0.50	9.03	4.02	31.20	39.00	129	63	808
BA	7-27	4.10	13.15	10.50	0.70	6.64	0.27	0.10	1.52	0.10	0.80	13.4	2.79	12.30	14.90	226	40	734
Bt_1	27-66	4.50	12.23	7.20	0.10	3.30	0.28	0.13	1.84	0.20	1.20	16.40	3.65	12.20	14.90	300	70	630
Bt_2	66-97	4.20	12.02	5.10	0.20	5.29	0.26	0.10	1.52	0.10	1.20	18.30	3.18	8.20	14.16	386	60	554
Bt_3	97-143	4.20	9.73	4.80	0.70	1.78	0.27	0.09	1.44	0.20	1.00	20.50	3.00	20.50	16.67	390	10	600
Bt_4	143-185	4.50	11.83	5.40	0.50	2.81	0.25	0.09	1.28	0.20	0.90	20.60	2.72	20.60	16.82	389	43	568
Mean		4.42	12.47	7.6	0.48	5.2	0.26	0.12	1.77	0.15	0.93	16.4	3.23	17.5	19.4	303	47.7	649
CV		7.5	16.1	43.6	56.2	66.5	4.6	17.5	36.5	36.5	28.5	27.5	15.9	47.7	49.8	35.5	45.8	15.5
Ranking		LV	MV	HV	HV	HV	LV	MV	HV	HV	MV	MV	MV	HV	HV	HV	HV	MV
A	0-13	5.3	5.00	11.40	0.70	6.05	0.24	0.01	2.92	0.20	0.30	8.78	3.77	29.00	39.66	130	80	790
Bt_1	13-49	4.1	14.62	2.40	0.70	4.91	0.26	0.01	1.36	0.20	1.60	13.98	3.52	13.00	13.73	270	10	720
Bth	49-80	4.1	12.41	10.80	0.70	3.95	0.26	0.01	2.08	0.10	1.40	15.66	4.17	15.44	16.40	270	30	700
Bt_2	80-120	4.1	12.04	6.60	0.10	14.91	0.25	0.01	1.60	0.40	0.40	14.32	2.59	9.96	16.69	260	20	720
Bt_3	120-171	4.4	8.70	6.60	0.90	1.67	0.26	0.01	1.60	0.10	2.50	16.82	5.06	16.32	12.25	310	60	630
MEAN		4.55	9.6	8.2	0.63	6.3	0.25	0.01	2.08	0.2	1.08	13.1	3.81	18.8	23.1	228	47	725
CV		13.0	42.1	44.3	43.1	72.6	3.9	0.0	33.2	54.8	83.3	26.5	21.2	43.7	56.2	34.2	65.9	8.3
Ranking		LV	HV	HV	HV	HV	LV	LV	MV	HV	HV	MV	MV	HV	HV	MV	HV	LV
A_p	0-14	5.6	28.20	18.90	0.08	45.11	0.26	0.15	5.76	0.60	0.40	5.33	7.17	231.29	127.02	31	24	945
BA	14-31	5.2	17.86	8.40	0.02	16.22	0.26	0.13	1.84	0.10	0.20	3.73	2.53	61.71	62.47	41	29	930
B_1	31-85	4.6	11.20	8.10	0.07	3.48	0.27	0.27	1.60	0.20	0.40	4.42	2.74	48.93	52.94	56	39	905
B2	85-118	5.0	13.16	5.40	0.01	3.89	0.27	0.18	2.64	0.60	0.30	5.38	3.99	46.60	68.59	86	04	910
B3	118-156	4.8	13.21	5.40	0.03	6.26	0.28	0.11	2.56	0.40	0.30	5.38	3.64	42.44	68.59	86	19	895
MEAN		5.04	16.7	9.2	0.04	15.0	0.27	0.17	2.88	0.38	0.32	4.85	4.01	86	76	60	23.0	917.0
CV		7.6	41.0	60.5	74.2	117.5	3.11	37.3	56.0	60.0	26.1	15.4	46.5	94.5	38.6	42.2	56.3	2.2
Ranking		LV	HV	HV	HV	HV	LV	HV	HV	HV	MV	MV	HV	HV	HV	HV	HV	LV

Table 2 cont.

Horizon	Depth (cm) cm	pH H_2O	EC µS/cm	Org.C gkg^{-1}	N gkg^{-1}	P $mgkg^{-1}$	Na	K	Ca	Mg	E.A. $Cmolkg^{-1}$	CEC	ECEC (soil)	ECEC (clay)	BS (%)	Clay	Silt gkg^{-1}	Sand
AP	0-27	5.0	14.38	54	0.8	4.24	0.24	0.09	2.48	0.20	0.20	16.10	3.21	30.28	18.70	106	19	875
B_1	27-62	5.4	15.28	39	0.4	2.28	0.24	0.09	2.24	0.40	0.30	9.85	3.27	79.76	30.15	41	14	945
B_2	62-120	5.0	11.30	36	0.4	3.04	0.24	0.09	1.76	0.30	0.20	9.00	2.59	71.94	26.56	36	14	950
B_3	120-142	6.4	21.00	15	0.1	3.07	0.27	0.10	2.24	0.30	0.20	4.55	3.11	97.12	63.96	31	09	960
B_4	142-160	4.6	14.80	38	0.4	3.04	0.28	0.11	2.48	0.20	0.20	10.25	3.27	53.61	29.95	61	14	925
MEAN		5.28	15.4	36.4	0.42	3.13	0.25	0.10	2.24	0.28	0.22	9.9	3.09	67	33.9	55	14.0	931
CV		13.0	22.9	38.3	59.3	22.4	7.7	9.3	13.1	29.9	20.3	41.4	9.3	38.5	51.5	55.8	25.3	3.6
Ranking		LV	MV	HV	HV	MV	LV	LV	LV	MV	MV	HV	LV	HV	HV	HV	MV	LV
A_p	0-7	4.3	10.76	1.8	0.1	4.76	0.027	0.018	0.360	0.030	0.20	11.60	4.55	20.13	37.5	226	69	705
B	7-56	4.7	11.42	4.2	0.4	16.52	0.03	0.01	0.16	0.02	0.70	2.39	2.85	91.94	89.96	31	29	940
Bw_1	56-99	4.8	9.09	3.0	0.3	2.81	0.03	0.01	0.32	0.01	0.40	8.65	4.05	21.16	42.12	161	29	810
Bw_2	99-117	4.7	9.28	4.4	0.8	9.82	0.03	0.01	0.30	0.03	0.30	11.43	4.03	19.90	32.63	211	34	755
MEAN		4.62	10.14	3.35	0.40	8.5	0.03	0.01	0.29	0.02	0.40	8.5	3.87	38	51	157	40.2	802
CV		4.8	11.2	35.9	73.6	72.2	5.1	33.3	30.5	42.6	54.0	50.5	18.6	93.5	52.5	56.4	48.0	12.6
Ranking		LV	LV	HV	HV	HV	LV	MV	MV	HV	HV	HV	MV	HV	HV	HV	HV	LV
A_P	0-8	4.6	12.35	14.4	0.4	10.35	0.25	0.11	2.40	0.20	0.70	5.68	3.66	21.53	33.70	56	29	915
BA	8-28	4.2	12.50	9.00	0.5	10.61	0.24	0.09	1.68	0.30	0.80	9.10	3.11	10.37	15.22	146	24	830
Bw_1	28-61	4.2	12.07	6.90	0.2	72.32	0.27	0.10	2.56	0.60	1.40	8.44	4.93	15.90	22.57	166	4.0	830
Bw_2	61-105	4.2	10.05	2.40	0.3	17.13	0.26	0.11	1.12	0.20	1.10	9.78	2.97	8.03	9.11	186	9.0	805
Bw_3	105-144	4.3	5.78	6.00	0.5	1.93	0.24	0.09	1.36	0.10	0.90	9.55	2.65	6.80	9.12	191	9.0	800
Bw_4	144-170	4.3	9.56	3.60	0.7	2.34	0.24	0.09	1.44	0.20	0.80	10.77	2.77	6.93	9.82	201	4.0	795
MEAN		4.30	10.4	7.0	0.43	19	0.25	0.10	1.76	0.27	0.95	8.9	3.35	11.6	16.6	158	13.2	829
CV		3.6	24.8	61.0	40.4	139.6	5.1	10.0	33.4	65.7	27.2	19.7	25.4	51.2	59.5	34.0	81.2	5.4
Ranking		LV	MV	HV	HV	HV	LV	LV	MV	HV	MV	MV	MV	HV	HV	MV	HV	LV
A	**0-13**	**4.5**	11.04	9.6	0.09	9.91	0.37	0.015	3.84	0.60	0.80	7.42	5.76	52.36	66.85	110	60	830
BA	13-31	4.1	15.66	5.1	0.04	5.12	0.26	0.012	1.84	0.20	0.80	11.52	3.22	15.33	21.01	210	40	750
Bt_1	31-66	4.1	12.40	3.3	0.05	4.28	0.29	0.010	1.52	0.20	1.20	12.16	3.31	14.39	18.17	230	60	715
Bt_2	66-100	4.2	11.70	9.3	0.02	4.39	0.29	0.010	1.44	0.20	0.90	15.36	2.93	10.85	13.22	270	40	690
Bt_3	100-45	4.2	11.30	8.1	0.03	3.58	0.26	0.010	1.60	0.10	0.90	14.62	2.96	11.39	14.09	260	40	705
Bt_4	145179	4.3	10.52	7.5	0.06	3.92	0.27	0.010	1.60	0.30	0.70	16.00	2.97	10.24	14.19	290	60	650
MEAN		4.23	12.10	7.1	0.05	5.20	0.29	0.01	1.97	0.27	0.88	12.8	3.52	19.1	24.6	228	50.0	723
CV		3.6	15.3	34.6	51.4	45.5	14.3	18.3	46.8	65.7	19.5	24.9	31.4	86.0	85.1	28.3	21.9	8.5
Ranking		LV	MV	MV	HV	HV	MV	MV	HV	HV	MV	MV	MV	HV	HV	MV	MV	LV

between 25 and 75cm from the mineral soil surface. It was classified as Typic Dystrudepts at the subgroup level because it did not qualify as any other dystrudepts. At Family level, it was classified as Fine Loamy Kaolinitic Isohyperthermic Typic Dystrudepts by USDA taxonomyand locally as Kulfo series, which correlated as Haplic Ferralic Cambisols (Dystric, Rhodic) in WRB.

Pedon7 was classified as Udults at sub-order level, Rhodudults at great group level because of their colour , and Typic Rhodudult at sub group level. At Family level, they were classified as Fine Loamy Kaolinitic Isohyperthermic Typic Rhodudult under USDA soil taxonomy and locally as Orlu series, which correlated as Nitic Vetic Acrisols (Rhodic,Nudiargic) in WRB.

WRB system of soil classification is roughly equivalent to the great group level of USDA Soil Taxonomy, because the highest category in the classification system is generally based on the presence of diagnostic horizons, while the soil order is the highest category in USDA – based mainly on the consequences of climatic variations and diagnostic horizons. Thus, the two systems look intrinsically different – USDA Soil taxonomy is controlled by 12 soil orders while WRB is controlled by 32 Reference Soil Groups (RSG). Illustrating with this study, there are three major soil orders - by USDA –Ultisols, Inceptisols and Entisols.

Ultisols in WRB, is placed under soils generally with "clay-enriched subsoils" (WRB, 2015) and could be refered to as Acrisols and Alisols (Deckers et al, 2003), whereas ultisols in USDA is precisely pinpointed by the presence of argillic horizon and base saturation of ≤35 % at specific depths. This observation is consistent with the view that near-perfect correlation between the two major systems is only true for a few reference soil groups –Histosols, Vertisols and Andosols – the rest are currently at pro-parte matches (Deckers et al, 2003).

The attempt by WRB to reduce the heavy dependence on climatic data and rigorous laboratory information before classification can be precisely effected, especially in tropical countries where such data are not readily available, is commendable.

However, for more detailed comparisons required for management purposes, USDA Soil Taxonomy is more appropriate because of its comprehensive nature and hierarchical system especially in the inclusion of the family taxon/category in the classification system.

4.0 Conclusion.

This study revealed that the land of the University of Benin Teaching, Research and Integrated Farm site essentially consists of seven mapping units which were classified into Ultisols (Acrisols), Inceptisols (Cambisols) and Entisols (Arenosols). Morphologically, Sand fraction ranged from≤ 649 ≥ to 931 gkg^{-1}; Silt ranged from ≤ 13.2 to ≥ 47.7 gkg^{-1} while Clay ranged from ≤ 60 to 303 gkg^{-1} in all the pedons; clay fraction increased with increase in depth, forming argillic horizon in

Summary of classifications by USDA and WRB

Pedon	USDA soil taxonomy classification	WRB classification	Areal Extent (ha)	Areal coverage (%)
1,	Fine loamy,Kaolinitic,Isohyperthermic Rhodic Kandiudult	Nitic Vetic Acrisols (Rhodic, Hyperdystric)	15.18	24.43
2	Fine loamy,Kaolinitic,Isohyperthermic Rhodic Kandiudult	Nitic Vetic Acrisols (Rhodic, Hyperdystric)	14.59	23.47
3	Sandy, Kaolinitic, Isohyperthermic, Typic Udipsamment	Protic, hypoluvic Arenosols (Eutric)	4.06	6.53
4	Sandy, Kaolinitic, Isohyperthermic, Typic Udipsamment	Rubic Protic Arenosols (Dystric)	5.70	9.16
5	Coarse Loamy Kaolinitic Isohyperthermic Oxyaquic Dystrudept	Stagnic Fluvic Cambisols (Oxyaquic, Dystric)	3.11	5.01
6	Loamy Kaolinitic IsohyperthermicTypic Dystrudept	Haplic Ferralic Cambisols (Dystric, Rhodic).	3.95	6.35
7	Loamy Kaolinitic IsohyperthermicTypic Rhodudult	Nitic Vetic Acrisols (Rhodic, Nudiargic)	12.86	20.69

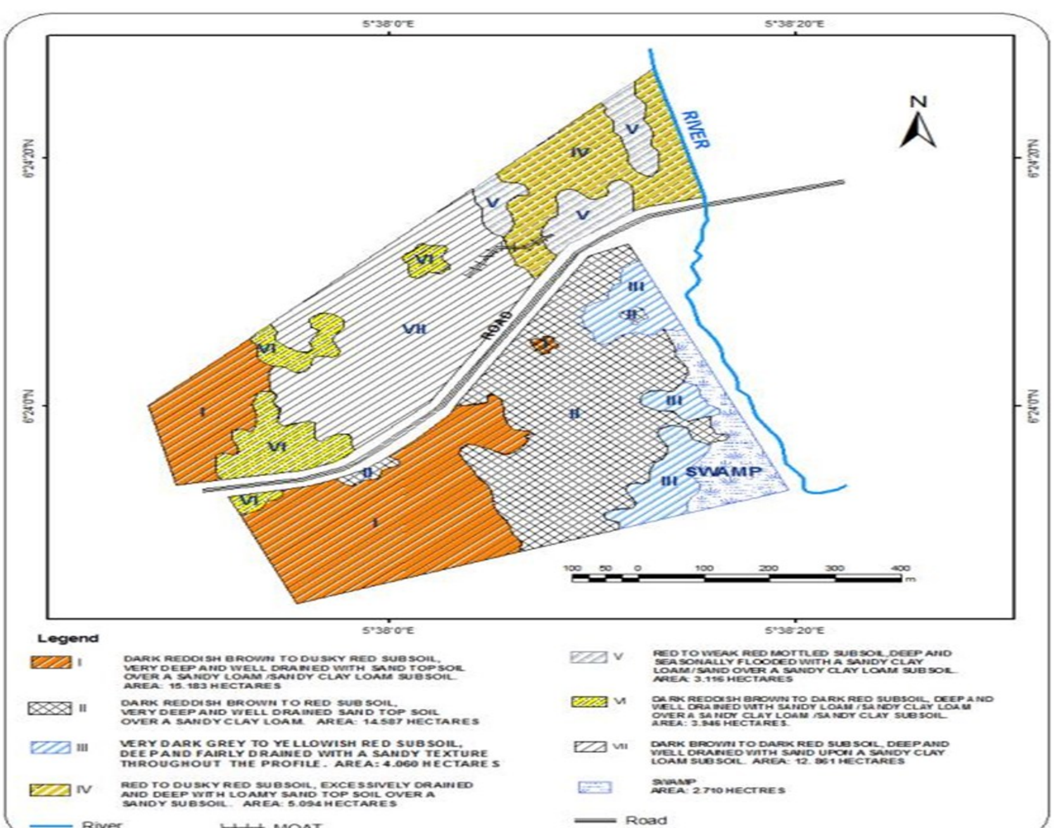

Fig. 4: Soil Map of a selected portion of the University of Benin Teaching, Research and Integrated Farm Site.

pedons 1,2 and 7. USDA soil taxonomy system of classification, though does not enjoy a comparative global acceptance, is recommended because of its seeming comprehensiveness and details in this study; especially because of the size of the work. Otherwise, on a general basis, WRB is to be preferred because of its seeming efforts to incorporate the peculiarities of the tropical environment into its classification system. Thus for a balanced work, classification in both systems should be done.

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