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Phosphorus Distribution along a Toposequence of Coastal Plain Sand Parent Material in Southeastern Nigeria

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Abstract: The distribution of various forms of phosphorus was evaluated along a topsequence located on a coastal plain sand parent material in Amaoba Ime, Ikwuano Local Government area of Abia State. The toposequence was delineated into different topographic units (Crest, Upper slope, Middle slope, Lower slope and Valley bottom). Soil samples were collected from identified horizons in profile pits in each topographic unit. The soil samples were analyzed for total, organic and available P forms. The active forms of P were also determined. The results obtained showed that total P ranged from 150-787.5 μgg^{-1} with a mean of 439 μgg^{-1}. Total P was highest at the upper slope and lowest at the middle slope. Organic P ranged from 33 to 186μgg^{-1} with a mean of 91μgg^{-1}. Organic P was highest at the valley bottom and lowest at the middle slope. The active P forms was in the order of Fe-P > Al- P > Ca-P, with Fe-P varying from 21-196 μgg^{-1} while Al-P ranged from 1.75-63.63μgg^{-1}. There was no regular pattern of distribution of active P forms along the toposequence. Available P ranged from 0.69 to 11.79μgg^{-1} with a mean of 3.63. The total P correlated positively with inactive p (r = 0.93**), organic P correlated positively with clay and negatively with sand (r = 0.43*, r = -0.53**). Fe-P and Al-P correlated with magnesium and sand respectively. Phosphorus distribution vary widely with each topographic unit.

Key words: Phosphorus fractions, toposequence

INTRODUCTION

In the humid tropics, soils frequently occur in a well defined and fairly regular sequence[1], these sequences have been referred to as toposequence[2]. A toposequence refers to a sequence of soils of about the same age, derived from similar parent material and occurring under similar climatic conditions, with different characteristics due to variations in relief and drainage[3]. Ogban[4] observed that the distribution of individual soil series on a toposequence as well as the spatial distribution of the toposequence itself has considerable influence on the soil properties and landuse pattern. Since farmers often cultivate the toposequence to the extent that all positions of the toposequence are found in a single farmland, Oluwatosin[1] recommended that agronomic practices should be made to farmers with due consideration for specific topographic locations which might influence the mineral availability and fertilizer recommendation.

Phosphorus (P) has been identified as one of the most limiting nutrient elements in the tropical soils[5]. This low availability of phosphorus in the tropical soils is attributed to the nature of the chemical forms of the soils phosphorus and the high contents of the oxides of iron and aluminium, which are associated with high phosphorus fixation[6]. The complexity of behaviour of phosphorus in soils and the factors influencing it has been studied by several authors[6-8]. The complexity of P in these soils is further compounded by the arable soils that are in most part acidic with high content of sesquioxides and Kaolinitic in nature.

Several authors have characterised the phosphorus contents of soils of southeastern Nigeria[7]. Also several studies have related soil properties to topography[3,9,1]. However, no detailed study on the distribution of phosphorus along a toposequence have been conducted. This study was therefore conducted to provide information on the distribution of phosphorus along a typical toposequence in Southeastern Nigeria.

MATERIALS AND METHODS

The study was conducted along a 582 m long toposequence in Amaoba Ime in Ikwuano local government area of Abia state, Nigeria (Latitude 05° 27^{1}N and Latitude 07°32E). The toposequence was delineated into crest, upper slope, middle slope, lower slope and valley bottom in Fig. 1. Soil samples were

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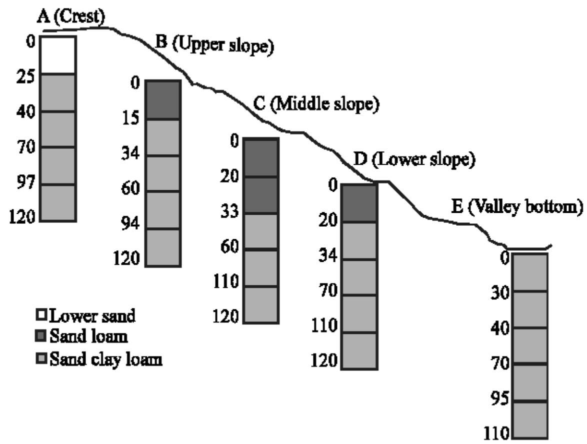

Fig. 1: Schematic presentation of the topsequence showing the different topographic units

collected from identified horizons in profile pits in each of the topographic units. The soils of the first four pedons were classified as Typickandiudalfs while the soils of the valley bottom was classified as Typickandiaquults[10].

The samples collected from the identified horizons were air-dried, crushed and sieved through a 2 mm sieve. A small portion of each of the sample was further ground and sieved with 0.5 mm mesh sieve and used for total P, organic P and organic carbon determination.

Particle size distribution was determined by the hydrometer method[11]. Soil pH was determined in 1:2.5 soil to water ratio using EEL pH meter. Organic carbon was determined by the wet oxidation method[12]. Exchangeable basic cations were extracted with neutral normal ammonium acetate with potassium (K) and sodium (Na) determined by flame photometry and Calcium (Ca) and Magnesium (Mg) by EDTA titrations Exchangeable acidity was by the Mclean[13] method. Total P was determined by $HClO_4$ digestion[14] and organic P was estimated by the difference between 13 M Hcl extractable P, before and after ignition, by the method. Inorganic P was fractionated by the method of Chang and Jackson[15]. Available P was extracted by the Bray and Kurtz No. 1 method[16]. Phosphorus in the extracts was determined colorimetrically[17].

The relationships between the forms of phosphorus and some of the soil properties were established using simple correlation method as outlined by Wahua[18].

RESULTS AND DISCUSSION

The physical and chemical properties of the soils are presented in Table 1. The soils are acidic with pH values ranging from 4.4 to 6.1. The pH of the top soil averaged 4.9 while the subsoil averaged 4.9 also. The acidity of the soils may be due to excessive rainfall, leaching and the nature of parent material[19]. This high acidity may inhibit the availability of phosphorus in this soil. The particle size distribution showed that the texture of the soil varied from loamy sand in the top soil to sandy clay loam in most of the subsurface horizons. This pattern is characteristics of the acid sands of southeastern Nigeria. The organic carbon content of the soils decrease with increase in depth. Generally the soils of the lower slope and valley bottom had the highest values of organic carbon. The trend in total nitrogen was similar to that observed for soil organic carbon with values ranging from 0.4 to 1.26 mg kg^{-1}. Exchangeable bases was in the order of Ca>Mg>K>Na.

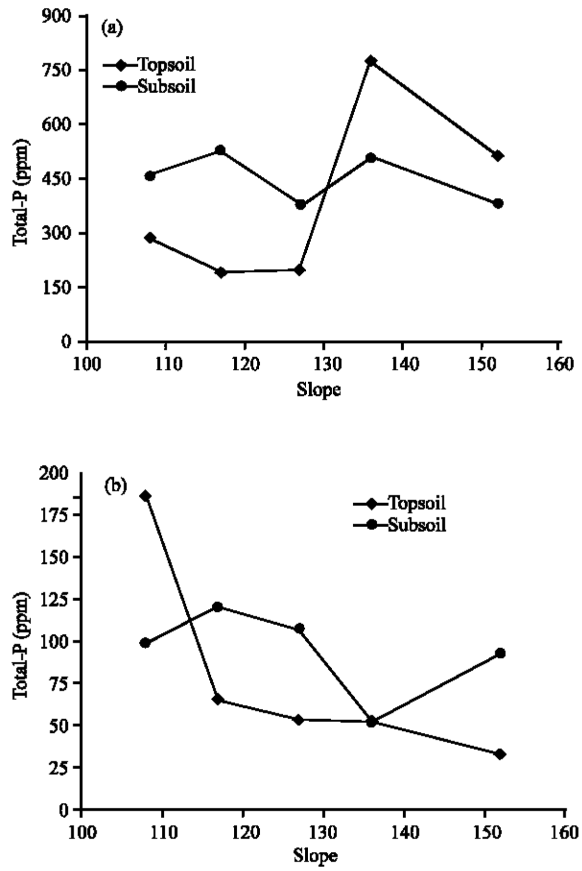

Fig. 2: a and b: Distribution of the total and organic phoshours along the toposequence

Total P: The total P content in all the profiles varied from 150-787.5 μgg^{-1} as shown in Table 2 with a mean of 439.5 μgg^{-1}. These values are comparable to the values reported by Ibia and Udo[8] for the some soils of the coastal plain sand parent material. Total P was generally highest in the upper slope and lowest at the lower slope (Fig. 2a). Also total P was highest in the top soils. This

Table 1: Some physical and chemical properties of the soils

Profile	Horizon	Depth (Cm)	Ph H_2O	Exchangeable acidity (Cmol/kg) AL^+	H^+	Exchangeable bases Cmol/kg Ca	Mg	K	Na	ECEC	BS %	Org.C %	N %	Avail P Mg/kg	Sand %	Silt %	Clay %	Textural Class
1.	AP	0.55	6.1	0.10	0.5	1.60	1.80	.499	.191	3.190	96.9	1.3	4.112	6.458	84.2	4.0	11.8	LS
	AB	25-40	6.0	0.4	0.2	1.60	0.40	.404	.179	2.983	88.5	0.63	.042	4.480	70.2	4.0	25.8	SCL
	Bt_1	40-70	5.6	0.9	0.1	2.00	1.20	.111	.189	4.400	79.5	0.55	.042	2.446	76.2	2.0	21.8	SCL
	Bt_2	70-79	5.5	0.10	0.1	2.00	0.80	.099	.204	4.203	73.8	0.15	.042	3.446	76.2	4.0	27.8	SCL
	Bc	97-120	5.2	0.60	0.1	1.20	0.80	.130	.194	3.807	57.9	0.28	0.28	3.791	74.2	2.0	23.8	SCL
2.	AP	0.15	4.4	2.4	0.4	1.20	0.40	.114	.180	4.294	44.1	1.3	4.070	2.068	80.3	3.6	16.1	SL
	AB	15-34	4.5	2.0	0.4	1.80	0.20	.090	.185	4.275	53.2	0.79	.42	4.285	76.3	3.6	20.1	SL
	Bt_1	34-60	4.7	2.0	2.0	0.40	-	.081	.315	0.796	28.4	0.43	..42	4.825	74.2	4.0	21.8	SCL
	Bt_2	60-94	5.1	2.0	0.8	0.40	0.40	.068	.184	1.052	34.4	0.35	.014	1.379	72.2	4.0	23.8	SCL
	Bc	94-120	4.9	2.0	0.4	0.80	0.40	.055	.175	1.430	41.6	0.1	6.098	2.757	68.2	6.0	25.8	SCL
3.	AP	0.20	4.6	2.4	0.0	0.80	0.40	.130	.172	3.902	38.5	1.4	2.042	1.723	80.3	3.6	16.1	SL
	AB	20.33	4.9	2.0	0.4	1.20	-	.066	.197	3.463	42.3	0.83	.04	3.689	78.2	4.0	17.8	SL
	Bt_1	33.64	4.7	1.6	0.4	1.20	0.80	.059	.167	3.826	58.2	0.43	.028	1.723	74.2	4.0	21.8	SCL
	Bt_2	64.110	5.0	1.6	0.8	1.60	0.40	.107	.182	3.889	58.8	0.29	.084	4.480	72.2	4.0	23.8	SCL
	Bc	110-120	5.0	2.0	0.4	0.80	0.40	.055	.175	3.497	41.2	0.2	0.084	2.068	74.0	3.6	22.1	SCL
4.	AP	0.20	5.0	2.0	0.4	1.20	0.40	.146	1.75	3.921	48.9	2.0	5.070	3.102	78.3	5.6	16.1	SL
	AB	20-34	4.7	2.6	0.6	0.80	0.40	.092	.194	4.086	36.2	0.99	.056	1.723	70.3	5.6	24.1	SCL
	Bt_1	34-70	4.7	2.4	2.4	1.60	0.80	.067	.188	5.055	52.5	0.47	.056	1.034	70.3	3.6	26.1	SCL
	Bt_2	70-110	4.6	2.4	2.4	1.20	-	.051	.187	3.838	37.4	0.3	9.42	1.034	66.3	4.0	29.8	SCL
	Bc	110-120	4.8	2.2	2.2	0.80	0.40	.047	.159	3.606	38.9	0.2	0.126	2.068	66.3	3.6	30.1	SCL
5.	AP	0-30	4.7	2.6	0.0	0.80	0.40	.089	.182	4.071	36.1	1.8	1.098	6.204	66.0	11.4	22.6	SCL
	AB	30-40	4.7	2.8	0.4	1.60	0.40	.060	.161	5.021	44.2	1.42	.0561	1.718	72.0	5.4	22.6	SCL
	Bt_1	40-70	4.9	2.0	0.8	0.80	0.40	.052	.176	3.428	41.6	0.83	.042	4.480	72.0	5.4	22.6	SCL
	Bt_2	70-75	4.9	1.8	0.0	0.80	0.40	.050	.162	3.212	43.9	0.47	.042	3.446	70.0	3.4	26.6	SCL
	Bc	95-110	4.7	1.6	0.0	1.20	0.40	.091	.175	3.466	47.8	0.3	2.028	6.204	72.0	3.4	24.6	SCL

Key: LS- Loamy sand, SCL-Sand Clay Loam, SL-Sandy Loam, Ap-Plough layers, AB-Transition between A and B, HORIZON, Bt_1-Illuviable layer of clay Bt_2-Increasing intensity of illuvation and clay, Bc-transition between B-horizon and parent materials. A-Crest, B-Upper slope, C- middle slope, D-lower slope, E-valley bottom

Table 2: Forms of phosphorus in the soils (mg Kg^{-1})

Horizon	Total-P	Organic-P	Fe-P	Al-P	Ca-P	Available-P	(Bray-1)	Inactive-P
	AP	512.5	33	73.5	35	3.5	6.46	361.04
	AB	612.5	99	35.0	3.0	3.5	4.48	467.02
1	Bt1	200.0	33	108.5	8.75	1.17	3.45	45.13
	Bt2	562.5	186	196.0	19.25	1.17	5.51	154.57
	Bc	150.0	53	35.0	8.75	7.0	3.79	42.46
	AP	775	53	35.0	33.25	3.5	2.06	648.19
	AB	775	59	45.0	36.75	4.7	4.29	625.26
2	Bt1	750	33	21.0	5.25	2.3	4.83	683.62
	Bt2	300	53	45.0	12.25	1.17	1.38	187.2
	Bc	200	66	84.0	19.25	3.5	2.76	24.49
	AP	200	53	77.0	17.5	2.3	1.72	48.48
	AB	300	33	85.75	26.25	5.8	0.69	128.51
3	Bt1	300	53	161.0	1.75	3.5	1.72	79.03
	Bt2	300	186	91.0	5.25	1.17	4.48	12.1
	Bc	612.5	156	21.0	8.75	1.17	2.07	423.51
	AP	200	66	56.0	17.5	3.5	3.10	53.9
	AB	200	59	63.0	1.75	4.7	1.72	69.83
4	Bt1	512.5	186	35.0	5.25	1.17	1.04	284.04
	Bt2	787.5	186	189.0	1.75	3.5	1.04	406.21
	Bc	612.5	49	126.0	6.12	5.8	2.07	423.51
	AP	287.7	186	42.0	12.25	5.8	6.20	35.25
	AB	562.5	83	42.0	22.75	1.17	11.79	401.79
5	Bt1	512.5	179	35.0	8.75	2.3	4.48	282.97
	Bt2	150	99	21.0	8.75	4.7	3.45	12.1
	Bc	612.5	33	63.0	63.0	3.5	6.20	443.8

trend could be due to accumulation of litters on the top soil. Total P correlated significantly with inactive P (r = 0.93**). However there was no correlation between total P and other soil properties.

Organic P: Organic P varied from 33 to 186 μgg^{-1} with a mean of 91 μgg^{-1} for all the profiles. These values are comparable to the values reported by Osodeke and Kamalu[7] for the Hevea producing soils of Nigeria. Organic P was highest in the valley bottom and lowest in the middle slope (Fig. 2b). This could be due to the deposition of organic material at the valley bottom from the upper slopes. This could be due to the deposition of materials from (organic P constituted 21, 9, 29, 24 and 27%

Table 3: Correlation coefficient between soil P and some soil properties

	Total P	Org. P	Fe-P	Al-P	Ca-P	Available P	Inactive P
PH	-0.14	-0.05	0.09	-0.08	-0.13	0.20	-0.15
Sand	-0.05	-0.53*	-0.24	0.40*	-0.06	-0.02	0.12
Silt	-0.13	0.35	-0.11	-0.06	0.18	0.27	-0.20
Clay	0.16	0.43*	-0.35	-0.39	-0.03	-0.07	-0.00
Org. C	-0.12	0.40*	-0.22	0.21	0.11	0.30	-0.07
N	0.25	-0.01	0.35	-0.18	0.03	-0.18	0.19
K	-0.12	0.14	-0.22	0.07	0.16	0.19	-0.04
Mg	-0.27	-0.02	0.48*	0.06	-0.08	-0.05	-0.37
ECEC	-0.07	0.28	0.14	-0.06	-0.19	0.13	-0.11

of the total P in the crest, upper slope, middle slope, lower slope and valley bottom respectively. This trend could be due to the relatively higher organic matter in the last three profiles". However there was no particular trend in the distribution of organic P within each of the profiles. Organic P correlated negatively but significantly with sand (r = -0.53*) (Table 3) and positively with clay and organic carbon. Similar trend was reported by Osodeke and Kamalu[7] in soils of the rubber belt of Nigeria.

INORGANIC P FRACTIONS

Total inorganic P is divided into active and inactive P forms, the former consisting of Al-P, Fe-P and Ca-P and the latter consisting of occluded, reductant soluble and residual P[7,6]. The main sources of plant available P in soils are generally accepted as active P forms[6].

The various active P forms are shown in Table 2, Fe-P varied from 21 to 196 μgg^{-1} with a mean of 11.43 μgg^{-1}, Al-P varied from 1.75 to 63 μgg^{-1} with a mean of 15.52 μgg^{-1} while Ca-P ranged from 1.17 to 7.0 μgg^{-1} with a mean value of 3.26 μgg^{-1}. Ca-P had the least value among the active P forms, this is due to the acidic 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 ion and aluminum phosphate in acid soils[20]. Fe-P is the least soluble of the inorganic P fractions and tends to accumulate at the expense of the more soluble Ca-P and Al-P and this accounted for the relatively higher content of Iron phosphate in these acid soils[20].

The active P form constituted about 21% of the total P forms with Fe-P dominating the active P forms. This value is lower than the value of between 11-67% reported by Osodeke and Kamalu[7] in the rubber growing soils of Southeastern Nigeria. The relative abundance of the various forms of inorganic P was in the order of inactive P>Fe>Al-P>Ca-P. Similar order has been reported by several authors[7,8].

Figures 3 a and b shows the distribution of Fe-P and Al-P along the toposequence. In the top soil, both forms of P were lowest in the valley bottom and highest in the crest. However in the subsoils the pattern of their distribution was different. While Fe-P recorded its highest

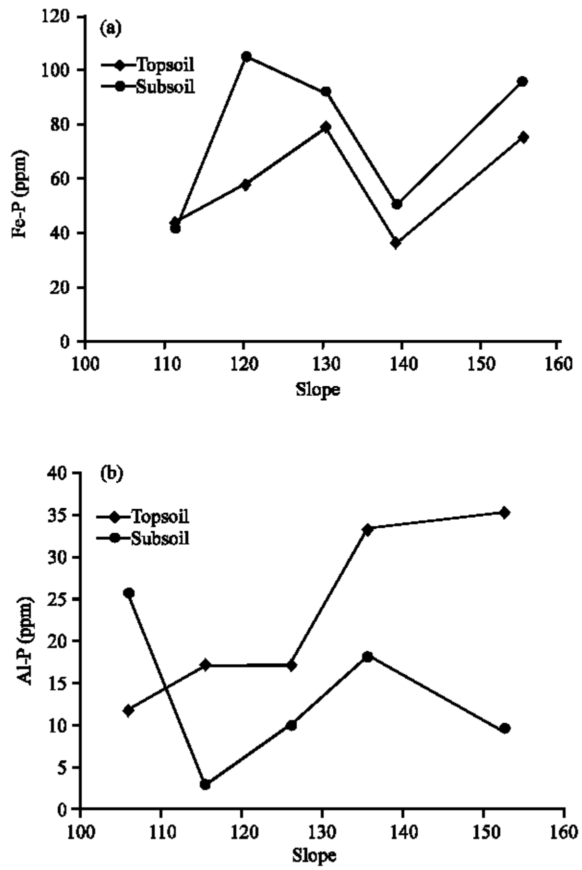

Fig. 3: Distribution of Fe-P and Al-P along the toposequence

value in the upper slope, Al-P had its highest value in the valley bottom.

Available P: Available P varied from 0.69 to 11.79 μgg^{-1} (Table 2) with a mean of 3.63 μgg^{-1}. Most of the soils had available P less than the critical level of 8μgg^{-1} set for the soils of the humid tropics[21]. Phosphorus distribution down the profiles did not indicate any particular trend. However, the top soils generally had the highest values in most of the profiles. Available P was highest in crest and lowest in the middle slope for the top soil (Fig. 4b). However, in the subsoil available P was highest in the

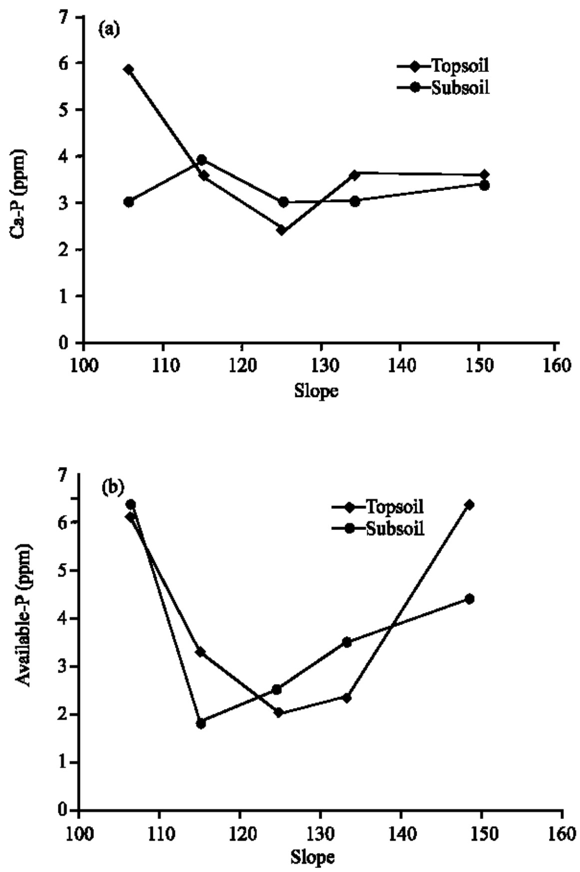

Fig. 4: Distribution of available P along the toposequence

valley bottom. This trend could be due to the deposition of P in the valley bottom of the toposequence.

In conclusion, this study has shown that phosphorus distribution along a toposequence vary with the different topographic units. In spite of these variability, P fertilizer recommendation are often made to farmers without due consideration for the specific topographic locations. This study therefore provides a valid evidence for the need to adopt different P fertilizer recommendation at the different topographic position for optimum yield.

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