Classification and fertility status of soils developed from quartz- mica- schists in Biase Local Government Area of Cross River State, Nigeria

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Abstract

Morphological, physicochemical, micronutrients and mineralogical properties of soils derived from Quartz-Mica-Schists in Biase, Cross River State, Nigeria were studied with a view to characterize and classify the soils, assessing their potentials and suggesting appropriate management strategies. Three profiles were dug on the landscapes of Ikot Ana, Akpet and Iwuru Obiontan. The soils were characterized as follows: deep profiles (>100cm) with texture of gravelly sandy clay loam to sandy clay; hues of 10YR – 2.5YR; structure of sub-angular peds with sticky consistence (wet); bulk density values of 1.1 – 1.7 Mgm^{-3}; total porosity of 41.50 – 55.20%; silt-clay ratios of 0.01 – 2. Others were soil reaction pH (H_2O) 4.2 – 5.6; organic carbon (1.8 – 23.14 gkg^{-1}); total nitrogen (0.56 – 1.58 gkg^{-1}); ECEC (1.97 – 8.50 $cmolkg^{-1}$); CEC (3.70 – 10.0 $cmolkg^{-1}$); available P (3.27 – 34.65 $mgkg^{-1}$); base saturation (44 – 47%). Micronutrients: Cu (1.01- 4.08 $mgkg^{-1}$); Mn (6.08- 78.39 $mgkg^{-1}$); Zn (6.41- 17.39$mgkg^{-1}$); Fe (6.93- 23.78 $mgkg^{-1}$); B (0.14- 0.20$mgkg^{-1}$) and minerals such as quartz (82.50%), kaolinite (81.32%), muscovite (4.72%), microcline (3.37%) and Sepiolite (1.08%) were observed. According to the criteria of the USDA Soil Taxonomy, the soils were classified as Loamy Skeletal, Mixed IsohyperthermicTypicKandiudults and DystricAcrisols for FAO-World Reference Base for Soil Resources.

Keywords: Classification, dystricAcrisols, fertility status, quartz-mica-schists, typicKandiudults.

Introduction

The assessment of soils ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth, development and reproduction are very important. Nutrient elements such as the micro and macro nutrient elements can be assessed through characterization and classification of the soils (NPFS, 2009).

Soils derived from Quartz-Mica-Schist occupy Ikot Ana, Akpet and IwuruObioNtan in Biase and some part of Akamkpa Local Government Area in Southern Cross River State of Nigeria

(Bulktrade, 1989; Ibanga and Amon, 1992). They originate from geologic materials of acid crystalline rocks within the Basement Complex rocks which are made up of granites, gneisses, quartzite and schist. These rocks undergo weathering and get transformed into soils that constitute about 42% of the total surface area of the study being part of the southern Cross River State (FDALR, 1985).

Studies have shown that Quartz-Mica-Schist undergoing weathering under tropical conditions can influence the morphological, physical and chemical as well as mineralogical properties of the soils (Zauyah, 1988). The properties of soil developed from Quartz-Mica-Schist in Malaysia were found to have reddish yellow colour, silty clay textures and blocky structures, low CEC and base saturation as well as low free iron oxide content. The diagnostic horizon of the soils was argillic, and found with high amount of weatherable minerals of amphiboles, schist and serpentine. The soils developed on Quartz- Mica-Schist in Biase have also been reported to be characterized by deep profiles, depending on the topography, with coarse to fine sand texture, low base status and acidic reaction. The clay fraction of the soils is rich in koalinitic clay mineral probably due to high amount of rainfall as well as high soil temperature among others (Bulktrade, 1989; Aki *et al.*, 2016).

The soils developed on Quartz-Mica-Schist in Biase support most agricultural crops such as food crops (plantain, banana, yam, cocoyam, cassava and vegetable) and tree crop plantations which include oil palm, rubber and gmelina trees. Industrialization drive of the Cross River State Government through the establishment of agricultural plantations and increase in human population have exerted great pressure on the soils of the study area, which serves as suburb to fast growing Calabar Metropolis. With more intensive cultivation pressure on the soils and associated consequential land degradation problems, there is need to characterized the soils developed from Quartz-Mica-Schist in Biase Local Government Area of Cross River State, Nigeria. This study was therefore conducted to characterize, classify and evaluate the fertility status of the soils developed from Quartz-Mica-Schist with a view to suggesting appropriate land use management measures.

Materials and methods

Description of the study area

Biase Local Government Area (Latitude $05^{0}00^{'}$ and $05^{0}36^{'}$N; longitudes $08^{0}0I^{'}$ and $09^{0}0$’E) is located in Southern Cross River State, Nigeria (Fig.1). The climate of the area is characterized by tropical humid conditions with a mean annual rainfall of 2500-3000mm, a mean annual temperature of 26-27^{0}C and a mean relative humidity of 80-90% at the peak of rainy season (Nwajiuba and Oyeneke, 2010; Aki *et al.*, 2014).

The soils of the area are derived from Basement Complex rocks and the present study locations at Ikot Ana, Akpet Central and Iwuru Obiontan are underlain by Quartz-Mica-Schist (Ekwueme, 2004). The landscape is gently to strongly undulating in some places and the original rainforest in the area has been destroyed by human activities.

Soil Sampling

A total of three representative soil profile pits of depths 0-200cm, 0-200cm and 0-100cm were dug at Ikot Ana (05^0 29, 99,, N; 008^{0}01'.73,E); Akpet Central (05^{0}36,39,,N; 008^{0}06,98,,E) and Iwuru Obiontan (05^{0}25'15''N; 008^{0}11'83''E) at elevations of 129m, 130m and 162m sea level respectively. The coordinates and the altitudes of the three profile sites were obtained using Garmin etrex 2000 GPS meter. Field characterization of the profiles was carried out in the East- west direction and soil samples were collected from the pedogenic horizons starting from the base of each profile to avoid contamination; the samples were preserved in polythene bags and were taken to the University of Calabar Soil science laboratory for physic-chemical analysis.

Laboratory Analysis

The Soil samples collected were air-dried and sieved through a 2mm mesh. The following analyses were carried out on the samples using standard procedures as outlined by Udo *et al.*, (2009). Particle size analysis was carried out by hydrometer method using sodium hexametaphosphate (calgon) as the dispersant. Soil pH was determined in soil water ratio of 1:2.5 using a glass electrode pH meter. Organic carbon was determined by the Walkley and Black method (Udo *et al.*, 2009).

Total nitrogen was by the Micro-Kjedahl digestion method. Available phosphorus was determined by the Bray and Kurtz No.1 method as outlined by Udo *et al.* (2009). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1*N* NH_4OAc at pH 7. Exchangeable potassium and sodium were determined with a flame photometer while Ca and Mg were determined by the EDTA titration method. Exchangeable acidity was determined by titration method using 1*N* KCI extract (Udo *et al*, 2009). Effective cation exchange capacity was estimated by summing the exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity. Percent base saturation was obtained by dividing the total exchangeable bases (Ca, Mg, K, Na) by the effective cation exchange capacity. Available micronutrients were determined by the DTPA extracting solution method and available Boron was determined by Hot water extraction method as described by (Udo *et al*., 2009). For x-ray analysis, particle size analysis was carried out on each sample to separate and prepare the clay fraction for the analysis. The sample was prepared for XRD analysis using a back loading preparation method. About 10% internal standard (fluorite) was added and the sample micronized. The micronized material was analyzed by XRD utilizing a PANalytical Empyrean Diffractometer with PIXcel detector and fixed slits with Fe filtered Co-ka radiation. The phases were identified using X'PertHighscore plus software. The XRD analysis was used to determine the crystalline mineral phases present in the sample. The abundance of each phase (weight %) was determined by the Rietveld Refinement method. An orientation specimen was prepared from each of the samples, the head and the clay (<2um) fraction. The glass slide was analysed by XRD to determine the mineralogy of the samples, the head and clay (<2um) fraction. The slide was then glycolated, and reanalyzed, heat treated and reanalyzed. The process of glycolation and heat treatment made it possible to identify, and quantify, the various phyllosilicates that occur in the clay fraction (Udo *et al.* 2009).

Results and discussion

Morphological Characteristics

Table 1 presents the abbreviated morphological description of profiles 1 to 3, which occurred at elevations of 129, 130 and 162m above sea level for profiles 1,2 and3, respectively. The soils were well-drained with deep profiles (>100cm) and strongly weathered. The profiles were characterized by gravelly sandy loam textures with a corresponding increase in alluvial clay at B horizons giving rise to gravelly sandy clay and gravelly sandy clay loam textures in the subsurface soils; matrix colour with hue of 2.5YR, 5YR, through 7.5YR to 10YR and dominant value of 3 and 4 or more in profiles 1, 2 and 3 while profile 1 and 3 have chroma of 3 or less in the surface soils; weak medium subangular blocky peds; slighty sticky/slighty plastic (wet) (Profiles 1, 2 and 3) and subsurface sticky plastic (wet) consistence; argillic or Kandic horizons with clay skins at the depth 17 to 200cm at ped faces. A model soil profile consisted of yellowish brown (10YR3/6), brownish yellow (10YR 3/4) sandy loam surface overlying brownish yellow 10YR 6/8) or strong brown 7.5YR 5/8) with mottle colour of Red (2.5YR 5/8) subsurface. Profile 3 with dark olive grey (5YR 3/2) and red (2.5YR 4/8) Matrix was due to iron oxide association with soil materials with mottles colour of red (2.5YR 5/8); this is an indication that the soils are either imperfectly drained or poorly drained during the rainy season in the study locations. Abundance of macro and micro pores; many fine and medium roots as well as animal activities with the presence of many termites, ants, earthworms; many fine mica flakes and fragments of quartzite, muscovite, biotite, schistose and weathered rocks; horizon delineation of clear smooth boundary occur in the surface to gradual smooth or diffuse smooth in the subsurface. Similar observations were reported for soils of Biase by Aki *et al.* (2016).

Physical Characteristics

Particle size distribution results of the surface soils in the three profiles revealed that soils are sandy (>770gkg^{-l}) with an overall texture of gravelly sandy loam overlying sand clay loam texture with sand fraction greater than 445gkg^{-1} in the subsurface (Table 2) clay fractions (profiles 1 to 3) on the average are 230gkg^{-1} and 395gkg^{-1} for surface and subsurface soils respectively. The soils are freely drained but with the clay content exceeding 200gkg^{-1} in the subsurface horizons, the soils can retain considerable amount of water for crop production and that the clay accumulation in the subsurface indicates the dominant pedogenic process of eluviation-illuviation in layers coded as Bt horizons in the three profiles (Akpan-Idiok, 2012).

Bulk density values increased with soil depth with overall surface and subsurface mean values of 1.3 and 1.5Mgm^{-3}which fall within the typical range (1.00 to 1.60 Mgm^{-3}) for mineral soils (Obi, 2000); the soils therefore have no mechanical impedance for plant roots and also have adequate aeration. The mean total porosity varies from 41.5 to 55.2% with the overall mean values of 49.10% and 45.80% in surface and subsurface soils of the three profiles. This range of values showed sandy materials which can enhance easy movement of water in the soils. Soils with 50% total porosity are well granulated and mayhave high moisture retention for crop plants (Landon 1991). Using silt/clay ratio of 0.15 (Van wambaka, 1962) or 0.25 (Asomoa, 1973); the considerable silt/clay ratio averaging. 1.0 for both surface and subsurface soils respectively indicate the parent material (Quartz-Mica-Schist) as being under advanced level of weathering (Akpan-Idiok and Opuwaribo, 1992).

Chemical Characteristics

The chemical properties of the soils are presented in Table 3. This show that the soils were generally strongly acidic with a mean value of 5.1 pH (H_2O) for surface and subsurface soils respectively (Table 3). The ΔpH values (pH in KCl – pH in H_2O) are negative with mean values of -0.7 and -0.86 for surface and subsurface soils. This showed that the soils have net negative charge in all the horizons and can retain basic cations. The exchangeable acidity values in the surface soil ranged from 0.34 – 4.4 cmolkg^{-I}. Indicating that all the soil profiles had acidity problems and for optimum crop yields, such soils need liming to raise pH to the range of 5.5- 6.0. The surface soils were rated moderate in organic carbon with a mean value of 11.25gkg^{-1}. These findings are consistent with the working of Ibanga*et al* (2005). Total nitrogen contents were low (0.56-1.58gkg^{-I}) as most values were below 4.50gkg^{-1}established by Holland *et al.*, (1989) for productive soils in the ecological zones. This low content of total nitrogen could be ascribed to rapid microbial activities, leaching of nitrates and crop removal in soil environment. Available P values were low with mean values of 14.31 and 9.05 mgkg^{-I} in surface and subsurface soils respectively (Table 3). Such soils require the application of phosphorus fertilizer for high yield of crops. Low levels of exchangeable Ca (1.0 – 2.6 cmolkg^{-I}), K (0.06 – 0.42cmolkg^{-I}), Na (0.03 – 0.21 cmolkg^{-1}), Mg (0.3 – 1.1 cmolkg^{-1}) as well as low levels of effective cation exchange capacity (ECEC) (1.9 – 8.50 cmolkg^{-1}) were recorded. Cation exchange capacity (CEC) by NH_4OAc (pH7) of (3.7-10 cmolkg^{-1}) were rated as low (Holland *et al*, 1989). This is an indication that the soils are leached and under advanced level of weathering. The rapid leaching of basic cations has been reported for soils developed from Quartz-Mica-Schist in Peninsular Malaysia (Zauyah, 1988). Although the mean base saturation of values ranged from 24 to 66%, basic nutrients occur in available forms in soil solution for plant uptake despite of the low cation reserves in the soils (Akpan-Idiok, 2012).

Extractable micronutrients mean values for surface and subsurface soils were as follows: Cu (1.32 and 2.51 mgkg^{-1}); Mn (57.26 and 8.01 mgkg^{-1}); Zn (12.76 and 7.49 mgkg^{-1}); Fe (13.7 and 15.9 mgkg^{-1}) and B (0.24 and 0.17mgkg^{-1}) (Table 4). These values were rated medium to high when compared with their threshold values of 1.0 mgkg^{-1} and 0.5mgkg^{-1} for Boron as outlined by Agbede, (2009) for respective micronutrients. Extractable boron was lower than the critical values 0.5mgkg^{-1} in the soils due to high acidity. The micronutrients concentrations had very little chances of causing toxicity. Measures must be taken to handle micronutrient problems by identifying and correcting any deficiency or toxicity before their visual symptoms manifest.

Mineralogical characteristics

Quartz

Quartz is one of the common minerals that occur in highly weathered soils of humid tropical regions. It is an intrinsic part of sand sized grain and can persist in soil because it is chemically inert (Akpan-Idiok and Ukwang, 2012; Aki *et al*, 2014). The x-ray diffraction analysis shows that quartz accounted for 82.50% in the clay fraction of the soils derived from Quartz-Mica-Schist (Fig 2). The high percentage (82.50%) of quartz suggests that the soils are at advanced stage of weathering with low percentage (<10%) of weathering mineral such as feldspars (microcline). The findings are consistent with the earlier work by (Wilson, 1970) who reported Quartz as a dominant mineral in clay fraction of soils derived from Biotite, Rich-Quartz- Gibbro in Aberdeen Shire in united kingdom. Chemically, Quartz mineral can hardly contribute to soil fertility or plant nutrition but it's interaction with other soil elements improves structural stability, water permeability biomass productivity, resistance to erosion, aeration among others (Akpan-Idiok and Ukwang, 2012). The x-ray diffractograms of the mineral are shown in Fig 3.

Kaolinite

Kaolinite has been recognized as a natural weathering product of Biotite (Fordham, 1990) reprecipitation under humid tropical conditions (Velbel, 1989). The x- ray diffraction data show that kaolinite constitutes about 8.32% in the soils formed on Quartz-Mica- Schist in Biase, Cross River State, Nigeria (Fig. 2). In the present study, kaolinite is one of the end products of weathering sequence of Quartz-Mica- Schist. The implications of the identified minerals, Quartz and kaolinite suggest that the soils have undergone advance stage of weathering with low activity clay, low charged surface area, low cation reserve and low fertility status (Aki et al, 2014). Fig. 3 presents the x-ray diffraction of the minerals.

Microcline

Microcline ($KAlsi_2O_8$)is one the important igneous rock- forming tectosilicate minerals such as feldspars, Biotite among others. Its formation arises from cooling of orthoclase but more stable at lower temperature than orthoclase. It can be transformed to sanidine as a polymorph of alkali feldspars under higher temperature. It is a common mineral in metamorphic regions such as Eastern Alps in Germany (Bemotat and Morteani, 1982). The x- ray diffraction data shows that microcline constitutes about 3.37% (Fig. 2) in the clay fraction of soils derived from Quartz- Mica-Schist of Biase in Cross River State, Nigeria. Microcline is of agricultural importance because it releases the essential nutrient, of potassium into soil solution for plant uptake. The x- ray diffractogram of the mineral are presented in Fig. 3.

Muscovite

Muscovite is one of the least weathered of the silicate clay mineral presumed to have been present in the original rock and Fe oxide represents the final stage in the mineral weathering (Kparmwang and Esu, 1990). It is the most common mica in granite and schist as a secondary mineral resulting from the alteration of feldspars. The x- ray diffractogram data shows that muscovite constitute about 4.72% of the soils formed from Quartz-Mica-Schist (Fig. 2). Muscovite fixes Fe oxides in the soils as that is its final stage in mineral weathering. The amount of muscovite in the soils is a clear evidence of their being inherited from Quartz- Mica-Schist parent material in the study area.

Sepiolite

Sepiolite is a naturally occurring clay mineral of sedimentary origin, a complex magnesium silicate with a typical formula ($Mg_4Si_{16}O_{15}$ $(OH)_2$ $(6H_2O)$, a non- swelling, light weight, porous clay due to aggregate (Garcia-Romero *et al*, 2010)andhas density of 2.0 to 22cm^3. The x-ray diffraction data shows that Sepiolite constitutes about1.8% of the soils developed on Quartz-Mica-Schist (Fig. 3). Sepiolite is one of the end products of weathering sequence of the parent material which contain large amount of available nutrients for plant use (Post *et al.,* 2007). It also modifies soil structure, decreasing excess compaction of original soils aggregates (Giustetto *et al.*, 2011). Figure 3 presents the x- ray diffractogram of the minerals.

Classification

On the basis of morphological, physico-chemical and mineralogical properties, the soils were classified based on the USDA Soil Taxonomy and FAO- World Reference Base Soil Resources. The three profiles had low base saturationof less 35%, Kandic horizon (ECEC<12 cmolkg^{-1} of clay or less), umbricepipedon (values of 3 or less, moist) for Ikot Ana and Akpet central and ochricepipedon (value of 4 or more, moist) for IwuruObiontan and therefore fit into the Ultisols order of the USDA Soil Taxonomy (Soil Survey Staff, 2014). The profiles had Udic soil moisture regime and brown/ brownish yellow kandic horizons properties in humid tropical conditions and were there fitted into the sub order of Udults. With Kandic horizon, increase in clay content with depth of 150 cm from the mineral soil surface, and irregular decrease or organic carbon with depth, the three profiles were placed in the great group Kandiudults and TypicKandiudults at the subgroup level. With less than 35% of clay and rock fragments as well as mixed mineralogy of quartz, kaolinite, muscovite, microcline (K- feldspars) and Sepiolite, the soils qualify as loamy skeletal, mixed IsohyperthermicTypicKandiudults and DystricAcrisols for FAO- WRBSR.

Conclusion

The investigation highlights the morphological, physico chemical and mineralogical properties of soils derived from Quartz-Mica-Schist in Biase Local Government Area of Cross River State, Nigeria. The soils were well drained with coarse textured materials. The soils were characterized by very strongly acid in reaction, moderate organic carbon and nitrogen as well as low available P and basic cations. Also, the micro nutrients (Cu, Mn, Zn, Fe and B) were moderate to high except B which was low. The soils had mixed mineralogy of quartz, kaolinite, muscovite, microcline and sepiolite under similar geologic and climatic condition and undergoing similar rate of weathering. Therefore, the soil fertility management should focus on reducing the basic nutrients from the soils through mulching, planting of cover crops, crop rotation, adoption of zero tillage as well as application of liming materials to reduce the strong acidity of the soils.

References

Aki, E. E.; Esu, I. E &Akpan-Idiok, A. U (2014).Pedological Study of Soils Developed on Biotlte-hornblende-Gneiss in Akamkpa Local Government Area of Cross River State, Nigeria. *International Journal of Agricultural Research*, 9(4): 187-199.

Aki, E. E., Esu, I. E &Akpan-Idiok, A. U (2016). Pedological Study of Soil Developed on Granodiorite in Biase Local Government Area of Cross River State, Nigeria. *Nigerian Journal of Soil Science*, 26: 250-269.

Agbede, O. O. (2009). *Understanding soil and plant nutrition*. Salman Press and Co. Nig., Ltd. Keffi, pp 1-260.

Akpan-Idiok, A. U. (2012). Physico Chemical Properties, degradation rate and vulnerability potential of soils formed on coastal plain sands in southeast, Nigeria. *International Journal of Agricultural Resources*, 7(7): 358-366.

Akpan-Idiok, A. U. & Ukwang, E. E (2012). Characterization and Classification of Coastal Plain Soils in Calabar, *Nigerian .Journal Agricultural Biotechnological Ecology*, 5(3): 19-33.

Akpan-Idiok, A. U. & Opuwaribo, E. E (1992). Particle size and extractable Iron oxides distribution in some soils of Rivers

State of Nigeria. *Nigerian Journal of Crop Soil & Forestry*, 2:118-132.

Asomoa, G. K. (1973). Particle Size and free Iron oxide distribution in some latosils and ground water laterites of Ghana.*Geodema*, 10: 285-297.

Bernotat, W. H. &Morteani, G. (1982). The Microcline/Sanidriae transformation Isograd in metamorphic regions Western Tauren window and meramo-mules-Anterselva Complex (Eastern Alps).*American Mineralogist*, 67: 43-53.

Bulktrade Investment Company Limited (1989). Main report on Soil land use survey of Cross River State, Nigeria. Ministry of Agriculture and Natural Resources, Calabar, pp376.

Ekwueme, B. N. (2004). The Precambrian geology and evolution of the southeastern Nigeria basement complex. University of Calabar Press. 135p.

FAO (2008). World Reference Base for Soil Resources by ISSS-ISRIC-FAO. World Soil Resources Report No. 103. Food and Agriculture Organisation, Rome, Italy.

Federal Department of Land Resources (1985). The Reconnaissance Soil Survey of Nigeria (1:650,000 soils report Vol. 4.

Fordham, A. W. (1990).Weathering of biotite into dioctahedral clay minerals.*Clay minerals*, 25: 51-63.

Garcia-Romero, E. S. & Suarez, M. (2010).On the chemical composition of sepiolite and palygorkite. *Clay and clay minerals*, 58: 1-20.

Giustetto, R,Ievy, D.,Wahyudi, O.,Ricchaidi, G. &Viltillo J. G. (2011) crystal structure refinement of sepiolite, indigo maya blue pigment using molecular modeling and synchrontron diffraction. *European Journal of mineralogy*, 23: 444-466.

Ibanga, I. J. &Amon, M. N. (1992). Report on the wetland soil of Cross River State. Cross River Agricultural Development, Calabar.

Ibanga, I. J, Udoma, G. H., Edet, A. B. & Akpan, F. S. (2005). Phsico-chemical properties of some limestone soils in Southeastern Mgera. *Nigerian Journal of Soil Science*, 15:81-85.

Kparwang, T & Esu, I. E. (1990). Mineralogical studies ofalfisols containing plinthite in two ecosystems in Nigeria. *Savanna*, II (1): 109- 121.

Holland, W. D. G., Barton, A. D & Morph, S. T (1989) Land Evaluation for Agriculture Recommendation of Cross River State National Park Oban Division Prepared by Oduki in Collaboration with INNF.

Landon, J. K. (1991) Booker Tropical Soil Manuel.A handbook for Soil Survey and Agriculture Land Evalution in the Tropics and Subtropics. England Longman Group, United Kingdom Limited.

Mirand-Trevino, J. C. & Cole, C.A (2003) Kaolinite Properties, Structure and influence of metal retention of pH.*Applied Clay Sciences*, 23:133-139.

National Pregramme for Food Security (NPFS) (2009). Manual on Soil Fertility Assessment Federal Fertilizer Department in Collaboration with National Programme for Food Security, Abuja pp 1-62.

Nwajiuba, C. &Oyeneke, R (2010). Effects of Climate on the Agriculture of Sub-Saharan Africa: Lessons from Southeast Rainforest Zone of Nigeria. oxford Business and Economic Conference Program, June 28-28 pp1-18.

Obi, M. E. (2000).Soil Physics. A Compendium of Lectures Department of Soil Science, University of Nigeria, Nsukka Published by Attanto Publisher, Nsukkapp 152.

Post, J. E., Bish, D. L & Heaney, P. J (2007).Sunchrotron Power X-ray diffraction study of the structure and dehydration behaviour of sepiolite, American Mineralogist 92:91-97 Proceeding 2nd Workshop on "Micronutrients and plant Nutrition" Mariut Egypt.

Soil Survey Staff, 2014. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys (4thed.) Natural Resources Conservation Service, USDA, Washington DC, USA, pp.869.

Udo, E. J, Ibia, T. O, Ogunwale, J.A, Ano, A. O &Esu, I. E (2009) Manual of Soil, Plant and Water Analysis.Sibon Books Publishers Ltd. Nigeria 183pp.

Van Wambeka, A. R. (1962). Criteria for Classification of Tropical Soils by age. *Nigerian Journal of Soil Science*, 13: 124-132.

Velbel, M. A. (1989). Weathering of Hornblende to Femuginous Products by adissolution-reprecipitation mechanism: Petrography and stoichiometry.*Clays and clay minerals,* 37(6): 515-524.

Wilson, M. J. (1970). The clay mineralogy of some soils derived from a biotite-rich quartz-gabbro in the strathdon area, Aberdeenshire, *clay minerals* 7:91-100.

Zauyah, S. (1988). Properties of Soils derived from some metamorphic Rocks in Peninsular Malaysia.*Pertanika*, 11(3): 375-384.

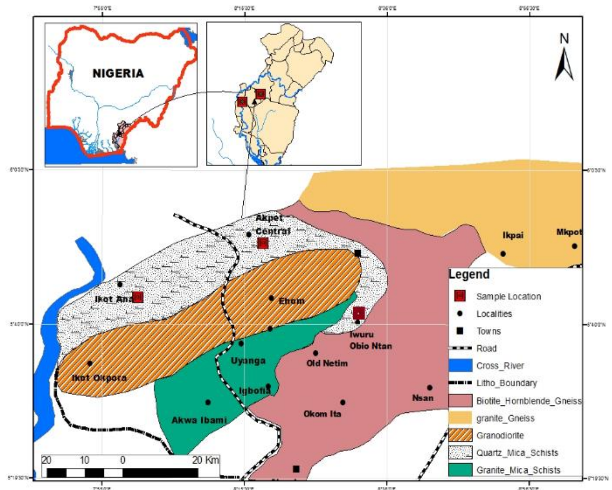

Fig. 1: Map of Biase showing sampling points at IkotAna,Akpet Central, and Iwuru Obiontan (Adapted from Ekwueme, 2004)

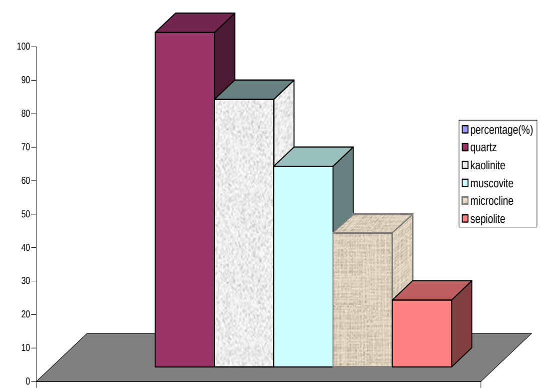

Fig. 2: Distribution of minerals in clay fractions of soils derived from Quartz-Mica-Schist

Table 1. Morphological properties of soils developed on Quartz-mica schists, Biase Local Government Area, Cross River State.

Location	Horizon Designation	Dept(cm)	Munsell Colour	Mottling	Texture	Structure	Consistence	Boundary	Other features
05⁰29.990N	Pedo 1 (Ikot Ana)								
008015733E	Ap	0-20	10YR3/6 yellowish brown	-	Gsl	1msbk	sssp	Cs	Termite, many mica flakes, worm cast; many medium roots; macro and micro pores
	Bt	20-48	7.5YR5/8 strong brown	-	Gl	2msbk	sssp	Gs	Common fine mica flakes; common fine and medium roots; clay skins in the peds
	B	48-08	10YR6/8 Reddish yellow	-	Gl	2msbk	Sp	Ds	Many large quartzite, muscovite, biotite schistose; common medium and fine roots; common macro and fine pores
	BC	88-157	10YR6/8 Reddish yellow	2.5 YR5/8 Red	Gscl	2msbk	Sp	Ds	Many large quartzite, muscovite, biotite schistose and weathered roots; common fine pores
	Cr	137-200	10YR6/8 Reddish yellow	2.5 YR5/8 Red	Gscl	2msbk	Sp		Many large quartzite, muscovite, biotite schistose and weathered roots; common fine pores
05⁰36.8395N	Pedon 2 (Akpat Central)		2.5YR5/8 Red	-					
008⁰06.989E	Ap	0-17	10YR ¾ yellowish brown		Gsl	1msbk	sssp	Cs	Earthworm's cast, Termite and ant activities: many fine roots macro and micro pores.
	Bt	17-62	7.5YR 6/8 Reddish yellow	-	Gsc	2fgr	sssp	Gs	Many common mica flakes, termite activities; clay skins in the peds
	B	62-113	7.5YR 6/8 Reddish yellow	2.5 YR5/8 Red	Gscl	3mcsbk	Sp	Ds	Many fine mica flakes, many medlum weathered rocks, fragments of quartzite schlstose; clay skins in the peds
	BC	113-147	7.5YR 6/8 Reddish yellow		Gsc	1msbk	Sp	Ds	Many mica, haemlte termite activities
	Cr	147-200	7.5YR 6/8 Reddish yellow		Gsc	1msbk	Sp		Many mica, haemlte and termite activities
05⁰25.157N	Pedon 3(IwuruObiotan)		7.5YR 6/8 Reddish yellow	-	Gsc				
008⁰11.833E	Ap	0-20	5YR 3/2 dark olive grey	-	Gsl	2msbk	sssp	Cs	Termite, worm casts, human activities; many fine and medium roots; many macro and micro pores
	Bt	20-49	7.5YR 4/6 strong brown		Gscl	2msbk	sssp	Gs	Common fine roots; common mocro and micro pores; micas flakes; clay skins in the peds
	B	49-60	7.5YR 6/8 Reddish yellow	-	Gscl	2msbk	Sp	Ds	Common fine roots; many micro pores; many mica flakes; clay skins in the peds
	Cr	60-8	7.5YR 6/8 Reddish yellow		Gscl	2msbk	Sp		Large quartzite, muscovite schist, biotite schist and weathered; common micro pores

Texture: gls = gravelly loamy sand; gsl = gravelly sandy loam; gscl = gravelly sandy clay loam; gsc = gravelly sandy clay ; Structure: 1 = Weak, 2 = Moderate, 3 = Strong, f = fine, m=medium, c=coatse, sbk=subangular blocky, gr=granular ; Consistency: sssp=slightly slightly plastic; sp=sticky and plastic.Boundary: cs=clear smooth; gs=gradual smooth; gd=gradual diffuse, cw=clear wavy; as=abrupt smooth.

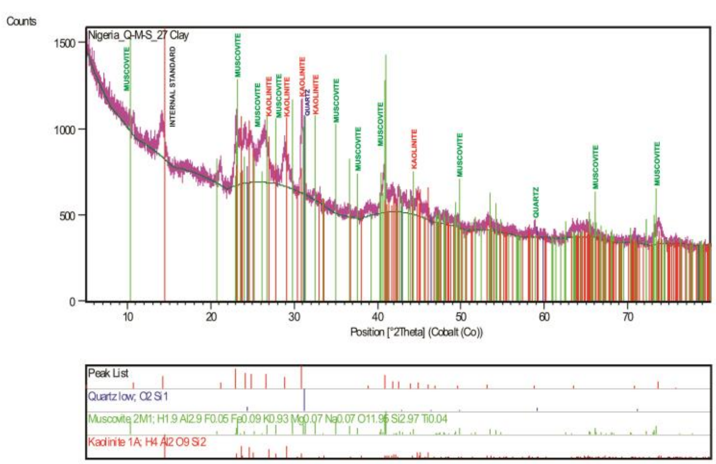

Fig. 3: X-ray diffractogram of clay fractions of soil developed on Quartz-Mica-Schists in Biase Local Government Area, Cross River State. Nigeria.

Table 2. Physical properties of soils developed from Quartz-mica-schistsBiase Local Government Area, Cross River State.

Location	**Horizon/ Designations**	**Horizon depth**	**Particle Size** **Sand**	**Silt**	**Clay**	**Gravel Content**	**Textural Classes**	**Bulk Density**	**Particle density Mgm^{-3}**	**Total Porosity**	**Silt/Clay Ratio**
		(cm)	gkg^{-1}	gkg^{-1}	gkg^{-1}	%		Mgm^{-3}		(%)	
Classification	Ikot Ana				**Loamy Skeletal Mixed IsohyperthcrmcTypicKandiudult**				(DystricAcrisol)		
05^{0}29'990"N	Pedon 1										
00801'733"E	Ap	0-17	550	320	130	38.3	gls	1.2	2.48	51.6	2.0
	Bt	17-62	490	280	250	66.9	gl	1.4	2.57	45.5	1.0
	B	62-113	470	300	230	29.2	gl	1.3	2.62	50.4	1.0
	BC	113-147	430	340	230	17.0	gl				1.0
	Cr	147-200	310	300	390	25.9	gcl				1.0
05^{0}36.395'N	Pedon 2(Akpet central)										
008^{0}006.939E	Ap	0.20	770	80	150	8.4	gsl	1.6	2.65	40.1	1.0
	Bt1	20.48	550	20	430	70.5	gsl	1.5	2.67	43.9	0.01
	Bt2	48.88	350	80	570	55.2	gsl	1.7	2.68	36.6	0.1
	CB	88.137	450	100	450	46.1	gscl				0.2
	Cr	137-200	530	40	450	40.7	gsl				0.1
05025.157'N	Pedon 3 (Obio-Ntan)										
008011.833"E	Ap	0-20	750	80	170	63.2	gsl	1.2	2.65	56.6	0.5
	Bt1	20-49	690	60	250	70.5	gscl	1.3	2.65	50.9	0.2
	Bt2	49-60	490	100	410	70.3	gscl	1.4	2.68	47.7	0.2
	Cr	60-100	530	40	430	78.5	gscl				0.1
Range			310-770	20-340	130-570	8.4-78.5		1.2-1.7	2.40-2.68	40.1-56.6	0.01-2.0
Surface Mean			633	140	570	53.0		1.3	2.58	49.1	1.0
Sub surface mean			445	175	295	45.0		1.5	2.64	45.8	1.0

Legend: gls=gravelly loamy sand, gl=gravelly loam, gcl=gravelly clay loam, gscl=gravelly sandy clay, gsl=gravelly sandy loam

Table 3. Chemical properties of soils developed from Quartz-mica-schistsBiase Local Government Area, Cross River State

Location	Horizon Designations	Horizon Depth	pH(1:1)		ΔpH	Organic Carbon	T:N	Avail P.	Ca	Mg	K	Na	TEB	ExchH +A	CEC	ECEC	Base Saturation
		(cm)	KCI	H_2O		gkg^{-1}	gkg^{-1}	Mgkg	$cmolkg^{-1}$			$cmolkg^{-1}$			pH 7	pH7	%
$05^0 29.993$''N	Pedon 1 (Ikot Ana)																
$008^0 01.733$''E	Ap	0-17	4.2	4.9	-0.7	23.14	1.68	3.27	2.2	0.8	0.40	0.09	3.46	2.8	6.9	5.4	66
	Bt	17-62	4.3	4.8	-0.5	8.38	0.70	3.06	1.4	0.5	0.10	0.00	2.90	3.0	7.2	5.3	41
	B	62-113	4.2	5.1	-0.9	2.19	-	-	1.4	0.4	0.07	0.08	1.95	2.0	6.8	3.0	75
	BC	113-147	4.3	5.6	-1.2	2.00	-	-	1.2	0.4	0.03	0.00	1.83	0.6	4.0	2.5	75
	Cr	147-200	4.0	5.4	-1.0	2.00	-		1.2	0.3	0.06	0.10	1.56	0.6	3.7	2.1	55
$05^0 36.395$'N	Pedon 2 (Akpet central)																
$008^0 06.989$''E	Ap	0-20	4.1	4.8	-0.7	12.74	1.12	5.01	1.8	0.7	0.28	0.12	2.90	1.6	4.5	4.2	64
	Bt1	20-48	4.2	4.7	-0.5	7.38	0.84	3.27	1.6	0.5	0.10	0.10	2.30	3.6	8.0	6.8	29
	Bt2	48-88	3.8	4.2	-0.4	3.99	-	-	1.8	0.5	0.19	0.10	2.59	4.4	10.1	8.4	48
	CB	88-137	4.0	5.1	-1.1	2.99	-	-	1.2	0.4	0.12	0.05	1.77	0.6	5.8	3.5	83
	Cr	137-200	4.0	5.2	-1.2	1.80	-	-	1.0	0.3	0.08	0.07	1.45	0.6	4.0	2.0	72
$05^0 25.157$N	Pedon 3 (Obio-Ntan)																
$008^0 11.833$'E	Ap	0-20	4.7	5.5	-0.8	20.15	1.54	34.65	1.6	0.4	0.42	0.05	2.47	0.2	6.2	2.8	91
	Bt1	20-49	4.6	5.6	-1.0	6.95	0.70	20.21	1.6	0.4	0.13	0.04	2.17	0.4	3.4	1.0	78
	Bt2	49-60	4.3	5.5	-1.2	4.59	-	-	1.6	0.3	0.13	0.03	1.46	0.4	3.0	2.0	86
	Cr	60-100	4.2	4.9	-0.7	3.19	-	-	1.6	0.4	0.08	0.03	2.11	1.8	3.9	2.0	46
Range			3.8 - 4.7	4.2 5.5	-0.7 - 1.2	1.8 23.14	0.70 1.68	3.06 34.65	1.0 1.8	0.3 - 0.8	0.06 0.42	0.03- 0.12	1.45- 3.46	0.2 4.4	3.7 10.0	1.0 8.4	29 91
Surface Mean			4.3	5.0	-0.7	23.15	1.55	14.32	1.86	0.60	0.37	0.08	2.14	1.5	5.9	4.1	62
Sub surface Mean			4.2	5.1	-0.86	0.75	0.75	8.85	1.35	0.40	0.11	0.07	2.01	1.4	5.5	3.54	68