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Characterization and identification of contemporary diagnostic (B) horizons of some soils in Ideato North local government area of Imo state Southeastern Nigeria

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ABSTRACT

Most soils in Nigeria have not been characterized and classified based on diagnostic B horizon and identification of diagnostic B horizon is essential in the study of soils. As a result, this study was carried out to characterize and classify these soils with special emphasis on the identification of diagnostic B- horizons. A free survey method was employed to locate the representative profiles. Ten profile pits were dug, studied macromorphologically, georeferenced and sampled based on identified horizons. Results were presented using descriptive statistics. Soil textural classes consisted of sand, loamy sand, sandy loam and sandy clay loam. Soil bulk density was low to high ranging from 1.23g/cm^3 to 1.94g/cm^3. Soil pH values were extremely acidic (pH 4.4) to slightly acidic (pH 6.1). Exchangeable calcium and magnesium were low to high, ranging from 0.20cmol/kg to 6.20cmol/kg for calcium and from trace to 30.20cmol/kg for magnesium while that of sodium and potassium were very low ranging from 0.005 to 0.052cmol/kg for sodium and from 0.003cmol/kg to 0.016cmol kg^{-1} for potassium. Cation exchange capacity was low to high ranging from 5.20cmol kg^{-1} to 51.20cmol kg^{-1}. Exchangeable acidity was trace to low; soil organic matter was low to high ranging from 0.07 g/kg to 5.00 g/kg. Percentage base saturation was low to very high ranging from 2.32% to 82.20%. Effective cation exchange capacity were low (1.457cmol kg^{-1}) to high (35.56cmol kg^{-1}). The available phosphorus is low ranging from 0.004cmol/kg to 0.013cmol/kg. Water dispersible clay values range d from 4.32% - 20.32%. The diagnostic criteria such as clay coatings/cutans, subsurface to surface clay ratio of 1.2, lithologic discontinuity, abrupt textural changes, artefacts, CEC. ECEC, etc. were identified. The two diagnostic B- horizons identified in the study areas were Kandic horizon and Argillic horizon (USDA) which correlate with Argic horizon (FAO/UNESCO (WRB).

1.0 Introduction

Man seems to have a natural tendency and urge to sort out and classify the natural objects of his environment (Akamigbo, 2010). Many soils in southeastern Nigeria have not been pedologically characterized and classified. All soil-based production or service systems require characterization and classification of soils in varying degrees (Ekwaoanya *et al.* 2001). This is dependent on the intended use of the soil and available resources. Soil characterization studies are needed to understand the soil, classify it and make the best use of it. Soil classification is the systematic arrangement of soils into groups based on their characteristics (Esu, 1999). Diagnostic horizons are soil horizons that combine a set of properties that are used for identifying soil units for classification purposes (Akamigbo, 2010). When formed below an A, E, or O horizon, they are known as diagnostic (B) horizons which may be exposed at the surface by truncation of the soil.

A soil horizon is commonly differentiated from the adjoining one at least partly based on characteristics that can be seen in the field. Several differentiating characteristics are used in the separation of the various categories of taxa of the Soil Taxonomy. The differentiating characteristics or differentiae observed in soil horizons are the effect of soil-forming processes. The processes themselves are not used as criteria but only their effect, expressed in terms of quantitatively defined morphological properties that have identification value. Bridges (1997) remarked that diagnostic horizons and properties are characterized by a combination of attributes that reflect widespread, common results of the processes of soil formation or indicates specific conditions of soil formation. FAO (2006) maintained that features of the diagnostic horizons can be observed or measured, either in the field or in the laboratory. They require a minimum or maximum expression to qualify as diagnostic such as certain thickness, certain morphological characteristics which include soil colour, odour, structure, textural differentiation, clay skin, slickenside, cracks, lithological discontinuity etc., thus forming a recognizable layer of soil. This can be proven through supplementary laboratory analysis to ascertain their analytical criteria such as amount of COLE, pH range, textural class, CEC range, base saturation etc. Examples of soil diagnostic characteristics include abrupt textural change, andic properties, secondary carbonates, lithological discontinuities etc. while diagnostic materials are those that influence pedogenetic processes significantly (FAO, 2006). They include mineral materials, artefacts and organic materials etc. A diagnostic horizon may encompass several genetic horizons, and the changes implied by genetic horizon designation may not be large enough to justify recognition of different diagnostic horizons. Genetic horizons express a qualitative judgment about the kinds of changes that are believed to have taken place in the soil. Two types of diagnostic horizons are known: diagnostic surface horizons also known as 'Epipedons' and the diagnostic subsurface horizons usually described as B horizons. Diagnostic horizons are used to carry out proper soil classification and differentiating one taxonomic unit from the other. Soils have therefore been classified with varying names for one soil due to poor identification of their B-diagnostic horizons.

There is poor knowledge of the diagnostic (B) horizons of soils of southeastern Nigeria and the contemporary processes responsible for their formation. This deficiency may be responsible for giving one soil type multiple taxonomic names, thereby causing confusion in the nomenclature of soils in the region. The aim of the study, therefore, was to characterize and identify the contemporary diagnostic (B) horizons of some soils of Ideato North Local Government Area of Imo State, southeastern Nigeria. The specific objectives were to: (i) characterize the soils of the area (ii) determine the macromorphological properties of the diagnostic (B) horizons of the soil profiles and (iii) classify the soils of the area.

2.0 Materials and Methods

2.1 Study site characteristics

Ideato North Local Government Area which is located within latitudes 5˚48' N to 5˚50' N and longitudes 7˚02' E to 7˚14' E was the study area and covers around 185.681 Km^2. The following towns are in the area of study; Urualla, Osina, Akokwa, Arondịzuọgụ, Obodoukwu, Uzii, Akpụlụ, Isiokpo, and Umualaoma. (Figure 1). The study area falls within the humid tropical zone. Jungerius, (1964) noted that the area has uniformly high temperature and seasonal distribution of precipitation with humidity being generally high except during the desiccating weather of harmattan. Two major seasons are the wet and dry seasons with the former lasting for eight months (March – October) and latter for four months (November – February). Total annual rainfall ranges from 1,500 – 1800mm while the maximum temperature ranges from 29^0C to 33^0C and minimum temperature ranges from 20.8^0C to 22.8^0C

A reconnaissance survey of the area was carried out and with the aid of a topographic map, nine villages were chosen for the study.

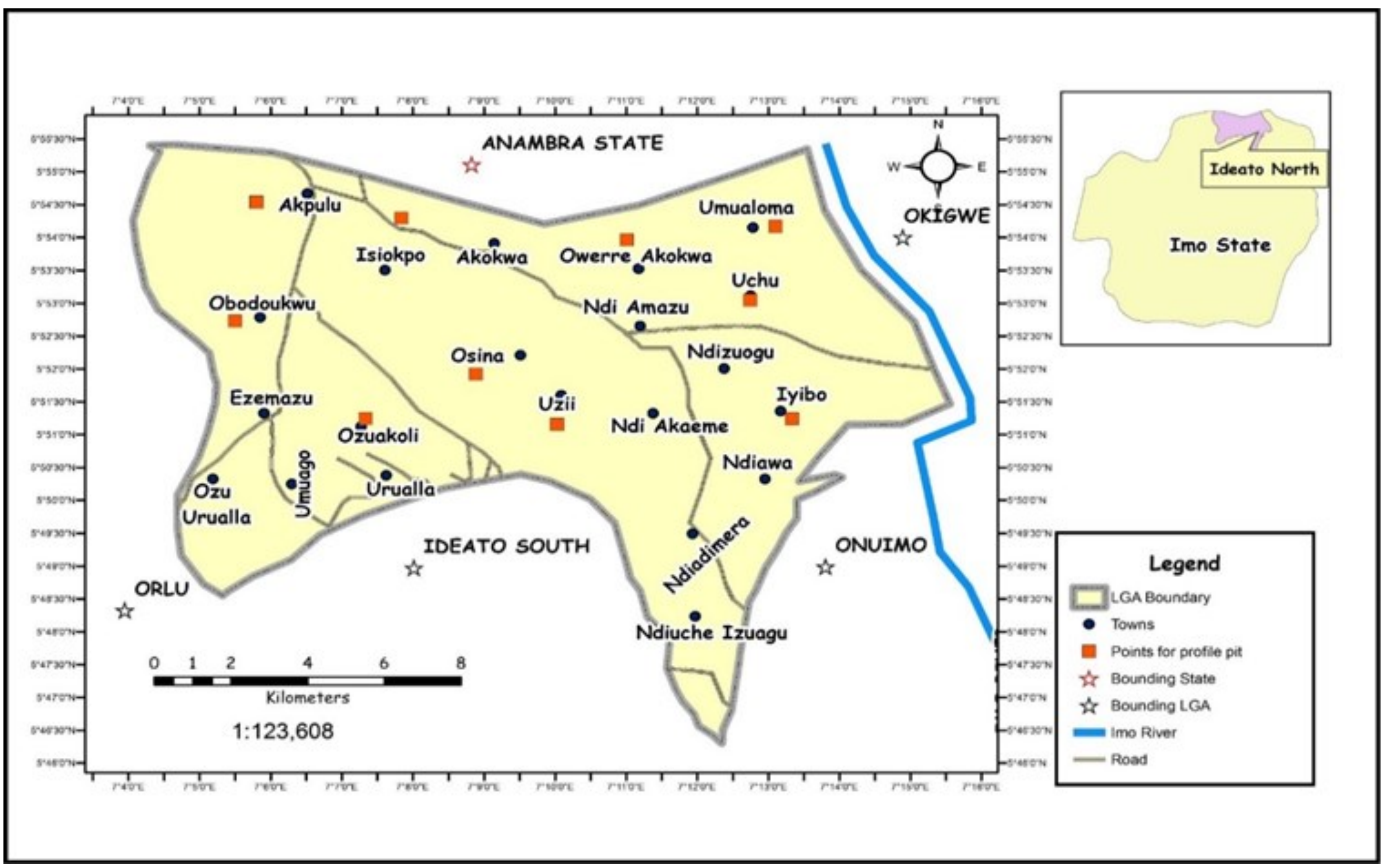

Figure 1: Map of the study area

2.2 Field Work

A free survey method was used; ten (10) profile pits were dug in the study area. The following towns were in the area of study with profile pit dug in each of them; Urualla, Osina, Akokwa, Arondịzuọgụ, Obodoukwu, Uzii, (formerly known as Isuọkpụ) Akpụlụ, Isiokpo, and Umualaoma**.** Soil samples and core samples were collected based on the identified horizons. 56 soil samples and 54 core samples were collected based on the identified layers. A total of 110 samples were collected from the 10 profile pits. The soil profiles were described and soil samples were collected for laboratory analysis. For each of the soil profile samples collected, records were taken on soil colour, texture, structure, consistency, stoniness, mottles, cutans and concretions. Major diagnostic (B) horizons were also identified using major morphological properties such as soil colour, odour, structure, textural differentiation, clay skin, slickenside, cracks, lithological discontinuity etc.

2.3 Laboratory analysis

Samples were prepared and routinely analyzed following the guidelines of IITA (1979).

Soil classification: The soils identified were classified according to FAO and UNESCO (2014) and USDA (2014).

3.0 Results and Discussions

3.1 Soil Physical Properties of the Studied Area.

The soil colours of profile numbers 1, 2, 3, 4, and 7 fell into the Hue of 2.5YR, with varying Values and Chroma having the following colours; Weak red, Dusky red, Reddish-brown Dark reddish-brown, Dark red and Red). Profiles 5 and 6 have a combination of two hues; 2.5YR and 5YR having the following colours; Dark reddish-brown, reddish-brown and red with varying values and chroma. Profiles 8 and 9 fell into Hues of 10YR, 5Y, 5YR, 7.5YR, 5GY and 10Y, having the following colours; grey, pale grey, light grey, brownish yellow, yellowish red, brown and pale brown. While profile 10 fell into Hues of 7.5YR, 5YR, and 2.5YR with varying values and chroma having the following colours; brown, yellowish red and reddish-brown. The colour of the soil was an indication of its drainage status and some chemical components. Grey soil coloration was evidence of reduced to depleted iron. The texture of the soils was more of coarse-textured over medium texture, the identified textural class in the epi-pedons of profiles 1, 2, 3, 4, and 5 were Loamy sand while the B horizon was of Sandy Loam, except for profile 2 that has Sandy clay loam in the $2Bt_1$ horizon. Profile 6 had sand and Loamy sand on the epipedon and also Loamy sand on the B horizons. Profile 7 had Sandy loam on the epipedon and in $3Bt_1$ while the $3Bt_2$ and $3Bt_3$ were of Sandy clay loam. Profiles 8 and 9 was characterized by Sandy clay loam in all horizons. While profile 10 has Loamy sand on the epipedon while the B horizons were all Sandy clay loam. Generally, the sand fraction of the soils were high compared to the silt and clay fraction. This could be as a result of long period of weathering to which the zone investigated had been exposed to and the paucity of this size fraction in the parent rocks were probable reasons for the deficiency of silt fractions and silty textures. Akamigbo and Asadu (1983) had similar result in the soils they studied and stated that silty texture can rarely be encountered in the area. Igwe *et al*., (1995) also noted that soils from this region are known for their very low silt fractions. There was generally decrease in sand content along the profile, increase in clay content along the profile and irregular pattern in silt content. Obi *et al.* (2009) stated that the increase in clay content along the profile depth from the upper horizon is an indication of eluviation from A horizon and illuviation at the Bt horizon. Yakubu, *et al..,* (2009) reported that the clay increase with depth in the soil infers the process of lessivation. The bulk density generally increased with depth. The increase in bulk density along the profile depth does not follow any pattern but fluctuates along the depth. The lower bulk density on the epipedons may be attributed to little content of clay, organic matter content and sand content, size and number of pores and compaction. Koorevaar *et al* (1983) remarked that high bulk density is an indication of small pore space and compaction. The total porosity generally decreased with depth but not in any regular trend. The porosity of soil is affected by bulk density, degree of cementation, agricultural management which affects pore sizes distribution as well as pore continuity and tortuosity. Consequently, bulk density shows an inverse relationship with total porosity. Odunze *et al.,* (2009) reported that the high values of the total porosity could be attributed to roots ramification, bioturbation by macro and micro-organisms, organic matter, soil biota and their multiple interactions which account for a significant increase of macropores. The water-dispersible clay values range from 5% to 7% in profiles 1, 2, 3, 4, 5, 6, and 7 while profiles 8, 9, and 10 have water-dispersible clay values ranging from 8% to 20% with exception of 3BtC horizon in profile 10 with a value of 4%. Hence the eluviation- illuviation are still occurring in pedogenesis in the area as Eswaran (1970) reported that the absence of water-dispersible clay confirms that illuviation is no more a current process.

3.2 Soil Chemical Properties of the Studied Area.

The result of soil pH in water shows that soils ranged from extremely acidic (4.6) to slightly acidic (6.5) for 1: 2.5, while 1:1 results in water gave the range 4.4 to 6.1. The high acidity observed in the studied areas can be attributed to the high intensity of rainfall in the area which causes leaching of the basic cation down the profile and the porous nature of the soils which is believed to have been inherited from the geology (Sandstones and Shales) (Igwe, *et. al.* 1999, Enwezor, 1981, Hazelton and Murphy, 2007). FDALR, (1990) stated that the problems of soil acidity are prevalent in southeastern Nigeria where coarse sedimentary parent materials have undergone earlier cycles of weathering before deposition. The values of exchangeable calcium were low to high, the values of exchangeable magnesium were low to very high. The values of exchangeable Sodium (Na) and Potassium (K) were very low. The values of the cation exchange capacity were low (5.20 cmol/kg) to very high (51.20 cmol/kg). The values of exchangeable bases which were low to high can be attributed to the high intensity of rainfall that is prevalent in the area resulting in leaching. Enwezor *et al*., (1981) reported that leaching of Calcium (Ca) and Magnesium (Mg) were high due to high rainfall intensity. On the other hand, the low to high exchangeable bases can be attributed to the nature of the parent material. Akamigbo and Asadu (1983), Ojanuga *et al.* (1981) reported that parent material has influence on total exchangeable bases. Hence Young (1976) asserted that parent materials of rock (Sandstone and Shale) are not alkaline and most of them are deficient in bases.The values of CEC is low to high and do not follow a regular trend in all the profiles, but fluctuate abruptly along the profile depth**.** Akamigbo and Asadu (1986) noted that low CEC could be as a result of high rainfall; clay type and content as well as previous land use. The amount of CEC in some of the profiles could be attributed to the clay type present, nature of parent materials, organic matter content and the quantity of exchangeable base yet to be leached, and rate of weathering (Landon, 1991). He also reported that the low organic matter in the soil was responsible for the amount of CEC status since the CEC is a property of the colloidal fraction of the soil derived mainly from clay and organic matter. This presupposes that low organic matter and clay content in any particular soil will result in low CEC. The higher CEC values were recorded in profiles that have their parent material as shale and those with high values of exchangeable bases. This could be attributed to the mineralogical compositions of the parent material and the poor drainage in the soil that prevent leaching away of exchangeable bases as seen in profiles 8 and 9. The variation in CEC could also be attributed to the variability in the mineralogy of the parent materials. Jungerius and Levelt (1964) observed that the soil of the area consists of dominant kaolinites, moderate montmorillonites and a small amount of quartz. The values of ECEC of the representative profiles were low to high. They ranged from 1.457 cmol/kg to 35.56 cmol/kg. This agrees with FPDD, (1989) and Onyekwere *et al;* (2012) that soils of South Eastern Nigeria are strongly weathered, have little or no content of weatherable rocks in the sand and silt fraction and predominantly kaolinites in their clay fraction. The characteristic low values of effective cation exchange capacity (ECEC) found in the soils agree with the general knowledge about soils of the tropics, and these low values have been attributed to the influence of climate that affects weathering, organic matter mineralization, leaching and erosion as well as mineral formations (Young 1976; Buringh 1979; Jenny 1980; Asadu and Akamigbo, 1990). The values of the percentage base saturation (%PBS) of the representative profiles were low to very high ranging from 2.00 % to 82.00 % respectively. According to Atofarati *et al*. (2012) percentage base saturation reflects the dominance of basic cations in the exchange complex. According to Mahilum (2004), some soils in the humid tropics are highly weathered and acidic and have low percentage base saturation. He also stated that low percentage base saturation is associated with low pH or high acidity. The values of exchangeable acidic cation of the soil profiles ranged from a trace to low in some horizons. The recorded values range from 0.40 to 5.00 cmol/kg soil for hydrogen ion ($\mathbf{H^+}$) and 0.20 to 4.0 cmol/kg for aluminum ion ($\mathbf{Al^{3+}}$). Enwezor (1981) stated that soils located in areas that experience excessive annual rainfall are strongly leached and deprived of basic cations, causing low fertility of the soils.The value of total nitrogen is very low ranging from 0.03 % to 1.12 %. Generally, the values of total nitrogen are very low. This can be attributed to the previous land use system due to limited land for cultivation, rapid mineralization, high pH values that hinder the action of some nitrifying bacteria and leaching since nitrogen is soluble (Enwezor *et al.,* 1989). It has been documented that temperature and moisture have profound effects on nitrogen availability through their effect on nitrogen mineralization, transformation and movement (Adepetu and Corey, 1985). The low content of total Nitrogen in the soils could also be attributed to low organic matter of these soils since inorganic Nitrogen is accounting for only a small portion of total N in soils (Almu and Audu 2001). The organic carbon ranges from 0.04% to 2.90% and is high in most of the epipedon than the underlying horizons. Some of the profiles show a regular decrease in organic carbon along the profile depth. The organic matter contents of the profiles are low to high. The higher values were recorded at the epipedon of most of the profiles. This can be attributed to the litter location of fall and point of decomposition. Asadu and Akamigbo, (1990) had a similar result that the relative contribution of organic matter in the A horizon was high in the soils they studied. In other words, the decomposition of organic materials is more at the surface or near the surface of the soils. On the other hand, extremes in soil pH (acid or alkaline) result in poor biomass production and, thus in reduced additions of organic matter to the soil. In strongly acid or highly alkaline soils, the growing conditions for microorganisms are poor, resulting in low levels of biological oxidation of organic matter (Primavesi, 1984). The available phosphorus content of the representative profiles was very low. It ranged from 0.004 to 0.013 cmol/kg. This low available P component of the soils could be due to the fixation of P by Fe and Al sesquioxides and the pH status of the soil as earlier reported by Uzoho and Oti (2004). Soil acidity can also reduce the availability of P by forming insoluble compounds when combined with Fe and Al oxides at pH less than 5.0 (Lathwall, 1979). Also, Kubrin *et al.*, (2000) noted that deficiency of phosphorus may occur in soils due to the strong adsorption of this nutrient by the soil colloids. On the other hand, the low available phosphorus content of the soils was attributed by Enwezor (1977) to the strong weathering and low pH values of the soils.

Diagnostic Characteristics, Contemporary Diagnostic B – Horizons Identified and Soil Classification

URUALLA PROFILE: SE/IM/IDN/URU – 1

In this profile, the sub-surface horizon was underlying a coarse-textured surface horizon (loamy sand), devoid of densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. The average CEC of the sub surface horizon was 7.73cmol/kg of soil (< 16cmol/kg) while the ECEC is 2.43cmol/kg of soil (< 12cmol/kg). The organic carbon decreased irregularly along the profile and the clay ratio of B/A was 1.27. The following characteristics qualify the subsurface horizon to be Kandic horizon. The possession of kandic horizon, base saturation of 10% (< 35%) and overlying epipedon of loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols.

Urualla profile falls into the Suborder Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub-group level, the soil falls into Arenic Rhodic Kandiudults (USDA) and Rhodic Acrisols (Arenic) (FAO) for having a texture class (fine-earth fraction) loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm; and Hue of 2.5YR.

ISIOKPO PROFILE: SE/IM/IDN/ISIKP – 2

The sub-surface horizon of Isiopko profile was underlying a coarse-textured surface horizon (loamy sand and sand), devoid of densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. The average CEC of the sub surface horizon is 11.20cmol/kg of soil (< 16cmol/kg) while the ECEC is 2.30cmol/kg of soil (< 12cmol/kg). The organic carbon decreased irregularly along the profile and the clay ratio of B/A is 1.60. The following characteristics qualify the sub – surface horizon to be Kandic horizon. The possession of kandic horizon, base saturation of 4.50% (< 35%) and overlying epipedon of loamy sand, sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Isiokpo profile falls into the Sub- order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub – group level, the soil falls into Arenic Rhodic Kandiudults (USDA) and Rhodic Acrisols (Arenic) (FAO) for having have a texture class (fine-earth fraction) loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm; and Hue of 2.5YR.

Akpulu Profile: SE/IM/IDN/AKP – 3

In this profile, the sub-surface horizon was underlying a coarse-textured surface horizon (loamy sand). The profile has no densic, lithic, paralithic, or petro-ferric contact within 50 cm of the mineral soil surface. The average CEC of the sub-surface horizon is 8.80cmol/kg of soil (< 16cmol/kg) while the ECEC is 2.30cmol/kg of soil (< 12cmol/kg). The organic carbon decreased irregularly along the profile and the clay ratio of B/A is 1.44. The following characteristics qualify the sub-surface horizon to be Kandic horizon. The possession of kandic horizon, an average base saturation of the sub-surface horizon of 9.90% (< 35%), overlying epipedon of loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Akpulu profile falls into the Sub-order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub-group level, the soil falls into Rhodic Kandiudults (USDA) and Rhodic Acrisols (FAO) for having throughout the entire kandic horizon Hue of 2.5YR.

Akokwa profile: SE/IM/IDN/AKO – 4

In this profile, the sub- surface horizon was underlying a coarse-textured surface horizon (loamy sand), no densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. The average CEC of the sub surface horizon is 8.10cmol/kg of soil (< 16cmol/kg) while the ECEC is 3.60cmol/kg of soil (< 12cmol/kg). The organic carbon decreased irregularly along the profile and the clay ratio of B/A is 1.53. The following characteristics qualify the sub-surface horizon to be Kandic horizon. The possession of kandic horizon, average base saturation of the sub-surface horizon of 21.4% (< 35%) and overlying epipedon of loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Akokwa profile falls into the Sub-order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub-group level, the soil falls into Arenic Rhodic Kandiudults (USDA) and Rhodic Acrisols (Arenic) (FAO) for having a texture class (fine-earth fraction) loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm; and Hue of 2.5YR.

Osina profile: SE/IM/IDN/OSI – 5

In this profile, the sub-surface horizon was underlying a coarse-textured surface horizon (loamy sand). There is no densic, lithic, paralithic, or petro-ferric contact within 50 cm of the mineral soil surface. The average CEC of the sub surface horizon is 12.0cmol/kg of soil (< 16cmol/kg) while the ECEC is 2.90cmol/kg of soil (< 12cmol/kg). The organic carbon decreased regularly along the profile and the clay ratio of B/A is 1.57. The following characteristics qualify the sub-surface horizon to be Kandic horizon. The possession of kandic horizon, base saturation of 18.7% (< 35%) and overlying epipedon of loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Osina profile falls into the Sub-order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub-group level, the soil falls into Arenic Kandiudults (USDA) and Haplic Acrisols (Arenic) (FAO) for having a texture class (fine-earth fraction) loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm.

Uzii profile: SE/IM/IDN/UZI – 6

In this profile, the sub- surface horizon was underlying a coarse textured surface horizon (loamy sand), with no densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. The average CEC of the sub-surface horizon is 8.1cmol/kg of soil (< 16cmol/kg) while the ECEC is 4.50cmol/kg of soil (< 12cmol/kg). The organic carbon decreased regularly along the profile and the clay ratio of B/A is 1.27. The following characteristics qualify the sub-surface horizon to be Kandic horizon. The possession of kandic horizon, base saturation of 17.80% (< 35%) and overlying epipedon of sand and loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Uzii profile falls into the Sub-order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Kandiudults. In the sub-group level, the soil falls into Arenic Kandiudults (USDA) and Haplic Acrisols (Arenic) (FAO) for having a texture class (fine-earth fraction) loamy sand throughout a layer extending from the mineral soil surface to the top of a kandic horizon at a depth of 50 to 100 cm.

Obodoukwu profile: SE/IM/IDN/OBO– 7

The subsurface horizon of this profile has a significantly higher percentage of phyllosilicate clay than the overlying soil material that is evidence of clay illuviation. The horizon forms below the soil surface, it meets the particle-size class criteria for fine-loamy (sandy clay loam). Clay films/ Cutans were present on the surface of the peds. The horizon also has 1.23 times more clay than the eluvial horizon. The following characteristics qualify the sub-surface horizon to be the Argillic horizon. The possession of Argillic horizon, base saturation of 17.40% (< 35%) and overlying epipedon of sand and loamy sand and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Ultisols. Obodoukwu profile falls into the Sub-order Udults for having Udic Moisture Regime, hence the soil is placed in the Great-group Paleudults having no densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. In the sub-group level, the soil falls into Rhodic Paleudults (USDA) and Rhodic Acrisols (Cutanic/ Differentic) (FAO) for having in all subhorizons in the upper 75 cm of the argillic horizon or throughout the entire argillic horizon more than 50 percent colours that have Hue of 2.5YR.

Arondizuogu -1 profile: SE/IM/IDN/ARO – 1 – 8 (wet land soil)

The subsurface horizon of this profile had a significantly higher percentage of phyllosilicate clay than the overlying soil material that is evidence of clay illuviation. The horizon forms below the soil surface, it meets the particle-size class criteria for fine-loamy (sandy clay loam). Clay films/ Cutans were present on the surface of the peds. The horizon also had 1.20 times more clay than the eluvial horizon. The following characteristics qualify the sub-surface horizon to be Argillic horizon. The possession of Argillic horizon, base saturation of 66.1% (>35%) and overlying epipedon of sandy clay loam and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Alfisols. Arondizuogu -1 profile falls into the Sub-order Udalfs for having Udic Moisture Regime, hence the soil is placed in the Great-group Hapluaalfs. In the sub – group level, the soil falls into Arenic Oxyaquic Hapludalfs (USDA) Gleyic Lixisols (Cutanic/ Arenic) (FAO) having redox depletions.

Arondizodu -2 profile: SE/IM/IDN/ARO – 1 – 9

The subsurface horizon of this profile had a significantly higher percentage of phyllosilicate clay than the overlying soil material that is evidence of clay illuviation. The horizon forms below the soil surface, it meets the particle-size class criteria for fine-loamy (sandy clay loam). Clay films/ Cutans were present on the surface of the peds. The horizon also had 1.34 times more clay than the eluvial horizon. The following characteristics qualify the sub-surface horizon to be Argillic horizon. The possession of Argillic horizon, base saturation of 59.70% (>35%) and overlying epipedon of sandy clay loam and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order Alfisols. Arondizuogu -2 falls into the Sub-order Udalfs for having Udic Moisture Regime, hence the soil was placed in the Great-group Hapludalfs. In the sub-group level, the soil falls into Typic Hapludalfs (USDA) Abruptic Lixisols (Cutanic) (FAO).

Umualaoma profile: SE/IM/IDN/UMU – 10

The subsurface horizon of this profile had a significantly higher percentage of phyllosilicate clay than the overlying soil material that is evidence of clay illuviation. The horizon forms below the soil surface, it meets the particle-size class criteria for fine-loamy (sandy clay loam). Clay films/ Cutans were present on the surface of the peds. The horizon also has 1.57 times more clay than the eluvial horizon. The following characteristics qualify the sub-surface horizon to be **Argillic horizon.** The possession of Argillic horizon, base saturation of 10.5% (< 35%) and overlying epipedon of loamy sand, sandy loam and increase in clay content along the profile (accumulation of low activity clay) qualify the soil to be placed into the Order **Ultisols.** Umualaoma profile falls into the Sub-order **Udults** for having Udic Moisture Regime, hence the soil is placed in the Great-group Paleudults having no densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface. In the sub-group level, the soil falls into Typic Paleudults (USDA) Leptic (Abruptic) Lix**isols** (Cutanic).

4.0 Conclusion

The characteristics and macromorphological properties of the diagnostic (B) horizons that were observed in the soil include: clay coatings, soil texture, lithologic discontinuities, and a certain thickness of horizon, nature of soil separates, organic carbon content, cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) etc. The results achieved led to the identification of the two contemporary diagnostic B horizons in the area which are Kandic horizons and Argillic horizons. The soils were classified as Ultisols and Alfisols. The above soil characterization, identified contemporary diagnostic B horizon of the studied area serves as an aid to correct soil classification and placing of soil in their taxonomic classes and to use the characterization, the contemporary diagnostic B horizon and classification as a benchmark in other locations with no data but same physiographic condition.

Table 1. Results of Physical Properties of the Soils of the Studied Area

PROFILE DEPTH/NAME/SYMBOLS	Clay g/kg	Silt g/kg	T/sand g/kg	C/sand g/kg	F/sand g/kg	Textural class	Bulk Density g/cm3	WDC g/kg
URUALLA								50
Ap 0-20	100	20	880	670	210	LS	1.64	
AB 20-75	120	20	860	680	180	LS	1.74	70
Bt$_1$ 75-105	140	40	820	640	180	LS	1.73	70
Bt$_2$ 105-160	160	40	780	640	140	SL	1.84	50
Bt$_3$ 160-205	160	20	820	650	170	SL	1.82	50
ISIOKPO								70
Ap 0-50	100	20	880	650	230	LS	1.24	
	120	20	860	650	210	LS	1.23	70
2Bb$_1$ 50-70								
2Bb$_2$ 70-100	80	20	900	760	140	S	Nil	50
Bt$_1$ 100-130	220	40	740	420	320	SCL	1.63	50
Bt$_2$ 130-180	160	20	820	570	250	SL	1.36	50
Bt$_3$ 180-200	160	20	820	540	280	SL	1.43	50
AKPULU								50
Ap 0-30	100	20	880	580	290	LS	1.49	
BA 30-45	140	20	840	530	310	LS	1.50	50
Bt$_1$ 45-70	160	40	800	460	340	SL	1.73	50
Bt$_2$ 70-110	160	40	800	520	280	SL	1.76	50
Bt$_3$ 110-150	180	20	800	440	360	SL	1.75	50
Bt$_4$ 150-200	180	20	800	440	360	SL	1.79	50
AKOKWA								50
Ap$_1$u 0-20	100	40	860	480	380	LS	1.65	
Ap$_2$u 20-35	120	20	860	500	360	LS	1.70	70
Abu 35-90	140	20	840	530	310	LS	1.59	70
Bt$_1$u 90-130	180	40	780	450	330	SL	1.84	50
Bt$_3$u 130-165	180	40	780	470	310	SL	1.89	50
Bt$_3$C 165-215	160	20	820	470	350	SL	1.87	50
OSINA								
Ap 0-20	100	20	880	700	180	LS	1.31	70
AB 20-55	140	40	810	660	150	LS	1.52	70
Bt$_1$ 55-100	180	40	780	560	220	SL	1.69	50
Bt$_2$ 100-140	180	40	780	630	150	SL	1.80	50
Bt$_3$ 140-200	160	20	820	600	220	SL	1.67	50

Table 1. Results of Physical Properties of the Soils of the Studied Area Continues

PROFILE DEPTH/NAME/SYMBOLS	Clay g/kg	Silt g/kg	T/sand g/kg	C/sand g/kg	F/sand g/kg	Textural class	Bulk Density g/cm3	WDC g/kg
UZII								50
Ap 0-15	80	20	900	620	280	S	Nil	
AB 15-80	100	40	860	660	200	LS	1.42	50
Bt$_1$ 80-115	120	40	840	620	220	LS	1.57	50
Bt$_2$ 115-165	140	40	820	600	220	LS	1.69	50
Bt$_3$ 165-210	140	40	820	600	220	LS	1.79	50
OBODOUKWU								50
Ap$_1$ 0-15	160	40	800	550	250	SL	1.33	
Ap$_2$ 15-35	160	40	800	540	280	SL	1.41	50
BA 35-70	160	60	780	550	230	SL	1.52	50
Bt$_1$ 70-115	180	40	780	620	160	SL	1.63	50
Bt$_2$ 115-165	200	40	760	580	180	SCL	1.65	50
Bt$_3$ 165-205	200	60	740	570	170	SCL	1.64	50
ARONDIZUOGU 1								100
Apg	180	90	720	210	510	SCL	1.48	
Btg$_1$	200	90	700	140	560	SL	1.66	100
Btg$_2$	200	110	680	120	560	SCL	1.88	160
Btg$_3$	200	90	700	120	580	SCL	1.86	180
Btg$_4$	240	70	680	120	560	SCL	1.81	200
W	240	70	680	120	560	SCL	W	200
ARONDIZUOGU 2								
Ap	200	110	680	280	400	SCL	1.59	100
Btg$_1$	280	70	640	210	430	SCL	1.71	120
2Btg$_2$	280	70	640	320	330	SCL	1.81	100
2Btg$_3$	320	50	720	360	360	SCL	1.83	200
2Btg$_4$	280	110	600	280	310	SCL	1.69	180
3Cg	260	110	620	270	350	SCL	1.67	180
UMUALAOMA								
Ap 0-20	140	60	800	51	740	LS	1.58	100
2Bt$_1$ 20-35	160	60	780	60	720	SL	1.60	100
2Bt$_2$ 35-90	240	40	720	50	670	SCL	1.72	100
2Bt$_3$ 90-110	240	20	740	40	700	SCL	1.75	80
2Bt$_4$ 110-140	240	20	740	90	650	SCL	1.74	80
2BtC 140-170	280	40	680	80	600	SCL	1.94	40

Table 2: Results of Chemical Properties of the Soils of the Studied Area

PPROFILE NAME/DEPTH/ HORIZON SYMBOLS	**pH1:2.5**		**EX. BASES cmol/kg**						**% BS**	**EX. ACID cmol/kg**		**% TN**	**% OC**	**% OM**	**Avail P**
	H_2O	**KCl**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**ECEC**		**H^+**	**Al^{3+}**				
URUALLA															
Ap 0-20	5.0	4.4	0.80	0.20	0.007	0.021	10.00	2.23	10.3	1.20	T	0.06	0.85	1.47	0.013
AB 20-75	5.3	4.1	0.80	0.40	0.009	0.031	6.40	3.04	19.4	1.80	T	0.13	0.15	0.27	0.090
Bt_1 75-105	4.7	4.0	0.80	Nil	0.007	0.021	8.40	2.83	9.9	2.00	T	0.17	0.66	1.13	0.008
Bt_2 105-160	4.6	4.1	0.60	Nil	0.009	0.026	6.00	2.64	10.6	2.00	T	0.04	0.15	0.27	0.007
Bt_3 160-205	4.9	4.1	0.80	Nil	0.010	0.016	8.80	1.83	9.4	0.80	0.20	0.08	0.31	0.54	0.007
PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^{3+}				
ISIOKPO Ap 0-50	4.9	4.0	0.40	0.20	0.009	0.052	8.00	1.86	8.26	1.20	T	0.10	0.70	1.20	0.007
$2Bb_1$ 50-70	5.1	4.2	0.40	T	0.010	0.047	6.40	1.46	7.14	0.80	0.20	0.07	0.66	1.13	0.008
$2Bb_2$ 70-100	4.8	4.0	0.20	T	0.005	0.036	10.40	1.84	2.32	1.60	T	0,06	1.39	2.40	0.009
Bt_1 100-130	4.6	3.9	0.60	T	0.007	0.047	15.20	2.85	4.30	1.80	0.40	0.13	1.55	2.67	0.008
Bt_2 130-180	5.0	4.0	0.60	T	0.005	0.016	9.20	2.22	6.75	1.20	0.40	0.08	0.50	0.87	0.008
Bt_3 180-200	5.0	4.0	0.20	T	0.005	0.021	9.20	1.63	2.46	0.80	0.60	0.06	0.43	0.73	0.007
PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^{3+}				
AKPULU Ap 0-30	5.4	4.6	1.60	0.60	0.003	0.036	13.60	3.04	16.5	0.80	T	0.14	0.81	1.40	0.010
BA 30-45	5.5	4.1	1.20	T	0.007	0.047	12.80	3.05	9.80	1.40	0.40	0.62	0.89	1.53	0.007
Bt_1 45-70	5.0	4.0	0.40	0.60	0.007	0.031	13.60	3.04	7.63	1.60	0.40	0.11	0.74	1.27	0.007
Bt_2 70-110	5.5	4.1	0.60	0.60	0.009	0.016	11.20	2.83	10.9	1.40	0.20	0.06	0.27	0.47	0.006
Bt_3 110-150	5.4	4.3	0.40	0.20	0.007	0.010	7.60	2.02	8.12	1.20	0.20	0.10	0.27	0.47	0.006
Bt_4 150-200	5.3	4.4	0.40	0.40	0.007	0.010	7.60	2.22	10.8	1.20	0.20	0.05	0.23	0.40	0.006
PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^{3+}				
AKOKWA Ap_1 u 0-20	5.5	4.4	0.80	0.50	0.009	0.016	13.60	2.25	9.74	1.20	T	0.17	0.66	1.13	0.009
Ap_2u 20-35	5.5	4.4	1.40	0.60	0.009	0.010	5.20	3.01	38.8	1.00	T	0.07	0.50	0.87	0.007
Abu 35-90	5.4	4.6	1.20	2.80	0.007	0.010	8.00	5.02	50.2	1.00	T	0.27	0.39	0.67	0.010
Bt_1u 90-130	5.4	4.2	1.40	0.20	0.007	0.010	8.00	3.02	20.2	1.00	0.40	0.10	0.27	0.47	0.007
Bt_2u130-165	4,8	3.9	0.40	0.20	0.005	0.010	8.40	2.82	7.32	1.80	0.40	0.74	0.04	0.07	0.006
Bt_3C 165-215	4.6	3.9	0.40	0.20	0.009	0.010	8.00	3.62	7.73	1.80	1.20	0.22	0.27	0.47	0.006

Table 2: Results of Chemical Properties of the Soils of the Studied Area Continues

PPROFILE NAME/DEPTH/ HORIZON SYMBOLS	**pH1:2.5**		**EX. BASES cmol/kg**						**% BS**	**EX. ACID cmol/kg**		**% TN**	**% OC**	**% OM**	**Avail P**
	H_2O	**KCl**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**ECEC**		**H^+**	**Al^3**				
OSINA															
Ap 0-20	5.3	4.5	1.20	1.80	0.007	0.010	11.20	3.82	26.9	0.80	T	0.95	1.82	3.13	0.008
AB 20-55	5.0	4.1	0.80	0.40	0.014	0.010	8.40	3.02	14.6	1.40	0.40	0.13	1.23	2.14	0.006
Bt_1 55-100	4.6	4.0	0.40	0.40	0.005	0.021	12.80	2.63	6.50	0.60	1.20	0.08	0.97	1.67	0.006
Bt_2 100-140	5.0	4.0	0.30	2.80	0.005	0.010	11.20	4.52	27.8	0.80	0.60	0.98	0.77	1.33	0.006
Bt_3 140-200	4.9	4.1	0.60	2.00	0.016	0.005	12.00	4.42	21.8	0.80	1.00	1.12	0.35	0.60	0.008

PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^3				
UZII															
Ap 0-15	5.0	3.9	0.60	0.40	0.007	0.021	10.00	4.83	10.3	3.00	0.80	0.06	1.28	2.20	0.007
AB 15-80	5.1	4.0	0.60	0.20	0.005	0.010	10.00	7.02	8.15	5.00	1.20	0.03	0.74	1.27	0.007
Bt_1 80-115	5.1	4.0	0.60	1.20	0.005	0.010	8.40	7.02	21.6	4.00	1.20	0.03	0.31	0.53	0.005
Bt_2 115-165	5.0	4.0	0.60	0.60	0.010	0.021	9.60	3.03	12.8	0.60	1.20	0.17	0.43	0.73	0.005
Bt_3 165-210	5.0	4.1	0.60	0.60	0.005	0.010	6.40	3.62	18.9	0.40	2.00	0.90	0.04	0.07	0.005

PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^3				
OBODOUKWU															
Ap_1 0-15	5.0	4.2	3.60	0.40	0.003	0.031	17.20	5.63	23.5	1.20	0.40	0.17	2.90	5.00	0.009
Ap_2 15-35	5.0	4.0	0.80	2.20	0.005	0.026	16.40	5.63	18.5	1.20	1.40	0.10	1.86	3.20	0.007
BA 35-70	4.9	4.0	1.00	2.00	0.005	0.016	11.20	4.62	26.9	1.00	0.60	0.43	0.89	1.53	0.008
Bt_1 70-115	4.8	4.0	0.80	1.60	0.007	0.021	13.20	4.43	18.4	0.80	1.20	0.06	0.66	1.13	0.007
Bt_2 115-165	4.7	4.0	0.60	1.20	0.007	0.016	8.40	5.02	21.7	2.80	0.40	0.04	0.39	0.67	0.007
Bt_3 165-205	5.0	4.1	0.40	0.80	0.005	0.016	10.00	3.22	12.2	0.40	1.60	0.45	0.27	0.47	0.007

PPROFILE NAME/DEPTH/ HORIZON SYM-BOLS	pH1:2.5		EX. BASES cmol/kg						% BS	EX. ACID cmol/kg		% TN	% OC	% OM	Avail P
	H_2O	KCl	Ca	Mg	K	Na	CEC	ECEC		H^+	Al^3				
ARONDIZUOGU 1															
Apg 0-25	5.0	3.9	4.20	6.00	0.005	0.041	22.84	13.45	44.9	2.00	1.20	0.13	0.79	1.33	0.007
Btg_1 25-55	5.5	4.4	3.20	7.20	0.007	0.016	18.40	11.82	56.6	0.80	0.60	0.06	0.70	1.20	0.008
Btg_2 55-100	6.1	4.9	4.80	8.60	0.007	0.026	18.40	14.63	73.6	0.80	0.40	0.10	0.39	0.67	0.005
Btg_3 100-150	6.5	5.3	4.80	9.60	0.010	0.016	22.84	15.63	63.2	1.20	T	0.03	0.29	0.47	0.004
Btg_4 150-192	6.1	4.9	6.20	9.80	0.012	0.016	26.00	17.03	61.6	1.00	T	0.04	0.19	0.33	0.007
W 192-195+	6.0	4.9	6.00	10.0	0.009	0.010	26.00	17.02	61.6	1.00	T	0.03	0.19	0.33	0.007

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