Int. J. Forest, Soil and Erosion, 2020 10(4)
ISSN 2251-6387

Research Paper

CHARACTERIZATION AND CLASSIFICATION OF SOILS OF WUKARI URBAN, NORTHEAST NIGERIA

*Osujieke, Donald Nweze, Imadojemu, Pedro Ezemon, Angyu, Micah Dantani and Ibeh, Kingsely

[1]Department of Soil Science and Land Resources Management, Federal University Wukari, PMB 1020 Wukari, Taraba State Nigeria.
bigdonax@yahoo.com, +2348030877200; imadojemu@fuwukari.edu.ng, +2348038738657; angyudantani@gmail.com, +2347066756720; kingibeh123@gmail.com, +2348109042108

*Correspondence Author: bigdonax@yahoo.com; +2348030877200

ABSTRACT

Pedological information is essential for sustainable soil use. This study was carried out to describe, characterize and classify soils of Wukari North East, Nigeria. A free survey was used to site profile pit on each of the three different sites in the study area. The profile pits were described and sampled base on horizon differentiation for laboratory analysis. Generated data were analyzed statistically using the coefficient of variation. The result indicated Ochric, argillic, kandic, and cambic diagnostic surface and sub-surface horizons were identified. Soils of the different profile pits have ustic soil moisture regime. The textural class of the soil comprised generally of loamy sand, sandy loam, sandy clay, and sand. Soil pH has mean values ranged from 5.44 – 5.65 among the profile pits. Organic carbon, total nitrogen and available phosphorus were generally low in all the profile pits. Base saturation had a mean of 73.24 %, 64.83 %, and 63.34 % for profile pits 1, 2, and 3, respectively. The coefficient of variation (CV) indicated that percent sand, pH (H_2O), cation exchange capacity, and base saturation had low variability (CV < 15 %) among horizons of all the profile pits. The soils were classified as Grossarenic Typic kandiustalfs (Hypereutric Lixisols) for profile pit 1, Arenic Kandiustalfs (Loamic Lixisols) for profile pit 2, and Typic Haplustepts (Eutric Cambisols) for profile pit 3 using the USDA soil taxonomy and world reference base system for soil classification. This will aid easy management of the soils and pedo-tranfer technology.

KEYWORDS: characterization, classification, horizon, morphology, profile pit, Wukari

INTRODUCTION

Soil is the foundation natural resource on which the life-supporting system and socio-economic development depends. However, due to the increasing rate of the population demanding food, the soil nutrients have been deteriorated and the productive capacity of soils has diminished through changes in soil characteristics. This demands systematic evaluation of soil resources concerning their extent, distribution, characteristics, and use potential, which is very important for developing an effective land-use system for augmenting agricultural production on a sustainable basis (Pulakeshi *et al.*, 2014). Different soils responses differently to management practices, their inherent ability to deliver ecosystem services, and also their resilience to disturbance and vulnerability to degradation (FAO, 2017). Different soil types support different land-use systems and require different management options for sustainable productivity. According to Fagbami (1990), the diverse nature of the soil is a major reason behind the allocation of land to wrong uses. Hence, a proper understanding of its nature and properties is necessary for judicious, beneficial, and optimal use on suitable bases (Jagdish *et al.*, 2009). Pedological characterization as a systematic way of gathering soil information provides a clear understanding of soils in terms of their morphological, physical, chemical, biological and mineralogical properties; hence their potential and limitations for crop production (Msanya *et al.*, 2016).

The main task of soil classification is to reflect the real diversity of soils to make-decisions about adequate or sustainable land use. Ukut *et al.* (2014) stated that a detailed study of the soil characteristics and classification will provide baseline information on the physical, chemical, and mineralogical characteristics of the soil for precision agriculture, land use planning, and management. Classification of soils is also useful to facilitate technology transfer and information exchange among soil scientists, decision makers, planners, researchers, and agricultural extension advisors (Assen and Yilma, 2010).

Farmers and other land-users subject soils to various land use without considering sustainable practices. Moreover, the prevailing land-use system and management interventions are not supported by information that shows the potentials and constraints of soil resources. On the other hand, land degradation due to the use of incompatible land management practices has continued unabated. To use the limited land resources more efficiently, site-specific management recommendations based on site-specific information are very much required. Hence, this study was initiated to morphologically describe the soil, characterize the physical and chemical properties of soils, and classifies the soil of Wukari urban.

MATERIALS AND METHODS

Study Area

The study was carried out in Wukari in Wukari Local Government Area of Taraba State North East, Nigeria. It lies between latitude 7˚51′ N to 7˚85′ N and longitude 9˚46' E to 9˚78' E of the Greenwich meridian. The entire area is a gently undulating plain, with a mean altitude of 200 m above sea level.

The mean annual rainfall value ranges from 1000 - 1500 mm. The unset of the raining season is usually around April while the offset period is October. The mean maximum temperature is being experienced around April at about 40 ˚C while the mean minimum temperature occurs between the period of December and February at about 20 ˚C (NIMET, 2015).

Geology

The geology of the area is the cretaceous sediment over igneous and metamorphic undifferentiated basement complex rock resulting in sandstone as the chief parent material.

Vegetation

The Wukari local government area falls within the Southern Guinea Savannah zone. The vegetation manifests seasonal pattern and it is mainly of tree savannah in which the dominant species is the large red heart (*Hymeno cardia)* providing a limited amount of shade. The accompanying shrubs and grasses are Guinea grass (*Panicum maximum*), spear grass (*Imperata cylindrica*), Morning glory (*Ipomea carnea*), Pignut (*Hyptis suaveolens*), Bahama grass (*Cynodon dactylon*), Spider wort (*Commelina benghalensis*), Wire grass (*Eleusine indica*), Lemon verbena (*Lippia dubai*), sedge flower (*Cyperus difformis*) etc. There are also restricted areas of hard wood (*Isober lina)* savannah woodland, which forms the forest reserves of the area. Other species include Eucalyptus (*Eucalyptus camaldulensis*), Neem tree (*Azadirachta indica),* Gmelina (*Gmelina arborea*), Locust tree (*Parkia filicoidea),* Guava (*Psidium guajava),* mango (*Mangifera indica),* and Cashew (*Canarcadium occidentale)* among others

Socio-economic Activities of the Study Area

The major socio-economic activities of the study area are farming Wukari is known for producing mostly annual crops such as rice, yam, groundnut, cowpea, maize, cassava, and melon. Also, few farmers are into cash crop production.

Field study

A profile pit was dug on each of the selected sites. Macro-morphological properties of the various horizons were determined in the field and samples were collected based on horizon differentiation from the soil profile pits according to Schoeneberger *et al.* (2012) guidelines. Soil colour was determined using the Munsell soil colour chart (Munsell, 2009) while other morphological properties (consistency, root composition, drainage, and structure) were determined by visual observation. A total of 15 soil samples were collected from the three profile pits. The soil samples were air-dried, crushed, and made to pass through 2.0 mm and 0.5 mm mesh sieve. The soil samples were subjected to routine laboratory analyses.

Laboratory Analyses

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH was measured electrometrically using glass electrode pH meter in a solid-water ratio of 1:2.5 (Thomas, 1996). Total nitrogen was determined by the micro-Kjeldahl digestion technique method (Bremner, 1996). Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Exchangeable acidity was got by a method described by (McLean, 1982). Total carbon was analyzed by wet digestion (Nelson and Sommers, 1996). Phosphorous was determined by Bray l method according to the procedure of (Olsen and Sommers, 1982). Cation Exchange Capacity was determined using neutral ammonium acetate leachate method (Summer and Miller, 1996).

Statistical Analyses

The data generated were analyzed statistically using the coefficient of variations as described by Wilding *et al.* (1994) to determine the degree of variation among horizons of each profile pit. Genstat statistical software versions 17 were used to run the statistical analysis.

Soil Classification

The soils were classified according to the USDA keys to Soil Taxonomy (SSS, 2014) and World Reference Base system of soil classification (IUSS, 2015).

RESULTS AND DISCUSSIONS

Morpho-genic properties

The major pedogenic processes observed include eluviation and lessivage (profile pit 1 and 2) leading to the depletion of clay in the epipedon and enrichment of clay in the B horizon. In Bt horizons of both soil groups, there was clay argillation (illuviation). According to Philips (2004), vertical translocation of clay involves lessivage or argilluviation, gravitational setting or solution-precipitation by percolating water.

The result (Table 1) showed that all soil had colour range of, 5YR 4/4 (reddish brown), 10 YR 6/4 (pale yellow), 5YR 6/8 (reddish yellow), and 5YR 6/8 (reddish yellow) among horizons in profile pit 1; 7.5YR 5/6 (strong brown), 5YR 5/6 (yellowish red), 5YR 6/8 (reddish yellow), and 2YR 6/8 (light red) among horizons in profile pit 2; and 7.5YR 4/6 (strong brow), 7.5YR 5/8 strong brown, 5YRS 7/6 (reddish yellow), and 7.5yr 5/8 (strong brown) among horizons in profile pit 3. The difference in soil coloration among horizons of each profile pit could be associated with mineralogical composition, organic matter content, texture, and drainage condition. However, the strong brown colour ting in surface horizon may be as a result of organic matter deposit. Researchers (Ashenafi *et al.,* 2010; Buol *et al.,* 2011; Nahusenay *et al.,* 2014; Alem *et al.,* 2015) also reported that variation in color change among the profile pits and within a profile pit could be attributed to difference in organic matter content and drainage conditions.

The textural classes observed in most of the horizons of the profile pits studied were sandy loam except for profile pits 2 and 3, which indicated loamy sand at the Bt1 and Ap horizons, respectively. The textural class of the studied site could be attributed to similarity in the parent material and climate of the study area. The soil structure has its form as granular, class as medium and grade as either weak(1) or moderate(2) at the A horizons of the profile pits while it has its form as sub-angular blocky, class as medium and grade as either weak(1) or moderate(2) or strong(3) among B horizons of the profile pits. However, the soil structure was granular at the Ap horizons therefore requires to be incorporated with organic matter to enhance nutrient and water retention for plants. Pressure faces on soil matrix due to micro-swelling, reduction in the abundance of plant roots and higher clay in the subsurface may be associated with the formation of blocky structure. The consistency (Table 1) was friable at the Ap and Bt1 horizons and firm at the Bt1 and Bt2 horizons of profile pit 1. In profile pit 2, consistency was friable at the Ap and AB horizons and firm at the Bt1 and Bt2 horizon while, at profile pit 3, the Ap and Bt1 horizons were friable and the Bt2 and Bt3 horizons were firm. The friable consistency observed in the surface soils of the profile pits could be attributed to anthropogenic activities. However, Mulugeta and Sheleme (2010) had reported on the contribution of organic matter in modifying soil consistency. Ashenafi *et al.* (2010) also reported that the friable consistency of the soils shows workability of the soils at appropriate moisture content.

The root presence varies from many very fine, many fine, many medium, common fine, few medium, few coarse, few fine, common medium among horizons of the profile pits. However, the roots as classified can appear one or in combination of two or more per horizon. The variation in root size and population was due to difference in plants species and shallow rooting system of most plants found in the studied sites. For any given soil, the greater the rooting depth, the larger the quantity of soil water available to the crop. This is particularly important for annual crops as they have less time to develop deep and extensive rooting systems than perennial crops (FAO, 2003). Roots provide the link between the soil and plant. Rooting patterns as a function of time are key factors for crop uptake of water and nutrients. Deep rooting patterns imply less susceptibility to moisture stress.

Soil depth based on the soil depth class as described by USDA (2010) shows that all the profile pits were moderately deep (< 150 cm). Idoga *et al.* (2007) attributed the extent of soil depth to the parent material, erosion and shape of the area. The boundaries of the horizons were clear and smooth in all profile pits except for the boundary of the Ap and Bt1 horizons of profile pit 1which was clear and wavy. The horizons of the studied profile pits were well-drained with ustic soil moisture regime.

Physical properties

The result as indicated in Table 4.2 shows that sand distribution had a mean of 58.13 % in profile pit 1, 78.35 % in profile pit 2 and 84.65 % in profile pit 3. The sand fractions decreased with an increase in the profile pits depth and dominate over other fractions of soil. The sand fraction had low variation (≥8.14 % ≤9.98 %) among the horizons of the profile pits 2 and 3 while it had a moderate variation (25.26 %) among the horizons of the profile pit 1. The rate of variation could be associated with a similarity in the parent material and climatic factors as reported by Osujieke *et al*. (2017) in the soils of Nigeria.

Silt fraction has mean values ranged from 2.22 % to 9.48 % among the profile pits. The silt fraction had high variation (52.17 %) among the horizons of the profile pit 1 and low variation among the horizons of the profile pits 2 and 3. The silt fraction had an irregular distribution pattern among the horizons of the profile pits. The profile pit 1 had high silt content compared to other profile pits while the A-horizon of profile pit 3 had the highest silt fraction among the horizons of the profile pits. Comparing soils under the various profile pits, one would conclude that the soils are highly weathered and pedologically mature due to the low silt content (Ahn 1993). However, low silt content in soil could be associated to further weathering of silt.

Clay fraction has mean values ranged from 9.98 % to 32.39 % among the profile pits. However, clay fraction had high variation (≥52.17 %, ≤52.55 %) among the horizons of the profile pits 1 and 2 while it had low variation (9.02 %) among the horizons of the profile pit 3. The Bt-horizons of the profile pit 1 and 2 has high clay fraction which is an indication of argillic horizon formation. The clay distribution shows that clay increases down with soil depth. This result is contrary to the finding of Imadojemu *et al.* (2017) in the soils of Northeast Nigeria but in concurrence with the findings of Osujieke *et al.* (2017) and Chikezie *et al.* (2009) that clay profile increases with an increase in soil depth. Higher clay content in the B horizon of the profile pits 1 and 2 can be associated to illuviation, predominant in situ pedogenetic formation of clay in the subsoil, and destruction of clay in the surface horizon, have been reported by (Chukwu, 2013; Yitbarek *et al.*, 2016; Kebede *et al.*, 2017).

The silt clay ratio has mean values ranged from 2.62 % - 32.39 % among the profile pits. The silt clay ratio had high variation (41.39 %) among horizons of pedon 1, moderate variation (≥15.23 % ≤17.10 %) among horizons of profile pits, 2 and 3. Soils with silt clay ratio of > 0.15 indicate the high intensity of weathering (Young, 1976). Ayolagha, (2001) on the other hand reported that old parent materials usually have a SCR below 0.15 while SCR above 0.15 is indicative of young parent materials. However, the results of this study showed that all the soils had silt/clay ratios above 0.2 indicating a high degree of weathering potentials and young parent material in all the soils. However, several researchers (Idoga *et al.* 2014; Imodejemu *et al.* 2017) have reported on soils of silt clay ratios > 0.15 in northern Nigeria. This could be associated to the Isohyperthermic temperature regime of the study area which facilitates high, intense weathering. The silt clay ratio is highly dependent on the textural composition of the soil which is dependent on parent material.

Chemical properties

The soil chemical properties as indicated in Table 3 shows that the soil pH has mean values ranged from 5.44 – 5.65 among the profile pits. The soil pH was moderately to strongly acidic, according to the rating of Chude *et al.* (2011). However, profile pit 1 was the most acidic among the studied profile pits. The result of the pH(H_2O) of the profile pits was in contrary to the findings of Kefas *et al,* (2018) in soils of Northeast Nigeria. However, the pH is within the tolerable limit for most crop production according to the rating of (Landon 1991). The pH of the soils could be associated to the nature of the parent material and climatic condition of the studied area as opined by Abua *et al,* (2010) and Osujieke *et al.* (2017).

Electrical conductivity (EC) has mean values ranged from 0.05 - 0.11 dSm^{-1} among the profile pits. The study sites are salt-free hence; they are below the tolerable limit recommended by (Landon, 1991). Electrical Conductivity had moderate variation among horizons of profile pits 1 and 3 and high variation among horizons of profile pit 2. The EC decrease down the profile pits 1 and 2 while it increased down the profile pit 1 in an irregular pattern. The horizons of the profile pit 2 had high EC over other horizons of the profile pits 1 and 3 while the Bt2 horizon had highest EC in profile pit 1. The result of the EC is in line with the findings of Kefas *et al*, (2018) in soils of Northeast Nigeria.

Organic carbon (OC) of profile pits was low according to the ratings of (Esu 1991) and (Landon 1991). Organic carbon has mean values ranged from 0.20 % to 0.78 % among the profile pits. However, organic carbon decrease down the profile pits 1 and 2, while it increases down in profile pit 3. The Ap horizon of the profile pits 1 and 2 had a high organic carbon over other horizons while in profile pit 3, the Bt3 horizon had high organic carbon over other horizons. The result of the organic carbon agrees with findings of Imadojemu *et al*, (2017) on soils of Northeast Nigeria. The organic carbon had a high variation (≥47.02 % ≤68.77 %) among horizons of profile pits 1 and 3 while it had moderate variation (23.64 %) among horizons of profile pit 2. The rate of variation of organic carbon is associated with high amount of organic matter deposit on the surface horizon, rate of decomposition, and mineralization of organic matter.

Total nitrogen (TN) has mean values ranged from 0.11 – 0.13 % among the profile pits. The total nitrogen was moderate when compared with the ratings of Chude *et al.* (2011). The total nitrogen had moderate variation (≥17.39 % ≤29.78 %) among the horizons of the profile pits 1 and 3 while it had a high variation (36.80 %) among the horizons of the profile pit 2. The rate of variation is dependent on availability of organic matter, rate of volatilization, crop removal, and plant uptake. This result conforms to the findings of (Idoga, 2014) in North central Nigerian soils. The result is also in concurrence with the findings of Ahukemere *et al*, (2017) in soils of Southeast Nigeria. Feller (1993) recorded that environmental factors determine organic matter contents and variation in tropical soils.

Available phosphorus was low in all the profile pits when compared with the ratings Landon, (1991) and Chude *et al.* (2011). Available phosphorus among the horizons had moderate variation (31.52 %) in the profile pit 1 and high variation (≥66.78 % ≤107.75 %) in the profile pit 2 and 3. The variations among the horizons could be attributed to the distributions of organic materials and P fixation within the profile pits. The available phosphorus decreased down the profile pits in no specific trend. The results of the available P are in line with the findings of (Idoga, 2014) in soils of North Central Nigeria. Phosphorus is one of the major elements that are in high demand by plants, therefore, needs to be sustained in the pedosphere.

The exchangeable bases (calcium, magnesium, potassium, and sodium) as indicated in Table 3 show that calcium and magnesium are the dominating elements in the exchange site in all the profile pits. However, calcium and magnesium are low in the all the profile pits, potassium is low in profile pit 2 and moderate in profile pits 1 and 3 while sodium was moderate in profile pit 2 and low in profile pit 3 according to the ratings of Landon (1991).

The cation exchange capacity (CEC) has mean values ranged from 3.72 - 4.21 cmol/kg among the profile pits. The CEC was low when compared with the ratings of Esu, (1991) and Landon, (1991). The general low value of CEC can be an index of low chemical weathering activity of the soil (Okusami and Oyediran, 1985) and high acidity. The low CEC of the soil could be attributed to the nature of clay mineral (Kaolinite) (Hassan *et al.,* 2011). Olorunfemi *et al.* (2016) stated that CEC determines the ability of soil to bind or hold exchangeable cations against leaching.

Base saturation had mean of 73.24 %, 64.83 %, and 63.34 % for profile pits 1, 2, and 3, respectively. The base saturation was high (>60 %) according to the ratings of (Landon 1991). The base saturation had low variation (≥5.91 % ≤6.92 %) among horizons of the profile pits which could be associated with similarity in climatic condition and parent material. The base saturation decreases down the soil profile in an irregular pattern in profile pits 1 and 3 while it has a specific increase down profile pit 2. However, Soil Survey Staff, (2014) classify soil base saturation > 50 % as eutric. These indicate that the soils of the study site are fertile. This site result is in concurrence with the findings of Imadojemu *et al.* (2017) on the soil of Northeast Nigeria.

Taxonomic classification

The soils of the study sites were classified using USDA soil taxonomy and World Reference Base systems of soil classification. According to the USDA soil taxonomy, the soil profile pits 1 and 2 have isohyperthermic temperature, ustic moisture regimes, argillic horizons and a base saturation above 35 % which qualified it as an Alfisol. The soil profile pit 3 has isohyperthermic temperature, ustic moisture regimes, cambic horizons and a base saturation above 60 % which qualified it as an Inceptisols .Considering the soil moisture regime they fall under the suborder Ustalfs for profile pits 1 and 2 while, profile pit 3 fell under Ustepts. The profile pits 1 and 2 have kandic horizon, high base saturation, and low cation exchange capacity which qualified them as Kandiustalfs while profile pit 3 has cambic horizon, high base saturation, and low cation exchange capacity which qualified it as Haplustepts (Soil Survey Staff, 2014). Profile pit 1 had 5 % or more (by volume) skeletans on faces of peds in the layer that has a 20 % lower clay content and, below that layer, a clay increase of 3 percent or more (absolute) in the fine-earth fraction and this classified the soils under the USDA soil taxonomy sub group as Typic Kandiustalfs (Hypereutric Lixisols). Profile pit 2 had loamy sand, or loamy fine sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 cm and this classified the soils under the USDA soil taxonomy sub group as Arenic Kandiustalfs (Loamic Lixisols). However, profile pit 3 had loamy sand or loamy fine sand throughout a layer extending from the mineral soil surface to the top of a cambic horizon at a depth of 75 cm and was classified under the USDA soil taxonomy sub group as Typic Haplustepts (Eutric Cambisols).

CONCLUSIONS

There was an observed variation in the pedogenic, physical and chemical properties that were analyzed across the horizons of the three profile pits. This can be attributed to the soil forming factors and soil forming processes. The soils were classified as Typic Kandiustalfs (Hyperceutric Lixisols) in profile pit 1, Arenic Kandiustalfs (Loamic Lixisols) in profile pit 2, and Typic

Haplustepts (Eutric Cambisols) in profile pit 3. This has provided soil information which will guide the land users on land -use practices to adopt and it will also encourage pedo-transfer thereby reducing the cost of production.

CONFLIT OF INTEREST

There is no conflict of interest.

REFERENCES

Abua, M.A., Offiong, R.A., Iwara, A.I. and Ibor, U.W. (2010). Impact of newly constructed roads on adjoining soil properties in Tinapa Resort, South-Eastern Nigeria**.** Annals of Humanities and Development Studies, Vol. 1(1): 176 – 184.

Ahukaemere, C. M, Obi, C.I. Ndukwu, B.N. and Nwamadi, N. J. (2017). Characterization and classification of soils of Egbema in Imo State, South-Eastern Nigeria. FUTOJNLS Vol. 2(1): 41 – 47.

Alem, H., Kibebew, K. and Heluf, G. (2015). Characterization and classification of soils of Kabe Subwatershed in South Wollo Zone, Northeastern Ethiopia. African Journal of Soil Science Vol. 3(7): 134 – 146.

Ashenafi, A., Abayneh, E. and Sheleme, B. (2010). Characterizing soils of Delbo Wegene watershed, Wolaita Zone, Southern Ethiopia for planning appropriate land management. Journal of Soil Science and Environmental Management Vol. 1: 184 – 199.

Assen, Y. and Yilma, S. (2010). Characteristics and classification of the soils of Gonde micro-catchment, Arsi highlands, Ethiopia. Ethiopian Journal of Science Vol. 33(2): 101 – 116.

Ayolagha, G.A. (2001). Survey and classification of Yenagoa meander belt soils in the Niger- Delta. In Proceedings of the 27th Annual Conference of Soil Science Society of Nigeria 5-9th Nov. 2001 Calabar, Nigeria.

Bremner, J.M. (1996). Nitrogen total. Sparks, D.L. (ed) methods of soils analysis, parts, chemical method. 2nd ed, SSSA Book Series No. 5, SSSA, Madison, W1 1085–1125.

Buol, S.W., Southard, R.J., Graham, R.C., McDaniel, P.A. (2011). Soil Genesis and Classification, 6th ed. John Wiley and Sons Ltd, UK. 543p.

Chikezie, A., Eswaram, H., Asawalam, D.O., and Ano, A.O. (2009). Characterization of the benchmark soils of contrasting parent materials in Abia State, Southeastern Nigeria. Global J. of Pure and Applied Science. Vol. 16(1) 23 – 29.

Chude, V.O., Malgwi, W.B., Amapu, I.Y. and Ano, A.O. (2011). Manual on Soil Fertility Assessment. Federal Fertilizer Department. FAO and National Programme on Food Security, Abuja, Nigeria. 62p.

Chukwu, G.O. (2013). Soil survey and classification of soils of Ikwuano Abia state Nigeria. Journal of Environmental Science and Water Resources Vol. 2(5): 150 – 156.

Esu, I.E. (1991). Detailed soil survey of NIHORT farm at Bunkure Kano state, Nigeria. Institute of Agricultural Research, Zaria. Pp. 72.

Fagbami, A. 1990. Land use plan of Norbru farms. Keffi for Soil Conservation, Productivity Sustenance, and Effective Farm Management.

FAO, (2017). Voluntary Guidelines for Sustainable Soil Management. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 16p. http://www.fao.org/3/a-bl813e.pdf

FAO, (2003). Optimizing soil moisture for plant production: The significance of soil porosity. Food and Agriculture Organization of the United Nations (FAO), FAO Soils Bulletin 79, Rome, Italy. http://www.fao.org/tempref/docrep/fao/006/y4690E/y4690E00.pdf

Feller, C. (1993). Organic Inputs, soil organic matter and functional soil organic components in low-activity clay soils in tropical zone. In: Mulongoy, K., Merckx, R. (Eds). Soil organic matter and sustainability of tropical agriculture. Wiley-Sayce Co-publication, Pp. 77 – 88.

Gee, G.W. and Or, G. (2002). Particle size. In: Dane J.H, & Topp, G.C. (eds). Methods of soil analysis. Part 4 Physical methods. Soil Science Society of America Madison, WI, Book Series No. 5 ASA and SSA 255 – 293.

Hassan, A.M., Raji, B.A., Malgwi, W.B., and Agbenin, J.O. (2011). The Basaltic soils of Plateau State, Nigeria. Properties, classification, and management practices. In M.K.A., Adebayo, A.J. Odofin, A.O. Osunde, A. Bala and S.O. Ojeniyi (Eds). Soil Resources Management, Global Climate Change, and Food Security. Proceedings of the 35th annual conferences of SSSN/Minna, Nigeria March, 7th to11th, 2011.

Idoga, S. (2014). Soil and urban land use planning: a case study of Markudi urban centre, Benue State of Nigeria. Nig. J. Soil Sci. Vol. 24(1): 51 – 58.

Idoga, S., Ibanga, I.J. and Malgwi, W.B. (2007). Variation in soil morphological and physical properties and their management implication on a toposequence in Samaru area, Nigeria. In Uyovbisere, E.O., Raji, B.A., Yusuf, A.A., Ogunwale, J.O., Aliyu, L. And Ojeniyi, S.O. (ed). (2007). Soil and Water Management for Poverty Alleviation and Sustainable Environment. Proceedings of the 31st Annual Conference of the Soil Science Society of Nigeria held at Ahmadu Bello University Zaria, Nigeria. Nov. 13th - 17th, 2006. Pp. 19 – 26.

Imadojemu, P.E, Osujieke, D.N. and Obasi, S.N. (2017). Evaluation of Fadama soils along a toposequence proximal to River Donga in Wukari area of Northeast Nigeria. Int'l Journal of Agric. and Rural Dev. Vol. 20(2): 3150 – 3158.

IUSS Working Group WRB. (2015). World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Jagdish, P., Ray, S. K., Gajbhiye, K. S. and Singh, S. R. (2009). Soil of Selsura research farm in Wardha district, Maharashtra and their suitability for crops. Agropedology, Vol. 19: 84 – 91.

Kebede, M., Shimbir, T., Kasa, G., Abera, D. and Girma, T. (2017). Description, characterization, and classification of the major soils in Jinka Agricultural Research Center, South-Western Ethiopia. Journal of Soil Science and Environmental Management Vol. 8(3): 61-69.

Kefas, P.K., Akamigbo, F.O.R., Asadu, C.L.A, Maniyunda, L.M and Philip, A.H. (2018). Characterization and classification of soils of Teaching and Research Farm of Taraba State University Jalingo, Nigeria. FUW Journal of Agric. and Life Science, Vol. 2(2): 137 – 152.

Landon, J.R. (Ed) (1991). Booker tropical soil manual: A Handbook for soil survey and Agricultural land Evaluation in the tropics and subtropics, Longman Scientific and Technical, Essex, New York. 474p.

McLean, E.O. (1982). Aluminum. In: Pages, A.L., Miller, R.H and Keeney, D.R. (Eds), Methods of soil analysis part 2 American Society of Agro Economy, Madison W.A. Pp. 978 - 998.

Msanya, B.M., Munishi, J.A., Amuri, N., Semu, E., Mhoro, L. and Malley, Z. (2016). "Morphology, genesis, physicochemical properties, classification and potential of soils, derived from volcanic parent materials in selected Districts of Mbeya Region, Tanzania," International Journal of Plant Soil Science, Vol. 10(4): 1 – 19.

Mulugeta, D. and Sheleme, B. (2010). Characterization and classification of soils along the toposequence of Kindo Koye Watershed in Southern Ethiopia. East African Journal of Sciences Vol. 4(2): 65 – 77.

Munsell Soil Color. Munsell Soil Colour Chart. 2009 revised edition. Macbeth Division of Kollmorgen Corporation, Baltimore, Maryland, USA, 2009.

Nahusenay, A., Kibebew, K., Heluf, G. and Abayneh, E. (2014). Characterization and classification of soils along the toposequence at the Wadla Delanta Massif, north-central highlands of Ethiopia. Journal of Ecology and the Natural Environment Vol. 6(9): 304 – 320.

Nelson, D. W. and Sommers, L. E. (1996). Total carbon, organic carbon and organic matter. In D. L. Sparks (ed). Methods of Soil Analysis Part 3, Chemical Methods. Soil Science Society of America Book Series Number 5. American Society of Agronomy, Madison WIE, Pp. 960 – 1010.

NIMET (Nigerian Meteorological Agency), (2015). Climate, Weather, and Water Information, for Sustainable Development and Safety.

Okusami, T.A and Oyediran, G.O. (1985). Slope-soil relationship variabilities in soil properties on aberrant toposequence in Ife area of Southwastern Nigeria. Ife J. Agric. Vol. 7: 1 – 15.

Olorunfemi, I.E., Fasinmirin, J.T. and Ojo, A.S. (2016). Modeling cation exchange capacity and soil water holding capacity from basic soil properties, Eurasian Journal of Soil Science, Vol. 5 (4): 266 – 274.

Olsen, S.R. and Sommers, L.E. (1982). Phosphorus. In: Methods of soil analysis part 2. Page, A.L, Miller, R.H., Keeney, D.R. (eds). America Society of Agronomy Madison Wisconsin. Pp. 15 – 72.

Osujieke, D.N., Imadojemu, P.E., Ndukwu, B.N and Okeke, O.M. (2017). Properties of soils in relation to soil depth, land-use, and landscape position on Soils of Ikeduru Area of Imo State, Southeastern Nigeria. Int'l Journal of Agric. and Rural Dev. Vol. 20(2): 3132 – 3149.

Philips, J.D. (2004). Geogenesis, pedogenesis, and multiple causality in the formation of texture- contrast soils. Catena Vol. 58: 275 – 295.

Pulakeshi, P. H. P., Patil, P. L. and Dasog, G. S. (2014). Characterization and classification of soil resources derived from chlorite schist in the northern transition zone of Karnataka. Karnataka Journal of Agricultural Science, Vol. 27(1): 14-21.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. (2012). Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Soil Survey Staff, (2014). Keys to Soil Taxonomy. 12th Ed. USDA-NRCS, Washington D.C.

Summer, M.E. and Miller, W.P. (1996). Cation exchange capacity. In: D.L. Sparks (ed) Methods of soil analysis. Part 2: Chemical Properties. (3rd ed) ASA, SSSA, CSSA, Madison, W.I. Pp. 1201 – 1229.

Thomas, G. W. (1982). Exchangeable cations. In: A. L. Page; R. H. Miller and D. R. Keeney (eds.). Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties. Madison, Wisconsin. Pp. 159 – 164.

Thomas, G.W. (1996). Soil pH and soil acidity. In: Methods of soil analysis, part 3- Chemical methods. L. D. Sparks (eds) SSSA book series. Pp. 159 – 165.

Ukut, A.N., Akpan, U.S. and Udoh, B.T. (2014). Characterization and classification of soils in steep-sided hills and sharp-crested ridges of Akwa Ibom State, Nigeria. Net J. of Agric. Sci. Vol. 2(2): 50 – 57.

USDA, (2010). From the surface down--An introduction to soil surveys for agronomic use. 2nd edition. United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), USA. Available at: [access date: 08.08.2017]: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052899.pdf

Wilding, L.P., Bouma, J. and Boss, D.W. (1994). Impact of spatial variability on interpretative modeling. In: Quantitative modeling of soil forming processes. Bryant, R.B. and Amold, R.W. SSSA. Special publication. No.39: 61.

Yitbarek, T., Beyene, S. and Kibret, K., (2016). Characterization and classification of soils of Abobo Area, Western Ethiopia. Applied and Environmental Soil Science Article ID 4708235.

Young, A. (1976). Tropical Soils and Soil Survey. Cambridge University Press, London. 46p.

Table 1: Morphological properties of the studied profile pits

Horizon	Depth (cm)	Colour (moist)	Textural class	Structure	Consistency (mosit)	Root	Drainage	Boundary
Pedon 1 (Coordinate= N 0584609, E 0867196, Elevation= 162 m)								
Ap	0-20	5YR 4/4 (reddish brown)	LS	1MGR	Friable	mvf-mf-mm	Well drained	cw
Bt1	20-44	10YR 6/4 (pale red yellow)	SL	2MSBK	Firm	mvf-cm	Well drained	cs
Bt2	44-83	5YR 6/8 (reddish yellow)	SC	3MSBK	Very firm	cf-fm	Well drained	cs
Bt3	83-118	5YR 6/8 (reddish yellow)	SC	3MSBK	Very firm	ff-fc	Well drained	
Pedon 2 (Coordinate= N 0585831, E 0872216, Elevation= 193 m)								
Ap	0-18	7.5YR 5/6 (strong brown)	LS	1MGR	Friable	cf-fm	Well drained	cs
AB	18-38	5YR 5/6 (yellow red)	LS	1MGR	Friable	mff-mfm	Well drained	cs
Bt1	38-81	5YR 6/8 (reddish yellow)	SL	2MSBK	Firm	vff-vfm	Well drained	cs
Bt2	81-108	2YR 6/8 (light red)	LS	2MSBK	Firm	vff	Well drained	
Pedon 3 (Coordinate= N 0588963, E 0872420, Elevation= 198 m)								
Ap	0-13	7.5YR 4/6 (strong brown)	S	1FGR	Friable	mvf-mf-mm	Well drained	cs
AB	13-14	7.5YR 5/8 (strong brown)	LS	2MGR	Friable	cf-cm	Well drained	cs
BA	44-89	5YR 7/6 (reddish yellow)	LS	1MSBK	Firm	cf-cm	Well drained	cs
B	89-118	7.5YR 5/8 (strong brown)	LS	1MSBK	Firm	ff	Well drained	

Texture: LS= loamy sand, SL= sandy loam, SC= sandy clay, S= sand; Structure: 1= weak, 2= moderate, 3= strong, F= fine, M= medium, GR= granular, SBK= sub-angular blocky; Roots: mvf= many very fine, mf= many fine, mm= many medium, fc= few coarse, cf= common fine, ff= few fine, cm= common medium, fm= few medium; Boundary: c= clear, s= smooth, w= wavy

Table 2: Soil physical properties of the studied profile pits

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class	SCR
Pedon 1 (Coordinate= N 0584609 and E 0867196, Elevation= 162 m)						
Ap	0-20	70.80	16.40	12.80	loamy sandy	1.28
Bt1	20-44	70.80	5.40	23.80	sandy loamy	0.23
Bt2	44-83	46.96	7.56	45.40	sandy clay	0.17
Bt3	83-118	43.96	8.56	47.40	sandy clay	0.18
Mean		**58.13**	**9.48**	**32.35**		**0.47**
CV (%)		**25.26**	**50.61**	**52.10**		**116.98**
Pedon 2 (Coordinate= N 0585831 and E 0872216, Elevation= 193 m)						
Ap	0-18	82.90	7.40	9.80	loamy sandy	0.76
AB	18-38	84.40	6.60	9.00	loamy sandy	0.73
Bt1	38-81	75.40	5.90	18.70	sandy loamy	0.32
Bt2	81-108	70.80	5.40	23.80	loamy clay	0.23
Mean		**78.38**	**6.33**	**15.32**		**0.51**
CV (%)		**8.17**	**13.75**	**46.71**		**53.75**
Pedon 3 (Coordinate= N 0588963 and E 0872420, Elevation= 198 m)						
Ap	0-13	87.40	3.90	8.70	sand	0.45
AB	13-44	85.40	3.90	10.70	loamy sandy	0.36
BA	44-89	82.40	7.60	10.00	loamy sandy	0.78
B	89-118	83.40	6.10	10.50	loamy sandy	0.58
Mean		**84.65**	**5.38**	**9.98**		**0.54**
CV (%)		**2.62**	**33.67**	**9.02**		**33.60**

SCR= silt clay ratio, CV= coefficient of variation, <15 %= low variability, ≥15≤35 %= moderate variability, >35 %= high variability.

Table 3: Soil chemical properties of the studied profile pits

Horizon	Depth (cm)	PH (H_2O)	EC (dSm^1)	OC	TN	Av. P (mg/kg)	Ca	Mg	K	Na	Al^{3+}	H	CEC	BS (%)
				→ % ←			→			cmol/kg	←			
Pedon 1 (Coordinate= N 0584609 and E 0867196, Elevation= 162 m)														
Ap	0-20	5.50	0.07	1.10	0.12	2.57	0.92	0.71	1.92	0.35	1.20	0.20	4.92	79.20
Bt1	20-44	5.30	0.06	0.22	0.06	1.21	0.83	0.67	0.34	0.87	1.20	0.30	3.93	68.90
Bt2	44-83	5.45	0.12	0.67	0.12	1.90	0.90	0.74	0.38	0.27	1.30	0.30	4.01	72.00
Bt3	83-118	5.50	0.10	0.32	0.13	2.57	0.90	0.73	0.28	0.37	1.40	0.20	3.99	69.60
Mean		**5.44**	**0.09**	**0.58**	**0.11**	**2.06**	**0.88**	**0.71**	**0.73**	**0.46**	**1.28**	**0.25**	**4.21**	**73.43**
CV (%)		**1.74**	**31.47**	**68.95**	**29.78**	**31.51**	**4.45**	**4.35**	**108.82**	**58.80**	**7.51**	**23.09**	**11.23**	**6.50**
Pedon 2 (Coordinate= N 0585831 and E 0872216, Elevation= 193 m)														
Ap	0-18	5.85	0.07	0.29	0.15	0.74	0.81	0.68	0.18	0.52	0.50	0.30	3.72	58.80
AB	18-38	5.75	0.02	0.19	0.12	1.84	0.81	0.68	0.14	0.52	1.20	0.40	3.36	63.90
Bt1	38-81	5.70	0.04	0.23	0.09	0.37	0.83	0.75	0.30	0.78	2.10	0.30	3.94	67.50
Bt2	81-108	5.30	0.03	0.22	0.06	0.00	0.83	0.67	0.34	0.87	1.20	0.30	3.93	68.90
Mean		**5.65**	**0.04**	**0.23**	**0.11**	**0.74**	**0.82**	**0.70**	**0.24**	**0.67**	**1.25**	**0.30**	**3.74**	**64.78**
CV (%)		**4.28**	**54.01**	**18.04**	**36.80**	**107.75**	**1.41**	**5.32**	**39.60**	**26.75**	**52.46**	**15.39**	**7.26**	**6.96**
Pedon 3 (Coordinate= N 0588963 and E 0872420, Elevation= 198 m)														
Ap	0-13	5.23	0.06	0.73	0.15	1.84	0.81	0.69	0.22	0.65	0.60	0.20	3.91	60.60
AB	13-44	5.35	0.05	0.77	0.14	2.91	0.81	0.70	0.22	0.70	0.90	0.30	3.87	62.70
BA	44-89	5.80	0.03	0.19	0.12	0.74	0.83	0.07	0.13	0.61	2.10	0.30	3.51	64.60
B	89-118	5.05	0.04	0.83	0.10	0.74	0.85	0.70	0.09	0.39	1.40	0.20	3.61	56.20
Mean		**5.36**	**0.05**	**0.63**	**0.13**	**1.56**	**0.83**	**0.54**	**0.17**	**0.59**	**1.25**	**0.25**	**3.75**	**61.02**
CV (%)		**5.97**	**28.69**	**47.02**	**17.39**	**66.78**	**17.30**	**58.03**	**39.70**	**23.27**	**52.46**	**23.09**	**5.25**	**5.91**

OC= organic carbon, TN= total nitrogen, CEC= cation exchange capacity, BS= base saturation, Av. P= available phosphorus, EC= electrical conductivity, CV= coefficient of variation, <15 %= low variability, ≥15≤35 % = moderate variability, >35 %= high variability.