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Characterization and classification of soils in steep sided hills and sharp-crested ridges of Akwa Ibom State, Nigeria

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ABSTRACT

Characterization and classification of soils in steep sided hills and sharp-crested ridges of Akwa Ibom State were investigated. The aim was to have baseline information that will assist farmers and other land users in decision making. With the help of global positioning system (GPS) and soil augering, two soil identification units based on the drainage pattern and elevation were identified in the study area. They were poorly drained soils and the well-drained soils. In each soil identification unit, three representative soil profile pits were dug. A total of 6 profile pits were dug in the study area. The pits were described in accordance with FAO (1990) guidelines for soil profile description. Soil samples were collected from each genetic horizon for laboratory analysis. The results revealed that clay is the dominant texture in the poorly drained soils, whereas loamy sand dominates the soil surface of well-drained soils and sandy clay loam dominates the subsoil. Soil pH varied from strongly acid to moderately acid (pH 5.1-5.8) in the poorly drained soils and very strongly acid to moderate acid (4.9 to 5.6) in the well-drained soils. The soils of the study area were non-saline and within the acceptable level for general crop growth. Organic carbon varied from low to very high (0.7 to 2.7%) in the study area. Total nitrogen of the poorly drained soils varied from moderately high to very high (0.2 to 0.8%) while well-drained soils varied from low to high (0.08 to 0.3%). Available P varied from low to moderate (5.8 to 15.0 mgkg^{-1}) in the study area. Exchangeable bases (Ca, Mg, Na and K) were generally low (Ca: 1.5 to 3.2 cmol/kg, Mg: 0.3 to 2.6 cmol/kg, K: 0.06 to 0.4 cmol/kg and Na: 0.03 to 0.2 cmol/kg) in the study area. CEC varied from very low to low (5.0 to 9.5 cmol/kg) in the poorly drained soils and low to moderate (10.0 to 12.0 cmol/kg) in the well-drained soils. Base saturation varied from low to high (24.0 to 81.0%) in the poorly drained soils and low to moderate (23.0 to 41.0%) in the well-drained soils of the study area. Poorly drained soils are classified as Typic Epiaquepts (USDA) or Cambisols (FAO/WRB) while well-drained soils are classified as Typic Hapludults (USDA) or Haplic Acrisols (FAO/WRB).

Keywords: Soil classification, soil type, soil characterization.

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INTRODUCTION

Different soil types exhibits diverse behavior due to differences in micro-morphological, morphological, physical, chemical and mineralogical properties. These variations are due to variations in soil forming factors and processes operating on different parent materials, under different climatic, topographic, and biological conditions over varying periods of time (Soil survey Staff, 1993). Different soil types support different land use and require different management options for sustainable productivity (Ogunkunle, 1986). According to Fagbami (1990), the diversity nature of soil is a major reason behind allocation of land to wrong uses. Soil characterization and classification contribute to the alleviation of the adverse effect of soil diversity and aid precision agriculture. Soil characterization and classification is the main information source for precision agriculture, land use planning and management (Ogunkunle, 1986). This is because characterization and classification provide information for the understanding of the micro-morphological, physical, chemical, mineralogical and microbiological properties of the soil (Ogunkunle, 1986).

In Akwa Ibom State, soils occupying the steep sided hills, valleys and sharp-crested ridges are the least studied soils (Petters et al., 1989). The soil is underlain by a simple pattern of sedimentary geological formation, consisting of medium to coarse - grained sandstones and siltstones. Settlements in these areas are restricted to isolated level portions (Petters et al., 1989; Usoro and Akpan, 2010). An in-depth study of the soil characteristics and classification will provide baseline information on the physical, chemical and mineralogical properties of the soil for precision agriculture, land use planning and management. Therefore, the objectives of the study were the characterization and classification of soils in the steep sided hills, valleys and sharp-crested ridges of Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Description of the study area

The study area is located in Akwa Ibom State, South-South Nigeria within latitudes 4°30′ and 5°30′ N and longitudes 7°30′ and 8°20′ E. The area is underlain mainly by sandstone, siltstone/shale and alluvial parent materials (Petters et al., 1989; Usoro and Akpan, 2010). The landscape consists of hills and ridges with steep sided valleys. No portion of the study area exceeds 175 m above sea level. The climate is humid tropical with annual rainfall of about 2500 to 3000 mm with 1 to 3 dry months in the year. The moisture regime is made up of udic in the elevated area and aquic in the low-lying area. Mean annual temperature varies between 27 and 28°C with relative humidity of 75 to 80% (Petters et al., 1989; Usoro and Akpan, 2010).

Field sampling

With the help of Global Positioning System (GPS) and soil augering, two soil identification units based on the drainage pattern and elevation were identified in the study area. They were poorly drained soils unit and the well-drained soils unit. In each soil identification unit, three representative soil profile pits were dug. A total of 6 profile pits were dug in the study area. The pits were described in accordance with FAO (1990) guidelines for soil profile description. Soil samples were collected from each genetic horizon for laboratory analysis.

Laboratory analysis

The samples were air dried before grinding and sieved with a 2 mm sized sieve. The samples were analyzed in accordance with standard laboratory procedures for the following parameters: *Particle size distribution* was determined by the hydrometer method as described by Gee and Bauder (1986). *Soil pH* was determined in water 1:2 soils: water ratio using pH meter with glass electrode (Thomas, 1996). *Exchangeable cations* were extracted with neutral NH_4OA_C. Calcium and magnesium were determined in the extract by EDTA titration and potassium and sodium by the use of flame photometer (Udo et al., 2009). *Exchangeable acidity* was extracted with one normal potassium chloride solution. The exchangeable acidity and the exchangeable aluminium were determined by titration as described by Thomas (1996). The exchangeable hydrogen was obtained by subtracting exchangeable aluminium from exchangeable acidity. Exchangeable acidity (Al +H) – Exchangeable Al = Exchangeable H. *Organic carbon* was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). The value was multiplied by 1.732 to obtained organic matter content. *Available phosphorus* was determined by the Bray-1 method as described by Kuo (1996). *Total nitrogen* was determined by the micro-kjeldahl digestion and distillation method as described by Bremner (1996). *Cation exchange capacity* was determined by method described by Sumner and Miller (1996). *Percentage base saturation* was calculated using the following formula:

$$\% \text{ base saturation} = \frac{\text{Summation of exchangeable bases}}{\text{CEC}} \times 100$$

RESULTS

Characteristics of the poorly drained soils unit

The range and mean of soil physical and chemical properties of the poorly drained soils are shown in Table 1 and 2, while Tables 3, 4, 5, 6, 7 and 8 show the physical and chemical properties of the pedons. The poorly drained soils of the study area are located within the lower and valley bottoms, underlain by alluvium parent material. The slope gradient is between 0 and 2% and elevation ranges between 0 and 12 masl. About 70% of the soils are characterized by mottles in the A-horizon while 30% are characterized by mottles in the B-horizon. The colour of the surface soil ranged from grey (2.5 YR 5/1) to light brownish grey (2.5YR 6/2) with reddish brown (5YR 4/5) or strong brown (7.5YR 4/6) mottles, while subsoil varied from light grey (2.5YR 7/1), grey (2.5YR 5/0)to light brownish grey (2.5YR 6/2) with reddish brown (5YR 5/4) or strong brown (7.5YR 5/6) or yellowish red (5YR 4/6) mottles. Sand content varied from 35.0 to 40.0% (mean 37.7 ± 2.5%) in the surface soil and 27.0 to 30.0% (mean 30.0 ± 2.6%) in the subsoil. The mean sand content of the surface soil is significantly higher ($P < 0.05$) than the subsoil. Silt content ranged from 4.0 to 20.0% (mean 11.3 ± 2.6 %) in the surface soil and 5.0 to 13.0% (mean 8.7 ± 4.0 %) in the subsoil.The mean silt content of the surface soil is significantly higher ($P < 0.05$) than the subsoil. Clay content varied from 45.0 to 56.0% (mean 51.0 ± 5.6%) in the surface soil and 60.0 to 64.0% (mean 61.0 ± 2.3%) in the subsoil. The soil pH in water varied from 5.5 to 5.8 (mean 5.6 ± 0.2) in the surface soil and 5.1 to 5.3 (mean 5.2 ± 0.1) in the subsoil. Electrical conductivity varied from 0.02 to 0.03 ds m^{-1} (mean 0.025 ± 0.01 ds m^{-1}) in the surface soil and 0.02 to 0.03 ds m^{-1} (mean 0.02 ± 0.01 ds m^{-1}) in the subsoil. Electrical conductivity of the surface soil was not significantly different ($P < 0.05$) from the subsoil. Organic carbon varied from 1.5 to 2.7% (mean 2.2 ± 0.7%) in the surface soil and 0.95 to 2.0% (mean 1.5 ± 0.5%) in the

Table 1. The range and mean of soil physical and chemical properties of the poorly drained soils of the study area.

Soil properties	Surface soils		Subsurface soils	
	Range	Mean	Range	Mean
Sand (%)	35.0 – 40.0	37.7 ± 2.5	27.0 – 32.0	30.0 ± 2.6
Silt (%)	4.0 – 20.0	11.3 ± 2.6	5.0 – 13.0	8.7 ± 4.0
Clay (%)	45.0 – 56.0	51.0 ± 5.6	60.0 - 64.0	61.3 ± 2.3
pH (water)	5.5 – 5.8	5.6 ± 0.2	5.1 – 5.3	5.2 ± 0.1
Electrical conductivity (ds m^{-1})	0.02 – 0.03	0.025 ± 0.01	0.02 – 0.03	1.5 ± 0.5
Org. carbon (%)	1.5 – 2.7	2.2 ± 0.7	0.95 – 2.0	1.5 ± 0.5
Total nitrogen (%)	0.33 – 0.79	0.5 ± 0.2	0.15 – 0.55	0.3 ± 0.2
Available P (mg/kg)	8.0 – 12.5	11.0 ± 2.6	5.8 – 10.5	8.5 ± 2.4
Ca (cmol/kg)	1.7 – 3.2	2.6 ± 0.8	1.5 – 2.8	2.0 ± 0.7
Mg (cmol/kg)	0.25 – 1.6	1.0 ± 0.7	0.35 – 2.0	1.2 ± 0.8
K (cmol/kg)	0.09 – 0.3	0.2 ± 0.1	0.22 - 0.24	0.2 ± 0.01
Na (cmol/kg)	0.11 – 0.21	0.1 ± 0.06	0.14 – 0.16	0.2 ± 0.01
Exch. acidity (cmol/kg)	1.5 – 2.1	1.7 ± 0.3	0.9 - 1.8	1.2 ± 0.5
Base sat. (%)	28.0 – 81.0	60.3 ± 28.4	24.0 – 68.0	52.0 ± 24.8
CEC (cmol/kg)	6.0 – 8.5	7.2 ± 1.3	5.0 – 9.5	7.4 ± 2.3

Table 2. The range and mean of soil physical and chemical properties of the well- drained soils of the study area.

Soil properties	Surface soils		Subsurface soils	
	Range	Mean	Range	Mean
Sand (%)	84.0 – 90.o	87.3 ± 3.1	70.0 – 75.0	71.7 ± 2.9
Silt (%)	4.0 – 5.0	4.3 ±0.6	2.0 – 2.0	2.0 ± 0.0
Clay (%)	6.0 – 11.0	8.3 ± 2.5	16.0 – 28.0	24.0 ± 6.9
pH (water)	5.4 – 5.6	5.5 ± 0.2	4.9 – 5.5	5.1 ± 0.3
Electrical conductivity (ds m^{-1})	0.03 – 0.13	0.08 ± 0.05	0.02 – 0.06	0.04 ± 0.02
Org. carbon (%)	1.7 – 2.15	1.9 ± 0.2	0.65 – 0.95	0.8 ± 0.2
Total Nitrogen (%)	0.12 – 0.35	0.3 ± 0.1	0.08 – 0.3	0.2 ± 0.1
Available P (mg/kg)	7.5 – 15.0	11.1 ± 3.8	6.8 – 10.3	8.1 ± 1.9
Ca (cmol/kg)	1.6 – 2.5	2.2 ± 0.5	1.8 – 2.8	2.3 ± 0.5
Mg (cmol/kg)	0.9 – 1.6	1.2 ± 0.4	0.9 – 1.8	1.5 ± 0.5
K (cmol/kg)	0.06 – 0.25	0.2 ± 0.1	0.07 – 0.4	0.3 ± 0.2
Na (cmol/kg)	0.05 – 0.14	0.1 ± 0.05	0.03 – 0.07	0.05 ± 0.02
Exch. Acidity (cmol/kg)	1.33 – 1.50	1.4 ± 0.09	0.95 – 1.35	1.1 ± 0.2
Base sat. (%)	33.8 – 38.0	36.6 ± 2.4	23.0 – 41.0	33.6 ± 9.4
CEC (cmol/kg)	10.0 – 12.0	10.7 ± 1.2	12.0 – 12.0	12.0 ± 0.00

subsoil. Mean organic carbon of the surface soil was significantly higher (P < 0.05) than subsoil. Total nitrogen varied from 0.3 to 0.8% (mean 0.5 ± 0.2 %) in the surface soil and 0.2 to 0.6% (mean 0.3 ± 0.2 %) in the subsoil. Mean total nitrogen was high in both surface and subsoil. Available P varied from 8.0 to 12.5 $mgkg^{-1}$ (mean 11.0 ± 2.6 $mgkg^{-1}$) in the surface soil and 5.8 to 10.5 $mgkg^{-1}$ (mean 8.5 ± 2.4 $mgkg^{-1}$) in the subsoil. Statistically, mean available P of the surface soil was not significantly different (P < 0.05) from the subsoil. Exchangeable Ca ranged from 1.7 to 3.2 $cmolkg^{-1}$ (mean 2.6 ± 0.8 $cmolkg^{-1}$) in the surface soil and 1.5 to 2.8 $cmolkg^{-1}$ (mean 2.0 ± 0.7 $cmolkg^{-1}$) in the subsoil. Exchangeable Mg ranged from 0.25 to 1.6 $cmolkg^{-1}$ (mean 1.0 ± 0.7 $cmolkg^{-1}$) in the surface soil and 0.35 to 2.0 $cmolkg^{-1}$ (mean 1.2 ± 0.8 $cmolkg^{-1}$) in the subsoil. Exchangeable K varied from 0.09 to 0.3 $cmolkg^{-1}$ (mean 0.2± 0.1 $cmolkg^{-1}$) in the surface soil and 0.22 to 0.24 $cmolkg^{-1}$ (mean 0.2 ± 0.01 $cmolkg^{-1}$) in the subsoil. Exchangeable Na varied from 0.11 to 0.21 $cmolkg^{-1}$ (mean 0.1 ± 0.06 $cmolkg^{-1}$) in the surface soil and 0.14 to 0.16 $cmolkg^{-1}$ (mean 0.2 ± 0.01$cmolkg^{-1}$) in the subsoil. Mean exchangeable bases (Ca, Mg and K) of the surface soil were not significantly different (P < 0.05) from the subsoil except mean exchangeable Na, which

Table 3. Physical and chemical properties of pedon 1 in floodplain soils of the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E.C $MScm^{-1}$	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H^+	Al^{+3}
Ap	0 - 10	38	10	52	C	5.5	4.8	0.015	2.69	0.33	1.50	1.00	0.50
AB	10 - 32	35	10	55	C	5.4	4.5	0.025	2.40	0.25	1.70	1.10	0.60
B	32 - 56	32	8	60	C	5.3	4.2	0.017	1.43	0.18	0.95	0.90	0.05
BC	56 - 72	30	12	58	C	5.2	4.2	0.033	0.98	0.12	0.88	0.72	0.16

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
12.5	3.20	1.60	0.09	0.11	7.0	72
9.3	4.80	4.00	0.14	0.12	10.2	89
7.6	2.80	2.00	0.23	0.14	7.6	68
5.4	2.40	1.60	0.34	0.19	7.4	61

Table 4. Physical and chemical properties of pedon 2 of poorly drained soils of the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E. C. ($MScm^{-1}$)	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H	Al^{+3}
Ap	0 - 11	35	20	45	C	5.5	4.3	0.034	2.43	0.79	1.50	1.30	0.20
AB	11 - 30	29	18	53	C	5.2	4.1	0.044	2.25	0.64	0.00	0.90	0.10
BC	30 - 45	27	13	60	C	5.1	3.9	0.026	1.97	0.55	0.90	0.80	0.10

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
12.40	2.80	1.20	0.27	0.21	6.0	81
8.10	2.00	1.20	0.23	0.09	5.0	73
10.45	1.60	1.20	0.22	0.16	5.0	64

Table 5. Physical and chemical properties of pedon 3 in floodplain soils of the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E.C. ($MScm^{-1}$)	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H^+	Al^{+3}
Ap	0 - 14	40	4	56	C	5.8	4.6	0.027	1.45	0.41	2.10	1.80	0.30
ABg	14 - 43	34	8	58	C	5.6	4.3	0.018	1.20	0.22	2.50	1.55	0.95
BCg	43 - 70	31	5	64	C	5.3	4.2	0.022	0.95	0.15	1.80	1.20	0.60

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
8.0	1.70	0.25	0.30	0.11	8.5	28
9.7	1.00	1.55	0.27	0.21	8.5	36
5.8	1.50	0.35	0.24	0.15	9.5	24

the mean content of the sub-surface soil was significantly higher ($P < 0.05$) than the surface soil. Total exchangeable acidity ranged from 1.5 to 2.1 $cmolkg^{-1}$ (mean 1.7 ± 0.3 $cmolkg^{-1}$) in the surface soil and 0.9 to

Table 6. Physical and chemical properties of pedon4 in the well-drained drained soils of the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E.C $MScm^{-1}$	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H^+	Al^{+3}
Ap	0 – 13	88	4	8	LS	5.4	4.1	0.125	1.70	0.12	1.33	1.22	0.11
AB	13 – 33	84	2	16	SL	5.2	4.1	0.017	0.95	0.10	1.25	0.95	0.30
$B+_1$	33 – 57	75	2	23	SCL	4.9	4.8	0.023	0.88	0.08	0.98	0.80	0.18
$B+_2$	57 – 130	70	2	28	SCL	4.7	4.0	0.017	0.70	0.07	0.85	0.70	0.15
BC	130 – 180	60	1	39	SC	4.4	3.6	0.022	0.43	0.05	0.62	0.50	0.12

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
7.5	1.60	0.90	0.25	0.13	10.0	33.8
9.8	1.85	1.50	0.35	0.06	8.5	48.4
7.3	2.15	1.80	0.40	0.05	12.0	36.7
6.5	1.70	1.20	0.39	0.07	15.5	20.1
4.9	2.50	1.85	0.40	0.05	15.0	31.2

Table 7. Physical and chemical properties of pedon 5 of well-drained soils of the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E.C $MScm^{-1}$	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H^+	Al^{+3}
Ap	0 – 13	90	4	6	LS	5.4	4.3	0.085	2.15	0.35	1.45	1.12	0.33
AB	13– 35	84	2	14	SL	5.2	4.2	0.075	1.18	0.32	1.20	0.90	0.30
$B+_1$	35– 82	70	2	28	SCL	5.0	4.1	0.064	0.95	0.30	0.95	0.80	0.15
$B+_2$	82– 106	68	2	30	SCL	4.9	4.1	0.042	0.85	0.25	0.88	0.75	0.13
BC	106– 170	60	2	38	SC	4.8	3.9	0.033	0.61	0.16	0.65	0.54	0.11

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
10.8	2.50	0.95	0.25	0.14	10.0	38.0
7.5	1.50	1.70	0.33	0.09	7.0	52.0
6.8	2.80	1.65	0.40	0.07	12.0	41.0
8.3	1.64	1.72	0.35	0.05	16.0	24.0
5.6	1.80	1.95	0.28	0.05	13.0	31.0

Table 8. Physical and chemical properties of pedon 3 of well-drained soils in the study area.

Horizon	Depth (cm)	Particle size analysis (%)			Texture	pH		E.C $MScm^{-1}$	Organic carbon (%)	Total N (%)	Exchange acidity (cmol/kg)		
		Sand	Silt	Clay		H_2O	KCl				TEA	H^+	Al^{+3}
Ap	0 – 12	84	5	11	LS	5.6	4.8	0.034	1.79	0.33	1.50	1.95	0.55
AB	12– 28	80	4	16	SL	5.4	4.8	0.024	0.76	0.25	1.20	0.90	0.31
$B+_1$	28– 81	70	2	28	SCL	5.5	4.7	0.028	0.65	0.11	1.35	0.85	0.50
$B+_2$	81– 124	68	2	30	SCL	5.3	4.6	0.023	0.54	0.04	0.95	0.80	0.15
BC	124– 170	54	4	42	SCL	5.2	4.4	0.025	0.50	0.03	0.80	0.70	0.10

Table 8. Continues.

Available P (mg/kg)	Exchangeable cations (cmol kg^{-1})				CEC (cmol kg^{-1})	B-S. (%)
	Ca	Mg	K	Na		
15.0	2.40	1.60	0.06	0.05	12.0	38
14.3	2.00	1.20	0.05	0.06	10.0	33
10.15	1.80	0.90	0.07	0.03	12.0	23
8.50	1.64	0.70	0.04	0.15	8.0	31
10.10	2.10	1.60	0.02	0.20	10.0	39

1.8 cmolkg-1 (mean 1.2 ± 0.5 $cmolkg^{-1}$) in the subsoil. Mean exchangeable acidity of the surface soil was not different ($P < 0.05$) from the subsoil. This showed that potential acidity of the surface soil was not significant different from the subsoil at 5% level. CEC ranged from 6.0 to 8.5 $cmolkg^{-1}$ (mean 7.2 ± 1.3 $cmolkg^{-1}$) in the surface soil and 5.0 to 9.5 $cmolkg^{-1}$ (mean 7.4 ± 0.01 $cmolkg^{-1}$) in the subsoil. Percentage base Saturation varied from 28.0 to 81.0% (mean 60.3 ± 28.4 %) in the surface soil and 24.0 to 68.0% (mean 52 ± 24.3%) in the subsoil.

Characteristics of the well-drained soils unit

The deep, well-drained soils unit are located on the gently and undulating portion, underlined by coastal plain sands or sandstone/shale parent materials. The slope varied from 2 to 4% while elevation varied from 48.3 to 70.0 masl. The soil colour ranged from very dark grayish brown (10 YR 3/2) to brown (7.5 YR 5/4) or dark brown (10 YR 4/3) on the soil surface and brown (7.5 YR 5/4) or strong brown (7.5 YR 5/6) or reddish yellow (7.5 YR 6/8) or yellowish red (5YR 5/6) in the subsoil. Sand fraction varied from 84.0 to 90.0% (mean 87.3 ± 3.1%) in the surface soil and 70.0 to 75.0% (mean 71.7 ± 2.9%) in the subsoil. Silt fraction ranged from 4.0 to 5.0% (mean 4.3 ± 0.6%) in the surface soil and 2.0 to 2.01% (mean 2.0 ± 0.00%) in the subsoil. Silt fraction is not statistically different ($P < 0.05$) between the surface soil and subsoil. Clay fraction ranged from 6.0 to 11.0% (mean 8.3 ± 2.5%) in the surface soil and 16.0 to 28.0% (mean 24.0 ± 6.9%) in the subsoil. soil. The soil pH in water varied from 5.4 to 5.6 (mean 5.5 ± 0.1) in the surface soil and 4.9 to 5.5 (mean 5.1 ± 0.3) in the subsoil. Mean soil pH of the surface soil was significantly higher ($P < 0.05$) than the subsoil. Electrical conductivity varied from 0.03 to 0.13 ds m^{-1} (mean 0.08 ± 0.05 ds m^{-1}) in the surface soil and 0.02 to 0.06 ds m^{-1} (mean 0.04 ± 0.02 ds m^{-1}) in the subsoil. Mean electrical conductivity of the surface soil was significantly higher ($P < 0.05$) than the subsoil. Organic carbon varied from 1.7 to 2.2% (mean 1.9 ± 0.2%) in the surface soil and 0.7 to 0.95% (mean 0.8 ± 0.2%) in the subsoil. Mean organic carbon of the surface soil was significantly higher ($P < 0.05$) than subsoil. Total nitrogen varied from 0.1 to 0.4% (mean 0.3 ± 0.1%) in the surface soil and 0.08 to 0.3% (mean 0.2 ± 0.1%) in the subsoil. Statistically, mean total nitrogen of the surface soil was not significantly different ($P < 0.05$) from the subsoil. Available P varied from 7.5 to 15.0 $mgkg^{-1}$ (mean 11.1 ± 3.8 $mgkg^{-1}$) in the surface soil and 6.8 to 10.3 $mgkg^{-1}$ (mean 8.1 ± 1.9 $mgkg^{-1}$) in the subsoil. Exchangeable Ca varied from 1.6 to 2.5 $cmolkg^{-1}$ (mean 2.2 ± 0.5 $cmolkg^{-1}$) in the surface soil and 1.8 to 2.8 $cmolkg^{-1}$ (mean 2.3 ± 0.5 $cmolkg^{-1}$) in the subsoil. Exchangeable Mg varied from 0.9 to 1.6 $cmolkg^{-1}$ (mean 1.2 ± 0.4 $cmolkg^{-1}$) in the surface soil and 0.9 to 1.8 $cmolkg^{-1}$ (mean 1.5 ± 0.5 $cmolkg^{-1}$) in the subsoil. Exchangeable K varied from 0.06 to 0.3 $cmolkg^{-1}$ (mean 0.2 ± 0.1 $cmolkg^{-1}$) in the surface soil and 0.07 to 0.4 $cmolkg^{-1}$ (mean 0.3 ± 0.2 $cmolkg^{-1}$) in the subsoil. Exchangeable Na varied from 0.05 to 0.1 $cmolkg^{-1}$ (mean 0.1 ± 0.05 $cmolkg^{-1}$) in the surface soil and 0.03 to 0.07 $cmolkg^{-1}$ (mean 0.05 ± 0.02$cmolkg^{-1}$) in the subsoil. Total exchangeable acidity varied from 1.3 to 1.5 $cmolkg^{-1}$ (mean 1.4 ± 0.5 $cmolkg^{-1}$) in the surface soil and 0.8 to 0.9 cmolkg-1 (mean 0.8 ± 0.03 $cmolkg^{-1}$) in the subsoil. Mean exchangeable acidity of the surface soil was not different ($P < 0.05$) from the subsoil. This showed that potential acidity of the surface soil was not significant different from the subsoil at 5% level. CEC varied from 10.0 to12.0 $cmolkg^{-1}$ (mean 10.7 ± 1.2 $cmolkg^{-1}$) in the surface soil and 12.0 to 12.0 $cmolkg^{-1}$ (mean 12.0 ± 0.00 $cmolkg^{-1}$) in the subsoil. Mean CEC of the surface soil was not significantly different ($P < 0.05$) from the subsoil. Percentage base saturation varied from 33.8 to 38.0% (mean 36.6 ± 2.4%) in the surface soil and 23.0 to 41.0% (mean 33.6 ± 9.4%) in the subsoil.

DISCUSSION

In the poorly drained soil unit, mean clay content of the sub-surface soil was significantly higher ($P < 0.05$) than the surface soil, while sand and silt contents were higher in the surface soil than sub-soils. Generally, clay is the dominant texture of both the surface and subsurface soil of poorly drained soils of the study area. The high clay content could be attributed to alluvial deposits by rivers in the study area. Mean soil pH of the surface soil was significantly higher ($P < 0.05$) than the subsoil, indicating moderately acid in the surface soil and strongly acid in the subsoil. This shows that hydrogen ions concentration in solution of the sub- surface soil was significantly higher than the surface soil. Electrical conductivity values indicated that the poorly drained soils of the study area were non-saline and within the acceptable level for general crop growth (Soil Survey Staff, 1993). Mean organic carbon of the surface soil was high while the subsoil was moderate. The high organic carbon of the surface soil can be attributed partially to the slow rate of decomposition during flooding period and to seasonal deposition of organic materials from plant debris during flooding (Jones, 1982). Total N was high in the poorly drained soil. Mean total nitrogen of the surface soil was not significantly different ($P < 0.05$) from the subsoil. Mean available P was moderate in the surface soil and low in the subsoil. The moderate available P could be attributed to the reactions of various phosphate compounds into soluble forms and phosphorous diffusion upon flooding (Jones, 1982). Exchangeable bases (Ca, Mg, Na and K) were generally low in the study area. The low exchangeable bases could be attributed to acidifying properties of organic matter, aluminum and leaching of exchangeable bases (Tisdale et al., 2004). Mean CEC of the surface soil was not significantly different ($P < 0.05$) from the subsoil. Generally, CEC was low in the study area. Mean percentage base saturation of the surface soil was high while subsoil was moderate. The high base saturation with low soil pH could be could be attributed to the fact that the cation holding power (CEC) of the soil was so low that even a deficient amount of exchangeable bases resulted in a relatively high saturation.

In well drained soils, sand fraction was significantly higher ($P < 0.05$) in the surface soil than subsoil while clay fraction was significantly higher in the subsoil than surface. The soil texture of the well- drained soils was predominantly loamy sand on the soil surface over sandy clay loam in the subsoil. The pH of both surface and subsoil were rated as moderate acid. Electrical conductivity values indicated that surface soil contains more soluble salts than subsoil, however the well-drained soils of the study area were non-saline and within the acceptable level for general crop growth (Soil Survey Staff, 1993). Mean organic carbon of the surface soil was high while the subsoil was low. Mean total nitrogen was rated high in the surface soil and moderately high in the subsoil. Mean available P was moderate in the surface soil and low in the subsoil. Mean exchangeable bases (Ca, Mg and K) of the surface soil were not significantly different ($P < 0.05$) from the subsoil except mean exchangeable Na, which the mean content of the surface soil was significantly higher ($P < 0.05$) than the sub- soil. Exchangeable bases (Ca, Mg, Na and K) were generally low in the study area. The low exchangeable bases could be attributed to acidifying properties of organic matter, aluminum and leaching of exchangeable bases (Tisdale et al., 2004). CEC varied from low to moderate in the study area. Mean percentage base saturation was low in the both surface soil and subsoil.

Soil classification

Based on USDA Soil Taxonomy (2010) and FAO/UNESCO (1990), WRB (2007), the poorly drained Soils of the study area have ochric epipedons over cambic B-horizon, with minimal soil development and shallow depth. This qualified for classification in the Inceptisols order of USDA Taxonomy or Cambisol (FAO/WRB). Pedons have ground water at or near the soil surface at some times during the normal year and are classified as Aquept (sub-order). Pedons have episaturation in which the ground water fluctuates from a level near the soil surface to below a depth of 200 cm, and are classified as Epiaquept or Cambisol. Pedons have low chroma (2 or less), indicating either long period of saturation or water near the surface in some period of the year and are classified as Typic Epiaquepts (USDA) or Cambisol (FAO/WRB).

Soils in the well-drained areas have ochric A-horizons and argillic B-horizon with low base saturation and are classified as Ultisols (USDA) or Acrisols (FAO/WRB). Pedons have udic moisture reqimes that are freely drained and are classified as Udult. Pedons have clay distribution in which the clay content decreases with increasing depth, by more than 20% from its maximum amount, within 150 cm of the mineral soils surface, and have a colour Hue of 5YR or yellower, a colour value of 4 or more (moist) in some sub-surface horizons, and are classified as Hapludults. Pedons are freely drained, and moderately deep or deeper to hard rock with a colour value, moist of 4 or more in any Ap horizon 18 cm or more thick and in any surface layer after mixing of the 18 cm are classified as Typic Hapludults (USDA) or Haplic Acrisols (FAO/WRB).

CONCLUSION

The study revealed that the soil area in which elevation varied from 48.3 to 70.0 masl is well-drained soils while 0 to 12 masl is poorly drained soils. Clay is the dominant texture in the poorly drained soils, whereas in the well-drained soils, loamy sand dominates the soil surface and sandy clay loam dominates the subsoil. Soil pH varied from strongly acid to moderately acid in the poorly drained soils while well-drained soils varied from very strongly acid to moderate acid . Electrical conductivity values showed that the soils of the study area were non-saline and within the acceptable level for general crop growth. Organic carbon varied from low to very high in both poorly drained and well-drained soils of the study area. Total nitrogen of the poorly drained soils varied from moderately high to very high while well-drained soils varied from low to high (0.08 to 0.3%). Available P varied from low to moderate in both poorly drained and well-drained soils of the study area. Exchangeable bases (Ca, Mg, Na and K) were generally low in the study area. CEC varied from very low to low in the poorly soils and varied from low to moderatein the well-drained soils. Base saturation varied from low to high in the poorly drained soils and low to moderate in the well-drained soils of the study area. Poorly drained soils are classified as Typic Epiaquepts (USDA) or Gleyic Cambisols (FAO) while well-drained soils are classified as Typic Hapludults (USDA) or Haplic Acrisols (FAO).

REFERENCES

Bremner JM, 1996. Total Nitrogen. In: D.L.Spark (eds.). Methods of Soil Analysis Part 3-Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. 1085-1122.

Fagbami A, 1990. Land use plan of Norbru farms. Keffi for Soil Conservation, Productivity Sustenance and Effective Farm Management. p: 7.

FAO, 1990. Guidelines for Soil Descriptions. 3rd Ed. FAO Rome.

FAO-UNESCO, 1990. Soil Map of the World Legend World. Soil Resources Report. Rome.

Gee GW, Bauder JW, 1986. Particle size analysis. In: Arnold Klute (eds). Methods of Soil Analysis, Part 1-Physical and Mineralogical Methods, SSSA Book Seria 5, Madison, Wisconsin, USA. pp: 383-412.

Jones US, 1982. Fertilizer and Soil Fertility. Reston Publishing, Virgina, U.S.A. pp: 340-398.

Kuo S, 1996. Phosphorus. In: D. L. Spark (eds.). Methods of Soil Analysis Part 3- Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. pp: 869-920.

Nelson DM, Sommers LE, 1996. Total carbon, organic carbon and organic matter. In: D. L. Spark (eds.). Methods of soil analysis part 3-chemical methods, SSSA Book Series 5, Madison, Wisconsin, USA. pp: 961-1010.

Ogunkunle AO, 1986. Spatial variability of some chemical properties in two mapping units in Southern Nigeria. Soil Survey Land Eval, 6:26-32.

Petters SW, Udo EJ, Obot UW, Okpon SN, 1989. Akwa Ibom State. Physical Background, Soils and Land Use and Ecological Problems. Technical Report of the Task Force on Soils and Landuse. Govt. Printer, Uyo. 602

Soil Survey Staff, 1993. Soil Survey Manual. Soil Conservation Service U.S. Department of Agriculture Handbook 18. U.S. Govt. Printing Office, Washington, D.C. 871.

Sumner ME, Miller WP, 1996. Cation Exchange Capacity and Exchangeable Coefficients. In: D. L. Spark (eds.). Methods of Soil Analysis Part 3-Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. pp: 1201-1230.

Thomas GW, 1996. Soil pH and Soil Acidity. In: D. L. Sparks (eds.). Methods of Soil Analysis Part 3-Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. pp: 475-490.

Tisdale SL, Havlin JL, Beaton JD, Nelson WL, 2004. Soil fertility and fertilizers :: An introduction to nutrient management. Prentice- Hall of India, New Delhi. pp: 161-194.

Udo EJ, Ibia TO, Ogunwale JA, Ano AA, Esu IE, 2009. Manual of soil, plant and water analysis. Sibon Book Limited, Lagos. pp: 82-92.

USDA Soil Taxonomy, 2010. Key to Soil Taxonomy.Soil Servey staff.11th Edition. USA.

Usoro EJ, Akpan PA, 2010. Akwa Ibom State: A Geographical Perspective. Immaculate Publication Limited, Enugu. pp: 23-51.

WRB, 2007. World Reference Base for World Soil Resources. World Soil Resources Reports 103, Rome.