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Effect of Topography on Phosphorus Forms and Distribution in Soils Formed in Mica Schist in Ife Area

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Abstract

This study was conducted to examine the effect of topography on phosphorus forms and distribution in soils formed in mica schist in southwestern Nigeria. The toposequence was delineated into different physiographic units and soil profiles were established, described and sampled at each of the units. Soil samples collected were subjected to routine analyses along with total-P, organic and available P forms. The active forms of P (Al-P, Fe-P, Ca-P and Occl-P) were determined by fractionation. Result showed that the available P was less that the critical level (10ppm P) set for soils of the humid tropics, and it decreased down the slope. The organic P ranged from 50 – 232.50 ppm (19 to 29 % of the total P) in the surface soil horizons and decreased with soil depth. It was highest at the upper slope and lowest at the valley bottom for the A-horizon. The relative abundance of other inorganic P forms was in the order of Fe – P > Al-P > Ca –P> Occl-P, with Fe-P varying from 137.2 to 224.2 ppm while Al-P ranged from 91.6 to149.5 ppm. Total P ranged from 763.1 to 418.7 ppm and was highest at the upper slope and lowest at the middle slope. The distribution of total P within the soil profiles was rather uniform for all the soils. The various forms of P decreased down the slope for the A-horizon while P forms in the B and C horizons were irregularly distributed. The soils of Egbeda, Olorunda and Oba series were classified as Typic Paleustult, Jago as Aquic Ustipsamment (USDA Soil Taxonomy) and as Lixisol and Fluvisol (FAO/UNESCO) respectively. In conclusion, P forms and within the profiles distribution varied with different topographic units. Due to this variability, P fertilizer recommendation would need to be made with due consideration to the physiographic units.

Keywords: Topography, Phosphorus, Mica schist, Soils,

Introduction

Topography is both an internal and external factor in pedogenesis that influences soil formation (Temgoua *et al*., 2005). It relates to the configuration of the land surface and is described in terms of differences in elevation, slope and landscape position. Differences in soil formation along a hill slope result in differences in soil properties (Brubaker *et al.,* 1993) which affect the pattern of plant and litter production, and decomposition (Wang *et al.,* 2001). Whereas organic matter (OM) varies with landscape position (Bhatti *et al*., 1991), C and N Processes affecting carbon (C) and N (N) transformation in the soil also affect the soil organic matter (Hobbie, 1996). In addition to the (SOM) which varies with landscape, landscape influences soil texture, penetration resistance (Bruand *et al.,* 2004) root development (Busscher *et al*., 2001) exchangeable basic and acidic cations (Stutten *et al.,* 2004), soil exchange chemistry (Clien *et al*., 1997), and nutrient budget (Mallarino 1996). Hence, the landscape is important in fertilizer management (Paz-gonzalez *et al*., 2000).

Phosphorus (P) is one of the major plant nutrients elements second in importance to nitrogen (N) in terms of nutrient requirements for increased crop production in most tropical soils. The quantity and relative distribution of various forms of P are of great importance to soil genesis and fertility studies. Kleinman *et al*. (1999) noted that the distribution of P was closely related to the pedogenetic evolution of soils with the matured soil having low P status. They observed that the distribution of the active fractions namely, Al-P, Fe-P, and Ca-P and their abundance in soil are dependent on pH, the solubility product of the different phosphate, parent materials, the cations present and the degree of weathering. In many tropical soils, the oxides, hydroxides and oxyhydroxides of Al and Fe and low activity clays (LAC) are the components that predominantly influence P availability (Borggard, 1983). There is paucity of information as regards P status of soils underlain in mica schist in Ife Area. Hence, the objective of this study was to have a better understanding of the P forms and distribution in soils formed in mica schist along a toposequence in Ife Area.

Materials and Methods

The study was conducted at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. It is a region within the southwestern part of Nigeria, which lies approximately between latitudes 7°32′ N and 7°33′ N and longitudes 4°32′ E and 4°40′ E. The toposequence ranged from 265 m to 296 m above mean sea level. The climate of the area is characterized by bimodal rainfall regime with precipitation of over 1400 mm per annum, high temperature and relative humidity. The vegetation of the area is tropical rain forest consisting mainly of cocoa, oil palm, and cocoyam. The toposequence was delineated into four topographic units (upper slope, middle slope, lower slope and valley bottom). Profile pits were established, described and sampled with one at each slope segment following the guideline for soil profile description according to FAO/UNESCO (2006) guideline. Soil samples were collected from profile pits in each of the topographic units.

Laboratory Analysis

The soil samples collected were air-dried, sieved through 2 mm sieve and used for the study. The particle size was analyzed using the hydrometer method of Bouyoucos (1962). Soil organic matter was determined using the Walkley-Black (1934) method as reviewed by Allison (1965). Soil pH was determined in 1:1 soil: water suspension using a glass electrode pH meter. Exchangeable cations of the soils were extracted with neutral ammonium acetate solution. The concentrations of Ca, Na and K concentrations were determined using a flame photometer while Mg was determined using titration method. Exchangeable aluminium and hydrogen were determined with buffered potassium chloride. The effective cation exchange capacity (ECEC) was determined by summation of exchangeable bases and exchangeable acidity (Tropical Soil Biology and Fertility, 1993).

Available P was extracted using the Bray and Kurtz (1954) method. Total P was determined after sodium carbonate fusion as described by Jackson (1958), Shenrell and Saunders (1966) and organic P was estimated by the difference between 13 M Hcl-extractable P, before and after ignition (Saunders and Williams 1955; Walker and Adams, 1958). Inorganic P was fractionated using the method of Williams *et al.* 1980. Phosphorus in the extracts was determined colorimetrically (Murphy and Riley, 1962). The relationships between forms of P and some of the soil properties were established using correlation method

Results and Discussion

Morphological and Physical Properties of the Soils

The results showed that the soils at the upper slope down to the lower slope were dark reddish brown (5YR 4/2) to yellowish red (5YR 4/8) in the surface horizon and grayish brown (10YR 4/2) in the valley bottom. Texturally, the soils were loamy sand to sandy clay in the Ap horizons, while the subsoil horizons were clay, sandy clay loam and sandy clay for Egbeda, Olorunda and Oba series respectively. Soils of the Jago series were loamy sand. The sand content of the soils ranged from 36 to 85%. The highest sand content was found in the surface horizons of all the profiles, with the highest recorded at the valley bottom

(Jago series). This could be as a result of deposition of alluvial sediments in the valley floor (Esu *et al.*, 2008).

The contents of silt in the soils were comparatively lower than those of the sand fraction. There was no consistent pattern of distribution of silt in all the profiles. The values ranged between 5 to 17 %. The low silt content of the soils irrespective of their location is in line with the reports of several researchers who worked in similar environment in the Basement Complex area of southwest Nigeria (Okusami and Oyediran, 1985).

The clay content varied from 1 to 31% in the surface horizons and from 39 to 52 % in the subsurface horizons. The lower clay content in the surface horizons could be attributed to the sorting of soil materials by biological and agricultural activities, clay migration or surface erosion by run-off or a combination of these (Malgwi *et al.*, 2000). The soils of Jago series did not show any appreciable increase in clay content with depth.

Chemical Properties of the Soils

The chemical data of the soils are presented in Table 2. The soils were acidic with pH range of 4.2 to 5.8 in water and 3.8 to 5.4 in 1 M KCl. The surface horizons of the soils are slightly acidic in reaction while the sub-soils are acidic to slightly acidic in reaction. In the surface horizons, the pH ranged from 4.7 to 5.8 and from 4.2 to 5.4 in water and 1 M KCl solution, respectively. This could be as a result of high rainfall in the area which made the soils fragile and susceptible to erosion and leaching (Udo *et al.,* 2009).

The content of cations followed the order: Ca> Mg >K >Na at the exchangeable site. The low values of exchangeable bases of the soils may be attributed to high rainfall intensity, intensity of weathering, leaching and lateral translocation of bases (Solarin, 2000). The results showed that ECEC ranged between 5.40 and 8.90 cmol/kg, indicating that the ECEC values of the soils were low. The values were within the range of values reported for Nigeria soils (Fasina, 2001).

Forms and Distribution of P in the soils

Available P

From Table 3, it could be observed that available P varied from 2.0 to 10.6 ppm in all the horizons in the profiles with the highest values at the surface soil horizons, an indication that SOM contributes significantly to the available P in these soils. The AP values were all considered low as they were below or only slightly above the 10 ppm critical limit recommended for most commonly cultivated crops in the area (Uponi and Adeoye, 2000). The low value of available P might be due to the fixation of P by iron and aluminum sesquioxides under well-drained and acidic conditions of the soils (Uzoho and Oti, 2004). The average values obtained showed that the concentration of available P decreased irregularly down the slope for the A-horizons while its distribution in the B and C horizons did not indicate any particular trend. Furthermore, the available P was highest in the upper slope and lowest in the mid slope areas for the topsoil (Fig 1a). However, in the sub-soils, available P was highest in the valley bottom. This trend could be due to the deposition of P through runoff in the valley bottom soils of the toposequence (Fig 1b).

Organic P

The results showed that organic P decreased with profile depth with high concentration at the Ap (Table 3) horizons. The organic P in the soil profiles ranged from 50 to 232.50 ppm. These values were slightly above the values reported for most of the soil horizon (173 ppm) by Adepetu and Corey (1976) for southwestern, Nigeria soils and 190.25 ppm obtained by Enwezor and Moore (1966) for some soils at Ibadan. Organic P constituted between 19 and 29% of the total P in the surface horizons which suggests an important role for this fraction in crop nutrition. The organic P values at the surface horizon conformed to the findings of Omotoso and Wild (1970) who stated that organic P constitutes a significant, 20 – 70% of the total P in the plough layer of southwestern Nigeria soils. In general, organic P decreased with depth and down the slope for A and B horizons (Fig 1a) in most of the soils except in Jago series where the values increased with depth. This could be attributed to SOM (Smeck, 1973) and to landscape movement of soil Phosphorus. Organic P had a positive significant correlation with organic carbon (r = 0.91**) as also reported by several workers (Heakal *et al.*, 1995).

Inorganic P fractions

The irregular distributions of various forms of inorganic P in the soils studied are shown in Fig 1a and b. The main sources of plant available P in soils are generally accepted as active P forms (Mokwunye and Batino, 2002). The content of Al-P was low ranging from 91.6 to 149.5 ppm and decreased with the profile depth for soils of Egbeda, Olorunda and Oba series (Table 3). Egbeda had the highest value for Al-P at surface horizon, whereas soils of Jago series had the highest value at both the B and C horizons. However, the values increased with depth in the soils of Jago series. This could be attributed to poor drainage and un-weathered nature of the soil. The Fe-P content varied from 137.2 to 224.2 ppm. The value also decreased with depth for profiles Egbeda, Olorunda. The value decreased down the slope for A-horizon while the value increased down the slope for B and C horizons. Occluded P ranged from 50.8 to 83.0 ppm and it was the least available form of P. It contributed very little to the total P. Results showed that the value was highest at the upper slope and lowest at the valley bottom for A-horizon. All the soil series showed a similar pattern for inorganic P, the values for all the forms of inorganic P decreased with depth in all the profiles. The relative abundance of the inorganic P fraction in all the soil series was in the order of Fe-P > Al-P > Occl-P > Ca-P. This is in line with the findings of Adepetu and Corey (1976) and Enwezor and Moore (1966) who reported that most of the inorganic P (native and applied) is found associated with Fe and Al minerals.

Total P

The total P content of the soils ranged from 763.1 to 418.7 ppm with the Ap horizon having the highest content. The values decreased down the profiles in the matured soils of Egbeda and Olorunda whereas, the values increased down the soil profile in the soils of Jago series. The results presented in Table 3 and Fig 1c showed that the values for coarser sand of Jago increased with depth and this agreed with the findings of Day *et al.* (1987) who stated that total P content in soils seemed to be directly associated with the amount of clay in each topographic position.

The total P contents of the soils were generally high when compared to the values of 217 to 638 ppm reported by Uzu *et al.*, (1975) in the basement complex and (191 to 243 ppm) in the sedimentary rock soils for temperate and tropical acid soils of southwest Nigeria (Loganathan and Sutton, 1987). These values are, however, much lower than values reported by Agbenin and Tiessen (1994) for Lithosols and Cambisols from the semi-arid northeastern Brazil.

Relationship Between the Soils' Physico-Chemical Properties And Phosphorus Forms

Results from the correlation analyses (Table 4) showed that the clay content of the soils had positive and significant relationship with TEB (r = 0.65**) indicating that the higher the clay content, the higher the TEB. This also confirmed the findings of Amusan (1991) who reported that clay content had been shown to be positively correlated (r= 0.99) with the exchangeable bases. The clay content was however negatively correlated with TEA (r = -0.76**) showing a decrease in TEA with increasing clay content. The contributions of clay to CEC in these soils were low. This probably indicates that the clay fraction of the soil is dominated by the LACs or was masked by the sesquioxides. The TEB was negatively correlated with TEA and positively correlated with ECEC (r = -0.58* and 0.95** respectively). Correlation analysis also showed that the SOM was significantly correlated with soil OP, AP and TP (r = 0.91**, 0.50* and 0.73** respectively) (Table 4). Agboola and Oko (1976) recorded a correlation of 0.74 between SOM and organic P for western Nigeria soils. They also noticed that organic P constituted 57% of the total P in savanna soils of Nigeria. This implies that SOM influences the level of organic P in the soils. There is a significant correlation between the organic P and available P, organic P and Al-P, organic P and Fe-P, organic and Ca-P, an indication that organic P contributes significantly to the available P in these soils (r = 0.65**, 0.51*, 0.50*, 0.54*) respectively (Table 4).

Conclusion

In conclusion, P forms and distribution vary with different topographic units. Inspite of this variability, P fertilizer recommendation are often made to farmers without due consideration for the topographic position for optimum yield. This study, therefore, provides evidence for the need to adopt different P fertilizer recommendations at the different topographic positions. Furthermore, SOM is found to influence the concentration of available P in the soils. Hence, the soils should be protected against erosion along the toposequence for effective fertility management with regards to P fertilizer management.

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Table 1: Some Physical Properties of the Soils

Horizon	Depth (cm)	Particle size distribution Sand	Silt (%)	Clay	Textural class ratio	Silt/Clay	Colour Moist
		Upper slope (Egbeda series)					
Ap	0-18	75	5	20	SC	0.25	5YR ¾
Bt_1	18-56	39	11	50	C	0.22	7.5YR 4/4
Bt_2	56-110	36	12	52	C	0.23	5YR 4/8
B	110-144	41	11	48	C	0.23	5YR 5/6
BC	144-186	44	10	46	C	0.22	5YR 4/8
		Mid slope (Olorunda series)					
Ap	0-13	63	6	31	S CL	0.20	7.5YR 4/2
Bt_1	13-25	49	9	42	S C	0.20	7.5YR 4/4
Bt_2	25-49	42	11	47	C	0.23	5YR 5/8
BC	49-116	43	11	46	C	0.24	5YR 4/8
		Lower slope (Oba series)					
Ap	0-20	64	7	29	SCL	0.24	7.5YR 3/2
AB	20-63	50	9	41	SC	0.20	5YR 4/6
B2	63-106	50	10	40	SC	0.25	5YR 4/8
2B	106-162	52	9	39	SCL	0.23	5YR 4/8
		Valley bottom (Jago series)					
Ap	0-8	82	17	1	LS	17.0	10YR 5/6
AB	8-19	83	15	2	LS	7.50	10YR 5/6
BC_g	19-25	85	13	2	LS	13.0	10YR 4/3

SC= Sandy Clay, SL= Sandy Loam, SCL=Sandy Clay Loam, L= Loamy, LS= Loamy Sand, C=Clay, CL= Clay Loam

Table 2: Chemical Properties of the Soils

Horizon	Depth (cm)	pH (H_2O) 1:1	pH (KCl) 1:1	△ pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	TEA	H^+	Al^{3+}	TEB	ECEC	OM (%)
					Exchangeable Bases									
					←				Cmol(+)/Kg →					
Upper slope (Egbeda series)														
Ap	0-18	5.8	5.4	-0.4	0.1	0.3	4.7	2.6	1.4	1.1	0.3	5.2	6.6	2.9
AB	18-56	5.5	5.1	-0.4	0.2	0.4	6.9	2.9	0.9	0.6	0.3	7.6	8.4	2.8
Bt	56-110	5.5	5.4	-0.2	0.2	0.1	6.7	1.7	1.0	0.7	0.3	7.1	8.1	2.3
Bt_2	110-144	5.6	5.4	-0.3	0.2	0.2	5.3	2.6	0.6	0.3	0.3	5.7	6.3	2.2
BC	144-186	5.5	5.1	-0.4	0.2	0.2	5.5	2.3	0.8	0.6	0.2	6.1	6.9	2.1
Mid slope (Olorunda series)														
Ap	0-13	5.7	5.1	-0.6	0.2	0.3	6.2	2.0	1.0	0.8	0.2	7.0	8.0	2.0
AB	13-25	5.3	4.7	-0.6	0.2	0.4	6.0	2.3	0.9	0.7	0.2	6.8	7.6	2.3
Bt	25-49	5.1	4.9	-0.3	0.2	0.3	5.0	2.3	0.6	0.3	0.3	5.6	6.2	1.5
BC	49-116	5.2	5.1	-0.1	0.2	0.4	6.5	2.3	0.8	0.5	0.3	7.2	7.9	1.3
Lower slope (Oba series)														
Ap	0-20	4.7	4.2	-0.5	0.2	0.4	5.4	3.5	0.7	0.4	0.3	6.2	6.9	2.3
AB	20-63	4.7	4.5	-0.2	0.2	0.3	7.6	5.2	0.6	0.3	0.3	8.3	8.9	2.4
B2	63-106	4.8	4.7	-0.1	0.2	0.3	5.0	2.9	0.5	0.2	0.3	5.6	6.2	1.7
2B	106-162	4.2	3.8	-0.4	0.2	0.1	4.1	2.0	1.1	0.7	0.4	4.5	5.6	2.0
Valley bottom (Jago series)														
Ap	0-8	5.4	5.2	-0.2	0.2	0.2	3.8	1.8	2.0	1.6	0.4	4.2	6.2	2.0
AB	8-19	5.5	5.2	-0.3	0.2	0.1	5.0	1.7	1.4	1.0	0.4	5.4	6.8	1.5
BC_g	19-25	5.5	5.0	-0.5	0.1	0.1	3.8	2.4	1.2	0.9	0.3	4.2	5.4	2.3

OC = Organic Carbon; TEB = Sum of Exchangeable Bases; TEA = Total Exchangeable Acidity; ECEC = Effective Cation Exchange Capacity

Table 4: Profile forms and distribution of P in the soils

Horizon	Depth (cm)	AP	OP	Al-P	Fe-P	Ca-P	Occ-P	TP
		←			(ppm)			→
				Upper slope (Egbeda series)				
Ap	0-18	10.6	232.5	149.5	224.2	58.1	83.0	763.1
AB	18-56	3.7	187.5	120.5	180.8	46.9	67.0	608.4
Bt_1	56-110	3.0	123.4	123.5	185.3	48.0	68.6	553.9
Bt_2	110-144	2.0	97.8	91.6	137.2	35.6	52.9	418.7
BC	144-186	2.0	75.0	106.1	159.1	41.3	56.9	442.3
				Mid slope (Olorunda series)				
Ap	0-13	6.3	106.7	139.8	209.7	54.4	75.8	595.0
AB	13-25	7.7	127.5	130.2	195.2	50.6	74.1	587.5
Bt_1	25-49	3.2	80.9	115.7	173.6	45.0	60.3	480.7
BC	49-116	2.6	68.7	104.6	156.9	40.7	59.0	434.2
				Lower slope (Oba series)				
Ap	0-20	8.7	157.9	144.6	217.0	56.3	78.5	665.4
AB	20-63	10.2	178.4	125.4	188.0	48.8	58.9	611.8
B2	63-106	5.8	67.3	125.4	185.3	40.7	60.2	483.5
2B	106-162	7.0	105.0	120.5	180.8	46.9	55.7	517.9
				Valley bottom (Jago series)				
Ap	0-8	6.7	96.0	121.5	178.8	49.2	50.8	506.0
AB	8-19	3.9	50.0	132.5	202.5	52.5	77.3	523.6
BC_g	19-25	7.9	134.7	135.0	191.5	55.5	80.0	607.4

AP = available P; OP = Organic P; SP = Soluble P; AlP = Aluminum P; Fe-P = Iron P; Ca-P = Calcium P; Occ-P = Occluded P; TP = Total P;

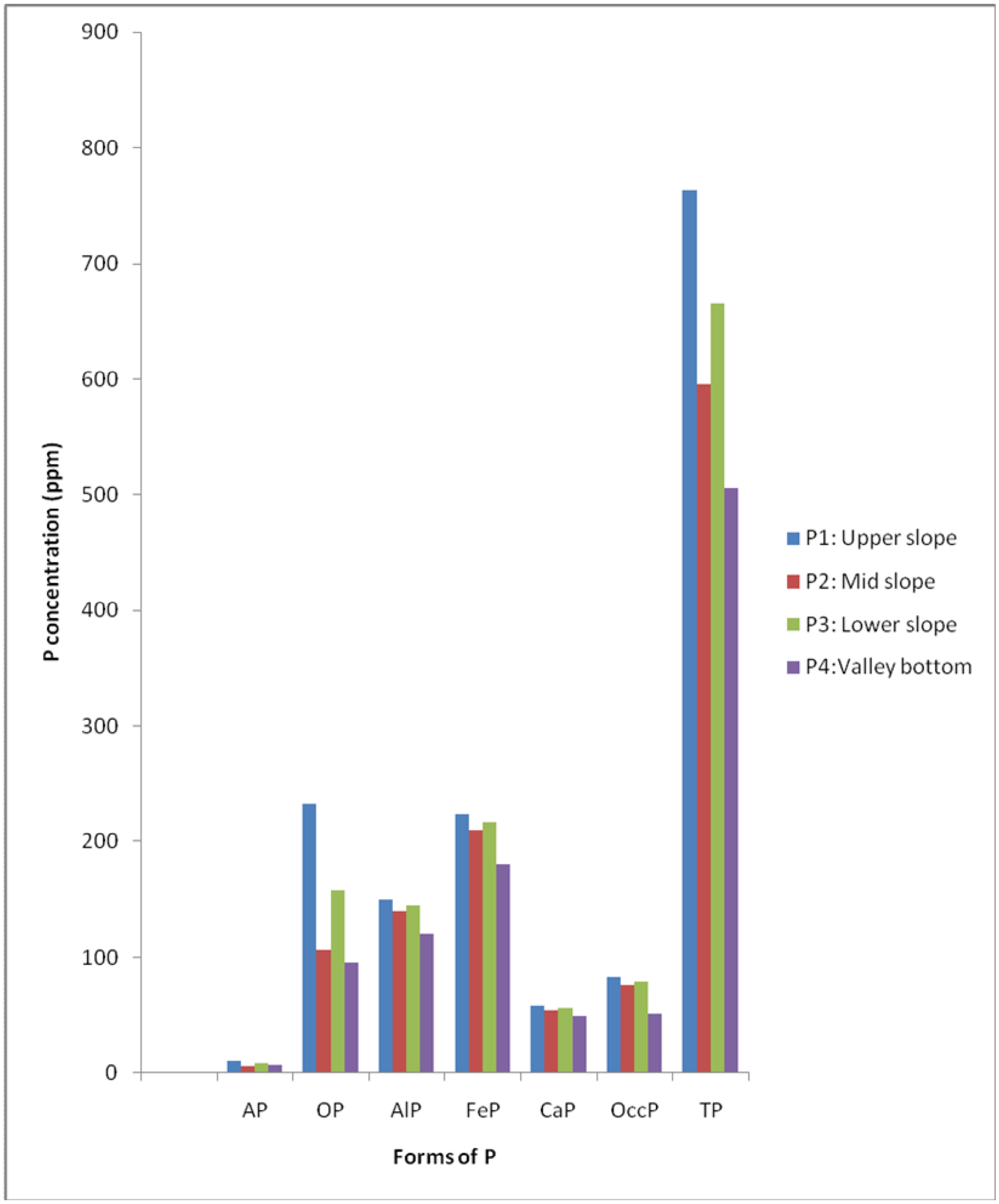

Fig 1a: Forms and physiographic distribution of P (A-horizon)
AP = available P; OP = Organic P; SP = Soluble P; Al P = Aluminum P; Fe-P = Iron P; Ca-P = Calcium P; Occ-P = Occluded P; TP = Total P;

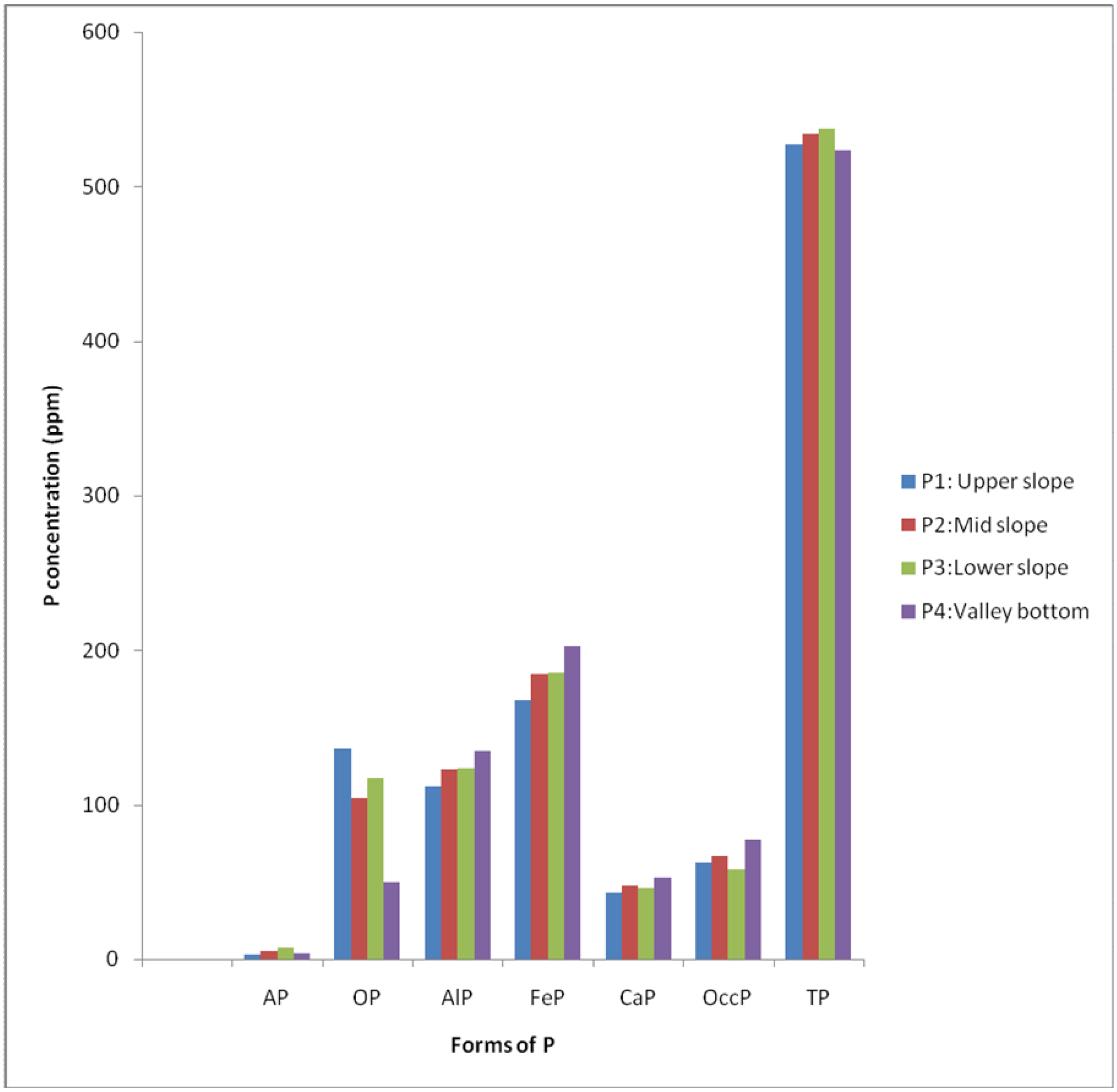

Fig b: Forms and physiographic distribution of P (B-horizon)
AP = available P; OP = Organic P; SP = Soluble P; Al P = Aluminum P; Fe-P = Iron P; Ca-P = Calcium P; Occ-P = Occluded P; TP = Total P;

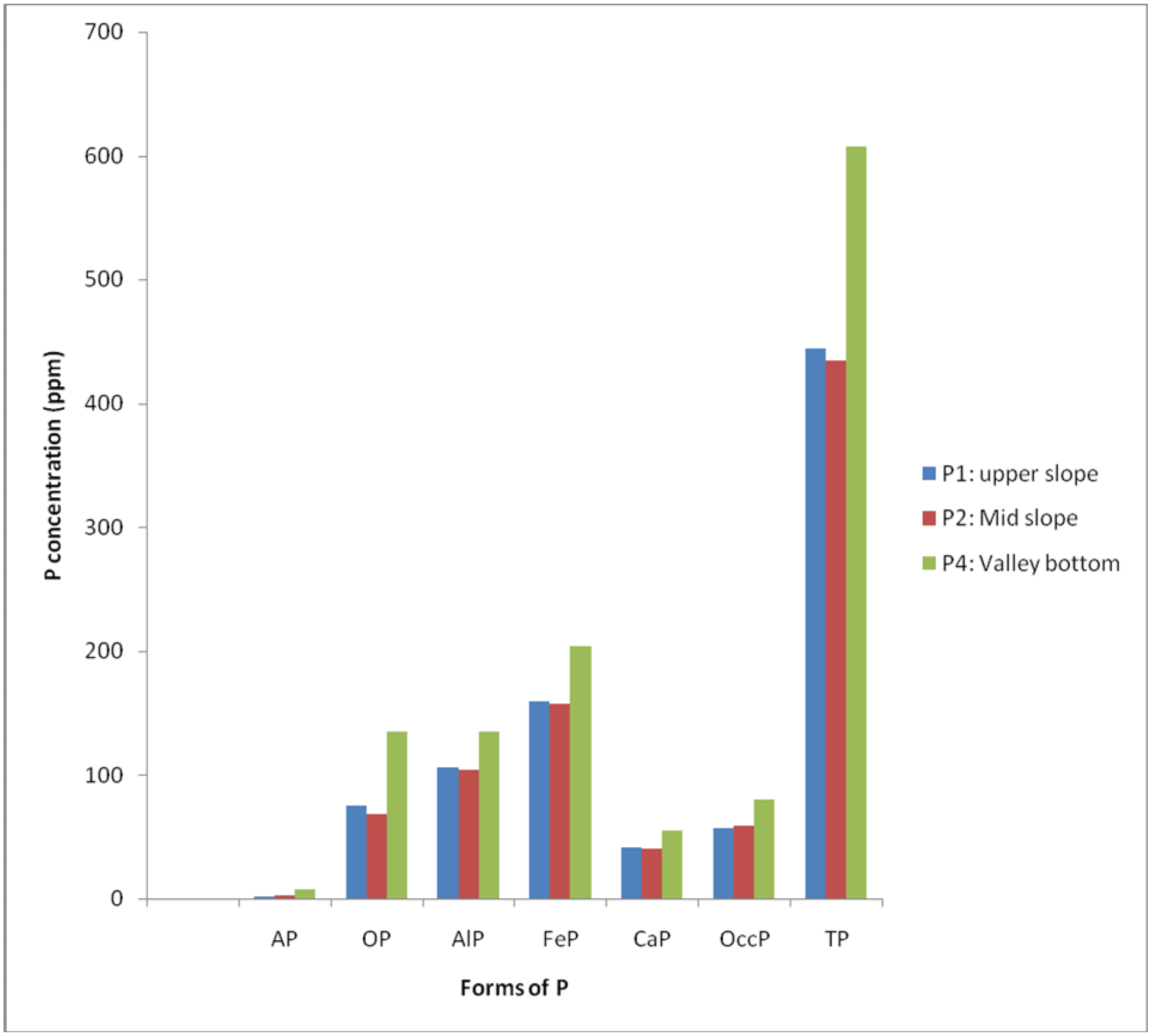

Fig 1c: Forms and physiographic distribution of P (C-horizon)
AP = available P; OP = Organic P; SP = Soluble P; Al P = Aluminum P;
Fe-P = Iron P; Ca-P = Calcium P; Occ-P = Occluded P; TP = Total P;

Table 4: Pearson Correlation Coefficients of the Physico-Chemical Properties of the Soils

	Clay	O.M	TEB	TEA	ECEC	OP	AP	AlP	FeP	CaP	OccP	TP
Clay												
O.M	-0.03											
TEB	0.65**	0.16										
TEA	-0.76**	0.12	-0.58*									
ECEC	0.47	0.22	0.95**	-0.31								
OP	0.03	0.91**	0.24	0.01	0.30							
AP	-0.29	0.50*	-0.11	0.33	-0.04	0.65**						
AlP	-0.42	0.37	-0.08	0.34	0.04	0.51*	0.75**					
FeP	-0.41	0.36	-0.06	0.32	0.06	0.50*	0.74**	0.99**				
CaP	-0.55*	0.42	-0.15	0.47	0.01	0.54**	0.73**	0.95**	0.94**			
OccP	-0.36	0.34	0.02	0.15	0.07	0.44	0.44	0.82**	0.82**	0.82**		
TP	-0.25	0.73**	0.09	0.22	0.19	0.86**	0.79**	0.87**	0.87**	0.87**	0.76**	

***: Indicates the significant correlation at ≤ 0.05**

****: Indicates significant correlation at p ≤ 0.05**

AP = available P; OP = Organic P; SP = Soluble P; AlP = Aluminum P; Fe-P = Iron P; Ca-P = Calcium P; Occ-P = Occluded P;
TP = Total P; TEB = Sum of Exchangeable Bases; TEA = Total Exchangeable Acidity; ECEC = Effective Cation Exchange Capacity; O.M = Organic matter

Reference to this paper should be made as follows: Adegbenro, R.O., Ojetade, J.O., and Amusan A.A. (2013), Effect of Topography on Phosphorus Forms and Distribution in Soils Formed in Mica Schist in Ife Area, *J. of Agriculture and Veterinary Sciences, Vol. 5, No.1, Pp. 86-105.*

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