NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 49 Number 1, April 2018. Pp. 101-108
Available online at: http://www.ajol.info/index.php/naj

FORMS AND PROFILES DISTRIBUTION OF PHOSPHORUS SOILS ALONG A TOPOSEQUENCE OF AMAOBA- IME, IKWUANO LGA, ABIA STATE, NIGERIA

[1]Nwosu, O.C., [1]Osodeke, V.E. and [2]Ohaeri, J.E.
[1]Michael Okpara University of Agriculture, Umudike
[2]National Root Crops Research Institute Umudike, Abia State
Email: owelleohuhu@yahoo.com.; drohaerije@gmail.com

ABSTRACT
The forms and distribution of phosphorus (P) in profile of soils along a toposequence at Amaoba Ime in Ikwuano LGA of Abia State of Nigeria were investigated in 2015. Five pedons representing crest, upper slope, middle slope, lower slope and valley bottom were assessed. A total 25 augur soil samples were collected from 0-20, 20-40, 40-60, 60-80 and 80-100cm depth in the five sampling units along the toposequence. The samples were analyzed for various forms of P and other physical and chemical properties. Soil P varied widely, the distribution of forms of P with depth along the toposequence was not uniform in the soils studied. The site has a very low (< 9%) organic P (P_O) contribution to the total P (TP). The occluded P constituted 75 to 79% to TP and total inorganic P (TP_I) forms in the soils, respectively. The occluded P and Fe-P occupied more than 90 % of the TP_I. Active P_I constitutes 22 % TP. Ca-P and Al-P were lower (< 8 %) than other forms of P in the soils, while Al-P was low in lower horizonsof the soil. The relative abundance of various forms of P_I were in the sequence of Ca-P < Al-P < Fe-P < Occluded P. The correlation coefficient indicates that the P forms are closely related. The multiple correlation analysis revealed TP correlated positively P (< 0.05) with Al-P, Fe-P and Occluded P. P_O had a significant negative correlation with sand (r = -0.56*), P_E (-0.41*) and positive relationship (P < 0.05) (r = 0.62*) with silt.Occluded P correlated negatively with Mg (r = -0.40*) and positively with Al-P, Fe-P, Ca-P, and total P. Al-P correlated positively with Fe-P, Ca-P, Occluded P and total P. Fe-P correlated positively with Al-P, Ca-P, Occluded P and total P. In general, soil P_E is above the critical level of 15mg/kg. In conclusion, status of the TP and their various forms in the Amaeke Ibeku soils do not depend upon their topography.

Keywords: Phosphorus, Status, Toposequence, Soils and Amaoba-Ime

Introduction

Phosphorus has been identified as one of the most limiting nutrient elements in the tropics (Ahn, 1993). The low availability of phosphorus in tropical soils is attributed to the nature of the chemical forms of soil phosphorus and a high content of sesquioxides, kaolinitic clays and aluminum associated with high phosphorus fixation (Agbenin, 2003; Igwe and Nkemakosi, 2007). The complexity of behaviour of phosphorus in the soils and the factors influencing it has been reviewed from time to time (Osodeke *et al.*, 1991; Buresh *et al.*, 1997; Ubah, 2000). In Nigeria, several studies have been conducted to evaluate the effect of toposequence on soil properties (Ibia and Udo, 1993; Oluwatosin *et al.*, 2001). Ogban *et al.* (1999) deduced that nutrient status and soil properties are related to topography of the land area. Osodeke *et al.* (2006), observed a wide variation in phosphorus distribution along a toposequence in south eastern Nigeria; where total phosphorus was found to be highest at the upper slope and lowest at the middle slope. Therefore, this study is aimed at investigating the effect of slope position on some chemical properties of soil in order to provide the basic information about the fertility status of these areas. Such information would be helpful in recommending the type and amount of fertilizer and other soil management practices in future crop production strategies on such soils. The objectives of the study therefore, are to: (i) determine some chemical and physical properties of soils, (ii) evaluate the effect of toposequence on the forms of phosphorus distributionand (iii) determinethe relationship between these various forms of P.

Materials and Methods

This study was conducted along toposequence in Amaoba Ime in Ikwuano Local Government Area of Abia State, South-Eastern Nigeria (Latitude $5^o27'$ N and longitude $7^0 32'$ E). The site was geo-referenced using handheld Global Positioning System (GPS) Receiver (Garmin Ltd Kansas, USA). The toposequence was delineated into five units viz Crest, Upper slope, Middle slope, Lower slope and Valley bottom. Soil sample were collected at the depth of 0-20, 20-40, 40-60, 60-80, 80-100 cm respectively using a soil auger. In the laboratory, the Soil samples were air-dried for 3 days at room temperature. They were gently crushed with a wooden roller and passed through a 2-mm sieve. A small portion of each sample were crushed with a mortar and passed through 0.5-mm sieve for analysis of organic carbon. The particle size distribution was determined by hydrometer method using sodium heaxmetaphosphate (calgon) as dispersing agent as outlined by Gee and Or (2002). The pH of the soil samples was determined in water by means of Bechman's pH meter using a soil to water ratio of 1:2.5 (Thomas, 1996). Organic carbon was determined by the dichromate wet oxidation method as described by Nelson and Sommers (1996). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) were extracted with 1 N ammonium acetate (NH_4OAc) at pH 7.0. Calcium and Mg in the extracts were determined by titration (Jackson, 1958) while Na^+ and K^+ were determined with flame photometer. Exchangeable hydrogen and Al^{3+} were determined by the method outlined by Mclean (1982). Effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases and total exchangeable acidity (Tan, 1996). Percentage base saturation was calculated as outlined by Coleman and Thomas (1967). Total phosphorus in the soils was determined by perchloric acid digestion method (Jackson, 1958) and organic P was estimated by the difference between 13 M HCl extractable inorganic P, before and after ignition, by the method of Leg and Black (1955). Inorganic P was fractionated by method of Chang and Jackson (1957) as modified by Peterson and Corey (1966). Available P was extracted by Bray and Kurtz No. 2 extractant (Bray and Kurtz, 1945), Phosphorus concentration in soil extracting solution was determined colorimetrically using ascorbic acid method (Kuo, 1996) on a spectrophotometer set to 880 nm.

Data analysis

In order to investigate the differences, data on soil P forms and selected soil chemical properties were collected and analyzed using the regression analysis by statistical computer package of GenStat Release computer (2013). Pearson correlation analyses were also performed to determine the intent of the relationship among the various P forms, between the P with other soil properties. The significance of the relationship was tested at $P < 0.05$.

Results and Discussion

The results of physico-chemical of the soils are given in Tables 1and 2. Silt/clay ratios ranged from 0.11-3.33with their means less than unity (0.66), indicating that the soils are old and highly weathered (Essoka and Esu, 2005).

Total phosphorus

As shown in Table 3, the Amaoba Ime soil, derived from Coastal Plain Sand, has a total P varied widely ranging from 89.52 - 2908.07 mg/kg with a mean of 942.02 mg/kg from 0-100 cm depth across the toposequence. These values are comparable with the values reported by Ohaeri and Eshett (2011) in Amakama Olokoro soils, derived from Coastal Plain Sand.The highest value was 2908.07 mg/kg at the crest at a depth of 80-100cm while the lowest was 89.52 mg/kg at lower slope at a depth of 20-40 cm.

Table 1: Selected physical properties the soils

Units	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Silt/clay Ratio
Crest	0-20	96.00	3.00	1.0	Sand	3.00
	20-40	94.00	2.00	4.00	Sand	0.50
	40-60	90.00	2.00	8.00	Sand	0.25
	60-80	90.00	1.00	9.00	Sand	0.11
	80-100	80.00	7.00	13.00	Sandy Loam	0.54
Upper slope	0-20	96.00	3.00	1.00	Sand	3.00
	20-40	91.00	2.00	7.00	Sand	0.28
	40-60	90.00	1.00	9.00	Sand	0.11
	60-80	84.00	4.00	12.00	Loamy Sand	0.33
	80-100	76.00	4.00	20.00	Sandy Loam	0.20
Middle slope	0-20	94.00	3.00	3.00	Sand	1.00
	20-40	92.00	2.00	6.00	Sand	0.33
	40-60	88.00	2.00	10.00	Sand	0.20
	60-80	88.00	2.00	10.00	Loamy Sand	0.20
	80-100	88.00	2.00	10.00	Loamy Sand	0.20
Lower slope	0-20	92.00	2.00	6.00	Sand	0.33
	20-40	91.00	3.00	6.00	Sand	0.50
	40-60	86.00	2.00	12.00	Loamy Sand	0.17
	60-80	85.00	2.00	13.00	Loamy Sand	0.15
	80-100	86.00	2.00	12.00	Loamy Sand	0.17
Valley bottom	0-20	85.00	5.00	10.00	Loamy Sand	0.50
	20-40	90.00	3.00	7.00	Sand	0.43
	40-60	87.00	10.00	3.00	Loamy Sand	3.33
	60-80	88.00	2.00	10.00	Loamy Sand	0.20
	80-100	85.00	5.00	10.00	Loamy Sand	0.50

Table 2: Selected chemical properties the soils

Units	Dept (cm)	pH(H_2O)	O/C(%)	TEA	Ca	Mg	K	Na	ECEC	BS(%)
					Cmol/kg					
Crest	0-20	4.40	0.71	21.6	6.0	3.6	0.18	0.62	32.0	32.50
	20-40	5.00	0.32	25.6	5.2	2.9	0.26	0.35	34.31	25.39
	40-60	5.20	0.78	17.2	6.0	2.0	0.18	0.29	25.67	33.00
	60-80	4.60	0.42	21.4	3.0	2.4	0.18	0.26	27.24	21.44
	80-100	4.40	0.28	17.4	4.8	3.6	0.20	0.22	26.22	33.64
Upper slope	0-20	4.50	2.30	17.2	4.0	3.2	0.14	0.33	24.87	30.84
	20-40	5.20	0.82	10.4	4.4	3.2	0.12	0.40	18.52	43.84
	40-60	5.40	0.35	9.2	4.4	2.4	0.10	0.82	16.92	45.63
	60-80	4.30	0.80	17.2	3.6	2.2	0.10	0.31	23.41	26.53
	80-100	4.20	0.57	8.0	4.8	3.2	0.13	0.39	16.52	51.57
Middle slope	0-20	4.50	1.21	2.0	4.4	4.0	0.15	0.65	11.20	82.14
	20-40	4.80	0.53	2.2	4.8	4.0	0.17	0.27	11.44	80.77
	40-60	4.80	0.17	2.0	4.0	2.8	0.12	0.20	9.12	78.07
	60-80	4.30	0.17	3.2	4.0	3.2	0.13	0.26	10.79	70.34
	80-100	4.80	0.21	2.0	3.6	2.8	0.13	0.25	8.78	77.22
Lower slope	0-20	4.60	1.10	5.32	4.4	2.4	0.18	0.38	12.56	58.60
	20-40	4.50	2.30	2.4	3.6	2.0	0.17	0.28	8.45	71.60
	40-60	5.80	1.28	4.8	5.2	2.0	0.14	0.49	12.63	62.00
	60-80	4.80	0.96	4.4	3.6	2.4	0.11	0.27	10.78	59.18
	80-100	5.00	0.49	5.6	4.8	2.4	0.13	0.33	13.26	57.77
Valley bottom	0-20	4.80	2.14	1.6	5.2	2.4	0.14	0.16	9.50	83.16
	20-40	4.30	0.49	2.4	4.0	3.6	0.39	0.33	10.72	77.61
	40-60	4.70	1.35	1.2	4.8	2.0	0.13	0.31	8.44	85.78
	60-80	4.40	0.60	2.0	3.2	2.4	0.12	0.51	8.23	75.70
	80-100	5.00	0.57	1.2	6.0	2.8	0.15	0.85	11.80	89.09

O/C = Organic carbon, TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity and BS = Base Saturation

Table 3: Forms of phosphorus in soils of Amaoba-Ime (mg/kg)

Units	Dept	Org-P	Tot-P	Occl-P	Fe-P	Ca-P	Al-P	Av.P
Crest	0-20	65.32	212.5	117.98	24.52	0.32	4.35	14.80
	20-40	35.48	113.71	50.65	14.03	4.35	9.19	25.80
	40-60	58.87	1180.24	885.73	110.00	61.61	64.03	14.20
	60-80	59.68	172.18	68.85	43.06	0.26	0.32	14.20
	80-100	62.09	2908.07	2122.48	468.06	105.16	150.32	15.30
Upper Slope	0-20	51.61	2214.52	1773.23	218.06	74.52	97.09	14.20
	20-40	64.52	226.61	115.16	39.84	0.21	12.42	22.50
	40-60	54.03	2904.03	2096.61	353.55	172.09	227.74	15.90
	60-80	45.97	2900.0	2216.77	330.97	148.71	157.58	32.90
	80-100	68.54	188.31	884.11	20.48	2.74	12.42	24.10
Middle Slope	0-20	43.54	500.81	373.23	71.29	5.16	7.58	16.40
	20-40	16.13	196.37	125.27	52.74	0.29	1.94	14.40
	40-60	61.29	222.58	119.31	37.42	0.20	4.35	24.70
	60-80	58.87	287.09	198.26	29.35	0.29	0.32	10.90
	80-100	58.87	170.16	90.24	20.48	0.24	0.32	14.80
Lower Slope	0-20	29.03	192.34	122.13	40.65	0.24	0.29	11.50
	20-40	63.70	89.52	10.55	14.84	0.16	0.26	14.20
	40-60	64.51	127.82	44.73	18.06	0.20	0.31	16.40
	60-80	19.35	1895.97	1854.77	21.29	0.23	0.32	10.40
	80-100	81.45	293.15	151.85	52.74	2.74	4.35	17.00
Valley Bottom	0-20	76.61	2895.97	1977.26	427.70	197.90	216.43	14.80
	20-40	75.00	234.67	124.84	7.58	9.19	18.06	16.80
	40-60	60.48	2893.95	2380.08	313.22	63.23	76.94	14.20
	60-80	30.65	287.09	231.39	24.52	0.26	0.29	13.10
	80-100	25.81	242.92	191.87	24.52	0.23	0.32	12.00

Avail-P=Available Phosphorus, Org-P=Organic Phosphorus, Occl-P=Occluded Phosphorus, Fe-P= Iron Phosphorus, Ca-P=Calcium Phosphorus, Al-P=Aluminium Phosphorus, Tot-P=Total Phosphorus.

Total P is higher in the location but not available in the soil for plant use. Total P correlated positively P (< 0.05) with silt (r = 0.54*) in (Table 4). However, there was no significant correlation between total P and pH on one hand and organic carbon on the other hand. Similar value was also reported by Osodeke and Kamalu (1992) in soils of Nigeria, Ohaeri and Eshett (2011) and Ohaeri (2012) in Cross River state of Nigeria. The results of the simple correlation coefficient (r) between the paired soil P forms were calculated and these are shown in matrix form in (Table 5). Total P correlated highly and positively with all the inorganic P forms (Al-P, Fe-P and occluded P) except, Ca-P. The correlation coefficient indicates that the P forms are closely related. These findings are in agreement with that of Azeez *et al*. (2013) that reported that all the P forms are closely related in Nigerian soils. The pattern of distribution of total P was not uniform with depth and across the toposequence in the soils studied (Udo and Dambo, 1979; Ohaeri and Eshett, 2011 and Ohaeri, 2012).

Organic P contents in the soils

Organic P contents in the soils varied widely depending upon the toposequence. The lowest being recorded at the middle slope at a depth of 20-40 cm with a value of 16.13 mg/kg (Table 3) while the highest was 81.45 mg/kg with a mean value of 53.26 mg/kg. These values constitute 5.6% of the total P in these soils. These values are comparable with the value of 1.0 - 90 mg/kg, 28.88 - 88 mg/kg, 31.03 - 127.71 mg/kg and 62.86 to 131.95 mg/kg reported by Lognathan *et al*. (1982), Osodeke and Kamalu (1992), Ohaeri and Eshett (2011) and Ohaeri (2012), respectively; butlower when comparedwith the values of 34 - 339 mg/kg and 30 to 900 mg/kg reported by Loganathan and Sutton (1987) in the Coastal Plain Sands of Rivers State and Uzu *et al*., (1975) in the soils of Southeastern Nigeria respectively**.** Soils from this location has a very low (< 9%) organic P contribution to the total P. This is at variance with the reports of Uzu *et al*. (1975), Enwezor *et al*. (1990), Osodeke and Kamalu (1992) that about 40% of the total P in the surface horizon are in organic P form. This variance could be because of continuous cultivation, old parent rock and overgrazing in the present studied areas. The pattern of distribution of organic P along the toposequence is irregular. Multiple correlation and regression analysis (Table 5) showed that the level of organic P in these soils did not correlate with other P forms in the soils but correlated positively ($P > 0.05$) with Avail-P ($r = -0.41^*$). This is contrary to the reports of Azeez *et al*. (2013). There was no significance correlation with organic carbon contrary to the reports of Uzu. (1975), Udo and Ogunwale (1977), Udo and Dambo (1979). But it was in agreement with the reports of Loganathan and Sutton (1987), Osodeke and Kamalu (1992***),*** Ohaeri and Eshett (2011) and Ohaeri (2012)**.**

Table 4: Correlation coefficient between soil properties and soil phosphorus forms

	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Available P	Total P
Sand	-0.21	-0.28	-0.21	-0.19	-0.25	-0.19	-0.26
Silt	0.34	0.57*	0.34	0.14	0.54*	-0.01	0.54*
Clay	0.06	0.03	0.06	0.14	0.02	0.21	0.03
Silt/Clay ratio	0.10	0.23	0.09	0.10	0.32	-0.15	0.29
pH	0.05	-0.04	0.05	0.01	-0.02	-0.18	-0.02
TEA	-0.07	-0.02	-0.09	-0.01	0.09	0.28	0.09
O/c	0.22	0.23	0.26	0.10	0.29	-0.19	-0.28
Ca^+	0.09	0.09	0.09	0.08	-0.01	-0.04	0.01
Mg^+	-0.17	-0.12	0.22	0.09	-0.23	-0.01	-0.22
K^+	-0.17	-0.19	0.19	0.13	-0.28	-0.04	-0.026
Na^+	0.001	-0.11	-0.03	-0.24	-0.10	-0.11	-0.10
ECEC	-0.06	-0.03	-0.11	-0.01	-0.19	0.09	-0.16
B.S	0.04	0.01	0.04	0.02	0.01	-0.29	0.02

*** Significant at 0.05.**

Table 5: Correlation coefficient between phosphorus forms

	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Available P	Total P
Al-P	-						
Fe-P	0.67**	-					
Ca-P	0.78**	0.86**	-				
Organic P	0.09	0.09	0.06	-			
Occluded P	0.69**	0.90**	0.91**	-0.09	-		
Available P	-0.01	-0.12	-0.41*	-0.41*	0.08	-	
Total P	0.73**	0.94**	0.08	0.08	0.98**	-0.01	-

* Significant at 0.05, ** Significant at 0.01.

Inorganic P

The distributions of the various forms of inorganic P are shown in Table 3. The occluded P had average range of 181.26 mg/kg in the middle slope to 1417.17 mg/kg in the upper slope with a mean value of 773.09 mg/kg. Occluded P constituted 75 to 94% of total inorganic P forms in the soils and between 66 and 84 percent of the total P in the various topo units. The range of percentage of occluded P to total inorganic P and total P are in firm agreement with the report of Osodeke and Kamalu (1992) (30 to 80% and 11 to 67% of occluded P to total inorganic P and occluded P to total P respectively); Ohaeri and Eshett (2011) and Ohaeri (2012) (40 to 80% and 26 to 68 of occluded P to total inorganic P and occluded P to total P respectively).

Fe-P ranged on average from 106.45in the middle slope to 169.51 mg/kg in the lower slope with a mean value of 147.33 mg/kg. The occluded P and Fe-P occupied more than 90% of the total inorganic P. This indicates the high degree of chemical weathering of these soils (Chang and Jackson, 1958). The content of Ca-P and Al-P are very low (< 8% of the total inorganic P). This is in agreement with the report of Uzu *et al.* (1975***),*** Ohaeri and Eshett (2011) and Ohaeri (2012)**.** The low Al-P content and the predominance of the occluded P in these soils suggest the limited capacity of these soils in supplying plant-available P from the inorganic P. The active P constitute between 19 and 22 percent of the total soil P. These values are comparable to the values of 13 to 33 percent reported by Osodeke and Kamalu (1992), and 18 and 38 percent by Ohaeri and Eshett (2011) and Ohaeri (2012). The relative abundance of various forms of inorganic P was in increasing order of Ca-P < Al-P < Fe-P <occluded P. Similar order was reported by several authors (Udo and Uzu, 1972 in adsorption by some Nigerian soils, Udo and Ogunwale, 1977 in selected Nigerian soils, Udo and Dambo, 1979 in Nigerian coasted plain sands, Loganathan *et al.*, 1982 in status of some coconut growing soils of Sir lanka, Loganathan and Sutton, 1987 in different geological deposit in the Niger Delta area of Nigeria, Osodeke and Kamalu, 1992 in Phosphorus status of Hevea growing soils of Nigeria, Ojo *et al.,* 2010,Ohaeri and Eshett, 2011 in selected soils formed over different parent materials in Abia of Nigeria and Ohaeri, 2012 in selected soils formed over different parent materials in Cross River state of Nigeria.). The high content of Al-P in the lower horizons of thesoil is due to poor drainage condition rather than degree of weathering. Similar reports were made from Uzu (1975), Ohaeri and Eshett (2011). In Table 4, Occluded P correlated negatively with Mg alone (r = -0.40*). Fe-P correlated positively with Occluded P, Ca-P, Al-P and total P. Occluded P correlated positively with Al-P, Fe-P, Ca-P, and total P (Table 5).

Available phosphorus in the soils

The Bray P 2 test values of available P ranged on average from 19.74 mg/kg in the middle slope to 29.96 in the valley bottom with meanvalue of 23.42 mg/kg. In general the soils of studied area had available P above the critical levels of 15 mg/kg by the Bray P 2 method (Enwezor *et al.*, 1989; Enwezor *et al.,* 1990). Available P did not correlatewith the selected soil Properties. However, Avail-P correlated negatively (P < 0.05) with Ca-P (r = -0.41*) and Organic-P (r = -0.41*).

Conclusion

The soil varied widely, depending upon the toposequence, in their P status. The pattern of distribution of total P with depth and toposequence was not uniform in the soils studied. Soils from this site has a very low (< 9%) organic P contribution to the total P. The occluded P constituted 66 to 74% and 75 to 79% of total P and total inorganic P forms in the soils, respectively. The occluded P and Fe-P occupied were more than 90% of the total inorganic P, while active inorganic P constitute 19 and 22% total P. Ca-P and Al-P were very low (< 8%) in soils. There was low content of Al-P in lower horizons, but high content of Fe-P in same soil. The relative abundance of various forms of inorganic P were in the sequence of Ca-P < Al-P < Fe-P < occluded P. In general, the soil available P were above the critical level 15 mg/kg).

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