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Original Research Article

Comparative analysis and evaluation of some pedons of sedimentary parent materials in South-Western Nigeria for crop production

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Abstract

A comparative analysis of some pedons formed on sedimentary parent materials in south-western Nigeria was made, and their potential for crop production was evaluated. Three locations (Eggua, Papalanto and Esan) were surveyed and sampled for the experiment. Three physiographic positions (Upper, Middle and Lower Slopes) were identified and soil sample was collected at the depth of 0-30cm and 30-60cm for each physiographic position for physical and chemical analysis. Descriptive statistical analysis was also carried out to evaluate measure of dispersion and mean for all variables. The variability of soil properties were measured by estimating the percentage coefficient of variation (%CV). The results of the study revealed that pH in water, pH in KCl, BS and BD had the least variation when compared with Na, ECEC and sand which showed low to moderate variation and TN, OC, P, Ca, Mg, K, Fe, Mn, Cu, Zn, silt and clay, which shows low, moderate, high to very high variation. Also results from the analysis of variance also show that landscape positions have significant ($P \leq 0.05$) effects on P, Fe, Mn, Cu, Zn, BS, Mg, Na, ECEC and silt, whereas, TN, OC, Ca, K, pH in water, pH in KCl, sand, clay and BD were not significantly ($P \leq 0.05$) influenced by physiographic positions. Soil depth did not significantly ($P \leq 0.05$) affect the availability, distribution and concentration of TN, P, Fe, Mn, Cu, Zn, BS, Ca, Mg, K, Na, ECEC, sand and silt. Significant ($P \leq 0.05$) differences in OC, pH in water, pH in KCl, Clay and BD were observed with soil depth in all the three location. Results from Land Capability Classification shown that all the pedons in the three location falls under the Capability Class of II (moderately suitable) with limitations of fertility, erosion, and low moisture content, which make them capable for sustainable crop production with improve management practices.

Keywords: Parent material, variability, physiographic position, depth, capability.

INTRODUCTION

In Nigeria, non-sustainable use of land has resulted in massive land degradation and low soil fertility (Udoh *et al*., 2002). Meeting the food and fibre needs of the ever-increasing growing population in this period of global recession has been a major concern to the agriculturists. In practice, particularly in south western Nigeria, the use to which land is put is not often related to the land potential capacity for the use type (Senjobi, 2007). Land has been utilized intensively for all purposes at the expense of its suitability thereby resulting in land degradation and altering the natural ecological conservational balances in the landscape. There have been several attempts to relate soil properties to physiograghic position for many landscapes (Wysocki *et al*., 2001). This may be partly due to the realization of the role topographic position plays in influencing runoff, soil erosion and hence soil formation (Babalola *et al*., 2007). Soil properties such as clay content has been found to be highly correlated with topographic position (Wang *et al*., 2001) while soil organic matter has been shown to vary with topographic position (Miller *et al*., 1988).Depending on the location on a slope, physical and chemical properties of the soil will also vary either minimally or maximally. Physiography influences soil texture, penetration resistance (Bruand *et al.,* 2004) root development (Busscher *et al*., 2001) exchangeable basic and acidic cations (Stutter *et al*., 2004), soil exchange chemistry (Chien *et al*., 1997) and nutrient budget (Mallarino, 1996) hence important in fertilizer management (Paz-gonzalez *et al*., 2000).High degree of soil variability in the tropics has long been recognized and this has made it difficult for most tropical soils to be mapped and predict accurately their management and productive potentials (Ogunkunle, 2003). Soil variability could either be spatial or temporal. Spatial variability is a variation in soil properties which occurs with distance, while temporal variability is a seasonal variation in certain soil properties that display continuous variation depending on the activities on them (Akinbola *et al*., 2010). Spatial variability could be attributed to changes in macro and micro flora and fauna (Lal, 2000). Stolt *et al*., (1993) also added that spatial variability is universal to all soils and could be induced by differences in weathering rates, lithology, topographic differences and hydrological characteristics of the soil. Temporal variability on the other hand, could arise from changes in soil properties such as bulk density, hydraulic conductivity, thermal conductivity, infiltration rate, water table depth, CO_2 accumulation, soil texture and even ground water quality (Cassel, 1983). Effiom *et al*., (2010) have also reported that variability in soil properties could result in some part of a cultivated field receiving sufficient inputs with the other part receiving excess of it. In a similar view, Brouwer *et al*. (1993) have opined that in the tropics, soil variability has traditionally been identified as a problem that can induce within-field crop growth differences which can reduce farmer's yield expectancy and complicate the interpretation of agronomic experiment. Therefore, the objective of this study was to evaluate and compare the variability of some pedons of sedimentary parent material, their potential and limitation for crop production in south-westhern Nigeria.

MATERIAL AND METHOD

Description of the Study Sites

The study was carried out based on data acquired from three different locations:

Eggua is located within Latitudes 07.0º and 07.05ºN and Longitudes 002.88º and 002.95º E, of Ogun State (Figure 1), with a humid tropical climate, characterized by seasonal rainfall, high temperatures and high humidity. The annual rainfall is about 1150 mm. The temperature is high, with slight variations throughout the year. The maximum temperature range is about 27.9^{o}C-34.7^{o}C and minimum temperature range is about 20.0^{o}C-22.8^{o}C. Relative humidity is fairly high with ranges of about 73-878, 38-748 and 83-95% at 09 hours, 15 hours and 21 hours respectively. Papalanto is located within latitudes 06.883º and 06.90º N and longitudes 003.16667º and 003.20º E in Ewekoro Local Government Area of Ogun State (Figure 1). The area has a hot and humid tropical climate like the rest of the southwestern Nigeria, characterized by seasonal rainfall, high temperature and high humidity. The total rainfall per annum ranges from about 790-1600mm. The temperature is generally high with minimal fluctuations, usually less than 5ºC throughout the year. The highest of the mean-daily maximum temperature are recorded in the month of February and March (38ºC), while the month of July and August have the lowest maximum temperature (28.3ºC) in the year. The relative humidity in the area is generally high throughout the year. Esan is located within latitudes 06.50833º and 06.56667º N and longitudes 006.18333º and 006.21667º E, of Edo State (Figure 1). The climate is characterized by two distinct seasons in the year. The total annual rainfall is generally more than 2000mm. The temperature in the area is generally high with very little fluctuation, usually less than 5ºC throughout the year. The month of February, March and April record the highest daily maximum temperature (31-36ºC), while the month of July and August have the lowest mean daily maximum temperature (27-29ºC). The relative humidity is generally high throughout the year, being more than 55% at any given point in time.

Sampling Collection and Method

Mapping units were identified in relation to physiographic position (i.e Upper, Middle and Lower Slope) on each of the site. Profile pits were sunk and described according to the FAO guideline (2006). The soil characteristics and morphological properties were described for each of the identified horizons (layers) in the profiles. Replicate soil core samples for bulk density determination were taken from each of the horizons of the soil profiles using Anderson and Ingram (1993) method. Replicate core samples for hydraulic conductivity were also taken from each of the horizons in each of the profile pits. After the description of the sites and soil profiles, samples were taken from each of the soil profiles at 0-30cm and 30-60cm, starting from lowest horizon upward, put into polythene bags and appropriately labeled for laboratory analysis. Replicate soil core samples for bulk density determination were taken from each of the horizons of

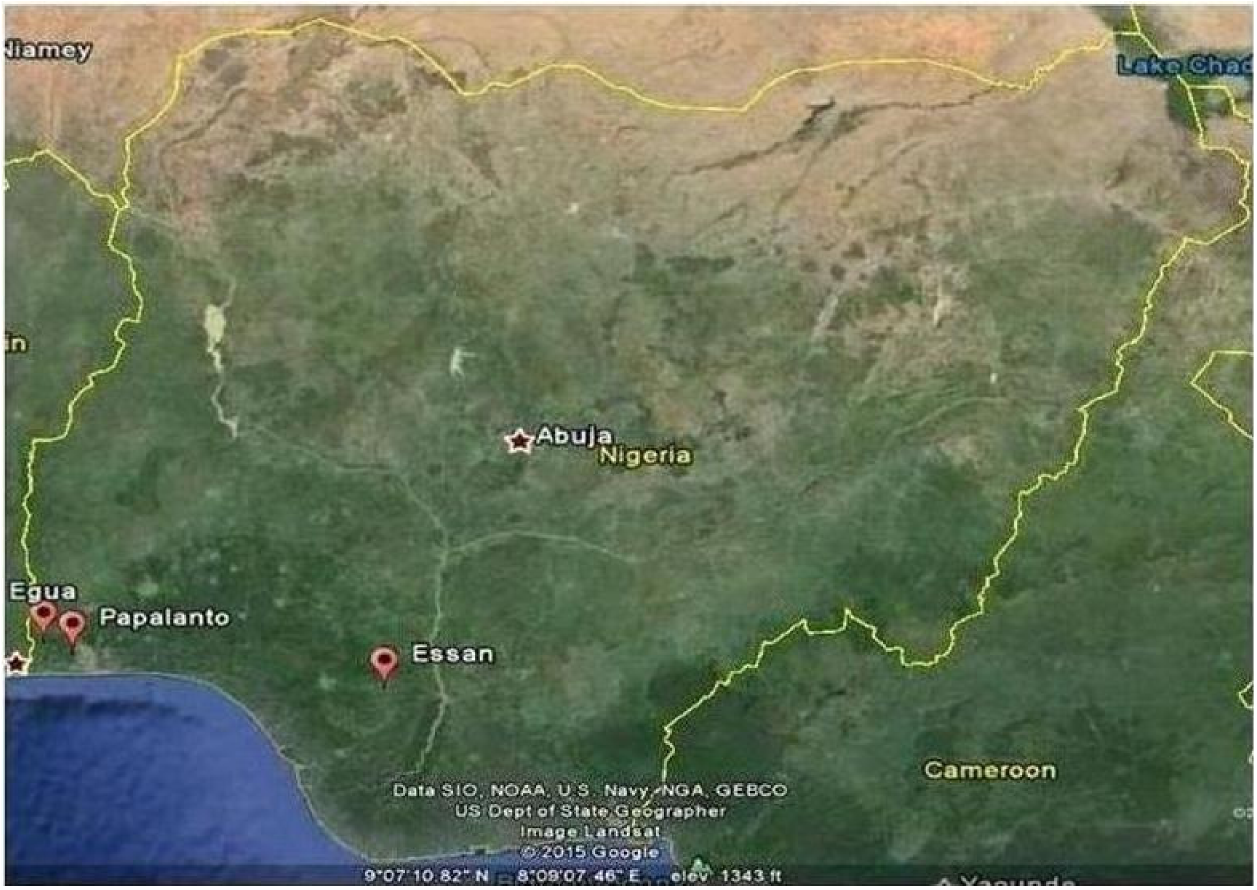

Figure 1. Map of the study locations

the soil profiles using Anderson and Ingram (1993) method.

Laboratory Analysis

The soils samples that were taken from the soil profile pits were taken to the laboratory for chemical properties and particle size analysis. They were air-dried, crushed and sieved through a 2mm mesh. Particles size fractions were determined by the Bouyoucos (1951), hydrometer method. Soil pH was determined in 1:1 soil: water ratio, and by KCl media using a glass electrode pH meter with calomel electrode (Bates, 1954). Organic carbon was estimated by the dichromate wet oxidation method of Walkey and Black (1934). Total nitrogen was determined by the micro-Kjedahl method of Jackson (1962). Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945); while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral NH_4OAC. Calcium, K, and Na were measured through a flame photometer, while Mg was determined by atomic absorption spectrophotometer (Rhoades, 1982). Exchangeable acidity was determined by INKC1 extraction and titrated with 0.05N Na04 solution (Black, 1975). Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micronutrients (Fe, Mn, Zn and Cu) were determined in 0.1N HC1 extract and evaluated using the atomic absorption spectrophotometer (Jackson, 1962).

Statistical Analysis

Descriptive statistical analysis was used with the aid of statistical package (SPSS) Version 20 to evaluate standard deviation and mean for all variable. The variability of soil properties was measured by estimating the percentage coefficient of variation (%CV), which was calculated as:

$$CV(\%) = \frac{Sd}{X} \times 100$$

Where Sd = Sample standard deviation
X = Sample mean

Table 1. Chemical properties of the soils in the three locations

Soil Depth	pH H_2O	pH KCl	TN	O.C	P	Ca	Mg	K	Na	ECEC	BS	Fe	Mn	Cu	Zn
			(g/kg)		(mg/kg)	(cmol/kg)					(%)	(mg/kg)			
Location 1															
Upper Slope															
0-30	6.5	4.5	0.88	7.62	9.03	4.0	3.6	0.6	1.0	9.75	95.15	98.64	228.74	6.33	15.54
30-60	5.0	3.2	0.81	5.10	8.19	3.2	3.8	0.6	0.9	10.48	86.85	83.63	161.43	5.46	11.03
Middle Slope															
0-30	5.8	3.5	0.49	15.21	3.01	3.0	2.6	0.6	0.8	8.70	88.70	84.37	158.38	4.53	20.58
30-60	5.1	2.9	1.12	8.11	0.70	2.6	2.7	0.6	0.7	13.58	64.10	95.88	86.18	4.40	14.00
Lower Slope															
0-30	6.0	4.3	1.51	20.42	2.17	8.9	8.0	0.7	1.1	19.22	97.80	220.68	319.18	9.34	51.92
30-60	5.3	3.2	0.98	6.32	7.98	6.9	9.5	0.8	1.4	19.00	97.75	236.83	311.39	9.83	52.88
Location 2															
Upper Slope															
0-30	5.7	4.7	0.57	5.42	3.75	1.3	1.4	0.1	0.3	3.95	76.55	101.45	345.50	0.91	5.61
30-60	5.2	4.0	0.18	1.71	0.13	0.9	1.0	0.0	0.3	3.96	55.80	61.25	147.80	0.48	4.17
Middle Slope															
0-30	5.2	4.2	0.43	4.09	0.98	1.0	0.8	0.1	0.3	3.44	63.10	141.15	63.70	1.28	4.65
30-60	4.7	3.5	0.13	1.24	1.04	2.3	0.6	0.0	0.3	5.44	58.80	43.60	59.10	0.25	4.34
Lower Slope															
0-30	5.7	4.8	1.16	11.21	2.66	1.6	2.1	0.1	0.3	4.62	86.80	91.25	357.50	1.77	5.60
30-60	5.1	4.2	0.27	2.57	1.16	1.3	1.5	0.0	0.4	3.91	80.40	50.70	123.80	0.76	3.70
Location 3															
Upper Slope															
0-30	5.0	4.4	10.88	30.43	23.17	4.2	2.8	0.7	0.8	12.13	71.25	204.45	99.40	9.12	32.42
30-60	5.0	4.0	2.11	14.65	13.13	4.3	3.3	0.9	0.9	12.89	72.70	184.00	103.00	9.73	28.16
Middle Slope															
0-30	5.5	4.5	7.02	24.42	6.86	4.9	3.0	0.8	0.9	11.76	80.50	129.60	99.70	8.11	27.37
30-60	4.6	3.8	5.27	17.39	3.63	5.0	3.6	0.8	0.9	16.41	62.70	124.85	92.75	8.47	27.87
Lower Slope															
0-30	4.7	4.1	5.28	21.63	9.50	4.6	2.9	0.8	0.9	13.64	67.75	203.00	94.35	8.55	34.14
30-60	4.8	3.8	4.24	15.54	9.18	4.3	3.2	0.8	0.9	13.74	67.15	241.90	152.50	10.21	42.24

RESULTS AND DISCUSSION

Chemical Properties of the pedons

The results in Table 1 show data on soil chemical properties of the three locations as influenced by physiographic positions and depth. Soil pH in water was generally acidic with values ranging between 4.6-6.0, but slightly acidic the at the topsoil (0-30cm) of upper slope in location 1, while Soil pH in KCl was also generally acidic with value ranges between 3.2-4.8, the values along the toposequence were similar but that of the upper and lower slope were slightly higher than that of the middle slope. The trend of soil pH obtained in this toposequence is an evidence of chemical weathering. This is in conformity with the findings of Babalola *et al*., (2007) who did similar work on soil properties and slope position in a humid forest and observed same trend of pH. Total nitrogen was relatively low in location 1 and 2 with values ranging from 0.13-1.51 which is below critical level of 2.0g/kg.

In location 3, Total nitrogen value was found to

Table 2. Bulk density and particle size distribution of the pedons along the toposequence of the three locations

Soil Depth (cm)	BD (g/cm^3)	Particle Size Distribution(g/kg)			BD (g/cm^3)	Particle Size Distribution(g/kg)			BD (g/cm^3)	Particle Size Distribution(g/kg)		
		Sand	Silt	Clay		Sand	Silt	Clay		Sand	Silt	Clay
		Location 1				Location 2				Location 3		
Upper Slope												
0-30	1.9	792	124	84	1.72	832	100	68	1.35	832	64	104
30-60	2.04	652	94	254	1.59	722	90	188	1.5	672	54	274
Middle Slope												
0-30	1.61	812	74	114	1.16	822	90	88	1.25	862	64	74
30-60	2.15	692	84	224	1.3	692	50	258	1.5	772	74	154
Lower Slope												
0-30	1.6	372	314	314	1.51	771	161	68	1.39	832	24	144
30-60	1.99	242	194	564	1.46	752	157	91	1.45	782	14	204

exceed the critical level. Organic carbon which has direct relationship with organic matter was high at the lower slope and reduces upward to the upper slope. This is in line with the findings of Paul and Clark (1989) which showed increase in Organic carbon down the toposequence. The available P values in all the slope position, except at the topsoil of upper slope of Location 3, is low ranging from 0.13-13.13mg/kg in all the three locations, physiographic positions and depth, available P is below critical level.Ca values along the toposequence in all the three locations and depth were low except in the lower slope of Location 1, ranging from 1.0-5.0cmol/kg based on the critical values of 5.0cmol/kg (Amalu, 1997). Na values along the toposequence were high in all 3 Locations ranging from 0.3-1.4cmol/kg based on the critical values of 0.02cmol/kg (Amalu, 1997). Mg values along the toposequence were also high in all the 3 Locations ranging from 0.6-9.5cmol/kg based on the critical values of 0.50cmol/kg (Onyekwere *et al*., 2003). The K values along the toposequence were above critical level ranging from 0.6-0.9cmol/kg in Location 1 and 3, and relatively low in Location 2 as against the critical level of 0.16–0.25 cmol/kg (Akinrinde and Obigbesan 2000). The ECEC values in the toposequence in all the 3 Locations ranges from 3.44-19.22cmol/kg, which is also low (<24cmol/kg) in all the three locations. The low ECEC have been attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly Kaolinite in their clay fractions. This finding is also in agreement with that of Korieocha *et al*. (2010) who worked on inland valley soils of south eastern Nigeria and observed low ECEC.

Particle Size Distribution and Bulk Density of the Pedons

The results in Table 2 show data on particle size distribution at each landscape position of the 3 Locations. The sand fraction generally dominated the soils along the toposequence. Within the horizons, the sand content decreased with depth in all the profiles, silt content decreased with depth except in middle slope of Location 1 and 3 in all the profile. The removal by eluviation of silty materials by rainwater or by erosion from the top slope and subsequent deposition down the slope could be the reason for the trend. These results are also in agreement with the findings of Voncir *et al*., (2008) who worked on profile distribution of some physicochemical properties of soil along a toposequence. The clay content increased with depth in all the landscape position in all the locations. The trend in the clay content at the upper horizon maybe as a result of processes like pedoturbation and in-situ weathering in the middle horizon, while the movement of clay down the profile through illuviation may have contributed higher content in the subsoil. Noma *et al.,* (2011) also reported similar results in a chrono-toposequence study of soils in Sokoto State, Nigeria. This is also in agreement with the findings of Udoh *et al*., (2010). The bulk density increases with depth in all the 3 Locations, except in Location 2 (upper and lower slope) where it decreases with depth.

Table 3. Variation in the physical and chemical properties of the soils in Location 1, 2 and 3

Soil Properties	Location 1			Location 2			Location 3		
	Range	Mean	CV (%)	Range	Mean	CV (%)	Range	Mean	CV (%)
pH(H_2O)	5-6.5	5.8	10.2	4.7-5.7	5.2	7.4	4.6-5.5	5.1	6.3
pH(KCl)	2.9-4.5	3.7	17.6	3.5-4.8	4.2	11.5	3.8-4.5	4.2	7.1
TN (g/kg)	0.49-1.51	1.0	34.0	0.13-1.16	0.7	59.1	2.11-10.88	6.5	45.6
OC (g/kg)	5.10-20.42	12.8	47.2	1.24-11.21	6.2	59.3	14.65-30.43	22.5	26.9
P (mg/kg)	0.7-9.03	4.9	74.4	0.13-3.75	1.9	68.4	3.63-23.17	13.4	50.6
Ca (cmol/kg)	2.6-8.9	5.8	44.3	0.90-2.30	1.6	31.6	4.2-5.0	4.6	7.4
Mg (cmol/kg)	2.6-9.5	6.1	48.9	0.60-2.1	1.4	40.5	2.8-3.6	3.2	9.2
K (cmol/kg)	0.6-0.8	0.7	12.0	0.0-0.1	0.1	109.5	0.7-0.9	0.8	7.9
Na (cmol/kg)	0.7-1.4	1.1	23.7	0.30-0.40	0.4	11.7	0.8-0.9	0.9	4.8
EA(cmol/kg)	0.43-4.87	2.7	65.1	0.55-2.25	1.4	47.4	2.32-6.13	4.2	30.4
ECEC(cmol/kg)	8.7-19.22	14.0	33.5	3.44-5.44	4.4	15.9	11.76-16.41	14.1	11.8
Fe (mg/kg)	83.63-236.83	160.2	44.8	43.6-141.15	92.4	40.1	124.85-241.90	183.4	25.0
Mn (mg/kg)	86.18-319.18	202.7	45.7	59.10-357.5	208.3	64.8	92.75-152.5	122.6	18.5
Cu (mg/kg)	4.4-9.83	7.1	33.5	0.25-1.77	1.0	54.6	8.11-10.21	9.2	8.8
Zn (mg/kg)	11.03-52.88	32.0	60.8	3.7-5.61	4.7	16.8	27.37-42.24	34.8	16.4
BS (%)	64.1-97.8	81.0	15.8	55.8-86.8	71.3	17.8	62.7-80.5	71.6	8.5
Sand (g/kg)	242-812	527	44.3	692-832	762	7.2	672-862	767	8.8
Silt (g/kg)	74-314	194	47.7	50-161	105.5	40.9	14-74	44	55.2
Clay (g/kg)	84-564	324	53.3	68-258	163	48	74-274	174	41.2
BD (g/cm^3)	1.6-2.15	1.9	12.2	1.16-1.72	1.4	14	1.25-1.5	1.4	7.1

Variation in physical and chemical properties of the pedons

The Coefficient of Variation (CV) in percentage of all the parameters evaluated among the three locations as affected by Landscape position and Soil Depth is presented in Table 3. pHw, pHk, BS and BD with CV (%) value ranging from 6.3-10.2, 7.1-17.6, 8.5-17.8 and 7.1-14.0 respectively, appears to show the least variation in all the parameters tested in all three locations. K with CV (%) values ranging from 7.9-109.5 shows a low variation in location 1 and 3 and very high variation in location 2. TN and OC with CV (%) values ranging from 34.0-59.1 and 26.9-59.3 respectively shows moderate variation in location1 and 3 and a high variation in location 2.

Ca and Mg with CV (%) values ranging from 7.4-44.3 and 9.2- 48.9 respectively show low variation in location 3 and moderate variation in location 1 and 2. Sand, Na and ECEC with CV (%) values ranging from 7.2-44.4, 4.8-23.7 and11.8-33.5 respectively appears to show low variation in location 2 and 3, and moderate variation in location 1. Fe with CV (%) values ranging from 25.0-44.8 was found to show moderate variation in all three locations. Mn and Cu with CV (%) values ranging from 18.5-64.8 and 8.8-54.6 respectively show between low, moderate and high variation in location 3, 1 and 2. Zn with CV (%) values ranging from 16.4-60.8 was found to show low variation in location 2 and 3, and high variation in location 1. Silt with CV (%) values ranging from 40.9-55.2 exhibits a moderate variation in location 1 and 2 and a high variation in location 3. EA and Clay with CV (%)values ranging from 30.4-65.1 and 41.2-53.3 respectively show moderate variation in location 2 and 3 and a high variation in location 1. P with CV (%) values ranging from 50.6-74.4 appears to show high variation in all three locations in all the parameters tested.

Land Capability Classification of Pedons of the Three Locations

The pedons from the three locations in accordance to their physiographic positions were ranked based on the evaluation of the type and level of severity of limitations for arable crop

Table 4. Land capability classification of the three locations as influenced by physiographic positions

Location	Physiographic Position	Capability Sub-class	Limitation
1	Upper Slope	IIf	Low Fertility
	Middle Slope	IIf	Low Fertility
	Lower Slope	IIf	Low Fertility
2	Upper Slope	IIe	Erosion
	Middle Slope	IIe	Erosion
	Lower Slope	IIes	Erosion, low fertility, low moisture content
3	Upper Slope	IIef	Erosion, low fertility
	Middle Slope	IIef	Erosion, low fertility
	Lower Slope	IIs	Low fertility, low moisture content

II = Capability sub-class
f, e and s = Limitations
f = Fertility
e = Erosin
s = Soil

production (Table 4). The limitations (fertility, erosion, and moisture content) are considered for soil conservation and management purposes. Location 1 falls under the capability class of II (Moderately suitable) with a major limitation problem of mainly fertility (f) in all the physiographic positions (upper, middle and lower slope). This limitation can be corrected for sustainable crop production by addition of nitrogen fertilizer, phosphate, potassium and lime (Ca and Mg) for satisfactory crop yields. Also, timing of fertilizer application to meet the period of maximum demand for crop growth is essential for efficient utilization by the crop on the soil. Location 2 also falls under the capability class of II (Moderately suitable) with major limitation problem of mainly erosion (e) at the upper and middle slope and erosion (e), fertility(f) and low moisture content (s) at the lower slope.

This limitation can be overcome by soil conservation measures that will encourage and ensure adequate land cover on the soil surface, and good maintenance of grass water ways should be put in place to minimize erosion. Similarly, no tillage, minimum tillage on these erosive soils should be adopted instead of the conventional tillage practice. Location 3 also falls under the capability class of II (Moderately suitable) with major limitation problem of erosion (e) and fertility (f) at the upper and middle slope and fertility (f) and low moisture content (s) at the lower slope.

CONCLUSION

This study has shown the relationship between soil properties, landscape position and soil depth, and potentials of the soil properties for crop production, The results of this study reveal that pH in water, pH in KCl, BS and BD has the least variation when compared with Na, ECEC and sand which shows least to moderate variation and TN, OC, P, Ca, Mg, K, Fe, Mn, Cu, Zn, silt and clay which shows least, moderate, high to very high variation in the 3 Locations investigated. Results from land capability classification reveal that all the pedons from the three locations investigated falls under the capability class of II (moderately suitable) with limitations of fertility, erosion, and low moisture content, which make them capable for crop production and can be corrected for maximum yield when put into cultivation.

REFERENCES

Akinbola GE, Ojo UA, Adigun MO (2010). Variability of properties of some pedons on basement complex of South Western Nigeria.Proceedings of the 34th Annual Conference of the Soil Science Society of Nigeria 22nd – 26th March, 2010, Ibadan, Nigeria.
Akinrinde EA, Obigbesan GO (2000). Evaluation of fertility status of selected soils for crop production in five ecological zones of Western Nigeria. *Proceedings of 26th Annual Conference of Soil Science Society of Nigeria*. Pp. 279-288.
Amalu UC (1997). Evaluation of properties of selected soils of Cross River State area and their management for increased cassava yields. *Glo. J. Pur. App. Sci.* 4(3): 243-249.
Anderson JM, Ingram JSI (1993). Tropical Soil biology and fertility. A Handbook of Methods. 2nd Edition. CAB Int. 221pp.
Babalola TS, Fasina AS, Tunku P (2007). Relationship between soil properties and slope position in a Humid forest of South Western Nigeria. *Agr. J.* 2(3): 370-374.
Bates R G (1954). Electrometric pH determination. John Wiley and Sons. Inc. New York.
Black CA (1975). Methods of soil analysis. Agronomy No. 9, part 2. *Ame. Soc. Agr.* Madison, Wisconsin.
Bouyoucos GH (1951). A recalibration of the hydrometer for making mechanical analysis of soils. *Agr. J.* 43: 434-438.
Bray RH, Kurtz LT (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* 59: 45-49.

Brouwer J, Fussel LK, Hermann L (1993). Soil and Crop growth Micro-variability.*Eco. Env.* 45: 229-238.
Bruand A, Hartmann C, Ratana-Anupap S, Sindtusen P, Poss R, Hardy M (2004).Composition, fabric and porosity of an ArenicHaplustalf of Northeast Thailand: Relation to penetration resistance. *Soil Sci. Soc. Am. J.* 68: 185-193.
Busscher WJ, Federick JR, Bauer PJ (2001).Effect of penetration resistance and timing of rain on grain yield of a narrow row corn on coastal plain loamy sand. *Soil Til Res.* 63: 15-24.
Cassel DK (1983). Spatial and Temporal variability of soil physical properties following tillage of a Norfolk loamy sand soil. *Soil Sci. Soc. Ame. J.* 47: 196-201.
Chien YJ, Lee DY, Guo HY, Honng KH (1997). Geoststisical analysis of soil properties of mid-west Taiwan soils. *Soil Sci.*, 162: 291-298.
Effiom O, Ayuk E, Thomas E (2010). Variability in soil properties along an Udalftoposequence in the humid zone, Nigeria. *Kas. J. Nat. Sci.* 44: 564-573.
FAO (2006). Guidelines for land evaluation for Rainfed Agriculture. FAO Soils Bulletin No. 52 FAO, Rome 237 pp.
Jackson ML (1962). Soil chemical analysis. Prentice Hall, New York.
Korieocha DS, Onyekwere IN, Ibia TO (2010). Fertility status and management of UsseOffot inland valley soils for increased rice yields in Akwa-Ibom State, Nigeria. *J. App. Agr. Res.* 2: 97-103.
Lal R (2000). Physical management of Soils of the tropics. Priorities of the 21st Century. *Soil Sci.* 165: 191-207.
Mallarino AP (1996). Spatial patterns of phosphorus and potassium in non-tilled soils for two sampling scales. *Soil Sci. Soc. Ame. J.* 60: 1473-1481.
Miller MP, Singer MJ, Nielsen DR (1988). Spatial variability of wheat yield and soil properties on complex hills. *Soil Soil Sci. Soc. Ame. J.* 52:1133-1141.
Noma SS, Tanko II, Yakubu M, Dikko AU, Abdullahi AA, Audu M (2011). ChronoToposequence Studies of Soils of Dundaye District, Sokoto State, Nigeria. A Paper Presented at the *35th Annual Conference of the Soil Science Society of Nigeria* held at FUT, Minna.
Ogeh JS, Ukodo E (2012). Profile distribution of physical and chemical properties in soils of a toposequence in Benin, Rainforest, Nigeria. *Nig. J. Bas. App Sci.* 20(1): 68-72.
Ogunkunle AO (2003). Spatial variability of some chemical properties in two Ultisols mapping units in Southern Nigeria. *Soil Sur. Land Eva*. 6: 26-32.
Onyekwere IN, Ano AO, Ezenwa MIS, Osunde AO, Bala A (2003). Assessment of exchangeable acidity status and management of wetland soils of Cross River State. *Proceedings of the 28th Annual Conference of the Soil Science Society of Nigeria*. Pp 52-59
Paul EA, Clark FC (1989). Soil Microbiology and Biochemistry. *Academic Press Inc.* San Diego California.
Paz-Gonzalez A, Vieira SR, Taboada-Castro MT (2000).The effect of cultivation on the spatial variability of selected properties of an umbric horizon. *Geo.* 97: 273-292.
Rhoades JD (1982). Methods of soil analysis. Part 2 Agronomy Monograph, No.9.
Senjobi BA (2007). Comparative assessment of the effect of land use and land type on soil degradation and productivity in Ogun State, Nigeria. Published Ph.D. thesis submitted to the Department of Agronomy, University of Ibadan, Ibadan. Pp161.
Stolt MH, Baker J, Simpson TW (1993). Soil landscape relationship, soil variability and parent material uniformity. *Soil Sci. Soc. Ame. J.* 57: 414-421.
Stutter MI, Deeks LK, Billett MF (2004). Spatial variability in soil ion exchange chemistry in agranitic upland catchment. *Soil Sci. Soc. Ame. J.* 68: 1304-1314.
Udoh BT, Harold KO, Adiole CU (2010).Variation in soil types and characteristics as Influenced by topography within an agricultural management unit in southeastern Nigeria. *J. App. Agr. Res.* 2: 105 – 111.
Voncir N, Mustapha S, Tenebe VA, Kumo AL, Kushwaha S (2008). Content and profile distribution of extractable zinc and some physicochemical properties of soil along a toposequence at Bauchi, Northern Guinea Savana of Nigeria. *Int. J. Soil Sci.* 3(2): 62 – 68.
Walkley A, Black IA (1934). AN examination of the Degitareff method for determining soil organic matter and proposed modification of the chronic acid titration method. Soil Sci. 37: 29 – 38.
Wang J, Fu BJ, Qiu Y, Chen LD (2001). Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. *J. Arid Env.* 48:537 550.
Wysocki DA, Schroeneberger PJ, Lagary AE (2001). Geomorphology of Soil Landscapes. In: Summer, M.E (Eds). *Handbook of Soil Sci*. CRC Press. Boca Raton, FL, USA.