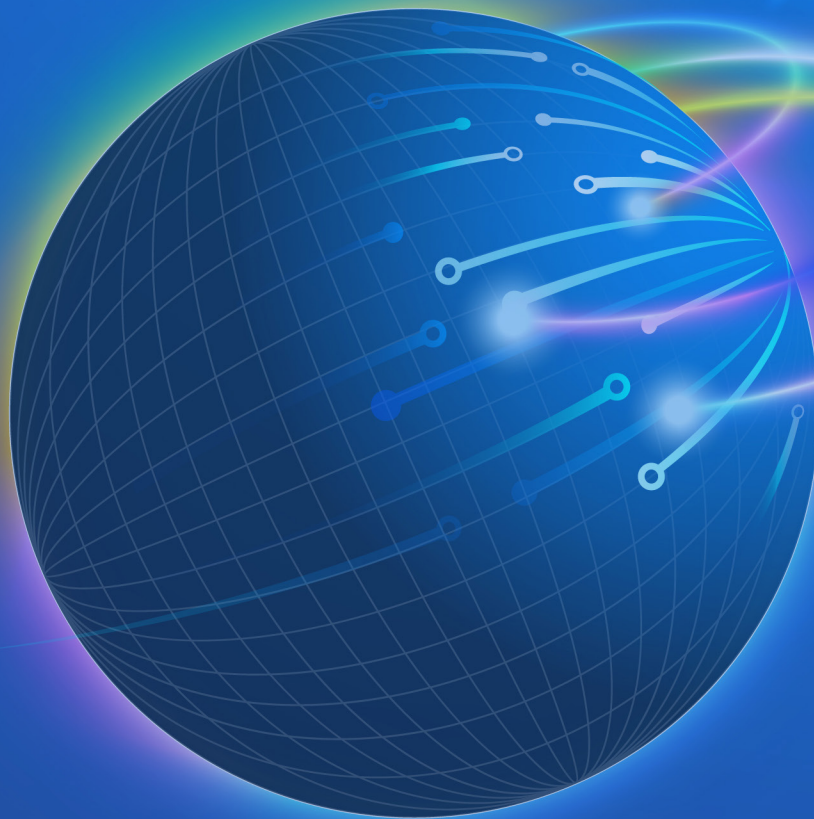




AMERICAN JOURNAL OF **GEOSPATIAL TECHNOLOGY (AJGT)**

ISSN: 2833-8006 (ONLINE)

VOLUME 3 ISSUE 1 (2024)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Forms and Distribution of Phosphorus along A Toposequence at the University of Benin, Nigeria

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Article Information

Received: February 27, 2024

Accepted: March 30, 2024

Published: April 02, 2024

Keywords

Slope Gradient, Soil Variability, Soil Nutrient, Soil Properties, Toposequence

ABSTRACT

The experiment was conducted at University of Benin, Nigeria, involving soil samples from four toposequence sites (Crest, Middle, Lower, and Bottom) at different depths (0-15 cm, 15-30 cm, and 30-45 cm). A total of 36 samples were collected and analyzed for various parameters using standard procedures. The parameters included particle size distribution, pH, total organic carbon (TOC), total nitrogen (N), available phosphorus (P), Carbon (C), Hydrogen (H), Magnesium (Mg), Potassium (K), Sodium (Na), ECEC, and Aluminum (Al). Results indicated that pH was lowest in the Crest area (pH 4.10 at 30-45 cm depth) and highest in the Bottom area (pH 5.80 at 0-15 cm to 30-45 cm depth). Different soil properties showed varying highest values across the toposequence depths. These properties included Total organic C, Total N, Available P, Ca, K, Mg, H, Na, ECEC, sand content, and the various forms of phosphorus. The correlation table revealed significant positive and negative relationships between different forms of phosphorus and various soil physical and chemical properties. The experiment demonstrated distinct variations in soil properties along the toposequence sites and depths. The findings contribute to a better understanding of soil characteristics in the studied region, aiding in informed agricultural practices and land management decisions.

INTRODUCTION

One of the naturally occurring soil forming factors that affect soil properties and controlling soil forming factors that affect soil properties and control soil erosion processes through the redistribution of soil particles and soil organic matter is topography (Ziadat & Taimah, 2013). Slope gradient is one of the important topographic factors that influence the process of drainage; runoff and soil erosion thereby affects physicochemical properties (Farmanullah, 2013). Soil loss would normally be expected to increase with the increase in slope gradient because of the respective increase in velocity of surface runoff and decrease in infiltration rate (Zhang & Hosoyamada, 1996). Soils vary in their characteristics primarily because of topography (Amhakhian & 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). The topography of agricultural fields can influence soil physicochemical properties (soil depth, texture, and mineral contents), biomass production, incoming solar radiation, and precipitation and affect crop production. As increased topography/elevation significantly increased soil moisture, precipitation, soil organic matter and labile carbon, whereas bulk density, pH and soil temperature were significantly lower at the higher elevations (Griffiths *et al.*, 2009).

The scale of soil variation depends on the specific soil characteristic that is being studied. Some soil properties, such as texture, pH, and porosity, are considered to be rather spatially static, while other features such as soil nitrogen N, soil available forms of P and K, and biological properties are highly spatially variable (Piotrowska & Długosz 2012). Soil spatial variability can occur across multiple spatial scales, ranging from the micro level (millimeters) to the plot level (meters) and up to the landscape level (kilometers) (Cobo *et al.*, 2010). The aim of the study was to determine the physical and chemical properties of soils found on Toposequence along University of Benin. The specific objectives were to determine the: physical and chemical properties of the soils and Phosphorus forms and distribution in the soil of the study area.

MATERIALS AND METHODS

This study will be carried out at the Ugbowo campus of The University of Benin, Benin City in Edo state, Nigeria. The area lies between latitude 6°23' 37" and 6°24' 26" North and longitude 5° 36' 25" and 5° 38' 09" East. It is a segment of the coastal plain sand, commonly called acid sand of Nigeria. The natural climate is humid tropics. The natural vegetation is rain forest. The rainy season is bimodal with peak in July and September. Average rainfall is between 1500-2500mm annually. Mean maximum and minimum temperature are 31 and 22°C. The soil has been mapped as ultisol with Rhodicpaleudult as the modal profile (Ogeh and Ogwurike 2006).

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Geography of Study Site

Point 1: latitude 6.398163° and longitude 5.631324°

Point 2: latitude 6.398695° and longitude 5.635270°

Point 3: latitude 6.402185° and longitude 5.635270°

Point 4: latitude 6.404832° and longitude 5.638472°

Sample Collection

Soil samples were collected from toposequence site at capitol in the University of Benin, Benin City, Edo State. Three different sites were selected for each toposequence and samples were collected in each selected site at different depths (0-15 cm, 15-30 cm and 30-45 cm) using an auger. Soil samples from same depth were bulked to make a composite sample. One composite soil sample was then prepared from the three sub samples for each soil depth. The composite soil samples were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties.

Soil Laboratory Analysis

The particle size distribution of the soil was assessed using the hydrometer method by Gee and Or (2002). The clay content was determined after 2 hours using the method described by Ibitoye (2008). The pH level of the air-dried soil was measured using a glass electrode pH meter with a 1:1 ratio, following the procedure outlined by Mclean (1982). Prior to the pH measurement, calibration of the pH meter was performed using buffer pH 4.0 and 9.0. The electrode was immersed in the liquid portion of the mixture to obtain the reading, which was then recorded. Soil organic carbon was determined by the Walkley-Black method procedure by wet oxidation using chromic acid digestion (Nelson & Sommer, 1996). Exchangeable K, Ca Na, and Mg were extracted with a 1 M NH_4OAc , pH 7 solution. Thereafter, K was analyzed with a flame photometer and Ca and Mg were determined with an atomic absorption spectrophotometer (Okelabo *et al.*, 2002). Exchangeable acidity procedures and results were reported in Cmolkg-1 according to the method described by Black (1965). Total N was determined using micro-Kjeldahl digestion and distillation techniques (Bremner, 1996); Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank *et al.*, 1998), Total phosphorus in the soils was determined by perchloric acid digestion and Inorganic P was fractionated by method.

Determination of Phosphorus as Aluminum Phosphate (Al-P)

One gram of air-dried soil (2 mm sieve) was weighed out placed in 250 ml plastic container. 35 ml of 1 N NH_4Cl was added, and the mixture shaken on a mechanical shaker for 30 minutes. To remove water soluble and loosely bound P and exchangeable Ca, the suspension was filtered (Whatman filter paper No. 42) and the filtrate discarded, leaving the soil residues. To the residues in the plastic bottle were added 35 ml of 0.5 N NH_4F , covered tightly and shaken for 1hr on a mechanical

shaker. The mixture was filtered, and the clear filtrates were used for Al-P determination. The soils residues in the plastic bottle were reserved for Fe-P extraction. For Al-P determination, aliquots (10 ml) of the extract were pipetted out into 50 ml volumetric flask and 15 ml boric acid added (0.8 M). Blue colour was developed using 4 ml of reagent B solution and made up to mark with distilled water. Absorbance readings were recorded at 660 nm wavelength using the UV/VIS Unicam spectrophotometer

Phosphorus Determination as Iron Phosphate (Fe-P)

The soil residue saved after Al-P extraction was washed twice with 25 ml saturated NaCl and filtered each time and the filtrate discarded. Thereafter, 35 ml 0.1 N NaOH was added to the plastic bottles, covered tightly and shaken for 17 hours. The suspensions were filtered, and clear extract collected for Fe-P determination. The soil residues in the plastic bottle were reserved for Ca- P extraction. For Fe-P determination, 5 ml aliquot of the clear solution was pipetted into 50 ml volumetric flask, 4 ml of reagent B was added for the blue colour development and made up to mark with distilled water. Absorbance readings were recorded at 660 nm wavelength using a UV/VIS Unicam spectrophotometer.

Phosphorus Determination as Calcium Phosphate (Ca-P)

The soil residues saved after the Fe-P extraction was washed twice with 25 ml saturated NaCl solution (10%), filtered each time and discarded, 35 ml of 0.5 N H_2SO_4 was added to the soil in the plastic bottles, covered tightly and shaken on the mechanical shaker for 1 hour. The suspensions were filtered, and clear solution obtained. 30 ml aliquot of the clear solution was pipetted into 50 ml of volumetric flask, 4 ml of the reagent B was added for colour development, and the volume made up to mark with distilled water. Absorbance readings were recorded at 660 nm wavelength using a UV/VIS Unicam spectrophotometer.

Determination of Total Phosphorus and Occluded Phosphorus

One gram of finely ground (0.5 mm scene) soil was weighed out each into 250 ml conical flasks and 25 ml of HNO_3 , 4 ml of perchloric acid and 2 ml of H_2SO_4 added respectively and mixed thoroughly. It was digested on a heater inside a fume cupboard until the colour due to organic matter disappeared. Then additional 20 minutes heating was allowed to dry completely. At this stage heavily white fumes due to HNO_3 , HClO_4 and H_2SO_4 appeared, and the insoluble materials looked like white sand. The flask was shaken occasionally during digestion. The digest was allowed to cool, and 70 ml of distilled water was added to the digest and heated to warm. The suspension was filtered into 250 ml volumetric flask and made up to mark with distilled water. Then, 10 ml aliquot was pipetted into 50 ml volumetric flask, 4 ml of the

reagent B was added and made up to mark with distilled water. The absorbance reading was recorded at 660 nm wavelength using a UV/VIS Unicam spectro-colorimeter. The occluded phosphorus (inactive P) was calculated as the difference between the total phosphorus and the active phosphorus (Al-P, Fe-P, Ca-P).

Statistical Analysis

Plant parameters measured were subjected to analysis of Variance (ANOVA) using GENSTAT 8th Edition while Duncan's New Multiple Range Test was used to separate the means at 5% level of probability.

RESULTS AND DISCUSSION

Effect of Toposequence on Soil Properties

Table 1 displays the physical and chemical properties of soil across different toposequence depths at the University of Benin, Benin City. The pH values were acidic in all Crest depths (0-15 cm: 4.60, 15-30 cm: 4.90, 30-45 cm: 4.10) and Middle depths, remaining consistently acidic. Lower depths showed a strong acidic trend (pH 5.5 to

5.0), while Bottom depths were moderately acidic (pH 5.80). Total nitrogen (N) varied with depths, ranging from low (Crest 0-15 cm: 1.0) to moderately low (Crest 30-45 cm: 1.30). Bottom 30-45 cm had the highest N (1.95 g/kg), and Lower 30-45 cm had the lowest (0.90 g/kg). Total organic carbon (C) increased with soil depths across all toposequence. Crest 30-45 cm had the highest C (17.00 g/kg - High), while Middle 30-45 cm had the lowest (7.10 g/kg - moderate), and the findings align with Chude *et al.*, (2011).

Cation exchange capacity (CEC) varied among toposequence and decreased with depth. Middle had the highest CEC values at various depths (11.04 cmolkg⁻¹, 11.56 cmolkg⁻¹), indicative of soil productivity and useful for phosphorus, potassium, and magnesium recommendations. High CEC values relate to organic matter and clay content, offering more negative electrostatic sites for positive cation attraction. These results support Vogelmann *et al.* (2010) findings on CEC correlation with organic matter and pH levels.

Table 1: Physical and Chemical Properties of Soils under various Toposequence

Toposeq.	Depth (cm)	pH	TOC	T.N	PO ₄	H	Al	K	Ca	Na	Mg	ECEC	Sand	Silt	Clay	TC
			→ g/kg ←		mg/kg		→ cmol/kg ←						→ g/kg ←			
Crest	0-15	4.60	15.40	1.9	3.91	0.50	0.00	0.08	0.96	0.10	0.65	2.29	677.20	80.00	242.80	SL
	15-30	4.90	9.50	1.1	1.35	0.60	0.00	0.21	0.80	0.10	0.65	2.36	801.20	20.00	178.80	SL
	30-45	4.10	17.00	1.95	2.38	0.40	0.00	0.04	0.64	0.10	0.97	2.15	791.20	20.00	188.80	SL
Middle	0-15	4.60	11.20	1.15	7.67	0.50	0.00	0.19	0.96	0.10	0.97	2.72	877.20	30.00	92.80	SCL
	15-30	4.30	9.00	1.08	2.61	0.50	0.00	0.04	0.96	0.10	0.97	2.57	797.20	50.00	152.80	SCL
	30-45	4.40	7.10	0.9	6.61	0.40	0.00	0.14	0.80	0.09	0.97	2.4	737.20	30.00	232.80	SCL
Lower	0-15	5.50	11.80	1.2	42.35	0.40	0.00	0.10	8.50	0.10	1.94	11.04	768.20	25.00	206.80	SCL
	15-30	5.20	11.00	1.11	21.23	0.40	0.00	0.14	9.30	0.10	1.62	11.56	758.20	75.00	166.80	SL
	30-45	5.00	12.80	1.3	19.94	0.50	0.00	0.10	5.61	0.10	0.65	6.96	778.20	69.00	152.80	SL
Bottom	0-15	5.80	8.80	1	9.25	0.40	0.00	0.15	5.29	0.12	0.65	6.61	668.20	55.00	276.80	SL
	15-30	5.80	11.80	1.2	6.06	0.30	0.00	0.21	6.09	0.09	0.97	7.66	648.20	35.00	316.80	LS
	30-45	5.80	11.80	1.2	6.06	0.30	0.00	0.21	6.09	0.09	0.97	7.66	648.20	35.00	316.80	LS

	30-45	5.80	10.60	1.16	5.11	0.40	0.00	0.16	4.33	0.11	0.97	5.97	668.20	55.00	276.80	SL
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Where: TC = Textural Class, SL = Sandy loam, SCL = Sandy clay loam, LS = Loamy sand

Table 1 further presents the results of soil separates from different toposequence locations. All land use types predominantly exhibited sandy texture (sand fraction: 877.20-801.20 g/kg, silt fraction: 80-20 g/kg, clay fraction: 318.80-92.80 g/kg). Sand content increased with depth, while clay content decreased. Soil texture remained similar across toposequence, as it is not significantly influenced by soil management or toposequence variation (Oyedele *et al.*, 2009). Hydrogen (H) content ranged from 0.30-0.60 cmol/kg across the toposequence. The highest H value (0.60 cmol/kg) was at Crest, depth 15-30 cm, while the lowest (0.30 cmol/kg) was at Bottom, depth 15-30 cm. Hydrogen content was relatively consistent throughout the toposequence. Aluminium (Al) was

not detected at any toposequence depth, indicating its absence throughout the area.

Available phosphorus content varied across toposequence. Bottom had moderate (9.25 mg/kg), low (6.06 mg/kg), and low (5.11 mg/kg) P content. Lower had high (42.35 mg/kg) and moderate (19.94 mg/kg) P content at 30-45 cm depth; Middle had low P content (7.61 mg/kg, 2.61 mg/kg, and 6.61 mg/kg). Crest exhibited low P content (3.91 mg/kg) at 0-15 cm depth and very low P content (1.35 mg/kg, 2.38 mg/kg) at other depths (Chude *et al.*, 2011). Higher phosphorus content in Lower may be due to its higher organic matter content, while lower phosphorus content in other areas could be attributed to fixation, abundant crop harvest, and erosion impacts (Yeshanch, 2015).

Table 2: Phosphorus availability on different toposequence site

Slope	Depth (cm)	Ca-P	Al-P	Fe-P	Occluded-P	Total-P
	→ (mg/kg) ←					
Crest	0-15	4.73	29.51	15.19	81.41	96.59
	15-30	3.73	34.52	16.90	81.74	98.64
	30-45	2.58	43.26	15.33	110.74	126.06
Middle	0-15	1.43	74.49	122.63	411.92	534.55
	15-30	6.02	33.95	63.32	17.72	81.04
	30-45	5.44	33.95	34.95	50.18	85.13
Lower	0-15	7.74	20.63	12.18	150.32	162.49
	15-30	7.16	16.62	7.88	151.75	159.63
	30-45	3.44	15.04	8.02	118.45	126.47
Bottom	0-15	7.45	73.20	8.45	307.94	316.39
	15-30	6.45	16.90	9.17	170.92	180.09
	30-45	2.44	9.88	12.61	96.68	109.28

Total Phosphorus

As shown in Table 2, the total P content in all the profiles varied from 81.04 to 534.55µg g⁻¹ with a mean of 173.03µg g⁻¹. These values are comparable to the values reported by Adeleye and Omueti (2006) for some soils derived from basement complex parent material. Total P was generally highest in the lower slope and lowest at upper slope. Also, total P was highest in the topsoil of crest apart from that of depth (30-45). This trend could be due to accumulation of litters on the topsoil as also suggested by Osodeke and Osondu (2006).

Ca –P varied from 9.88 to 74µg g⁻¹ with a mean of 33.5µg g⁻¹, Al – P varied from 1.43 to 7.74µg g⁻¹ with a mean of 4.88µg g⁻¹, Fe – P varied from 7.88 to 122.63µg g⁻¹ with a mean value of 27.4µg g⁻¹, Occluded – P varied from 17.72 to 411.92µg g⁻¹ with a mean value of 145.8µg g⁻¹. Ca – P had the least value among the active P forms while the Occluded – P had the highest value. This could probably

be due to the acidity nature of the soils and the fact that it is the most soluble of the inorganic forms and tends to revert to the less soluble iron and aluminium phosphate in acid soils as suggested by Aghimien *et al.* (1988). Al – P is the least soluble of the inorganic P fraction and tends to accumulate at the expense of the more soluble Al – P and Ca P and this accounted for the relatively higher content of iron phosphate in the acidic soils (Agbimien *et al.*, 1988).

Mokwunye and Bationo (2002) also reported that the main sources of plant available P in soils are generally accepted as active P form rather than inactive P form. And secondary Phosphate as Al-P, Fe – P and Ca – P increase in content with strengthening of weathering and pedogenesis in the soil. Lambers *et al.* (2008) suggested that relationship exist between P content and forms in soils and stages of soil development. All soil P is in the primary mineral form (mainly Al- P and Ca – P mineral)

at the beginning of soil development. With time, these inorganic P weather giving rise to P in various other forms mainly organic P (reservoir) occluded P and available P.

Correlation Matrix

Correlation coefficient for Crest

Table 3 shows the correlation coefficient (r) between forms of P (Al-P, Ca-P, Fe-P, Occluded-P and Total-P) with some soil of physical and chemical properties of

toposequence at crest. Iron forms of P were positively and significantly correlated with Clay (r=0.997), K (r=0.997) at (P<0.05) but negatively and significantly correlated with Sand and Silt (r=0.997), (r=0.997) at (P<0.05). Total form of P were negatively and significantly correlated with pH (r=0.998) at (P<0.05) having other forms of P (Al-P, Ca-P, Fe-P and Occluded-P) not positively nor negatively significantly correlated with some soil of physical and chemical properties of toposequence at the Crest Level.

Table 3: Crest Correlation Coefficient

CREST	AL-P	Ca-P	Fe-P	Occluded-P	Total-P
Av. P	-0.897	-0.993	-0.368	-0.685	-0.722
Ca	-0.668	0.578	0.796	-0.887	-0.861
Clay	-0.155	0.040	0.997*	-0.491	-0.445
EC	-0.995	0.977	0.182	-0.967	-0.979
ECEC	-0.514	0.412	0.897	-0.782	-0.748
H	0.155	-0.040	-0.997	0.491	0.445
K	0.001	-0.116	0.997*	-0.350	-0.300
Mg	0.778	-0.845	0.562	0.508	0.533
Na	-0.177	0.289	-0.966	0.179	0.127
O.M	0.464	-0.563	0.845	0.124	0.176
Sand	0.155	-0.040	-0.997*	0.491	0.445
Silt	0.155	-0.040	-0.997*	0.491	0.445
Total N	0.646	-0.913	-0.378	0.337	0.386
pH	-0.933	0.885	0.435	-1.000	-0.998*

Correlation Coefficient for Middle

Table 4 shows the correlation coefficient (r) between forms of P (Al-P, Ca-P, Fe-P, Occluded-P and Total-P) with some soil of physical and chemical properties of toposequence at middle. Al-P and Total-P were positively and significantly correlated with Available P (r=0.999) and

(r=0.998) at (P<0.05) respectively; Ca-P and Occluded-P were positively and significantly correlated with Silt (r=1.000) and (r=0.999) at (P<0.05) respectively, but Fe-P were not positively nor negatively and significantly correlated with some physical and chemical properties of toposequence at Middle.

Table 4: Middle Correlation Coefficient

Middle	AL-P	Ca-P	Fe-P	Occluded-P	Total-P
Av. P	0.999*	-0.986	0.963	0.992	0.998*
Ca	0.311	-0.198	0.596	0.239	0.303
Clay	0.918	-0.958	0.744	0.945	0.921
EC	-0.987	0.999	-0.885	-0.996	-0.998
ECEC	0.408	-0.299	0.676	0.339	0.401
H	-0.500	0.396	-0.749	-0.434	-0.493
K	-0.500	0.597	-0.200	-0.563	-0.507
Mg	0.692	-0.603	0.885	0.636	0.686
Na	-0.500	0.597	-0.200	-0.563	-0.507
O.M	-0.063	-0.053	0.376	0.011	-0.055
Sand	_____	-0.116	-0.317	0.074	0.008
Silt	-0.994	1.000*	-0.908	0.999*	-0.995
Total N	-0.030	-0.686	-0.346	0.044	-0.023
pH	0.918	0.865	0.996	0.998	0.915

Correlation Coefficient for Lower

Table 5 shows the correlation coefficient (r) between forms of P (Al-P, Ca-P, Fe-P, Occluded-P and Total-P) with some soil of physical and chemical properties of toposequence at lower. Ca-P were negatively and significantly correlated with Total N (r = -0.986) at (P < 0.05), Fe-P were positively and significantly correlated with Mg (r = 1.000) at (P < 0.05).

Occluded-P were positively and significantly correlated with H and Na (r = 0.999), (r = 0.999) at (P < 0.05) respectively. Total-P were positively and significantly correlated with Ca and H (r = 0.997), (r = 0.997) at (P < 0.05) respectively while Al-P were not positively nor negatively correlated with some soil of physical and chemical properties of toposequence at lower.

Table 5: Lower Correlation Coefficient

Lower	AL-P	Ca-P	Fe-P	Occluded-P	Total-P
Av. P	0.431	-0.198	0.683	0.354	-0.250
Ca	0.718	0.992	0.475	0.999	0.997*
Clay	-0.947	-0.950	-0.805	-0.887	-0.932
EC	0.936	0.536	0.999	0.392	0.491
ECEC	0.961	0.935	0.832	0.865	0.915
H	0.718	0.992	0.475	0.999*	0.997*
K	0.547	-0.065	0.774	-0.226	-0.118
Mg	0.962	0.604	1.000*	0.467	0.561
Na	0.718	0.992	0.475	0.999*	0.997
O.M	0.979	0.904	0.872	0.824	0.881
Sand	0.987	0.886	0.892	0.800	0.861
Silt	-0.243	0.388	-0.525	0.533	0.437
Total N	0.880	-0.986*	0.696	0.951	0.979
pH	0.991	0.871	0.906	0.994	0.843

Correlation Coefficient for Bottom

Table 6 show Occluded-P and Total P were positively and significantly correlated with EC (r = 0.998), (r = 0.999) at (P < 0.05) respectively, while Al-P, Ca-P and Fe-P were

not positively nor negatively and significantly correlated with some soil of physical and chemical properties of toposequence at bottom.

Table 6: Bottom Correlation Coefficient

Bottom	AL-P	Ca-P	Fe-P	Occluded-P	Total-P
Av. P	0.871	0.297	-0.271	0.721	0.729
Ca	0.912	0.945	-0.936	0.986	0.984
Clay	0.971	0.542	-0.519	0.880	0.885
EC	0.981	0.847	-0.832	0.998*	0.999*
ECEC	0.287	0.866	-0.879	0.517	0.508
H	0.101	0.756	-0.774	0.346	0.336
K	-0.194	0.532	-0.555	0.657	0.046
Mg	-0.585	-0.982	0.987	-0.769	-0.762
Na	0.995	0.654	-0.634	0.938	0.942
O.M	0.217	-0.512	0.535	-0.034	-0.023
Sand	-0.985	-0.598	0.576	-0.910	-0.915
Silt	0.585	0.982	-0.987	0.769	0.762
Total N	0.361	-0.377	0.402	0.117	1.000
pH	0.996	0.785	-0.768	0.987	0.988

DISCUSSION

The study shows a very low positivity, negativity and significantly correlated with soil properties and that can be traceable to; Phosphorus been a major limiting factor

in the growth and function of many forest, because P is a mineral nutrient derived from the weathering of rocks and drift where it deficiencies tend to become more acute as landscapes and soils age due to progressive

leaching and sequestration (Vitousek, 2004). P deficiency is particularly widespread in rain-fed upland farming systems throughout the tropics and remains a major plant nutrient constraint. It is also attributed to some combination of soil parent material, soil age, topography, climate, and biological activity, high weathering intensity and loss by soil erosion (Fairhurst *et al.*, 1999). Paulos (1996) indicated that the concentrations of active P forms were related to the degree of chemical weathering. Hence, all the forms of P can exist in all soils, but P bound by Al and Fe is abundant in highly weathered acidic soils and such is the case of the study area.

CONCLUSION

Phosphorus is an essential nutrient that is utilized for energy transport and growth by all organisms, where it is involved in many critical biological processes, such as energy metabolism, the synthesis of nucleic acid, and photosynthesis, and is highly needed in this study location as to help increase its availability for plant growth and metabolism.

Acknowledgment

The work is that of Bachelor of Agriculture project registered at the Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin, Nigeria. Special thanks to Dr. Mrs. Anthonia Bakare for guidance.

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