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CHEMICAL PROPERTIES OF SOILS ALONG A TOPOSEQUENCE UNDERLAIN BY COARSE GRAINED GRANITE GNEISS IN IFE AREA SOUTH WEST NIGERIA

OJEDOKUN R.O*, FAWOLE O. A., ASABIA L.O, OLUWAPONLE A.I, ADEOLA M.J.
Forestry Research Institute of Nigeria, P. M. B. 5054, Jericho, Ibadan.
Corresponding author: ojedokun.ro@frin.gov.ng 08132962137

ABSTRACT
Research has shown that soil profiles are influenced by five separate, yet interacting factors: parent material, climate, topography, organisms and time which give soil profiles their distinctive character. Topography however, plays a major role in the variation of soil properties and nutrient distribution along a non-uniform agricultural landscape. This study was conducted to investigate the effects of topography on chemical properties of soil underlain by coarse grained granite gneiss at the teaching and research farm of Obafemi Awolowo University Ile Ife. Three profile pits was established at different physiographic positions along a toposequence (upper, middle and lower positions) were considered for this study. A total of eleven (11) samples were collected for routine laboratory analysis from the established horizons. The results revealed that the clay content increased with increase in profile depth while sand content decreases. Organic matter content was relatively low 0.2 – 1.35%, a result of continuous cultivation in the area. The values of available P (1.29 – 5.40ppm) showed that it is inadequate for crop production. The pH, exchangeable cations and exchangeable acidity values fluctuate across the pedons under investigation. The correlation between slope position and chemical properties showed that no singular property consistently showed the same level of significance on the entire slope.

For effective management of the soils, organic inputs and usage of vegetal cover such as planting of cowpea and other crawling plants of economic importance should be adopted to assist in improving the organic matter content, conservation management practices should also be employed to prevent rapid soil degradation across the topography.

INTRODUCTION
Topography has a significant impact on soil formation as it determines runoff of water. It plays a vital role in biogeochemical processes which performs key environmental, economic and social functions (Griffiths *et al.*, 2009 and Bingqin *et al.*, 2019). Soils vary in their characteristics primarily because of topography (Amhakhian and Achimugu, 2011) which modifies soil water relationships and to a large extent influences rainfall, drainage, soil erosion, textural composition and other soil properties that affect plant growth within a field (Meng *et al.*, 2017). Topographic variability associated with crop production is an integrated reflection on soil properties and factors affecting agricultural productivity (Dinaburga *et al.*, 2010). Sloppiness of agricultural fields can influence soil physicochemical properties (soil depth, texture, and mineral contents), biomass production, incoming solar radiation, precipitation which on the long run affect crop production. At a higher elevation, soil moisture, precipitation, soil organic matter and labile carbon significantly increased, while bulk density, pH and soil temperature decreases (Nahusenay and Kibebew, 2016).

Nature of parent material has also been found to influence development and characteristics of soils. The ability of a soil to support plant growth depends on its properties which have been found to play significant roles in crop production. A soil that supplies adequate nutrients needed by plants with favourable soil pH will produce better crops quality and yield if other conditions of growth such as biological and physical properties of the soil are favourable. The quality of soils does not depend on its ability to supply adequate nutrients alone but the nutrients must be in the right proportion as needed by plants (Ayeni *et al.*, 2011). Parent material composition has a direct impact on soil chemistry and fertility.

Topography plays a vital role in biogeochemical processes which performs key environmental, economic and social functions (Griffiths *et al.*, 2009). Any spatial patterns depend on soil forming processes, our understanding of which is still limited, especially in regards to topographic effects. As the landscape is undulating, soil characteristics at different topographic positions differ. Soils vary in their characteristics primarily because of topography (Amhakhian and Achimugu, 2011) which modifies soil water relationships and large extent influences on rainfall, drainage, soil erosion, textural composition and other soil properties that affect plant growth within a field (Atofarati *et al.*, 2012). Topographic variability associated with crop production is an integrated reflection on soil properties and factors affecting agricultural productivity (Dinaburga *et al.*, 2010).

Parent materials rich in soluble ions-calcium, magnesium, potassium, and sodium, are easily dissolved in water and made available to plants. Soils developed on parent material that is coarse grained and composed of minerals resistant to weathering are likely to exhibit coarse grain texture. (Ritter, 2006). The soils of the basement complex vary a lot in characteristics; therefore intense understanding of the slope processes and spatial distribution is of great importance for sustainable management of the soil. To come up with sound management practices, investigating the impacts of topography is imperative. The main objective of this study was therefore to investigate the effects of topographic positions on soil chemical properties underlain by coarse granite gneiss at the Teaching and Research Farm of Obafemi Awolowo University ile ife.

MATERIALS AND METHODS

Description of the Study area

The study site is a section located approximately between latitudes 7° 32´N and 7° 33´N and longitudes 4° 39´E and 4° 40´E and are underlain by coarse grained granite gneiss within Obafemi Awolowo University (O.A.U.) Teaching and Research Farm (T&R-F) (Rahaman, 1988). The area is in the same ecological zone (tropical rainforest) as Ile-Ife with hot, humid tropical climate having distinct dry and bimodal rainy seasons. The mean annual rainfall is about 1500 mm with the peaks in April and August and the mean monthly air temperature is approximately 31°C (Soil Survey Staff, 2006). The influence of the north-east trade wind, which loses all its moisture as it passes over the Sahara desert towards the equator, is felt in the study area as 'harmattan' (cold dry wind) between late December and early January (FMANR, 1990).

Sampling Procedure and Laboratory analysis

A toposequence which is slightly undulating with relatively flat top was selected for the study. Three (3) soil profile pits were established along the toposequence at different physiographic positions. The toposequence is approximately 400 m long from the valley bottom to the crest with an elevation of 295.9 m above mean sea level (amsl) at the upper slope position, 276.9 m amsl at the middle slope and 268.6 m amsl at the lower slope (valley bottom) position respectively. All the pedons were described following the procedures in the guidelines for soil profile description (FAO. 2001) and horizon designations of the Soil Survey Staff (2006). Soil samples were collected from each of the identified genetic horizons for routine laboratory analysis to study the influence of the landscape on the soil properties. The samples collected were air dried, crushed with mortar and pestle and sieved with a 2mm sieve and the fractions of the samples less than 2mm were used for the laboratory analysis.

The particle size distribution was evaluated by the modified Bouyoucos hydrometer method (Bouyoucos, 1965) as reported by (Gee and Or, 2002) using 5% w/v sodium hexametaphosphate (calgon) as the dispersing agent. The soil pH was determined in 1.0 M KCl (1:1 soil: solution ratio) using glass electrode pH meter (Kent model 720) after equilibration for 30 minutes (Thomas, 1996). The exchangeable cations (Ca, Mg, K and Na) were extracted with 1.0 M ammonium acetate (NH_40AC) solution at pH 7.0 (Thomas and Throp, 1985). Calcium, Ca^{2+}, sodium, Na^+, and potassium, K^+ ions in the extract were determined with the use of flame photometer (Gallenkamp Model FH 500), while magnesium (Mg^{2+}) ion in the extract was determined by titration. The exchangeable acidity was determined by extraction with 1.0 M KCl solution and titrated with NaOH and HCl solutions to measure total acidity (Al^{3+} and H^+) concentrations respectively (McLean, 1965) as reported by (Bertsch and Bloom, 1996). The available phosphorous by Bray No. 1 method (Bray and Kurtz, 1945) as reported by (Kuo, 1996). The organic carbon was determined by the Walkley Black method (Allison, 1965) as reported by (Darrell *et al.*, 1994).
Data generated from the results of the laboratory analysis were subjected to Pearson's correlation analysis to determine the relationships between the soil parameters assessed and the influence of topography on its distribution across the slope.

RESULTS AND DISCUSSION

The particle size distribution of the soil (Table 1) revealed that the clay content increased with profile depth. The increase with the depth could be accounted for by the translocation of clay from the surface horizon to the subsoil which is a common occurrence with the soils in southwestern Nigeria (Ojanuga, 1969). In an earlier study of clay distribution by Smyth and Montgomery, (1962), weathering by biological processes, physical and at times chemical processes were suggested to be the major causes of clay elluviation from the top soil to the subsoil. Thus, the relatively high value of clay in sub horizons is an indication that severe weathering had occurred in the environment. A variation in the silt content (values ranged from 3.76-15.76%) was observed within each profile which does not follow a specific pattern in the profile at the upper and middle slope positions but increases with depth at the lower slope profile. The silt contents in all the profile pits were lower than the sand and clay contents and this agreed with the earlier finding of Ojanuga, (1969) and Osinuga *et al.* (2020) that soils from the basement complex in humid tropical lowland of Southwestern Nigeria have low silt content. In all the profile pits, the sand content decreased down the horizon although there were some variations in the sand content with depth. This condition may be accounted for by the selective removal of clay particles by runoff or illuviation or both across the toposequence. Another possible cause of the high sand content may be the acidic nature of the parent materials. Therefore the soil texture ranged from sandy clay loam to clayey in the profile pit at the upper slope position, while the texture was observed to be majorly characterized by sandy loam at both the middle and lower slope position.

The pH values of the soils (Table 1) in 0.1M KCl solution were much lower than those in distilled water and the values ranged from 4.0 - 5.2 and 4.5 - 5.3 in KCl and distilled water respectively. In the pit at the upper slope, the pH in water ranged from 4.5 - 5.0, while in KCl it ranged from 4.0 - 4.3. Also in the pit at the Mid slope, pH in water ranged from 5.2 - 6.1 and 4.1 - 5.2 in KCl while in the pit at the lower slope position, it ranged from 5.0 - 5.2 in water and from 4.0 - 4.3 in KCl. Generally, the pH was observed to fluctuate down the profile for all the three pits. This is in line with the previous research carried by Smyth and Montgomery, (1962) on soils in Southwestern Nigeria and Okenmuo *et al.* (2020) on the soils of the lower Niger floodplain of Atani, southeastern Nigeria. The acid nature of the soil can be ascribed to high rate of leaching of bases which is prevalent in the humid tropics, and the acidic nature of the parent rock (granite-gneiss). The higher pH values observed at the soil surface horizons according to Fasina *et al.* (2005) might be due to liming effect of bush burning and bio cycling of nutrients. The pH in 1M KCl was lower than the pH in water (H_20), thus the difference in soil pH values between the pH in KCl and H_20 (as expressed by $\Delta pH = pH (KCl) – pH (H_20)$) were all negative ranging from -0.5 to -1.2. This suggests the dominance of silicate clay minerals over oxides (Van Raij *et al.*, 1972 and Lydia *et al.*, 2018).

In general, the soils were low in organic matter which ranged from 0.2 - 1.35% and decreased down the horizon except at the lower slope pit where there is a slight increase at the subsoil (Table 1). A good relationship was found between the organic matter content and the surface horizons of individual profile (Table 1). The upper horizons has the highest amounts of organic matter which were 1.1% at the upper slope, 1.3% at the mid slope and 1.27% at the lower slope. Usually within a soil profile, organic matter is highest in the upper 10 cm depth, decreasing markedly to lesser amount below this depth (Soil Survey Staff, 2006). However, with the low organic matter contents of the soils, one of the management problem agronomists would have to contend with is the maintenance of organic matter in the soil under continuous cultivation across the slope. This is because these soils would become markedly depleted in organic matter once they are put under continuous cultivation due to rapid humidification of organic matter that promotes activities of microorganism, ants and termites hence lead the disruption of the natural built-up of organic matter.

The values of the available P in the profiles are extremely low (Table 1). The values in all the profiles varies from 1.29 - 5.40 ppm. The values obtained ranged from 1.45 - 5.40 ppm at the upper slope profile, 1.32 -2.21 ppm at the mid slope profile and 1.29 - 2.62 ppm at the lower slope profile (Table 1). Based on the values of the available P obtained across the slope, it showed that it is inadequate for maximum yield of specific crops. This is because the moderate value of available P required for crops maximum yield is between 10-20 ppm (Loganathan, 1987).The amount of exchangeable cations (K, Mg, Na, and Ca) varies in all the profile as some increased and some decreased with increasing depth (Table 1). At the upper slope position, the value of K varied from 0.46 to 0.95 cmol/kg while at the mid slope profile, it varied from 0.83 to 1.1 cmol/kg, and at the lower slope, it increased with increasing depth varying from 0.31 to 0.37 cmol/kg. This values according to Loganathan, (1987) were classified as moderate to high for crop production in the area. The values of Na, Ca and Mg varied in all profiles. The values of Na decreased with increasing depth at the upper slope profile which ranged from 0.11 to 0.12 cmol/kg, varied from 0.10 to 0.12 cmol/kg at the middle slope profile and also varied from 0.10 to 0.12 cmol/kg at the lower slope profile. The values of Mg varied from 0.83 to 0.90 cmol/kg at the upper slope profile, 0.50 to 0.88 cmol/kg at the middle slope profile and from 0.36 to 0.50 cmol/kg at the lower slope profile. The values of Ca were much higher at the upper slope profile and ranged from 3.37 to 11.26 cmol/kg, 3.83 to 3.98 cmol/kg at the middle slope profile and from 2.88 to 3.20 cmol/kg at the lower slope profile.

Generally, the total exchangeable bases fluctuated with soil depth owing to nutrient biocycling (Ajiboye and Ogunwale, 2010), and could also be due to differential weathering that had taken place or as a result of plant uptake and leaching losses. Like in most tropical soils, the exchangeable sites of the soils studied were dominated by exchangeable calcium.

The exchangeable acidity of the soil is low. H^+ was noticed to be more abundant compared to $Al^{3+.}$ The values of exchangeable H^+ and Al^{3+} fluctuates down the profile. H^+ was most abundant in horizon B2 at the upper slope profile (0.85 cmol/kg) while is lowest in horizon AB at the middle slope profile (0.04 cmol/kg). Al^{3+} is highest in horizon B22 at the lower slope profile (2.0 cmol/kg) and lowest in horizon AB at the middle slope (0.3 cmol/kg).

Table 1:Physical and Chemical properties of the soil studied

Horizon	Depth (cm)	Sand	Silt	Clay	Textural Class	pH			OM (%)	Avail. P (ppm)	Exchangeable Cations (Cmol/kg)					Total	
		←	%	→		H_2O	KCl	ΔpH			Na	K	Mg	Ca	TA	Al	EH
								Profile 1 (Upper Slope)									
Ap	0-24	59.8	8.76	31.44	SCL	4.7	4.1	-0.6	1.1	5.40	0.11	0.79	0.85	11.3	0.6	0.4	0.4
AB	24-87	44.8	3.76	51.44	C	4.5	4.0	-0.5	0.74	1.45	0.11	0.46	0.83	3.36	0.55	0.51	0.04
B2	87-143	35.8	12.76	51.44	C	5.0	4.3	-0.7	0.20	1.73	0.12	0.95	0.90	3.52	1.45	0.60	0.85
								Profile 2 (Mid Slope)									
Ap	0-13	71.8	4.76	23.44	SL	6.1	5.2	-0.9	1.35	1.55	0.12	1.13	0.88	3.87	0.7	0.6	o.1
AB	13-38	39.8	14.76	45.44	L	5.2	4.2	-1.0	1.14	2.21	0.11	1.10	0.50	3.96	0.4	0.3	0.1
B21	38-85	36.8	3.76	59.44	SL	5.2	4.3	-0.9	1.08	1.44	0.10	0.83	0.53	3.98	0.7	0.5	0.2
B22	85-120	27.8	8.76	63.44	SL	5.3	4.1	-1.2	0.34	1.32	0.12	0.99	0.57	3.83	1.2	1.0	0.2
								Profile 3 (Lower Slope)									
Ap	0-35	71.8	7.76	20.44	SL	5.2	4.3	-0.9	1.27	2.62	0.10	0.31	0.36	2.83	0.6	0.5	0.1
AB	35-67	29.8	10.76	59.44	S	5.0	4.0	-1.0	0.40	1.29	0.11	0.33	0.50	3.20	2.0	1.8	0.2
B21	67-117	27.8	12.76	59.44	SL	5.0	4.1	-0.9	1.22	1.39	0.11	0.37	0.43	3.13	2.0	1.9	0.1
B22	117-156	25.5	14.52	59.98	SL	5.1	4.2	-0.9	1.21	2.12	0.11	0.38	0.45	3.18	2.1	2.0	0.1

Table 2: Pearson correlation of the chemical properties of the soil studied

Parameters	**pH (H20)**	**pH (KCl)**	**OM (%)**	**Avail. P**	**Na^+**	**K^+**	**Mg^+**	**Ca^+**	**TA**	**Al**	**EH**
					Upper Slope						
% OM	0.99718*	0.73704									
Avail P	-0.05138	-0.12623	0.76348								
Na	0.91766	0.94491	-0.91766	-0.44398							
K	0.95152	0.92574	-0.42673	0.25829	0.75096						
Mg	0.99187	0.99863*	-0.77145	-0.17805	0.96077	0.90464					
Ca	-0.09718	-0.17164	0.79232	0.99895*	-0.48466	0.21366	0.22304				
TA	0.93618	0.95993	-0.89690	-0.39915	0.99878*	0.78268	0.97330	-0.44083			
Al	0.54877	0.60999	-0.98614	-0.86307	0.83577	0.26503	0.65069	0.88535	0.80761		
EH	0.99870*	0.99206	-0.64622	-0.00050	0.89626	0.96594	0.98411	-0.04642	0.91709	0.50552	
					Mid Slope						
pH KCl	0.96604*										
%OM	0.47135	0.66694									
Avail. P	-0.19795	-0.11244	0.46138								
Na	0.59904	0.37796	-0.29047	-0.17499							
K	0.58309	0.49199	0.29896	0.51223	0.71176						
Mg	0.99676**	0.95871*	0.43073	-0.27560	0.59450	0.52555					
Ca	-0.46963	-0.22958	0.54289	0.51095	-0.92327	-0.38731	-0.49619				
TA	0.00000	-0.19838	-0.83852	-0.83098	0.47238	-0.27766	0.06293	-0.77152			
Al	0.10390	-0.11175	-0.80715	-0.79391	0.59131	-0.14181	0.16112	-0.85339	0.99004**		
EH	-0.52981	-0.56980	-0.70124	-0.72548	-0.30151	-0.87195	-0.46007	-0.08058	0.69631	0.58835	
					Lower Slope						
pH KCl	0.94388**										
%OM	0.56290	0.80399									
Avail. P	0.99188**	0.96714**	0.63222								
Na	-0.87039	-0.77460	-0.39122	-0.80946							
K	-0.44783	-0.19537	0.29360	-0.33066	0.75665						
Mg	-0.81004	-0.88999	-0.78709	-0.80056	0.86173	0.35644					
Ca	-0.83744	-0.79317	-0.49979	-0.78440	0.98533**	0.66123	0.92567				
TA	-0.83619	-0.73698	-0.36074	-0.76941	0.99784**	0.78311	0.85187	0.98590**			
Al	-0.81513	-0.69611	-0.29682	-0.74170	0.99327**	0.82313	0.81517	0.97322**	0.99771**		
EH	-0.52223	-0.77460	-0.99802**	-0.59783	0.33333	-0.35310	0.74683	0.44437	0.30167	0.23649	

Note: S = Sandy; C = Clayey; L = Loamy; SL = Sandy Loam; SCL = Sandy Clay Loam; *=0.05 significant, **=0.01 significant, ***= 0.001 significant

Correlation between the chemical properties of the soils studied

Table 2 shows the correlation matrix of the chemical properties along the slope. Here, the correlation of Mg/pH (KCl) (r = 0.99), Ca/available P (r = 0.99) and OM/pH (H_2O) (r = 0.99) were positively significant in profile 1. This is an indication that the cations are pH dependent. This implied that an increase in one parameter would bring about corresponding increase in the other to the magnitude indicated. In profile 2, Mg/pH (KCl) (r=0.96) were also positively significant and Mg/pH (H_2O) (r = 0.99) were positively significant in profile 2 which indicated that an increase in one parameter would lead to a corresponding increase in the other. Also, in the profile 3, available P/pH (KCl) (r = 0.967), Al/Ca (r = 0.973) were positively significant. It was observed that none of the soil properties showed consistently the same level of significance on the entire slope.

Conclusion and recommendation

This study aimed at assessing the impact of topography on the soil along a Toposequence underlain by coarse grained granite gneiss in Ife area Nigeria. The study shows that landscape position, soil depth and drainage significantly influenced variation in soil properties. Generally, the soils were low in organic carbon and available phosphorus. The soil pH (both in water and 1N KCl solution) showed that the soils were slightly acidic which resulted from the nature of the parent rock as well as leaching enhanced by heavy annual rainfall which is a common occurrence in the studied area. This will require the addition of organic manure and crop residue. Exchangeable bases were rated medium to higher. Pedogenic processes resulted in clay enrichment at the subsoils of the profiles while sand was higher in all the profiles under examination. The whole toposequence will require addition of organic manure and crop residue since they are all characterized by low organic matter due to intensive continuous cultivation in the study area. The upper slope will require terracing to control the rate of erosion on the units, while the lower slope position, in addition, will require construction of drainage channels to reduce excess water in the soil for optimum plant growth.

REFERENCES.

Allison, L. E. (1965). Organic Carbon. Pp 1367-1378. In C.A. Black *et al*., (edition). Methods of soil analysis. Part 2. *Agronomy Monograph* 9 ASA. Madison, WI. Pp

Amhakhian, S.O., & Achimugu, S. (2011). Characteristics of soil on toposequence in Egume, Dekina Local Government Area of Kogi State. *Production Agriculture and Technology*, 7(2), 29-36.

Amhakhian, S.O., and Achimugu, S. (2011). Characteristics of soil on toposequence in Egume, Dekina Local Government Area of Kogi State. *Production Agriculture and Technology*, 7(2), 29-36.

Atofarati, S. O., Ewulo, B. S., & Ojeniyi, S. O. (2012). Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria. *International Journal of Agricultural Science*, 2(7), 642-650.

Atofarati, S. O., Ewulo, B. S., and Ojeniyi, S. O. (2012). Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria. *International Journal of Agricultural Science*, 2(7), 642-650.

Ayeni LS, Adeleye EO (2011) Soil nutrient status and nutrient interactions as influenced by agro wastes and mineral fertilizer in incubation study in the Southwest Nigeria. *International Journal of Soil Science* 6 (1):60-68

Bertsch, P. W. and Bloom, P. R. (1996). Aluminium. In Sparks, D. L. (ed.), Methods of Soil Analysis Part 3: *SSSA* Book Series No. 5. *Soil Science Society of America Inc., American Society of Agronomy Inc.,* Madison, Wisconsin, 517 – 550pp.

Bingqin Zhao, Lun Zhang, Zhenyao Xia, Wennian Xu, Lu Xia, Yongzhe Liang, Dong Xia, (2019) "Effects of Rainfall Intensity and Vegetation Cover on Erosion Characteristics of a Soil Containing Rock Fragments Slope", *Advances in Civil Engineering,* vol. 2019, Article ID 7043428, 14 pages, 2019. https://doi.org/10.1155/2019/7043428

Bouyoucos, G. J. (1965). Hydrometer method improved for making particle size analysis of soils. *Soil Science Society of America Proceeding* 26: 917 – 925pp.

Bray R.H and Kurtz, L.T (1945) Determination of Total Organic and Available Forms of Phosphorus in Soils. *Soil Science*, 59, 39-45.

Darrell, T., Maes, P., Blumberg, B. and Pentland, A. P. (1994). A Novel Environment for Situated Vision and Behavior. MIT Media Laboratory, *Perceptual Computing Section Technical Report.* No. 261pp

Dinaburga, G., Lapins, D., and Kopmanis, J. (2010). Differences of soil agrochemical properties in connection with altitude in Winter Wheat. *Engineering for Rural Development*, 79-84.

FAO, (2001). Lecture notes on the major soils of the world. *World Soil Resources Reports,* 94. Rome. Pp 334.

FMANR (Federal Ministry of Agriculture and Natural Resources) (1990). *Literature review on soil fertility investigations in Nigeria*.5 2:92-95; 5:252-261.

Gee, G. W. and Or. (2002). Particle size analysis. In: J. H. Dane and G. C. Topp (eds) Methods of soil analysis part 4, Physical methods. Soil Science Society of America Book series no. 5, *American Society of Agronomy and Soil Science Society of America, Madison*, Pages 255-293pp.

Griffiths, R. P., Madritch, M. D., & Swanson, A. K. (2009). The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. *Forest Ecology and Management*, 257, 1-7.

Griffiths, R. P., Madritch, M. D., and Swanson, A. K. (2009). The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. *Forest Ecology and Management*, 257, 1-7. http://dx.doi.org/10.1016/j.foreco.2008.08.010

Kuo, S. (1996). Phosphorus. In Sparks, D. L. (ed.), Methods of Soil Analysis Part 3: *SSSA* Book Series No. 5. *Soil Science Society of America Inc., American Society of Agronomy Inc.,* Madison, Wisconsin, pp 869 – 920.

Lydia Solomon Jongs, Alexander Asanja Jock, Okon Eno Ekanem, Aliyu Jauro (2018) Investigating the Industrial Potentials of Some Selected Nigerian Clay Deposits *Journal of Minerals and Materials Characterization and Engineering* Vol.06 No.06(2018), Article ID:88482,18 pages 0.4236/jmmce.2018.66041

Meng, C. C., H. L. Zhang, and P. P. Yang (2017) "Effects of simulated vegetation types and spatial patterns on hydrodynamics of overland flow," *Journal of Soil & Water Conservation*, vol. 31, pp. 51–56.

Nahusenay Abate and Kibebew Kibret, (2016). Effects of Land Use, Soil Depth and Topography on Soil Physicochemical Properties along the Toposequence at the Wadla Delanta Massif, Northcentral Highlands of Ethiopia. Environment and Pollution; Vol. 5, No. 2; 2016 ISSN 1927-0909 E-ISSN 1927-0917

Okenmuo F.C., Anochie C.O., Ukabiala M.E., Asadu C.L.A., Kefas P.K. and Akamigbo F.O.R. (2020) Classification And Assessment Of Agricultural Potential Of The Lower Niger Floodplain Soils Of Atani, Southeastern Nigeria *Journal of Tropical Agriculture, Food, Environment and Extension* Volume 19 Number 3 (July 2020) pp. 51 – 61

Osinuga O.A., Aiboni V.U. and Oyegoke C.O. (2020). Classification and suitability evaluation of soils along a toposequence for rice production in alabata, southwest Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension* Volume 19 Number 4 (October 2020) pp. 43 – 50

Rahaman, M. A (1988). Recent advances in the study of the basement complex of Nigeria. *In: Geological Survey of Nigeria (Ed)Precambrian Geol Nigeria*, 11–43 pp.

Ritter, Michael E. The Physical Environment: an Introduction to Physical Geography. 2006.

Smyth, A. J. and Montogomery, R. F.(1962). Soils and land use in central western Nigeria. Western Nigeria Government, Ibadan Pp 265.

Soil Survey Division Staff, (2006). Soil Survey Manual. USDA Handbook No. 18. Govt. printing office, Washington D.C. Pp 279.

Thomas, G. W., (1996). Soil pH and Soil Acidity. In Sparks, D. L. (ed.), Methods of Soil Analysis Part 3: *SSSA* Book Series No. 5 *Soil Science Society of America Inc., American Society of Agronomy Inc.,* Madison, Wisconsin, pp 363 – 376pp.

Thomas, M. F. and Throp, M. B. (1985). Environmental Change and Episodic Ectoplantation in the Humid Tropics of Sierra Leone: The Koidu Etchplain: In Douglas, and Spencer, T. (ed.) *Environmental Change and Tropical Geomorphology*. George Allen and Unwin, London, pp.239-267.