Classification and fertility status of soils developed on granite- gneiss in southern Cross River State, Nigeria

*Ene E. Aki, Victoria F.Ediene and ***Otobong B.Iren***
[1]Department of Soil Science, University of Calabar, Nigeria
*Corresponding Author's Email Address: ***myirenlady@gmail.com***

Abstract

Morphological, physical, chemical and mineralogical properties were determined with a view of classifying the soils using the United States Department of Agriculture (USDA) Soil Taxonomy System and correlated with the Food and Agriculture Organization- World Reference Base (FAO-WRB) for Soil Resources and assess the soil fertility status. Three representative soil profile pits were dug in Mkpot, Ikpai and Ojok in Akamkpa Local Government Area of Cross River State. The soils studied had deep profiles (> 100cm) with mainly sandy loam in the surface and sandy clay loam to sandy clay at the subsurface horizons. Bulk density (1.2 – 1.5 Mgm^{-3}) increased with increase in soil depth. The soil pH (H_2O) ranged from 4.8 – 6.8, organic carbon from 1.2 – 24.34 gkg^{-1}, total nitrogen from 0.42 – 1.69 gkg^{-1},effective cation exchange capacity ranged from 1.77 – 5.61 cmolkg^{-1}and base saturation from 36 – 99%. Extractable micro nutrients such as copper (Cu), manganese(Mn), zinc (Zn) and iron (Fe) were medium to high except boron (B) which was low due to high soil acidity. Minerals such as quartz (59.13%), Kaolinite (21.72%), Microcline (7.18%), Muscovite (2.91%), Hornblende (2.1%), Diopside and plagioclase (1.71%) were identified. Based on the USDA soil taxonomy criteria, the soils were classified as loamy, skeletal, mixed, Isohyperthemic typickandiudults, its equivalent by Food and Agriculture Organization – World Reference Base for soil Resource of the soils were Dystric Acrisols. The soils can be managed through mulching, crop rotation and adoption of zero tillage to reduce the leaching of basic nutrients, liming as well as cultivating acid tolerant crops.

Keywords: Classification, fertility, granite-gneiss, typickandiudults, soil properties, minerals, parent materials

Introduction

Basement complex rocks are the oldest rocks in Nigeria and they are made up of granites, quartzite, schist and gneiss (Iloeje, 2004). It has been reported that basement complex, (senile parent materials) has less influence on soil formation over time or space compared to the juvenile parent materials (Esu, (2010).

Soils in the study locations; Mkpot, Ojok and Ikpai, all in Akamkpa Local Government Area of Cross River state are rich in Granite-gneiss. Granite-gneiss are crystalline in structure and are an intercalation of igneous and metamorphic rocks, which are easily weathered with deep profile (> 100 cm) under humid conditions (Amah *et al*., 2012). It has been reported that highly weathered granite-*gneiss* under humid environment influences fertility properties as well as mineralogical properties of the soils (Fordham, 1990; Amusan, 2002; Akpan-Idiok and Ukwang, 2012). In the tropics, intensive weathering of granite-s is associated mainly with pronounced leaching and the principal factors commonly suggested to encourage rapid leaching are acidic precipitation all year round, high soil temperature (>31^0 C) and mineralogical composition of the parent materials. The weathering process of granite-gneiss can result in the formation of inter-layered minerals like illite/montmorrilonite, and can rapidly weather to Kaolinite with further weathering to hornblende gneiss through dissolution and re-precipitation (Velbel, 1989; Amusan, 2002). Soil physical, chemical, biological and mineralogical properties, which are indicators of soils' fertility status are influenced by the type of parent materials and human activities, such as farming, deposition of industrial wastes and others (Ibanga *et al*., 2008). Soils developed on biotite-hornblende-gneiss in Akamkpa have been documented as having deep profiles with coarse to fine sand texture (Iren and Ibanga, 2008; Aki *et al*., 2014). The soils are reported to be classified as TypicKandiudults. However, these soils support arable and tree crop plantations (Iren and Amalu 2012). The objective of this research was to classify, observe nutrient dynamics, and assess the fertility status of soils developed on granite-gneiss in Mkpot, Ojok and Ikpai with a view to make recommendations for appropriate management practices.

Materials and Methods

Site description

The study was conducted in the Akamkpa Local Government Area (Latitude 5^{0}00' and 5^{0}57'N; Longitude 8^{0}' 06' and 9^{0}0'E) of Cross River State, Nigeria (Figure 1). The climate is characterized by humid tropical conditions with an annual rainfall in the range of 2500 – 3000 mm, annual temperature of 26 – 27^{0}C and relative humidity of 80 – 90% (Afangide *et al.,* 2010).

The soils of the study sites (Mkpot, Ikpai and Ojok) are dominated with granite- and gneisses developed on basement complex rocks (Ekwueme, 2004; Amah *et al.,* 2012). The relief is gently to strongly undulating with secondary regrowth (Aki *et al.,* 2014).

Field study

Three soil profile pits were dug to the depths of 0 -159cm, 0 – 174cm and 0 – 120cm at Mkpot (05^0 32' 06"N; 008^{0}44' 51" E) Pedon 1; Ikpai (05^0 32' 3"N; 008^0 47' 73" E) Pedon 2 and Ojok (05^0 36' 23" N; 008^0 49' 28"E) Pedon 3, with a slope of 0-2%, respectively on the crest position. The locations were uplands fallowed for about 3 - 5 years.

The coordinates and altitudes of the three profile pits were marked using GPS meter by garminextrex 2000. Profile description and soil sampling from the pedogenic horizons were obtained by working from the base of the profiles to the top in order to avoid contamination. The core method was used in sampling soil for bulk density. Soil samples collected were properly labeled and taken to the Department of Soil Science, University of Calabar laboratory for physico-chemical analysis.

Laboratory studies

The soil samples collected were air-dried, pulverized and sieved through a 2-mm sieve. Soil samples were analyzed following the procedures described in Udo *et al*. (2009). Particle size analysis was determined by the hydrometer method. Bulk density was determined by oven-drying the undisturbed sample collected in 100 cm^3 metal cylinders to a constant soil mass at 105^0C. The oven-dry mass of the soil sample in the core was divided by total volume of the soil in the core. Soil pH determination was done both in water and in 1 *M*KCl solutions in a 1: 2.5 soil: water ratio, using a pyeunicam model 290 Mk pH meter. Delta pH (ΔpH) values were calculated by subtracting pH in H_2O with that of KCl.

Soil organic carbon was determined using the acid dichromate wet oxidation method of Walkley and Black. Total nitrogen was determined by the macro Kjedahl method. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) were determined by ammonium acetate (NH_4OAc) method. Exchangeable acidity was by titration method. Cation exchange capacity was by NH_4OAc saturation method. Effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases and exchangeable acidity. Available phosphorus was determined by the Bray-1 method. Base saturation was calculated by dividing the sum of exchangeable bases (Ca, Mg, K and Na) by CEC.

The 0.1*M* HCl extraction method of Osiname *et al*. (1973) was used in the determination of HCl extractable micronutrients. Particle size distribution for X-ray analysis was done on each sample by separating the clay fraction using a black loading preparation method. The micronized materials were analyzed by XRD utilizing a PAN analytical empyrean diffractometer with Pixel radiation. The phases were identified using X' pert high score plus software. The XRD analysis was used to determine the crystalline mineral phases present in the sample. Each phase (weight %) of the mineral was determined by the Rietveld refinement method. An oriented specimen was then prepared from each of the samples, the head and the clay (< 2um) fraction. The glass slide was analyzed by XRD to determine the mineralogy of the samples, glycolated, heated and reanalyzed. Glycolation and heat treatment processes helped in identifying and quantifying the different phyllosilicates in the clay fraction.

Results and discussion

Morphological properties

Table 1 shows the morphological descriptions of the representative soil profiles (Pedons 1 to 3). All the soils were deep and well-developed with depth > 100 cm profiles. The dark-red mottles of 2.5YR 6.8 at the bottom of the profile (Pedon 3) indicate the presence of Fe^{3+} in that layer.

The pedons are deep and will permit crop roots proliferation and elongation. Horizon delineations of clear smooth boundary were observed at the surface with gradual diffusion to gradual smooth and wavy at the subsurface. Similar observations by Shaboyo *et al.* (2013) have been reported for soils developed on gneisses in the Northern Guinea Savanna of Nigeria, while Aki *et al*. (2014) also reported for soils developed on gneisses in Akamkpa in Sothern Cross River State, Nigeria.

Physical properties

The soils were mainly sandy loam in the surface and sandy clay loam to sandy clay at the subsurface horizons with sand content in the surface horizon greater than 730 gkg^{-1} and >530 gkg^{-1} in the subsurface (Table 2). Clay contents for Pedons 1– 3 had mean values of 223 and 323 gkg^{-1} for surface and subsurface horizons, respectively. Clay content above 300 gkg^{-1} in the subsurface horizon implies that these soils can retain adequate amount of water for crop production (Akpan-Idiok, 2012).The accumulation of clay in the subsurface horizons of these soils indicates that the dominant pedogenic processes are eluviation, illuviation in the Bt horizons (Aki et al., 2014; Esu, 2010). Silt/clay ratio had means of 0.4 and 0.3 in the surface and subsurface horizons for all the pedons, respectively.

Bulk density values increased with increase in soil depth, with mean values of 1.2 and 1.4 $Mgm^{-3}$for surface and subsurface soils, respectively, which is within the critical limit or range (1.0 to 1.8 Mgm^{-3}) for minerals soils (NPFS, 2009).

The mean total porosity ranged from 43.4 – 58.0% while particle density values ranged from 2.42–2.78 Mgm^{-3}. The values of particle density in the studied soils fall within the critical value of 2.66 Mgm^{-3} for mineral soils (Essoka and Esu, 2001; Akpan-Idiok, 2012).

Chemical properties

The soils were strongly acidic with mean pH values of 5.6 and 5.3 for the surface and subsurface horizons, respectively (Table 3). The soil exchangeable acidity values at the surface soil were mostly within the threshold range of 0.5 – 2.0 $cmolkg^{-1}$ for productive soils (Landon, 1991). This indicates that soil acidity is not likely to be a threat to crops in the area. The ΔpH values (pH in H_2O – pH in KCl) were positive with means of 1.0 and 0.83 in the surface and subsurface, respectively, indicating that the soils have net negative charges in all the horizons. Negatively charged soils have the potential to hold down exchangeable bases and heavy metal pollutants (Aki *et al*., 2014; Esu *et al.*, 2008).

There was a decrease in organic carbon and total nitrogen contents as the soil depth increases (Table 3) while available P contents were low to medium in the surface horizon based on the criteria given by Aduayi *et al*. (2011) for soils of humid tropical zone. Exchangeable calcium, magnesium, potassium and sodium were generally low relative to their critical values of 5, 1, 0.3 and 0.3 cmolkg^{-1} (Holland *et al.,* 1989) for the respective cations, this indicates that the soils are severely leached. Amusan (2002) and Nwaka and Kwari (2000), documented rapid leaching of exchangeable bases in soils derived from granite- gneiss in south western Nigeria.

The effective cation exchange capacity (ECEC) and CEC were rated low as mean values were less than 4.00 cmolkg^{-1} and 16 cmolkg^{-1}, respectively, in most horizons (Table 3). The mean values of base saturation ranged from 29- 87 % in the studied soils. However, Akpan-Idiok (2012) noted that basic nutrients can still occur in available forms for plant uptake in-spite of the low cations reserve in the soils.

The C/N ratio values ranged from 7.1 – 14.1 in the surface horizon. These values are less than the separating index of 25 and indicate the dominance of mineralization over immobilization (Paul and Clark 1989). This indicates narrow C: N ratio in the soil reflecting high microbial activity, rapid decomposition of organic matter and availability of nutrients for plant uptake.

Calcium: magnesium (Ca:Mg) ratio values ranged from 3:1 to 4:1 and fall within the normal range of 3:1 to 5:1 as given by Udo *et al.* (2009) for productive soils. Magnesium: potassium (Mg:K) ratio values ranged from 2:1 – 10:1.These show that interactions between Mg and K in the soils are high enough to support plant growth (Landon 1991).

Extractable micronutrients Cu, Mn, Zn and Fe were medium to high (Table 4) while extractable boron was lower than its critical value of 0.5 mgkg^{-1} in the soils probably due to high acidity.

Mineralogical properties and its fertility implication

Quartz

The x-ray diffraction result shows that quartz accounted for up to 59.13% in the clay size fraction of the studied soils (Figure 2) indicating that the soils are in advanced stage of weathering. The findings are with the report given in Amusan (2002), who observed quartz to be the most dominant mineral in soils derived on granite-gneiss in Aberdeen Shire, United Kingdom. Usually quartz does not contribute chemically to soil fertility but its interaction with some soil elements can improve water permeability, structural stability and resistance to erosion.

Kaolinite

Result showed that kaolinite accounts for about 21.72% in the studied soils (Figure 2). The occurrence of kaolinite mineral in the studied soils implies that high degree of weathering has resulted in the production of low activity clay, low surface charged area, low cation resource and low fertility status (Aki *et al*., 2014).

Microcline

The X-ray diffractions showed that microcline constitutes about 7.18% (Figure 2) in the clay fraction of the studied soils. Microcline mineral is of great agricultural importance because of its contribution to availability of essential nutrients, like potassium (K) in the soil solution for uptake by plants.

Muscovite

The x-ray diffraction analysis showed that muscovite constitutes about 2.91% of the soils (Figure 2). Muscovite fixes iron oxide in the soils as that is the final stage in mineral weathering. The amount of muscovite observed in soils at the study area is a clear indication of being inherited from the under laying granite- gneiss parent materials.

Hornblende, Plagioclase and Diopside

Hornblende and plagioclase are amphiboles, which are Ortho-silicates. They contain anorthite and oligioclase, which indicate that they are highly weathered in the soils. The x-ray diffraction data showed that hornblende constitutes about 2.1% while plagioclase and diopside constitute about 1.71% (Figure 2) in the soil clay fractions. Therefore, due to high degree of weathering, they tend to release basic nutrients such as basic cations, N, P and S into the soils (Gribble, 1988; Smedskjaer *et al*., 2008).

Soil classification

Some of the studied soils have low base saturation (< 35%) by CEC method (Table 3), Kandic horizons with effective cation exchange capacity per clay < $12 cmolkg^{-1}$, umbricepipedon value of ≤ 3 (moist) and Ochricepipedon value of ≥ 4 (moist) thus classified under the Ultisols order (Soil Survey Staff, 2014). Udic soil moisture regime in the tropical humid climate qualifies them as Udults. An increase in clay mineral content in kaolinitic horizons, within the depth of 150 cm from the soil surface with an irregular decrease of organic carbon down the profile, allows for the placement of these soils in the great group kandiudults and typickandiudults at the subgroup level. The presence of clay and rock fragments with less than 35% content, mixed mineralogy of Quartz, Microcline (K-feldspars), kaolinite, muscovite, Hornblende and Plagioclase and diopside, qualifies these soils as loamy skeletal, mixed isohyperthermic typicKandiudults, according to the criteria of USDA (Soil Survey Staff, 2014) and correlated as Haplic Acrisols (loamic,ochric) (FAO, 2012).

Conclusions

The investigation highlights the morphological, physicochemical and mineralogical properties of soil derived from granite gneiss in Akamkpa, Southern Cross River State, Nigeria. The soils are well drained, well developed with coarse texture materials. The soils were characterized by very strongly acid in reaction, moderate to high organic carbon and nitrogen as well as moderate to high except for B which was low. The soil had mixed mineralogy of quartz, microcline, kaolinite, muscovite, hornblende, plagioclase and diopside under the same rate of weathering. The soils were classified as loamy skeletal, mixed isohyperthermic Typic kandiudults and correlated with FAO-WRB as Haplic Acrisols (Loamic ochric). Therefore, the soil fertility management strategies should be geared towards reducing the leaching of basic nutrients from the soils through mulching, planting of cover crops, crop rotation, and adoption of zero tillage. Liming of these acid soils also becomes inevitable.

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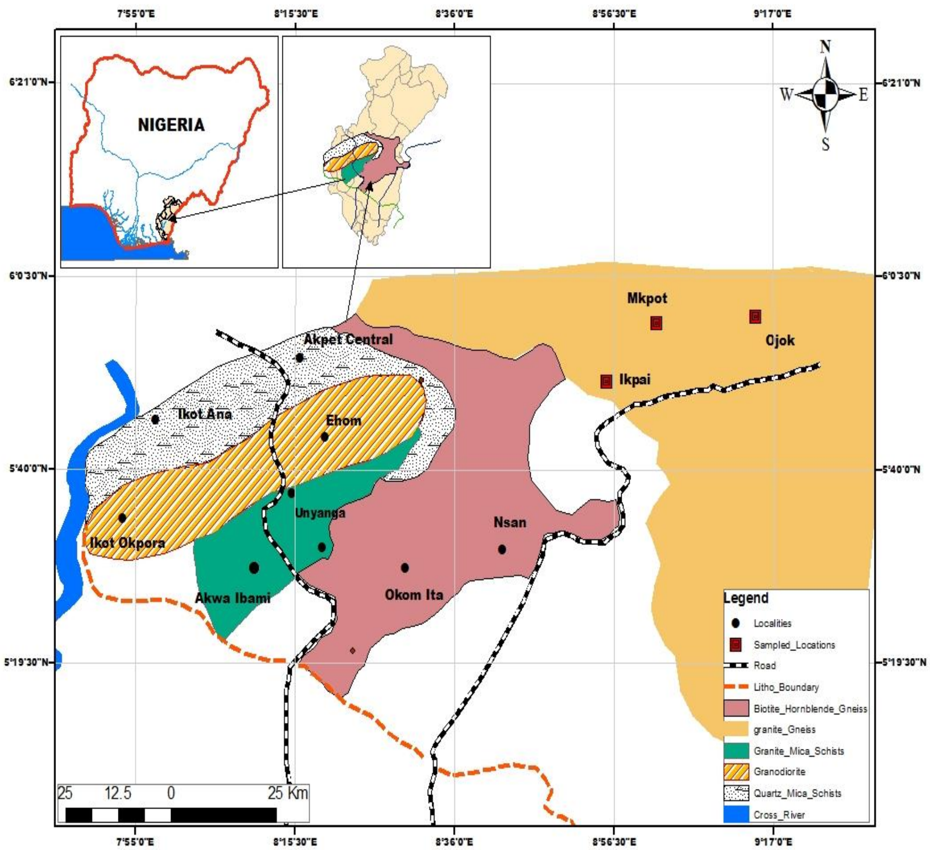

Figure 1: Geology map of the study area showing sampling locations at Mkpot, Ikpai and Ojok in Akamkpa Local Government Area

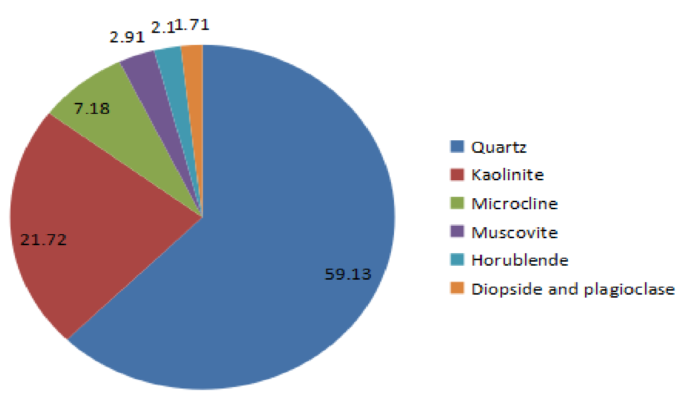

Figure 2: Percentage Distribution of minerals in clay fractions of soils derived from Granite-Gneiss

Table 1: Morphological properties of soils developed on Granite- Gneiss in Akamkpa LGA, CRS

Location	Horizon Designation	Dept (cm)	MunsellColour	Mottling	Texture	Structure	Consistence	Boundary	Other features
05^{0}32.064N	Pedon 1 (Mkpot)								
008^{0}44.513E	Ap	0-15	10YR3/3 dark brown	-	Sl	1msbk	sssp	cs	Termite, many mica flakes, worm cast; many medium roots
	Bt	15-53	10YR5/6 yellowish brown	-	L	2msbk	sssp	gs	Common fine mica flakes; common fine and medium roots; clay skins in the peds
	B	53-91	10YR6/8 yellowish brown	-	L	2msbk	sp	ds	Many large quartzite, muscovite, biotite schistose; common medium and fine roots
	BC	91-120	7.5YR5/8 strong brown	-	Scl	2msbk	sp	ds	Many large quartzite, muscovite, biotite schistose and weathered roots
	Cr	120-159	7.5YR5/8 Reddish yellow	-	Scl	2msbk	sp		Many large quartzite, muscovite, biotite schistose and weathered roots
05^{0}32.327N	Pedon 2 (Ikpai)		2.5YR5/8 Red	-					
008^{0}47.728E	Ap	0-23	10YR 3/2 very dark brown		Sl	1msbk	sssp	cs	Earthworms cast, Termite and ant activities: many fine roots
	Bt	23-43	7.5YR 5/6 strong brown	-	Sc	2fgr	sssp	gs	Many common mica flakes, termite activities; clay skins in the peds
	B	43-74	5YR 5/6 yellowish red	- -	Scl	3mcsbk	sp	ds	Many fine mica flakes, many medium weathered rocks, fragments of quartzite schistose; clay skins in the peds
	BC	74-110	5YR 5/6 yellowish red		Sc	1msbk	sp	ds	Many mica flakes termite activities
	Cr	110-174	2.5YR 4/8 Red		Sc	1msbk	sp		Many mica, haemite termite activities
05^{0}23.232N	Pedon 3(Ojok)								
008^{0}49.279E	Ap	0-11	10YR 3/1 very dark grey	-	Sl	2msbk	sssp	cs	Termite, worm casts, human activities; many fine and medium roots
	Bt1	11-30	10YR 6/6 brownish yellow		scl	2msbk	sssp	gs	Common fine roots; common macro and micro pores; micas flakes; clay skins in the peds
	Bt2	30-65	10YR 5/8 brownish yellow	-	scl	2msbk	sp;fi	ds	Common fine roots; many mica flakes; clay skins in the peds
	Crt	65-116	7.5YR 5/8 Reddish yellow	2.5YRLight red	sc	2msbk	sp;fi	dw	Large quartzite, muscovite schist, biotite schist and weathered Few moderate cutans on peds, many Fe and decay granitic gneisses observed
	Cr	11-120	10YR5/8 yellowish brown	2.5YRLight red	sc	2msbk	sp;fi		

Texture: ls = loamy sand; sl = sandy loam; scl = sandy clay loam; sc = sandy clay
Structure: 1 = Weak, 2 = Moderate, 3 = Strong, f = fine, m=medium, c=coarse, 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.

Table 2: Physical properties of soils developed from Granite- Gneiss in Akamkpa LGA, CRS

Location	Horizon/ Designations	Horizon depth (cm)	Sand	Particle Size(g kg^{-1}) Silt	Clay	Gravel Content %	Textural Classes	Bulk Density Mg m^{-3}	Particle density Mg m^{-3}	Total Porosity (%)	Silt/Clay Ratio
Classification	Mkpot			**Loamy Skeletal Mixed IsohyperthermicTypicKandiudult**					Haplic Acrisol (loamic,ochric)		
05^{0}32'064"N	Pedon 1										
008^{0}44'513"E	Ap	0-15	810	60	130	16.3	sl	1.2	2.58	53.5	0.5
	Bt	15-53	690	40	270	22.3	scl	1.3	2.66	51.1	0.1
	B	53-91	630	60	310	55.1	scl	1.5	2.65	43.4	0.2
	BC	91-120	570	100	330	44.0	scl	-	-	-	0.3
	Cr	120-159	630	80	290	44.2	scl	-	-	-	0.3
05^{0}32.327'N	Pedon 2(Ikpai)								Haplic Acrisol (ochric)		
008^{0}47.728E	Ap	0-23	770	80	150	9.80	sl	1.4	2.62	46.7	0.5
	Bt	23-43	570	100	330	30.8	scl	1.4	2.65	47.2	0.3
	B	43-74	530	80	390	49.7	sc	1.3	2.66	51.1	0.2
	BC	74-110	630	100	270	51.8	scl	-	-	-	0.3
	Cr	110-174	550	100	350	27.1	sc	-	-	-	0.4
05^{0}36232'N	Pedon 3 (Ojok)								Haplic Acrisol (ochric)		
008^{0}49279"E	Ap	0-11	730	120	170	3.1	sl	1.2	2.65	56.6	0.5
	Bt1	11-30	570	140	290	42.8	scl	1.3	2.65	50.9	0.2
	Bt2	30-65	570	140	490	56.1	scl	1.4	2.68	47.7	0.2
	BC	65-116	590	100	310	25.0	scl	-	-	-	0.1
	Cr	116-120	570	60	370	18.2	scl	-	-	-	0.2
Range			530-810	40-140	130-490	3.1-56.1		1.2-1.5	2.58-2.68	43.4-56.6	0.1-0.5
Surface mean			770	87	150	9.73		1.3	2.61	52.3	0.5
Sub surface mean			592	91	333	39.0		1.4	2.66	32.2	0.2

Legend: ls= loamy sand, l= loam, cl= clay loam, scl= sandy clay, sl= sandy loam

Table 3: Chemical properties of soils developed from Granite- Gneiss in Akamkpa LGA, CRS

Location	Horizon Designation	Horizon Depth (cm)	pH(1:1) H_2O	pH(1:1) KCl	ΔpH	Org. carbon gkg^{-1}	TN gkg^{-1}	Avail P. $mgkg^{-1}$	Ca (cmolkg^{-1})	Mg (cmolkg^{-1})	K (cmolkg^{-1})	Na (cmolkg^{-1})	TEB (cmolkg^{-1})	H+A1 (cmolkg^{-1})	CEC7 (cmolkg^{-1})	ECEC pH 7.0 (cmolkg^{-1})	Base Saturation %
05^{0}32.064"N	Pedon 1 (Mkpot)																
008^{0}44.513"E	Ap	0-15	6.8	4.7	2.1	15.96	1.12	10.59	2.4	0.6	0.19	0.03	3.22	0.2	5.5	3.4	59
	Bt	15-53	5.1	4.2	0.9	6.58	0.70	3.27	1.2	0.4	0.09	0.02	1.71	1.2	5.0	2.6	34
	B	53-91	5.2	4.0	1.2	7.58	-	-	1.0	0.3	0.06	0.01	1.37	2.4	6.1	3.8	26
	BC	91-120	4.8	4.2	0.6	4.19	-	-	2.0	0.5	0.06	0.05	2.61	3.0	7.2	5.6	36
	Cr	120-159	5.1	4.1	1.0	1.20	-	-	1.0	0.3	0.04	0.03	1.37	1.6	5.3	2.9	25
05^{0}32.327'N	Pedon 2(Ikpai)																
008^{0}47.728"E	Ap	0-23	5.3	4.9	0.4	24.34	1.68	8.47	3.8	0.9	0.16	0.03	4.89	0.4	5.6	4.9	87
	Bt	23-43	5.5	4.6	0.9	5.59	0.42	4.24	2.0	0.5	0.05	0.04	2.59	0.4	4.2	2.6	62
	B	43-74	5.4	4.7	0.7	5.59	-	-	1.2	0.3	0.04	0.03	1.57	0.2	4.8	1.7	33
	BC	74-110	5.3	4.9	0.4	4.59	-	-	1.4	0.4	0.04	0.03	1.87	0.2	4.5	2.1	42
	Cr	110-174	5.5	4.4	1.1	2.99	-	-	1.6	0.5	0.03	0.03	2.16	0.4	4.7	2.6	46
05^{0}32.232N	Pedon 3 (Obio-Ntan)																
008^{0}49.279'E	Ap	0-11	5.4	4.8	0.6	16.36	1.26	7.89	2.0	0.8	0.33	0.02	3.15	0.4	5.1	3.6	62
	Bt1	11-30	5.7	4.8	0.9	4.19	0.56	3.27	1.8	0.4	0.09	0.02	2.31	0.2	5.0	2.3	46
	B	30-65	5.2	4.5	0.7	1.49	-	-	1.4	0.5	0.05	0.02	1.97	1.0	4.2	2.9	46
	Crt	65-116	5.6	4.8	0.8	2.79	-	-	1.8	0.4	0.05	0.01	2.26	0.2	4.9	2.5	46
	Cr	116-120	5.8	5.0	0.8	3.19			1.6	0.6	0.05	0.02	2.27	0.2	4.0	2.3	46
Range			4.8 - 6.8	4.0 - 5.0	0.4 - 2.1	1.2 - 24.34	0.42-1.68	3.27 - 10.56	1.0 - 3.8	0.3 - 0.9	0.03 - 0.33	0.01 - 0.05	1.37 - 4.89	0.2 - 3.0	4.0 - 7.20	1.7 - 5.6	26 - 87
Surface mean			5.6	4.7	-1.0	12.17	1.35	8.98	2.0	0.6	0.15	0.03	3.75	0.1	5.1	3.2	58
Subsurface mean			5.3	4.5	-0.83	3.7	0.56	3.59	1.4	0.4	0.05	0.03	1.83	0.1	5.8	2.9	39