CHARACTERIZATION AND CLASSIFICATION OF SOME SOILS OF EDO STATE FORMED UNDER DIFFERENT PARENT MATERIALS

Supported by tetfund

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Received: October 24, 2017 **Accepted:** February 24, 2018

Abstract: Soils systematic arrangement into groups or categories on the basis of their characteristics has become imperative in view of the ever increasing need for the soil-with particular reference to sustainable landuse. Soils of Edo state Nigeria were characterized with a view to understanding its intricate properties and classify it using the United States department of agriculture (USDA) soil taxonomy and correlated with the world reference base (WRB). A free survey technique was used in identifying soil mapping units under different parent materials using the Edo state geological and mineral map. Pedons 1, 2 and 3 were marked as Ekpoma, Benin and Okpella soils respectively. Pedon 1 is derived from clayey sands, pedon 2 from sands and pedon 3 from shale and mudstones. Results showed that in all the three different parent materials sandy and loamy sands were the dominant textural classes. Pedon 3 was found to have more sand followed by pedon 2 and pedon 1, respectively. The C/N ratios in all the profile showed the trend similar to that of OC. Ca and Mg were found to range from very low to low in pedon 1 and 2 and moderate in pedon 3. The available phosphorus did not follow any regular pattern but decreased down the profiles. Total exchangeable acidity (TEA) was lowest in pedon 3(0.05 cmol/kg) and highest in pedon 1(1.12 cmol/kg).the effective cation exchange capacity (ECEC) of the soils were critically low, an indication that these soils requires amendment for crop production. The percentage base saturation has relatively high mean values 67.48, 55.50 and 97.68% for pedons 1, 2 and 3 respectively and the LDS showed significant difference among the three different parent materials. There were positive correlations between the soil pH and OC, CN, available phosphorus, TEB (Ca, Mg, K, Na). pedons 1 and 2 were classified as Alfisols (Isohyperthermic Psammentic Arennic Hapludalfs) while pedon 3 was classified as typic kandiustalfs. The landuse potential in Edo state under these different materials is high provided integrated soil fertility management practice is put in place.

Keywords: Characterization, classification, Edo state, landuse, parent materials

Introduction

Soil characteristics are intrinsic properties conferred largely by parent materials as modified by agents of weathering. Other properties such as porosity, bulk density, hydraulic conductivity, aggregate stability, texture, structure, pH, soil colour, CEC and buffering capacity as well as soils capability capacity are defined by parent material and the extent of weathering. Osodeke (2017) stated that soils formed from nutrient rich parent materials will also be rich in essential nutrients for growth and development.

Soil contain spaces, most of which appear in vertical, oblique and horizontal forms, porosity is a measure of such pore spaces. Total porosity within soil aggregate and their connectivity with inter aggregate spaces influence the movement and retention of solutes, aeration and biological activities (Revil and Cathles, 1999).

Characterization of soils provides the basic information necessary to create functional soil classification schemes and assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al.*, 2004). According to Eswaram (1977), different uses of soil characterization data include to aid in useful classification of the soil and enable other scientists see the soil in their taxonomic or classification systems and to serve as a basis for more detailed evaluation of the soil as well as gather preliminary information on nutrient, physical or other limitations needed to produce capability class.

Therefore, characterization is a major building block for understanding the soil; classify it and getting the best understanding of the environment (Esu, 2005). Also, Akamigbo (2001) noted that soil characterization and classification usually means criteria based on soil morphology in addition to characteristics developed during soil formation. Therefore, there is need to under study the soils formed under different parent for sustainable uses. Hence, this study was conducted to characterization and classification of some soils formed under different parent material in Edo state.

Materials and Methods

Study area

The study was carried out in Ekpoma, Benin and Okpella of Edo state Southsouth, Nigeria. It lie on latitude 5° 35′ N - 7° 3′ N and longitude 5° 00′ E – 6° 32′ E. Rainfall is between 1270 – 1520 mm in the northern part while 1250 – 2540 mm in the southern part. The mean annual temperature is 28°C. Temperature may reach 34°C between the months of February and March. The annual maximum relative humidity usually coincides with the peak of monthly rainfall in May/June and September/October. The humidity recorded highest value of 80 - 90% around August and lowest of 40 – 50% from November-March (Edo State Year Book, 2004). The landscape slope ranges from gentle slope to uplands with some savannah features in northern part. The state has three vegetation belts; mangrove, fresh water and the savannah. The dominant type of land use in the state is agriculture. The major crops grown are cassava, plantain, yam, potato, cocoa, oil palm, pineapple, maize and rice in low lying areas of Illushi and Agenegbode. Intercropping is commonly practiced. The major geological materials from which the soils are formed are sand, shale and limestone. The landscape slope ranges from gentle slope to uplands with some savannah features in northern part.

Soil sampling

A free survey technique was used in identifying soil mapping units under different parent materials using the Edo state geological and mineral map (Fig. 1). Profile pit was sunk in each soil mapping unit. The profiles were described and samples were collected according to the guideline of FAO (2006) for laboratory analyses using standard procedures.

Laboratory analysis

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH (H_2O) was determined electrometrically using glass electrode pH meter in a solid-liquid ratio of 1:2.5 (Hendershot *et al.,* 1993). Total nitrogen was determined by micro-Kjeldahl digestion method (Bremner, 1996). Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1996). Exchangeable acidity was determined by a method described by McLean (1982). Total carbon was analyzed by wet digestion Nelson and Sommers (1982). Available phosphorous was determined by Bray ll method according to the procedure of Olsen and Sommers (1982). Bulk density was determined by the core method Grossman and Reinsch (2002). Total porosity (P_o) was obtained from bulk density (ℓp) values with assumed particle density (ℓs) 2.65 Mgm^{-3} as follows,

Porosity (Po) =100 – (ℓp/ℓs) ×100/1.

Statistical analyses

Variability among soils under different parent materials was analyzed using completely randomized design of Analysis of variance (ANOVA) and mean comparisons were made using the least significant difference (LSD) method at p<0.05 levels (Wahua, 1999). Coefficient of variation as used by Wilding *et al.* (1994) was used to estimate the degree of variability existing among horizons of the studied pedons. However, correlation was used to determine the relationship among studied soil properties.

Table 1: Soil physical properties of the studied pedons

Horizon	Depth (cm)	MC (%)	Po (%)	BD (g/cm^3)	EC (µS/cm)	SAND (%)	CLAY (%)	SILT (%)	TC
Ekpoma (Clay, Clayey, Sands and Shale)									
Ap	0-15	59.7	62.3	1.0	123	88.2	5.0	6.8	S
AB	15-45	46.6	58.5	1.1	91	84.2	7.0	8.8	S
Bt_1	45-86	55.2	62.3	1.0	83	78.7	13.6	6.7	LS
Bt_2	86-120	63.4	62.3	1.0	39	76.2	13.6	9.2	LS
Mean		**0.38**	**61.35**	**1.03**	**84**	**81.83**	**9.8**	**7.87**	
Benin (Sands and Clay)									
Ap	0-15	42.1	55	1.2	47	81.2	2.5	16.3	LS
AB	15-45	41.8	55	1.2	21	83.2	3.0	13.8	LS
Bt_1	45-86	25.8	51	1.3	19	80.2	13.6	6.2	LS
Bt_2	86-120	36.7	55	1.2	16	77.2	7.6	13.7	LS
Mean		**36.6**	**54**	**1.23**	**25.75**	**80.45**	**6.68**	**12.5**	
Okpella (Shale and mudstone)									
Ap	0-15	36.9	55.6	1.2	788	91.2	3.0	5.8	S
AB	15-45	32.8	58.5	1.1	80	80.7	4.6	4.7	S
Bt_1	45-86	31.5	55	1.2	59	79.2	10.0	10.0	LS
Bt_2	86-120	27.6	51	1.3	45	73.7	19.6	19.6	LS
Mean		**32.2**	**55.02**	**1.2**	**243**	**81.2**	**9.3**	**10.03**	
LSD (0.05)		**10.39**	**3.824**	**0.099**	**337.6**	**8.71**	**9.36**	**7.55**	

MC= moisture content, Po= porosity, BD= bulk density, EC= electrical conductivity, TC= textural class, LSD= least significant difference

Results and Discussions

The physical properties of the soils formed from three different parent materials were showed in Table 1. Texturally, the soils were found to be sandy and loamy sand. Okpella soils were found to have more sand percentage (mean= 81.20%) over soils of Benin (mean= 80.45%) and Ekpoma (mean= 80.83%) and the LSD showed no significant difference in all the soils studied. It was also found that clay percentage mean values (9.80) were highest in Ekpoma soil with clay bulge in the Bt_2 horizon and no significant difference between all the soils. Silt percentage content where 12.50, 10.03 and 7.88% for Benin, Okpella and Ekpoma soils respectively and no significant difference between all the soils. The percentage moisture content was highest in Ekpoma soil with mean value of 56.23%. This may be due to high organic matter content, clay content and higher annual rainfall; this was closely followed by Benin (36.6%) and Okpella (32.2%) significant difference was observed between Okpella/Ekpoma and Benin/Ekpoma. The bulk density of the studied soils was found to range from 1.23 g/m^3 in Benin to 1.02 g/m^3 in Ekpoma and the LSD showed significant difference between Ekpoma/Okpella and Ekpoma/Benin soils. The porosity of the soil was highest in Ekpoma (61.35%), the high porosity may be due to the parent materials which is largely sands influenced by clayey content which confers higher water holding capacity on the soil (Eswaran, 1977). It can be seen that the mean porosity value for Benin and Okpella at 54.00 and 55.03%, respectively and the LSD showed significant difference between Benin/Ekpoma and Okpella/Benin soils. The electrical conductivity mean value was highest in Ekpoma (84 µs/cm followed by 50.50 µS/cm in Okpella and 25.75 µS/cm in Benin, while there was no significant difference in all the soils. The low electrical conductivity value in Benin soils may be due to higher amount of rainfall and the sandiness of the parent materials.

Table 2 shows the chemical properties of the studied soils. In all the profiles, soil acidity was observed to be a problem. The mean value pH of Okpella was moderately acidic compared to that of Ekpoma and Benin which were found to be very acidic and in all the profiles, pH values were found to decrease down the profile. The mean values of 5.59, 4.87 and 4.82 for Okpella, Benin and Ekpoma respectively. The LSD showed a significant difference between Ekpoma and Okpella and between Benin and Okpella. These soils with such low pH with require amelioration. The organic carbon percentage (OC) increased down the profile, this was the pattern in all the profiles studied the mean values were 0.66, 0.47 and 0.76% for Ekpoma, Benin and Okpella soils respectively and there was no significant difference. The organic matter content followed the pattern of organic carbon in all the profiles with mean values of 1.14, 0.84 and 1.32% for Ekpoma, Benin and Okpella soils, respectively. The total nitrogen level in the soils were found to range from low to moderate as indicated by the mean values of 0.15, 0.14 and 0.09% for Ekpoma, Benin and Okpella soils respectively and there was no significant difference in the organic matter. The low values in Okpella soils may be due to the derived forest- grassland ecosystem and low rate of organic matter residue return in the area (FAO, 2001). The C/N ratios in the profiles also exhibited a trend close to that of organic carbon and total nitrogen in the soils.

Their mean values were found as 3.75:1, 7.5:1 and 7:1 for Ekpoma, Benin and Okpella soils respectively and LSD showed no significant difference was observed. The available phosphorus had irregular pattern in the Ekpoma soils with mean value of 3.00 mg/kg followed in a downward decreasing pattern is the Benin profile with mean value of 4.56 mg/kg and an increasing trend in Okpella profile with mean value of 4.48 mg/kg. FAO (1979) rated available phosphorus of <7 as low and such soils will require phosphorus fertilization to meet crop demand LSD showed no significant difference. The Ca and Mg contents in the soils were found to range from very low to low in Ekpoma and Benin pedons whereas it was moderate for Okpella soils, their mean values are 0.29, 0.04 and 0.58 cmol/kg/Ca for Ekpoma, Benin and Okpella soils, respectively and the LSD showed significant difference between Benin and Opkella and between Ekpoma and Okpella. That of Mg was 0.38.0.04 and 0.51 cmol/kg/Mg for Ekpoma, Benin and Okpella soils, respectively and no significant difference in all the soils. Ca and Mg are known as indicators for soils fertility and usually dominate the cation exchange capacity. The exchangeable sodium was generally moderate according to the rating of the FDALR (1990); their mean values were 0.44, 0.45 and 0.43 cmol/kg for Ekpoma, Benin and Okpella soils respectively. The exchangeable sodium percentage (ESP) was found to be high in the soils with mean values of 16.43, 19.23 and 21.40% for Ekpoma, Benin and Okpella soils respectively and higher ESP is deleterious to crops as it encourages reverse osmosis resulting in wilting but the LSD showed no significant difference in all the soils. The potassium content of the soil decreased down the profile and also ranged from low to moderate, the mean values of 0.28, 0.10 and 0.44 cmol/kg for Ekpoma, Benin and Okpella soils respectively and no significant difference in the soils. The soil total exchangeable acidity (TEA) is governed by the presence of high amount of aluminium and hydrogen in the soils of the tropics. The amount of TEA in the soil is responsible for the declining fertility status of tropical soils as they take hold of the exchange site and dominate it (Igwe *et al.*, 2002). The propensity for a soil to be acidic/alkaline is measured by pH meter. The mean values of TEA were 1.12, 0.73 and 0.05 for Ekpoma, Benin and Okpella soils, respectively and there was significant difference between Okpella and Ekpoma soils. The aluminium saturation (%) of the TEA was found as 38.93, 42.32 and 1.38%. The low Al-sat in okpella may be due to lower amount of rainfall as compared to the other profiles of Benin and Ekpoma soil which are very large and LSD showed there was significant difference between Okpella/Benin and Okpella/Ekpoma soils . The total exchangeable bases (TEB) which the sum of all the soil exchangeable cations such as Ca, Mg, K and Na. this was found to have mean values of 1.54, 0.84 and 1.95 cmol/kg for Ekpoma, Benin and Okpella soils respectively and LSD showed significant difference between Benin/Okpella soils. The ECEC of the soil were critically low, an indication that the soil is not suitable for crop production without amendmentR). Their mean values are 2.66, 1.56 and 1.99 cmol/kg for Ekpoma, Benin and Okpella soils respectively and LSD showed significant difference between Benin/Ekpoma and Okpella/Ekpoma soils. The percentage base saturation (B-sat), was largely dominated by cations in moderately to very high rating and their mean values are 67.48, 55.5 and 97.68% for Ekpoma, Benin and Okpella soils, respectively and the LSD showed significant difference between Benin/ Okpella soils. The consistent high B-sat in Okpella soils suggests that the soil have more weatherable parent materials than the soils of Ekpoma and Benin soil and as such can be inferred as having the order of Alfisol-Mollisol mix (Esu, 2010).

Table 2: Soil chemical properties of the studied pedons

Horizon	Depth (cm)	pH (H_2O)	OC (%)	OM (%)	TN (%)	C/N (%)	Av.P (mg/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	K (cmol/kg)	Av.S (cmol/kg)	TEB (cmol/kg)	TEA (cmol/kg)	ECEC (cmol/kg)	BS (%)	ESP (%)	Al sat (%)
Ekpoma (Clay, Clayey, Sands and Shale)																		
Ap	0-15	5.44	1.02	1.76	0.26	4.1	1.29	0.42	1.42	0.59	0.48	1.09	2.91	0.13	3.04	95.7	19.6	2.96
AB	15-45	4.77	0.88	1.52	0.19	5.1	5.89	0.30	0.04	0.50	0.21	1.05	1.05	1.88	2.93	35.8	17.0	56.65
Bt_1	45-86	4.63	0.55	0.86	0.09	6.1	3.30	0.40	0.04	0.36	0.28	1.96	1.08	1.40	2.48	43.5	14.5	52.41
Bt_2	86-120	4.44	0.22	0.40	0.06	4.1	2.41	0.02	0.02	0.32	0.16	1.90	1.12	1.06	2.18	94.9	14.6	44.00
Mean		**4.82**	**0.67**	**1.14**	**0.15**	**4.85**	**3.22**	**0.29**	**0.38**	**0.44**	**0.28**	**1.50**	**1.54**	**1.12**	**2.65**	**67.48**	**16.43**	**39.00**
Benin (Sands and Clay)																		
Ap	0-15	4.94	0.74	1.30	0.08	9.3	8.76	0.06	0.06	0.55	0.16	1.23	0.83	0.29	1.12	74.1	4.91	25.00
AB	15-45	4.96	0.45	0.78	0.06	7.5	3.59	0.04	0.04	0.54	0.15	1.60	0.83	0.99	1.82	45.6	29.6	53.80
Bt_1	45-86	4.88	0.38	0.66	0.03	12.7	3.30	0.02	0.02	0.41	0.06	1.83	0.89	0.94	1.83	48.6	22.4	49.00
Bt_2	86-120	4.68	0.33	0.60	0.40	0.8	2.60	0.02	0.02	0.30	0.04	1.82	0.79	0.68	1.47	53.7	20.0	41.49
Mean		**4.86**	**0.47**	**0.83**	**0.14**	**7.58**	**4.56**	**0.04**	**0.04**	**0.45**	**0.10**	**1.62**	**0.84**	**0.72**	**1.56**	**55.5**	**19.23**	**42.32**
Okpella (Shale and mudstone)																		
Ap	0-15	5.59	0.64	1.10	0.01	6.4	1.06	0.50	0.54	0.52	0.64	1.73	2.20	0.02	2.22	99.0	23.4	1.00
AB	15-45	5.74	0.52	0.89	0.08	6.5	4.30	0.50	0.45	0.52	0.55	2.45	2.02	0.07	2.09	96.6	24.8	2.87
Bt_1	45-86	5.87	0.9	1.60	0.10	9.1	6.17	6.17	0.54	0.34	0.39	2.45	1.89	0.06	1.95	96.9	17.4	2.05
Bt_2	86-120	5.18	0.96	1.70	0.16	6.1	6.40	6.40	0.49	0.34	0.16	2.08	1.67	0.03	1.70	98.2	20.0	0.58
Mean		**5.59**	**0.75**	**1.32**	**0.09**	**7.03**	**1.62**	**3.39**	**0.51**	**0.43**	**0.43**	**2.17**	**1.95**	**0.04**	**1.99**	**97.67**	**21.4**	**1.62**
LSD(0.05)		**0.502**	**0.418**	**0.738**	**0.188**	**4.44**	**3.911**	**3.090**	**0.64**	**0.186**	**0.240**	**0.617**	**0.870**	**0.744**	**0.525**	**32.10**	**10.31**	**25.55**

OC= organic carbon,TN= total nitrogen, Av.P= available phosphorus, Av.S = available sulphur, TEA= total exchangeable acidity, ECEC= effective cation exchange capacity, TEB= total exchangeable bases, BS= base saturation, ESP= exchangeable sodium percentage, Al sat= aluminium saturation, OM= organic matter, Ap= plough layer, Bt1 and Bt2= argillic horizons

Table 3: Horizon variation of soil physical and chemical properties under studied pedons

Soil properties	EKPOMA SOIL				BENIN SOIL				OKPELLA SOIL			
	Mean	SD	CV	Ranking	Mean	SD	CV	Ranking	Mean	SD	CV	Ranking
pH (H_2O)	4.84	0.44	9.02	LV	4.86	0.13	2.63	LV	5.59	0.29	5.35	LV
OC (%)	0.67	0.36	56.56	HV	0.47	0.18	38.61	HV	0.75	0.21	27.73	MV
TN (%)	0.15	0.09	61.34	HV	0.14	0.17	121.33	HV	0.09	0.06	70.68	HV
Ca (cmol/kg)	0.29	0.18	64.67	HV	0.04	0.02	54.71	HV	3.39	3.40	98.49	HV
Av.P (mg/kg)	3.22	1.96	60.80	HV	4.56	2.83	62.01	HV	1.62	1.03	63.69	HV
Mg (cmol/kg)	0.38	0.69	182.47	HV	0.04	0.02	54.71	HV	0.51	0.04	8.63	LV
K (cmol/kg)	0.28	0.14	49.76	HV	0.10	0.06	59.81	HV	0.43	0.21	48.39	HV
C:N	4.85	0.96	19.74	MV	7.58	5.00	66.07	HV	7.03	1.39	19.84	MV
ECEC (cmol/kg)	2.65	0.40	15.05	MV	1.56	0.33	21.65	MV	1.99	0.22	11.18	LV
Na(cmol/kg)	0.44	0.13	28.25	MV	0.45	0.12	26.36	MV	0.43	0.11	24.17	MV
Sand (%)	81.83	0.50	33.16	MV	80.45	2.50	3.11	LV	81.20	7.31	9.01	LV
Silt (%)	7.87	1.31	16.63	MV	12.50	4.37	34.95	HV	10.03	6.78	67.63	HV
Clay (%)	9.80	4.46	45.54	HV	6.68	5.16	77.24	HV	9.30	7.49	80.55	HV
BD (g/cm^3)	1.02	0.50	4.87	LV	1.23	0.05	4.08	LV	1.20	0.08	6.80	LV
TEA (cmol/kg)	1.12	0.72	66.16	HV	0.72	0.32	44.17	HV	0.04	0.02	52.90	HV
Po (%)	61.35	1.90	3.10	LV	54.00	2.00	3.70	LV	55.02	3.09	5.61	LV
BS (%)	67.48	32.28	47.85	HV	55.50	12.84	23.14	MV	97.67	1.12	1.15	LV
MC (%)	0.38	0.69	182.47	HV	36.60	7.61	20.80	MV	32.20	3.83	11.91	LV
TEB (cmol/kg)	1.54	0.91	59.34	HV	0.84	0.04	4.94	LV	1.95	0.22	11.47	LV
Al sat (%)	39.00	24.60	63.06	HV	42.32	12.61	29.80	MV	1.62	1.03	63.69	HV

OC= organic carbon,TN= total nitrogen, Av.P= available phosphorus, ,Av.S = available sulphur, TEA= total exchangeable acidity, ECEC= effective cation exchange capacity, TEB=total exchangeable bases, BS=base saturation, ESP=exchangeable sodium percentage, Al sat= aluminium saturation, OM=organic matter

Table 4: Correlation between soil physical and chemical properties

	pH (H_2O)	OC (%)	TN (%)	CN (%)	Av.P (mg/kg)	ECEC (cmol/kg)	BS (cmol/kg)	Av.S (cmol/kg)	TEB (cmol/kg)	TEA (%)	Po (g/cm^3)	BD (μS/cm)	EC (%)	SAND (%)	CLAY (%)	SILT
pH	1															
OC	0.523	1														
TN	-0.168	0.169	1													
CN	0.244	0.066	-0.720	1												
Av.P	0.042	0.390	-0.095	0.386	1											
ECEC	0.083	0.331	0.079	-0.276	-0.458	1										
BS	0.637*	0.293	-0.151	-0.069	-0.065	-0.027	1									
Av.S	0.364	-0.265	-0.250	0.149	0.006	-0.303	0.371	1								
TEB	0.764	0.573*	0.036	-0.136	-0.336	0.510*	0.732	0.080	1							
TEA	-0.765	-0.334	0.31	-0.097	-0.038	0.331	-0.827	-0.357	-0.643*	1						
Po	-0.178	-0.052	0.094	-0.492	-0.386	0.669	0.055	-0.203	0.269	0.301	1					
BD	0.195	0.049	-0.105	0.485	0.365	-0.671	-0.040	0.199	-0.255	-0.319	-0.998	1				
EC	0.384	0.106	-0.307	-0.041	-0.422	0.205	0.339	-0.066	0.448	-0.309	0.008	0.042	1			
SAND	0.389	0.273	-0.152	0.045	-0.398	0.475	0.049	-0.515*	0.487	-0.111	0.209	-0.173	-0.698	1		
CLAY	-0.306	-0.030	-0.004	0.059	0.080	-0.025	0.035	0.412	-0.156	0.149	-0.165	0.134	-0.345	-0.732-	1	
SILT	-0.229	0.189	0.271	-0.090	0.584*	-0.628*	-0.013	-0.093	-0.375	-0.148	-0.503*	0.493	-0.356	-0.501*	0.215	1

OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, Av.S = available sulphur, TEA= total exchangeable acidity, ECEC= effective cation exchange capacity, TEB=total exchangeable bases, BS=base saturation, ESP=exchangeable sodium percentage, Al sat= aluminium saturation, Po = porosity

Significant correlation existed between some soil properties (Table 4). There exist positive correlation between soil pH and OC, CN, phosphorous and TEB (Ca, Mg, K, Na). Increase in soil ph has been shown to increase phosphorous availability in soil (Sato and Comerford, 2005). This is because as soil pH increases phosphorous fixation (due to Fe and Al compounds) common in highly weathered tropical soils is reduced. There was a significant correlation between ph and percentage base saturation, this may also be related to the fact that most plant nutrients are readily available at slightly acidic to neutral soil ph. There was also significant positive correlation between available phosphorous, ECEC and silt and positive correlation with clay and negative with sand. The positive correlation may be due to the high surface area of silt and clay as well as the colloidal nature is able to hold and exchange most plant nutrients in the soil. Mitchell and Soga (2013) stated that over geologic time, lithification and chemical reaction change sand into sandstone or clay into mudstone or shale. They however found that over engineering over time, behaviour of soils can alter as stresses redistribute after mechanical disturbances. Fine grained soils and clay have properties and behaviour that change over time as a result of consolidation, shear, swelling, chemical and biological changes. whereas before now, according to Charlie *et al.* (1992) and Daramola (1980), cohesionless soil were not appreciated to exhibit this behaviour; that recently disturbed or deposited granular soil gain stiffness or strength over time at constant effective stress- due to phenomenon called aging and both concluded that hotter climate experience densification faster than cooler climate and suggested a correlation between the rate of aging and mean air temperature. Significant correlations were recorded between total exchangeable bases and OC. Soil organic matter had been found to relate to all soil nutrients and its activity accounts for 95% of crop yield in the tropics (Agboola *et al.*, 1998; Vagen *et al.*, 2006). Negative correlations were recorded between CN and most soil properties correlated. Positive correlations were recorded between porosity and most soil properties. Negative correlation between clay BD, TEA, TN, ECEC pH and significant negative correlation exists between sand and sulphur in the soil. This clay interaction was also observed by Mitchell and Soga (2013) were they opined that isomorphous substitution in all of clay mineral with possible exception of those in the kaolinite group, gives clay particles a net negative charge. They further stated that for clay to preserve electrical neutrality, cations are attracted and held between the layers and on the surfaces and edges of the particles. Many of these cations are exchangeable cations because they may be replaced by cation of another type.

Taxonomic classification

The diagnostic criteria for classification of Pedons 1 (Ekpoma soil) and 2 (Benin soil) according to the USDA Soil Taxonomy (Soil Survey Staff, 2006) include an udic soil moisture regime, ustic moisture regime for pedon 3 and a hyperthermic soil temperature regime characteristic of semi arid to subhumid subtropical climate. The high silt/clay ratio (>0.25) suggests advanced stage of weathering and highly leached soils which is a characteristic of Ultisols and Alfisols but which still contains weatherable minerals in the soil. The high preponderance of sand indicated a dominance of low activity clay such as kaolinite. There was consistent clay increase in the 3 pedons leading to formation of argillic horizon in Bt horizons. The soils had mean base saturation >50%, which suggested kandic horizons because ECEC is <16 cmol/kg densic and paralithic contact within the 150 cm of the mineral soil. There was high sandy distribution and irregular clay movement down the horizon in pedons 1 and 2. Pedons 1 and 2 were therefore classified as isohyperthermic psammentic Arenic Hapludalfs and pedon 3 classified as Typic Kandiustalfs.

Conclusion and Recommendations

The result obtained from laboratory analyses indicated that the investigated soils were dominated with sandy soil fractions. Silt/clay ratios were very high indicating that soils were highly leached and highly weathered but still hold weatherable minerals and which were Alfisols. The soils generally has a favourable bulk density mean values of 0.49 glcm^3 compared to the critical limit of 1.85 g/cm^3 for ease of root penetration. Soil pH ranges from very strong to strong acidity, Organic carbon, organic matter and total nitrogen were low, the low carbon- nitrogen which is an indication of ease of mineralization. ECEC of the soils were low being less than 4.0 g/kg in all investigated soils this may be as a result of parent materials which has witness intense leaching of exchangeable cations in these soils.it was observed to TN Ca, mg, CN ratio, TEA, BD, and clay all showed high variability with the studied soils. Sand and silt showed medium to low variation. Pedons 1 and 2 were classified as isohyperthermic psammentic Arenic Hapludalfs and pedon 3 classified as Typic Kandiustalfs.

The soils were very low in basic cations, therefore farmers should be encouraged to use organic manure along side the inorganic fertilizers to improve soil fertility (integrated soil fertility management) and due to the high amount of rainfall which has increased the incidence gully erosion over the state, deforestation should be slowed down. Problem of farmers' mismanagement of the soil could be mitigated by agricultural extension services. A suitability study is recommended as the soils hold high potential for agricultural uses.

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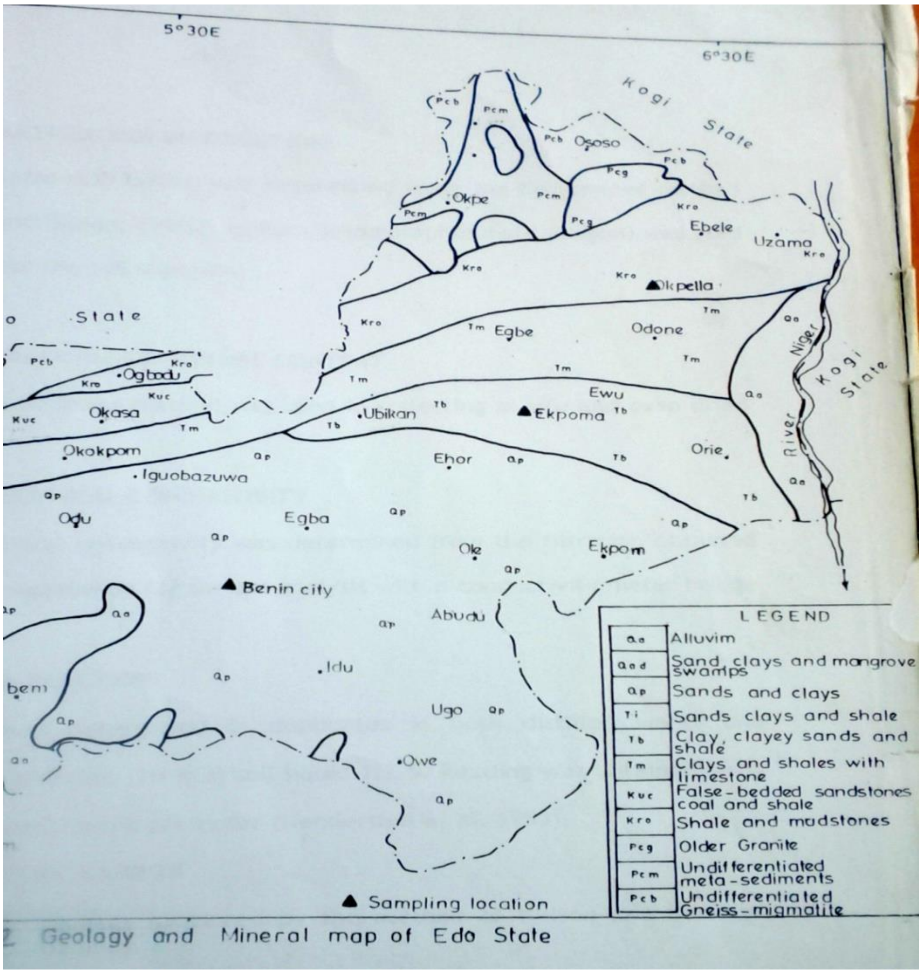

Source: Cartographic Unit of the Department of Geology, Federal of University Owerri
Fig. 1: Geology and mineral map of Edo state