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Research Article

Characterization and Classification of Soil on Varying Lithology in Okigwe Imo Southern Eastern, Nigeria

Patricia Akunna ORIAKU[a] ID, **Christopher Ikechukwu OBINECHE**[b*] ID

[a] *Department of Soil Science Technology, Federal College of Land Resources Technology, P.M.B.1518 Owerri, NIGERIA*

[b] *Department of Agricultural Engineering Technology, Federal College of Land Resources Technology, P.M.B. 1518 Owerri, NIGERIA*

(*): Corresponding author, ikechiobineche@gmail.com

ABSTRACT

The field study was carried out in Okigwe South-eastern Nigeria. Three profiles were sunk in soils of each of each parent material. Soil samples were subjected to routine and standard laboratory analysis for selected physic- chemical properties. The morphological and physic-chemical properties of the soils varied widely, sand size particles dominated other particle sizes with the mean values of 448, 538 and 648 g kg^{-1} on sandstone, while soils derived from Imo clay shale was 583 g kg^{-1} for Umuna. Clay in Imo Clay Shale and bulk density recorded highest values at NIHORT 1, 416 and 15 g kg^{-1} respectively. All pedons exhibited sandy clay loam on topsoil and relatively more clayey subsoil. Total nitrogen correlated positively and significantly (0.5) with organic matter in both soils. Clay correlated negatively with ECEC in sandstone and positively in clay shale, and both were not significant. The soils derived from false bedded sandstone (NIHORT 1, 2 and 3) were classified according to USDA soil Taxonomy as Inceptic Paleudults which translate to Dystric Nitisols in WRB system. Soils from Umuna were classified as Typic Hapludalf USDA and soils from NIHORT 1, 2 and 3 were classified as class II of the USDA capability classification system. Umuna was classified in class III. In conclusion the soils of these two parent materials sustain farm produce, if proper land use practices and special conservation for selected crop production are adopted.

RESEARCH ARTICLE

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INTRODUCTION

Soil is an important resource for the production of food and fibre necessary for the sustenance of an increasing world population (Papendick and Parr, 1992). Soil is a dynamic resource, hence it supports plant life. It is made of different sized mineral particles, organic matter, and numerous species of living organisms. Thus, soil has biological, chemical, and physical properties, some of which are dynamic and can change in response to how the soil is managed. Soils are classified as natural bodies on the basis of their profile characteristics (Brady and Weil, 1999). Conserving and improving soil quality during the cultivation activities are the basics of sustainable agriculture (Çelik *et al.*, 2017). Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Changes in the capacity of the soil to function are reflected in soil properties that change in response to management or climate. Its production can be limited by the factors such as the soil characteristics, agro-ecological factors, topography, parent material, land use and management among others. To avert this limitation, the need for a systematic appraisal of the soil resource with respect to their extent, distribution characteristics, behavior and nutrient status is crucial for developing a productive and sustainable agricultural system.

Most farmers in south-eastern Nigeria regard the soil to be the same in every aspect because they are all the same based on geographical location. Igwe (2003) posit that most soils in southeastern Nigeria are not classified but are utilized in land use activities leading to water erosion. Onweremadu (2007) stated that characterization and classification of soil of any given location help in generating soil related data which are useful in proper and sustained use of soil resource. Presently, there is an increased request of information on soils with respect to food production. Agriculture overtime as become the major economic activity in Nigeria, because of the development in agriculture and its increased demand for experimental data much work is carried out on soil characterization in Nigeria. This makes available elementary information essential to generate efficient schemes for the classification of soils as well as assessing the fertility of the soil so as to unpick certain exceptional complications of soil in an ecology (Lekwa, 1998). The combination of soil mapping, characterization and classification of soil offers a potent source to the advantage of mankind, specifically to ensure adequate environmental sustenance and food security. Knowledge acquired from the characterization of soils would as well assist agriculturalists to reasonably plan the development and the use of lands accordingly, so as to put accessible agricultural lands to their optimum uses for sustainable production of food. Varying soil characteristic requires dissimilar management practices, land use activities for best and sustainable performance. The possibility lies on adequate information with respect to the physicochemical parameters of the soil category under investigation. In addition, several, agriculturalists and most land users in Nigeria; especially the south easterners have handled the soils of this sub-region in a similar method, erroneously considering that all the soils are the same. The low return on investment can be attributed to the erroneous concept and methodology used in both for agricultural production and other land use categories. Based on the notion, the study therefore focused on the characterization and classification of soil on varying lithology in Southeastern Nigeria for sustainable agriculture for food security. The major focus of this study is to characterize and classify some soils derived from two different parent materials. The USDA Soil Taxonomy and World Reference Base (WRB) were utilized, and the specific objectives includes the estimation of the degree of variability of some soil properties among the different soil groups and to establish the amount of relationship between various soil properties in the study area.

MATERIAL and METHODS

Okigwe, Southeastern Nigeria is the experimental area. It is situated on latitudes 5° 45'N - 6° 00'N and longitudes 7º 15'E - 7º 30'E with an altitude of approximately 300 m and above. Okigwe has a humid tropical climate, having a mean annual rainfall range of 2000-2250 mm. Mean annual temperature range of 27-28°C and relative humidity varies with seasons as 80 -90% range occurs at 10 am in the rainy season while 60-80% relative humidity is recorded at 10 am during the dry season. Okigwe has a humid tropical climate, having a mean annual rainfall range of 2000-2250 mm. Mean annual temperature range of 27 -28°C and relative humidity varies with seasons as 80-90% range occurs at 10 am in the rainy season while 60-80% relative humidity is recorded at 10 am during the dry season. The soils of the area are derived from false bedded sandstones (Ajali Formation) of the Maastrichtian geologic era and proximal to the upper coal measures (Nsukka Formation) of the Danvan geologic age and Imo Clay shale.

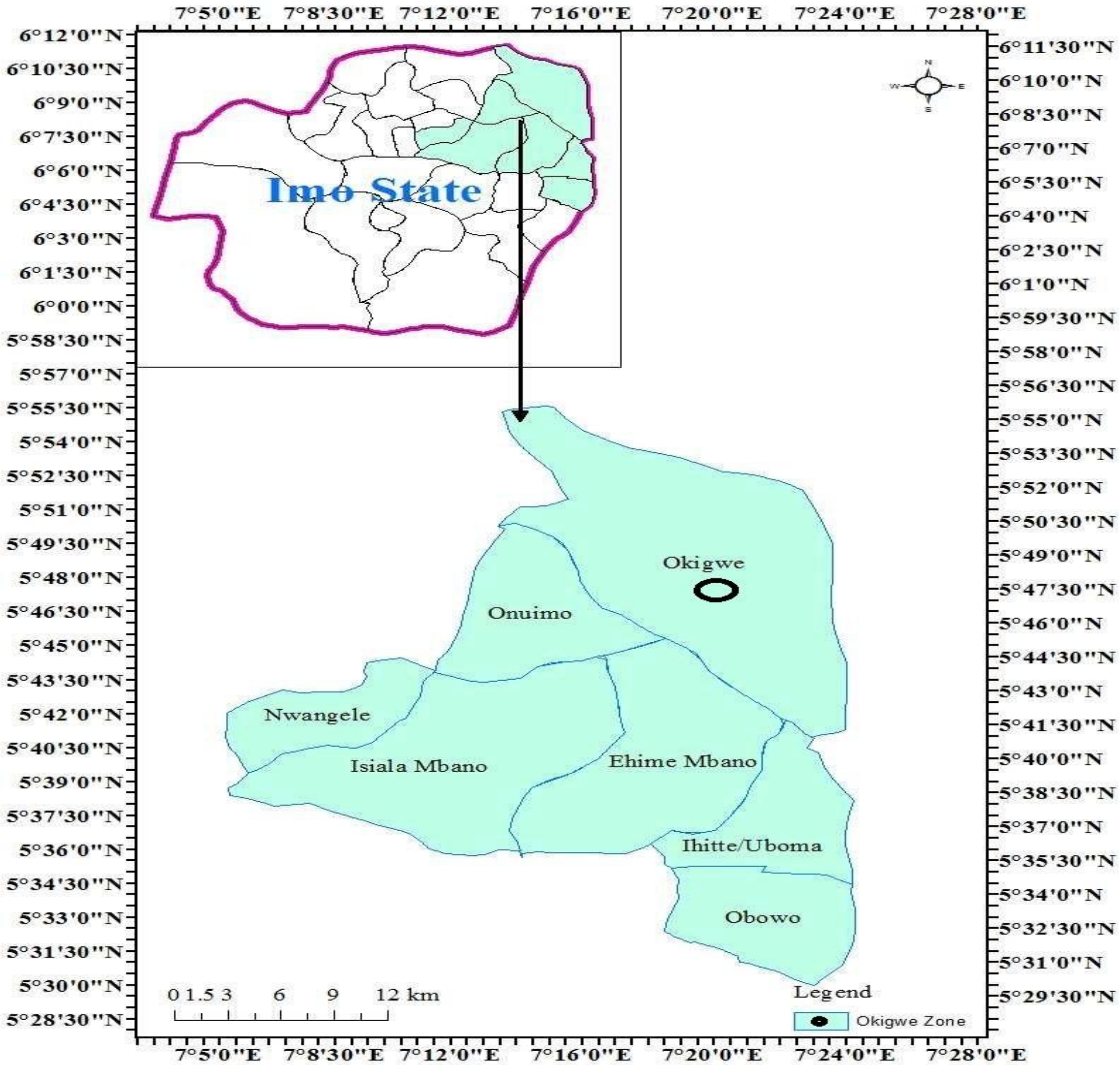

Figure 1. Location map of the study area.

Geology of The Experimental Area

The experimental zone is a complicated geological location in Southeastern Nigeria. Hence, the following stratigraphic components inspire the area; Benin, Ogwashi-Asaba, Bende-Ameki, Imo Shale, Nsukka and Ajali Formations (Nwosu *et al.*, 2010). The Benin Formation is superimposed by lateritic overburden and underlain by the Ogwashi-Asaba Formation which is in turn underlain by the Ameki Formation of Eocene to Oligocene age. The Benin Formation consists of course- grained gravelly sandstones with minor intercalations of shales and clay. The sand soil units which are usually coarse grained; pebbly and poorly arranged comprise lenses of fine-grained sands (Onyeaguocha, 1980). The raining period commences in April and terminates in October with a peak in the month of June and July whereas, dry period last from November to March.

Field Work

An inspection visit was carried out on the experimental zone, materials such as location map, topographic map, geology maps and munsell colour chart were used handheld Global Positioning System (GPS) receiver (Gamin Ltd Kansas) was utilized to geo-reference sampling site. A free-soil survey technique was used to locate the sampling point from the two geological formations of the study area. The following were the study site located, False bedded sandstone (NIHORT 1, NIHORT 2, NIHORT 3) and Imo Clay shale (Umuna). The study area is a complex geological environment in Imo State. The following stratigraphic units underlie the area; the Benin formation, the Ogwashi-Asaba formation, the Bende – Ameki formation, Imo state formation, Nsukka formation and Ajali formation.

Table 1. Geo-location of sampled sites.

Position	Latitude(N)	Longitude (E)	Elevation (m)
NIHORT 1	5^0 52. 67'N	7^0 18.47'	156
NIHORT 2	5^0 52. 68'N	7^0 18.54'	153
NIHORT 3	5^0 52. 87'N	7^0 18.54'	153
UMUNA	5^0 46. 08'N	7^0 14.97'	129

Sample Collection and Preparation

Soil profiles were described according to FAO (1983) procedure. A total of five profiles were sunk, three on each parent material. Delineation of horizon boundary was accomplished before actual sample collection. Soil samples collection was based on horizon differentiation. The samples collected were stored in polythene bags and labeled. Samples collected were air-dry and 2 mm sieve was used in the preparation to various laboratory analyses.

Laboratory Analyses

The soil samples were analyzed for certain selected properties that are necessary for proper scientific classification of the soils. These include physical properties such as particle size distribution, bulk density and hydraulic conductivity. Chemical properties such as soil pH, exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) exchangeable acidity (Al^{3+} and H^+), total nitrogen, available phosphorus and organic carbon. The hydrometer method was utilized in the determination of the particle size distribution as posited by Gee and Or (2002). Silt clay ratio was obtained by calculation, soil moisture content was determined gravimetrically by weighing an oven drying soil sample collected from the field at 105°C until a constant weight was attained (Obi,1990), Bulk density was determined using the core samplers as noted by (Grossman and Reinsch, 2002). Soil pH was determined by the use of distilled water on Beckman Zeromtic pH meter using a glass electrode at a 1: 2: 5 soil water ratio (Thomas, 1996), exchangeable acidity and organic carbon (OC) was determined by an unbuffered saturated solution such as in KCL at the pH of the soil (Mclean, 1982) and Walkey and Black wet oxidation method (Nelson and Sommer, 1982) respectively. Ca, Mg, K, Na (exchangeable bases) were determined from the soil in 1 m ammonium acetate solution (Thomas, 1996), soil organic matter was determined by calculating

%organic matter = %organic carbon x 1.724, Where; 1.724 = correlation factor (Van Bemelies constant factor), exchangeable potassium and sodium in the extract was determined by the use of flame photometric method while calcium and magnesium was determined using ethylene diamine tetra acetic acid titration method (EDTA).

The Micro-Kjedahl digestion method was used in the determination of total nitrogen and available phosphorus (Bremner and Mulvaney, 1982) and Bray 11 method (Olsen and Sommers, 1982) respectively. Summation of all exchangeable bases and acidty was used to determine effective cation exchange capacity (ECEC) (Carter, 1993), total exchangeable base (TEB) was determined by summation of all the exchangeable bases. Percentage base saturation was determined using the following formula:

Percentage base saturation $=\frac{TEB}{CEC} x\ 100$ (1)

Aluminum saturation was calculated using the formula $\frac{AL}{CEC} x\ 100$ (2)

USDA soil Taxonomy and world reference base for soil resources (WRB) was used in the soil classification and soil properties.

Data and Statistical Analyses

Simple descriptive statistics, means, standard deviation and co-efficient of variation (CV) was used during the data calculation. Variability of soil properties on the two parent materials was estimated using coefficient of variation. Ranking of variability and sample regressions was performed using (Wilding, 1985).

Correlation analyses of the model $[D=i + s_1 X_1 + s_2 X_2 + s_3 X_3 + \ldots\ldots\ldots + s_n X_n + U]$ was used.

Where,
D = dependent variable,
i = intercept (constant),
s = slope,
X = independent variable,
U = stochastic factor.
Co- efficient of variation as ranking according to Wilding (1985).

Table 2. The coefficient of variation as ranked by Wilding (1985).

Level %	Ranking
CV < 15	Low Variation
CV 15 – 35	Moderate Variation
CV < 35	High Variation

RESULTS and DISCUSSION

The soil texture result is shown in Table 4. This indicates that the soil texture ranges from sandy loam to sand clay loam. Umuna soil had sandy loam on the top soil and sandy clay down the profile. This is in line with the work of Eshett (1985), who observed that the texture of surface horizons of soils in humid tropics is dominated by loamy sand to sandy loam. The matrix colour at the top soil (A horizon) was darker than the subsoil. This is shown in Table 3.

Table 3. The soil morphological characteristics of the experimental site.

Horizon	Depth (cm)	Matrix colour	Texture	Structure	Consistency	Drainage
UMUNA						
A	0 – 15	Dark Reddish Brown (5YR $^3/_4$)	SCL	Granular	Loose	wd
AB	15 -40	Dark Brown (7.5YR $^3/_4$)	C	Sbk	Firm	wd
Bt1	40 – 80	Brown (7.5YR $^4/_4$)	SC	Sbk	Firm	wd
Bt2	80 – 120	Strong Brown (7.5YR $^4/_6$)	SC	Sbk	Firm	wd
Bt3	120 - 150	Strong Brown (7.5YR $^4/_6$)	LS	Sbk	Firm	Pd
NIHORT 1						
A	0 - 15	Reddish Brown (5YR $^4/_3$)	SCL	Sbk	Loose	wd
AB	15 - 45	Yellowish Red (5YR $^4/_6$)	SCL	Sbk	Firm	wd
Bt1	45 - 80	Red (2.5YR $^4/_8$)	C	Sbk	Firm	wd
Bt2	80 - 120	Red (2.5YR$^5/_8$)	SL	Granular	Firm	wd
Bt3	120 - 180	Red (10 YR $^4/_8$)	SL	Sbl	Firm	wd
NIHORT 2						
A	1 - 18	Strong Dark Brown (7.5YR 2.5/3)	SCL	Sbk	Loose	wd
AB	18 - 50	Dark Brown(7.4YR $^3/_4$)	SCL	Sbk	Firm	wd
Bt1	50 - 75	Red (10YR $^4/_6$)	SL	Granular	Firm	wd
Bt2	75 - 120	Red (2.5YR $^8/_8$)	SCL	Sbk	Firm	wd
NIHORT 3						
A	1 - 20	Very Dark Brown(2.5YR $^{2.5}/_2$)	SCL	Sbk	Firm	wd
AB	20 - 60	Very Dark Brown(7.5YR $^4/_3$)	SCL	Sbk	Firm	Pd
Bt1	60 - 90	Brown (7.5YR $^4/_3$)	SCL	Granular	Firm	Pd

SL = sandy loam, C = clay, LS = loamy sand, SCL = sandy clay loam, sbk = sub angular blocky, wd = well drained, pd = poorly drained.

Physical Properties of Soil Derived from Imo Clay Shale and False Bedded Sandstone

Tables 4.1. and 4.2 shows the result of the physical properties of Imo clay shale and false bedded sandstone in the study areas, the soil moisture content at Umuna improved via depth and has a mean value of 85 g kg^{-1} in clay shale. Salako (2003) reported similar increase in water retention and clay content down the profile in Guinea Savana zone of Nigeria. Soil from sandstone (NIHORT 1, 2 and 3) has no definite distribution pattern of soil moisture content. Clay content was high generally in the subsoil of all the profile of the two parent materials but low at the top, increasing down the profile before decreasing in the last horizon as shown in depth function of clay in the pedons. Eshett (1985) noted that the increment in the content of clay down the profile could be diagnostic of existence of illuviation. Silt content ranges from low to moderate. The highest mean silt value was recorded at NIHORT 1 (136 g kg^{-1}). Bulk density ranges from 12.9 g kg^{-1} to 16.9 g kg^{-1} on both soil types. It would be observed that the bulk density on the two parent materials was lower, hence it oppose the quoted value of the minimum bulk density at which root – constraining situations occur in the sandy loam soils (175-180 g kg^{-1}) (USDA NRCS, 1996) sand (16 g kg^{-1}) and clay (1.4 g kg^{-1}). The low amount in bulk density shows that the soils were not compacted. Hence, it may attribute to the improvement of soil tilt and porosity through the continuous addition of organic matter from decay plants residues in soil surfaces.

Table 4.1. Physical properties of soil derived from false bedded sand stone.

Horizon	Depth (cm)	Soil moisture content (smc)	Sand →	Silt g kg^{-1}	← Clay	Textural class	Silt/Clay ratio (g kg^{-1})	Bulk density (mg m^{-3})	Soil hydraulic (kgs m^{-3})
A	0 - 15	62.6	628	120	252	SCL	0.48	14.7	0.3
AB	15 - 45	96.5	508	160	332	SCL	0.48	14.9	0.2
B1	45 - 80	80.9	328	80	592	C	0.13	16.9	0.2
B2	80 - 120	62	388	140	472	SC	0.29	14.2	0.9
B3	120 - 160	64.4	388	180	432	SC	0.41	15.5	1.4
Mean		73.7	448	136	416		0.36	15	0.7
A	1-18	118.1	648	80	272	SCL	0.29	13.4	0.19
AB	18 - 50	95.2	468	100	432	SC	0.23	15.1	0.12
B1	50 - 75	76	368	160	472	SC	0.33	13.9	0.13
B2	75 - 120	113.3	668	20	312	SCL	0.38	15	0.23
Mean		100	538	90	372		0.3	14	0.2
A	1-20	73.7	628	100	270	SCL	0.37	14.3	0.12
AB	20 - 60	92	728	60	210	SCL	0.28	14	0.24
B	60 - 90	112.1	588	140	272	SCL	0.51	13.9	0.13
Mean		93	64.8	100	251		0.44	14	0.2

SL = Sandy Loam, C = Clay, LS= Loamy Sand, SCL = Sandy Clay Loam

Table 4.2. Physical properties of soil derived from Imo Clay Shale.

Horizon	Depth (cm)	Soil moisture content (smc)	Sand →	Silt (g kg^{-1})	← Clay	Textural class	Silt/ Clay ratio	Bulk density (mg m^{-3})	Soil hydraulic conductivity (g kg^{-1})
UMUNA									
A	0 – 15	64.6	588	180	232	SCL	0.77	13.9	1.1
AB	15 – 40	95.2	328	160	512	C	0.31	15.8	0.5
B1	40 – 80	87	388	160	452	SC	0.35	14.6	0.1
B2	80 – 120	73.0	808	110	820	SC	1.34	14.8	0.2
B3	120 – 150	103	820	60	112	LS	0.53	12.8	1.2
Mean		85	588	134	278		0.4	14	0.4

SL = Sandy Loam, C = Clay, LS = Loamy Sandy, SCL = Sandy Clay Loam

Chemical Properties of Soil Derived from Imo Clay Shale and False Bedded Sandstone

The result of the chemical properties of the two areas under study is as stated in Tables 5 and 6 respectively. The pH was reported to be moderately acidic (4.63-5.74). The pH in H_2O was higher than the pH in KCL in the soil, this is in accordance with Ukaegbu and Akamigbo (2004). The organic carbon ranges from 3.9-18.6 g kg^{-1} and has a mean value of 14 g kg^{-1}, the highest value was recorded at the surface. This is in line with Igwe (2003), who observed that when soils erode negative soil properties such as sealing, crusting, nutrient depletion and loss of organic matter occur. Also in sand stone the highest mean value was recorded at the surface horizon of NIHORT 1 and 2, except NIHORT 3 where the highest value was at the subsoil AB horizon and decreases down profile. Total nitrogen and organic matter ranges from 0.3-2.1 g kg^{-1} and 6.8-42.3 g kg^{-1}, while their mean values are 1.2 g kg^{-1} and 24 g kg^{-1} respectively. The C/N ratio of clay shale have a mean value of 12.3%, this is in line Onweremadu and Anikwe (2007) who reported a C/N ratio range from 9% to 16% in the top soil of the shale soils of Isienyi Ibeku and Igbokwe *et al.*, (1982) which ranged from 8.2 to 12% at Afikpo. Similarly there was low C/N ratio in sandstone which ranges from 13.0 %, 12.3% and 12.6% in NIHORT 1, 2 and 3 respectively the C/N ratio has irregular distribution pattern on all the pedons. The mean values of exchangeable calcium and total exchangeable bases were 2.30 g kg^{-1} and 4.5 g kg^{-1}; while available phosphorous was 3.1 mg kg^{-1} respectively. The highest value of magnesium was recorded at the topsoil (A horizon) in clay shale 2.40 cmol kg^{-1} and the mean value 1.76 cmol kg^{-1}. The potassium value of Umuna (clay shale) ranges from 0.18-0.31 cmol kg^{-1}, while, NIHORT 1 (sandstone) has a potassium value lowest 0.15 cmol kg^{-1}. Exchangeable sodium was generally low in both soils of different parent materials as shown in the tables 4.1 and 4.2. The mean values of ECEC in sand stone were 5.5, 6.8 and 6.9 cmol kg^{-1} they had irregular distribution pattern at all the physiographic position with the highest value recorded in NIHORT 3 (8.53 cmol kg^{-1}). The Ca/Mg ratio ranges from 0.5-1.71 on the Imo clay shale, while the ration on false bedded sandstone ranges from 1.2-2.5. This indicates an increasing unavailability of Mg and increases availability of Ca required. According to Landon (1991); Ca: Mg ration less than 3.0 negatively influences calcium and phosphorus availability in the soil. Sandy soils have relatively high bulk density since total pore space in sands is less than that of clay soils, hence a high clay content achieved a higher bulk density.

Table 5. Chemical properties of soils derived from false bedded sand stone of NIHORT 1, 2 and 3.

Horizon	Depth cm	pH H_2O	KCL →	O.C g kg^{-1}	← O.M	T.N	C:N Ratio	TEA	AL →	H	Ca cmol kg^{-1}	← Mg	K	Na	TEB	CEC	BS%	Ca:Mg Ratio	K:Mg Ratio	Avl.P g kg^{-1}
NIHORT 1 (false bedded sand stone)																				
A	0 -15	5.08	3.71	30.3	52.2	0.26	11.6	2.4	0.9	1.5	3.5	1.4	0.22	0.11	5.23	7.31	73.3	2.5	0.15	9.37
AB	15 -45	4.96	3.6	10.4	17.8	0.08	13.0	1.4	1.0	0.4	3.2	1.6	0.16	0.09	5.05	6.45	78.2	2.0	0.11	2.82
Bt_1	45 -80	5.67	3.47	6.8	11.2	0.05	13.6	2.7	1.4	1.3	1.6	1.0	0.15	0.12	2.87	5.61	51.8	1.6	0.15	1.49
Bt_2	80–120	4.34	3.72	6.7	11.6	0.05	13.4	1.5	0.9	0.7	2.6	1.2	0.26	0.19	4.25	5.75	73.9	2.1	0.12	2.34
Bt_3	120–160	5.79	3.59	6.7	11.6	0.05	13.4	0.6	0.4	0.2	2.2	1.2	0.15	0.07	4.25	4.2	85.7	1.8	0.12	0.96
Mean		5.1	3.6	12.0	24.0	0.1	13.0	1.6	0.9	0.8	2.6	1.2	0.2	0.1	4.3	5.8	59.7	2.0	0.13	3.3
NIHORT 2 (false bedded sandstone)																				
A	1- 18	5.11	3.72	14.6	25.1	0.12	12.6	2.2	1.2	1.0	3.0	1.2	0.24	0.1	4.54	6.74	67.3	2.5	0.2	4.68
AB	18 – 50	5.74	4.41	7.4	12.7	0.06	12.33	1.8	1.2	0.6	1.8	1.2	0.25	0.12	3.37	5.17	65.1	1.5	0.2	1.69
Bt_1	50 – 75	5.67	3.57	14.9	25.7	0.12	12.41	2.0	1.2	0.8	3.8	2.2	0.24	0.15	6.39	8.39	76.1	1.7	0.1	2.16
Bt_2	75 – 120	5.13	3.72	12.4	21.3	0.1	12.41	1.9	0.9	1.0	3.2	1.6	0.26	0.12	5.18	7.17	73.5	2.0	0.16	2.87
Mean		5.4	3.8	12.0	21.0	6.1	12.3	1.9	1.1	0.8	2.9	1.5	0.2	0.1	3.8	6.8	70.5	1.9	0.2	2.2
NIHORT 3 (false bedded sandstone)																				
A	1 – 20	4.33	3.27	5.5	9.6	0.04	13.75	0.8	0.3	0.5	1.8	1.4	0.23	0.14	3.57	4.37	81.6	1.2	0.16	1.42
AB	20 – 60	5.21	4.73	14.2	24.4	0.12	11.8	0.9	1.0	0.9	3.5	2.6	0.32	0.21	6.63	8.53	77.7	1.3	0.14	2.66
Bt_1	60 – 90	5.28	4.89	12.4	21.3	0.1	12.4	1.7	1.1	0.6	3.66	2.2	0.29	0.22	6.37	8.01	78.7	1.66	0.13	2.54
Mean		4.9	4.3	12.0	13.0	0.08	12.6	0.6	0.8	0.5	2.9	2.0	0.2	0.2	5.5	6.9	79.3	1.3	0.14	2.2

OC =organic content, OM= organic matter, TN= total nitrogen, TEA=total exchangeable acidity, AL= aluminum, H= hydrogen,Ca= calcium, Mg= magnesium, potassium, Na= sodium, TEB= total exchangeable base, CEC= cation exchangeable capacity, BS=base saturation, Avl. P = available phosphorus

Table 6. Chemical properties of soil derived from Imo Clay Shale.

Horizon	Depth (cm)	pH (H_2O)	KCL →	O.C $g\ kg^{-1}$	O.M ←	T.N	C:N ratio	TEA	AL	H	Ca →	Mg	K cmol kg^{-1}	Na ←	TEB	CEC	BS%	Ca:Mg ratio	K:Mg ratio	Avl. P $g\ kg^{-1}$
UMUNA Imo clay shale																				
A	0 -15	5.43	4.84	24.5	42.3	2.1	11.6	0.5	0.4	0.1	1.2	2.4	0.31	0.2	4.11	7.41	93.0	0.5	0.12	3.86
AB	15 -40	5.46	4.74	3.9	6.8	0.3	13	2.0	1.2	0.8	1.8	1.2	0.24	0.16	3.4	4.6	56.5	1.5	0.2	0.66
Bt_1	40 -80	5.74	4.54	14.9	25.7	1.2	12.4	1.9	1.1	0.8	3.3	2.0	0.3	0.27	5.87	7.7	75.5	1.65	0.15	4.06
Bt_2	80 - 120	5.68	4.73	18.6	31.9	1.5	12.4	0.8	0.3	0.5	2.75	1.6	0.18	0.12	4.65	5.45	85.3	1.71	0.11	5.46
Bt_3	120 - 150	4.63	3.63	8.7	15.1	0.7	12.4	1.0	0.7	0.3	2.6	1.6	0.27	0.18	4.65	5.65	82.3	1.62	1.6	1.51
Mean		5.3	4.3	14.0	24.0	1.2	12.3	1.2	0.8	2.5	2.3	1.76	0.26	0.18	4.5	6.1	78.5	1.4	0.4	3.1

OC =organic content, OM= organic matter, TN= total nitrogen, TEA=total exchangeable acidity, AL= aluminum, H= hydrogen,
Ca= calcium, Mg= magnesium, potassium, Na= sodium, TEB= total exchangeable base, CEC= cation exchangeable capacity, BS=base saturation, Avl. P = available phosphorus

Table 7. Variability of some selected soil properties of false bedded sandstone.

Soil properties	NIHORT 1	Ranking CV %	NIHORT 2	Ranking CV %	NIHORT 3	Ranking CV%	UMUNA	Ranking CV %
Sand	27.0	MV	27.0	MV	11.0	LV	39.6	HV
Silt	28.0	MV	64.0	HV	40.0	HV	36.2	HV
Clay	31.0	MV	26.0	MV	14.0	LV	70.0	HV
S/clay ratio	42.0	HV	21.0	MV	30.0	MV	64.0	HV
SHC	21.0	MV	20.0	MV	21.0	MV	19.0	MV
BD	7.5	LV	6.5	LV	1.4	LV	8.1	LV
pH (H_2O)	11.0	LV	6.5	LV	11.2	LV	8.1	LV
TEB	22.0	MV	26.0	MV	31.2	HV	20.0	MV
ECEC	20.0	MV	19.0	MV	33.0	MV	54.0	HV
BS	53.0	HV	7.5	LV	3.2	LV	18.0	MV
OM	85.0	HV	28.0	MV	42.0	HV	57.0	HV
Ca : Mg ratio	17.0	MV	23.0	MV	17.0	MV	36.2	HV

MV= Moderate variation, HV= High variation, LV= Low variation, SHC= Soil moisture content, BD=Bulk density, TEB= Total exchangeable base, TEA= Total exchangeable acidity, ECEC= Exchangeable cation exchange capacity, BS= Base saturation, OM= Organic matter

The result of the bulk density, pH and base saturation as shown in Table 7, indicates low variation. This might be accredited to the high incidence of leaching of base cation under high annual rainfall saturation. TEA and ECEC, Ca:Mg ratio and hydraulic conductivity had a moderate variation. Sand and clay had a moderate variation in NIHORT 1, 2 and NIHORT 3 recorded a low variation. Hence, it could be ascribed to the existence of argillic horizons in most of the study area. This argillation in soils of southeastern Nigeria has been reported by Onweremadu and Anikwe (2007). Organic matter contents were high in NIHORT 1 and 3 but moderate in NIHORT 2 as this could be attributed to the land sue of the area, while the moderate variation is ascribed to leaching of organic carbon under annual precipitation. The relationship among selected physic-chemical properties of the studied soils at the two soils shows that sand correlated negatively with clay (-0.973** and -0.943**) and highly significant in the two parent materials. Clay correlated negatively with ECEC in sandstone (-0.519^{NS}) and positively to clay shale (0.337^{NS}).

Taxonomy Classification

Taxonomy classification of the selected soils around Okigwe L.G.A. based on the physical, chemical and morphological characteristics and it was classified using USDA soil taxonomy system (Soil survey staff, 2003) and World reference base system (W.R.B). The soils at NIHORT 1, 2 and 3 had argillic (Bt) horizon as determined by the distribution of clay down the profile and low silt/clay ration indicating advanced stage of weathering. In addition, percentage base saturation greater than 35% is recorded in the soil of false bedded sand stone, therefore the soil belong to the soil order Alfisol, suborder Udalf, great group Hapludaf, sub-group Typic Hapludaf, W.R.B soil class Luvisols, W.R.B soil unit Arenic luvisols. Soils of Umuna had argillic horizons and low silt / clay ratio and it was classified as Alfisol, suborder Udalf, great group Hapludaf, sub-group Typic Hapludaf, W.R.B soil class Luvisols, W.R.B soil unit Arenic luvisols.

Land Capacity Classification of Soil According to USDA System

The physicochemical properties of the soils, the nature of the landscape and the soil depth, the soils of NIHORT 1, 2 and 3 were grouped as class II of the USDA capability classification system. They are moderately suitable due to uneven plain of the slope which ranges from 2-6% and are derived from sand stone. The moderate susceptibility to water erosion, soil stoniness of 20-27%, depth to root limiting layer of about 60 cm and slow subsoil permeability resulted in the placement of Umuna in class III.

CONCLUSION

An unrestricted soil survey techniques used was aided with geological map of the area. Three (3) soil profiles were sunk, profile pit was defined based on the FAO procedure and samples were collected according to the horizon differentiation. The samples were exposed to laboratory analysis for the selected physicochemical properties and the results were analyzed using suitable statistical tools. The result from various soils as shown in the tables suggests that soils vary not only in parent materials but then again in many key physicochemical properties. Consequently their capability to support varying categories/kinds of land use is anticipated to vary. The soil properties from the characterization of the selected soil on the study area were utilized in the classification of the soil according to the USDA soil taxonomy and WRB soil classification systems. Hence it is observed that the false bedded sand stone were in class II and Umuna (Imo clay shale) in class III. Finally, it is found that soils from the selected areas are suitable for agricultural practices, lowland crops like rice can be grown on about 42% of the soils due to the seasonal fluctuations of water table. This study will go a long way to assist researchers, farmers and agriculturist who will want to embark on massive agricultural production in different countries of the world that has similar land terrain. This study can also be expanded in the future to accommodate other regions of the country and the world at large.

DECLARATION OF COMPETING INTEREST

We author hereby affirm that there is no conflicting of interest whatsoever.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors hereby declare that the contributions given are correct.
Christopher Ikechi Obineche: Writing original draft and Investigation
Patricia Akunna Oriaku: Validation, Review and Methodology.

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This article does not require any ethical committee decision.

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