Impacts of Land Use and Soil Depth on Phosphorus forms in Soils of Basement Complex Geology, Ogun State, Nigeria

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Abstract

Soils derived from basement complex geology were investigated to assess the impact of land use and different depths on phosphorus forms. Two locations were selected across the basement complex geology and consequent upon the land use types (cultivated arable crop and fallowed arable crop land)in each of the locations, two profile pits were dug. Results showed that the soils were similar in texture (loamy sand surface horizons overlying sandy clay loam subsurface horizons), while soil pH (5.95-7.15), Ca (2.5-5.8 cmol/kg), Mg (1.0-15.5 cmol/kg), total exchangeable acidity (TEA) (0.1-1.5) and OC (0.4-10 g/kg) varied across the geological formation. The abundance of the P forms followed the pattern: Iron-P (33.73 mg/kg) > Labile-P (32.76 mg/kg)> Aluminum-P (17.98 mg/kg)>Water soluble-P (15.38 mg/kg)>Ca-P (4.49 mg/kg), indicating that the distribution of the P forms in the geology had Fe-P as the most abundant P-forms and Ca-P as the least abundance. There was negative and significant relationship between the Al-P and Avail-P, Ca, Mg, k, pH and Ca-P in all the land uses and soil depths, indicated that an increase in the Al-P will lead to decrease in the Avail-P and Ca-P in the soils. Since the relationship among the element was the same across the land uses and the soil depth, it was concluded that land use and soil depth had no significant influence on the forms of phosphorus of the basement complex geology.

Key words: phosphorus forms, land use, soil depth

INTRODUCTION

In tropical and subtropical soils, phosphorus deficiency in plants represents a major constraint to agricultural production (Palomo *et al.,* 2006). Furthermore, under acid conditions, exchangeable iron and aluminum come into solution leading to iron (Fe) and or aluminum (Al) toxicity in extreme cases and causing the deficiency of some nutrients especially phosphorus. The deficiency of phosphorus occurs through adsorption reactions making it one of the most limiting nutrients for food production in the tropical and subtropical regions (Jubrin *et al.,* 2000). The fate and efficiency of native and applied phosphorus remains one of the biggest problems in arable crop production in the tropics. This is because applied P fertilizer can largely be fixed by oxides, hydroxides and oxyhydroxides of Fe and Al and clay minerals in acidic soil, and this process makes it less available or effectively unavailable to plants (Shen *et al.,* 2001). The availability of both applied and native phosphorus is largely controlled by sorption and desorption characteristics of the soil.

Batjes (2010) reviewed that amounts, forms (organic and inorganic), and distribution of P in the soil vary with different soil processes: the natural processes determine soil mineralogy and sorption characteristics, the human controlled processes such as application and timing of P-containing fertilizers, organic and lime material. More so, under natural processes, weathering and dissolution of rocks and relatively insoluble P-containing minerals is a slow process. In acid soils, P is fixed by the various forms of Iron (Fe), Aluminium (Al), and Manganese (Mn) oxides, while in calcareous soils P is mainly found in the form of Ca-compounds by varying solubility (Rafique *et al.,* 2006). Ultimately, the form of P in the soil will influence P-availability to plant; actual uptake will be determined by soil water condition, crop type and growth rate, root morphology and plant specific characteristics to extract P through excretion of exudates (Richardson *et al.,* 2009), fungi may also be important in this respect (Hoffland *et al.,* 2004).

It has been reported by Panasiewicz *et al.* (2020) and Tiecher *et al.* (2012) that conventional tillage system, which involves deep tillage with extensive and frequent harrowing resulting in homogenization of agricultural soils affect the availability of P required for plant uptake

The fixation of phosphorus is said to be a common phenomenon in tropical soils due to its high volume of Iron (Fe) and Aluminum (Al) hydrous oxides (Igwe 2010). More so, the pH of a soil determines the type of phosphorus fixation that occurs, acidic soils tend to fix either Iron (Fe) or Aluminium (Al) phosphorus compound, while alkaline soil fixes Calcium (Ca) phosphorus compound (Ikhajiagbe *et al.*, 2020). Hence, the aim of this study was to determine how land use and soil depth affect phosphorus fractions across basement complex geological formation of the state.

MATERIALS AND METHODS

Study area

This research was carried out on the soils of different land use systems of the basement complex geology of Ogun State, Nigeria. Ogun State is between Latitude 6.2^0N and 7.8^0 N and Longitude 3.0^0 E, and 5.0^0 E, and covers a total land mass of 16,409.2 km^2. The State shares an international boundary with the Republic of Benin to the West and interstate boundaries with Oyo State to the North, Lagos and Atlantic Ocean to the South and Ondo State to the East.

The climate of Ogun state follows a tropical pattern with the rainy season starting about March and end in November, followed by dry season. The mean annual rainfall varies from 1280mm in the Southern parts of the State to 1050mm in the Northern areas. The average monthly temperature ranges from 23^0C in July to 32^0C in February. The northern part of the state lies within the derived savanna ecology, while the central part falls within the rain forest belt and the Southern part of the state falls into mangrove swamp.

Field work

Two locations were selected: the Federal University of Agriculture Abeokuta Teaching and Demonstration farms, main campus and the school research farmland at Iwoye-ketu. Two profile pits were sunk on the teaching and demonstration farm, main campus; first was on a cultivated arable land (7.23602^0N, 2.74522^0E) and the other on an uncultivated fallowed land (7.22881^0N, 3.42098^0E) respectively. Also, another two profile pits were sunk on the school research farmland in Iwoye-ketu; cultivated arable land (7.57142^0N, 2.74522^0E) and uncultivated fallowed land (7.57483^0N, 2.74426^0E) respectively. The soil profile pits were described according to the FAO (2006) guidelines on soil profile description, and soil samples were collected from the pedogenic horizons of the profiles in a well labeled sample bags, transported to the laboratory and analyzed for physical and chemical properties, and for forms of phosphorus.

Laboratory analysis

All the samples collected were air dried and sieved using 2 mm sieve before taking for laboratory studies. Particle size analysis was determined using the hydrometer method as described by Bouyocous (1962) while Soil pH was determined electrometrically in 1:2 (soil: water ratio) suspension (Mclean, 1965). Total soil organic carbon was determined using acid dichromate wet-oxidation procedure of Walkley and Black method as described by Nelson and Sommers (1982). The available P was extracted using Bray-1 extractant at a soil: extractant ratio of 1:5, while the concentration of the available P in the extract was determined by vanado-molybdate blue method of Murphy and Riley (1962) using spectrophotometer at 882 nm wavelength. Finally, the phosphorus forms in the soil were determined by sequential fractionation method of Chang and Jackson (1957) as modified by Manojlovic *et al.* (2007).

RESULTS

Morphological and Physical Properties of Soils of the study area

The soil colour in the two locations of this formation, FUNAAB and Iwoye-ketu varied from dark reddish brown (5YR3/2) at the surface to dark yellowish brown (10YR4/3) on the subsurface (Table 1). The FUNAAB profiles had similar soil texture in the surface and subsurface, the soil texture varied from loamy sand at the surface to sandy clay loam at the subsurface. Whereas, Iwoye-ketu profiles had different soil texture, pedon 1 had loamy sand at the surface and sandy loam at the subsurface, while, pedon 2 was sandy loam at the surface and sandy clay loam at the subsurface. The structures of the soils varied across locations in the formation, FUNAAB pedon 1 had structure that ranged from fine sub-angular blocky in the surface to medium sub-angular blocky in the subsurface, whereas, the pedon 2 had structures that varied from crumb in the surface, fine sub-angular blocky to medium sub-angular blocky in the sub-surfaces. The consistency of FUNAAB Pedon 1 was moderately friable down the horizons, while Pedon 2 varied from very friable at the surface to moderately firm at the subsurface horizons. Likewise, Iwoye-ketupedon 1 was very friable in the surface horizon and Loose in the subsurface, pedon 2 was friable down the profile.

The particle size distribution in this formation (Basement complex) were similar in the profiles, the sand content decreased with increasing soil depths, while the clay contents increased with increasing soil depth.

Similarly, the silt content also increasing with the corresponding increase in the soil depths.

Chemical Properties of Soils of the study area

The soil pH and the Ca content of this formation ranged from 6.85 to 7.15 and 3.70 to 5.80 cmol/kg in the surface horizons of the cultivated land respectively, while the subsurface ranged from 5.95 to 7.20 and 2.90 to 6.00 cmol/kg respectively. However, the uncultivated soil had pH and Ca content that ranged from 6.85 to 7.20 and from 2.50 to 5.80 cmol/kg, respectively. Meanwhile, the Mg and total exchangeable acidity (TEA) content in the surface soils of the cultivated land ranged from 2.80 to 15.50 cmol/kg and 0.10 to 1.50 cmol/kg, while, the subsurface ranged from 3.50 to 7.00 cmol/kg and 0.10 cmol/kg respectively. The Organic Carbon and Available P in this formation ranged from 1.00 to 3.40 g/kg, 8.83 to 8.97 mg/kg in the surface horizons of the cultivated lands respectively. The subsurface soils had OC and Available P that ranged from 1.40 to 3.80 g/kg and 3.99 to 9.11 mg/kg respectively. However, the uncultivated land had Organic Carbon and available P in the surface horizons that ranged from 3.20 to 4.40 g/kg and 6.12 to 11.25 mg/kg respectively, while the subsurface horizons ranged from 4.00 to 2.60 g/kg and 3.13 to 7.27 mg/kg respectively (Table 2).

Forms of phosphorus distribution across the land use types

The Calcium-P (Ca-P) content ranged from 2.14 to 8.46 mg/kg in the cultivated arable land, while the uncultivated fallow land had Ca-P content that ranged from 2.09 to 6.49 mg/kg (Table 3) distributed irregularly down the depth. The Ca-P content in the soils of the cultivated arable land (1) of FUNAAB ranged from 2.91 to 7.28 mg/kg, while the uncultivated fallow lands (2) had Ca-P content that ranged from 2.09 to 6.49 mg/kg. Similarly, the Ca-P in the cultivated arable land (3) of Iwoye-ketu ranged from 2.14 to 8.46 mg/kg, while the uncultivated fallow land (4) Ca-P ranged from 2.86 to 5.02 mg/kg (Table 3). Considering the Aluminum P (Al-P) content in the soil of the Basement complex, the pattern of profile distribution was irregular across the locations. The FUNAAB soils had Al-P content that ranged from 6.70 to 12.28 mg/kg in the cultivated arable land (1), while the uncultivated fallow land (2) ranged from 3.91 to 94.30 mg/kg down the horizons. However, the Iwoye-ketu soils had Al-P content that ranged from 9.49 to 17.86 mg/kg in the cultivated arable land (3), and the uncultivated fallow land (4) had Al-P content that ranged from 5.58 to 22.32 mg/kg.

Similarly, the profile distribution of iron P (Fe-P) and water soluble P (WS-P) content in the soil of FUNAAB were irregular, but ranged from 12.76 to 80.99 mg/kg and from 7.77 to 27.452 mg/kg in the cultivated arable land (1) respectively. However, the uncultivated fallow land had (2) Fe-P and WS-P content that ranged from 3.33 to 32.73 mg/kg and 3.29 to 13.16 mg/kg respectively. Considering the Fe-P and WS-P in the soil of Iwoye-ketu, the cultivated arable land (3) had contents that ranged from 28.29 to 61.02 mg/kg and 15.47 to 40 mg/kg respectively. The uncultivated fallow land had Fe-P and WS-P that ranged from 11.09 to 13.21 mg/kg and 1.10 to 5.48 mg/kg respectively. Furthermore, the Labile-P content ranged from 25.96 to 38.93 mg/kg and 11.44 to 48.25 in the cultivated land of FUNAAB respectively, while Iwoye-ketu soil had Labile-P content that ranged from 18.30 to 27.68 mg/kg and 43.68.62 mg/kg respectively (Table 3).

Interaction effects of Land use and Depth on Phosphorus forms

The effects of land use and depths on the P forms of the geological formation was observed that Al-P, Ca-P were significantly affected ($p<0.05$), while Labile-P, Fe-P and Water Soluble-P were not significantly affected by the interactions (Table 4).

The values of the Ca-P content in the surface soils significantly varied across the land use system. The Ca-P content in the surface soils of the cultivated arable lands was significantly lower than those of the uncultivated fallow lands. The Ca-P content in the cultivated arable soils increased with the soil depth, while, those of the uncultivated fallow soils were not significantly different ($p<0.05$) in the surface and sub-surface soils. The Al-P contents on the surface soils varied significantly with the Land use system but, no significantly different ($p<0.05$) in the subsurface soils. Comparatively, the mean value of Al-P on the cultivated arable soils were significantly higher and different ($p>0.05$) from those of the uncultivated fallow soils (Table 4).

Relationship between the Soil Properties and Phosphorus Forms

The correlation between some selected soil properties and P forms in the geological formationshowed that %silt, Calcium (Ca), Magnesium (Mg) and water soluble P (WS-P) contents in the soils were significant ($p<0.001$) and positively correlated with Organic carbon in the soils (Table 5). Also, Calcium-P (Ca-P) content was significant ($p<0.05$) and positively corrected with Organic carbon. The percentage sand and silt were significant ($p<0.001$) but negatively correlated with %clay content. More so, Mg had significant ($p<0.01$) and positive relationship with the clay content. The water soluble-P (WS-P) content and the soil pH were significant ($p<0.001$) but negatively corrected with the %silt content. Conversely, Avail-P, Ca, Ca-P, Mg, k and pH were significant ($p<0.001$) but negatively correlated with the Aluminum P (Al-P) content of the soils. More so, the Avail-P content of the formations was significant ($p<0.001$) but negatively correlated with Ca, Mg and k respectively. The Ca contents of the formations was significant ($p<0.001$) but had negative relationship with the Ca-P, Fe-P and pH, but was significant ($p<0.001$) and positively correlated with Mg and WS-P respectively (Table 5). The Ca-P in the formations had significant ($p<0.001$) and positive relationship with the soil pH and Mg, but was significant ($p<0.001$) and negatively corrected with Fe-P, TEA and k of the soil respectively. Similarly, the Fe-P contents of the soils had significant but negative relationship with the TEA ($p<0.001$) and Mg ($p<0.05$) of the soils respectively. The Labile-P contents of the formation was also significant but negatively correlated ($p<0.001$) with k and Mg (Table 5).

DISCUSSION

The depth of the Basement Complex ranged from 0-140 cm with present of gravels and plinthites, this is an indication of sedimentary origin, the soil texture ranged from loamy sand at the surface to sandy clay loam at the subsurface. Generally, the soil colour of South-western Nigeria ranged from dark brown at the surface to reddish brown at the subsurface. This is an indication of high content of oxides of iron in the formations. (Schwertmann, 1993).The distribution of the P forms in the geology had Fe-P as the most abundant P forms and Ca-P as the least abundance; this is because hydroxides and oxyhydroxides of Fe are the predominant, whereas Calcium is the lowest in this geological formation. This is similar to Mustapha *et al.,* (2007), who reported that Fe-P was more abundant in the soils of Bauchi Local Government Area. The non-significant effect of Land use and soil depth of P distribution in this study could be attributed to the season (planting season) when the soils samples used in this study were collected. Fertilizer application on the cultivated arable farmland might have replenished the phosphorus in the soils and phosphorus fixation might have taken place due to the soils having high affinity for Phosphorus. It was also observed that there was no statistical difference in the means of Fe-P and Labile P down the profile, this was an indication that the soils of Ogun State have high amount of iron, and soil nutrient leaching might have contributed to labile P down the soil depth.

CONCLUSION

This study was designed to examine the effects of land use and soil depth on phosphorus forms. The negative and significant relationship between the Al-P and Avail-P, Ca and Ca-P indicated that an increase in the Al-P leads to decrease in the Avail-P and Ca-P in the soils. It was observed that land use and soil depth had no significant effects on phosphorus fractions of basement complex soil. It is therefore recommended that further study be conducted at different planting seasons to further understand the non-effects of land use types on the phosphorus content of the basement complex geology of Ogun State.

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Table 1: Morphological and Physical Characteristics of the Basement Complex

Location	Profile	Horizon	Depth (cm)	Particle Size Distribution (g/kg) Sand	Clay	Silt	Texture	Structure	Consistency	Colour
FUNAAB	1	Ap	0-21	74.58	24.86	5.6	LS	Fsbk	mfr	Dark reddish brown(5YR3/2)
		B1	21-42	74.22	23.42	2.36	LS	Fsbk	mfr	Dark brown(10YR4/3)
		B2	42-60	68.36	28.86	2.78	SCL	Msbk	mfr	Dark yellowish brown(10YR4/4)
	2	Ao	0-17	73.08	25.35	1.57	LS	Cr	Vfri	Dark reddish brown(5YR3/2
		B1	17-25	69.72	26.93	3.35	LS	Fsbk	mfr	Dark yellowish brown(10YR3/4)
		B2	25-44	68.58	27.37	4.05	SL	Msbk	Mfir	Dark brown(7.5YR3/4)
		B_t	44-110	59.08	32.49	8.43	SCL	Msbk	LO	Dark brown (7.5YR4/4)
Iwoye-ketu	3	Ap	0-20	73.36	26.3	3.5	LS	Cr	LO	Dark yellowish brown(10YR3/4)
		B1	20-50	69.22	27.5	3.28	SL	Cr	LO	Dark brown(7.5YR3/4)
		B2	50-90	68.43	28.22	3.35	SL	Cr	LO	Yellowish red(5 YR4/6)
	4	A	0-20	73.5	25.01	1.49	SL	Fsbk	FR	Very Dark brown(10YR2/2)
		B_t	20-140	68.5	31.5	10	SCL	Fsbk	FR	Dark yellowish brown(10YR4/6)

1= cultivated arable land, 2= uncultivated fallow land, GR=granular, Fsbk=fine subangular blocky, Msbk=Medium subangular blocky, Cr=crumb, Cabk=coarse angular blocky,Lo= loose; Vfr=very friable, Mfi=moderately firm, LS =loamy sand, SCL =sandy clay loam

Table 2: Chemical Properties of the Soils

Formations	Location	Profile	depth(cm)	pH(H_20)	Ca	Mg cmol/kg	TEA	OC (g/kg)	Avai-P (mg/kg)
Basement Complex	FUNAAB	Cul.	0-21	7.15	2.70	15.5	1.50	BLD	8.97
			21-42	6.35	2.90	5.90	0.10	10.00	8.40
			42-60	5.95	3.40	3.50	0.10	3.80	8.97
		Uncul.	0-17	6.85	5.80	1.00	0.10	3.00	11.25
			17-25	6.95	3.10	4.60	0.30	4.40	6.12
			25-44	6.95	3.50	3.90	0.10	1.20	0.00
			44-110	6.05	6.00	7.20	0.30	2.60	3.13
	Iwoye-ketu	Cul.	0-20	7.15	3.70	2.80	0.10	3.40	8.83
			20-50	7.20	3.00	4.70	0.10	1.40	3.99
			50-90	6.75	6.00	7.00	0.10	1.80	9.11
		Uncul.	0-20	7.20	2.50	5.30	0.40	3.20	11.25
			20-140	6.35	3.60	4.40	0.60	0.40	7.26
			Mean	6.74	3.85	5.48	0.32	4.00	7.27
			CV (%)	6.73	33.95	65.55	128	15.83	46.65

Cul. =cultivated arable land, Uncul. = uncultivated fallow land, TEA= total exchangeable acidity, BLD = Below detection limit

Table 3: Phosphorus Distribution Pattern of the Geology

Formation	Location	Profile	Depth (cm)	Ca-P mg/kg	Al-P (mg/kg)	Fe-P mg/kg	WS-P (mg/kg)	Labile-P (mg/kg)
Basement Complex	FUNAAB	1	0-21	3.38	6.7	72.11	25.22	25.96
			21-42	2.91	12.28	12.76	7.77	38.93
			42-60	7.28	7.24	80.99	27.42	29.52
		2	0-17	6.49	11.16	3.33	3.29	31.26
			17-25	4.6	94.3	32.73	13.16	48.25
			25-44	2.09	3.91	23.3	5.48	11.44
			44-110	5.5	14.45	23.85	12.2	24.13
	Iwoye-ketu	3	0-20	2.14	10.58	42.16	40.58	27.68
			20-50	8.46	9.49	28.29	27.42	25.6
			50-90	3.26	17.86	61.02	15.47	18.3
		4	0-20	2.86	22.32	13.21	5.48	68.62
			20-140	5.02	5.58	11.09	1.1	43.87

Table 4: Effects of Land use and Depth on the Phosphorus forms

	Ca-P		Al-P		Fe-P		Labile-P		Water Soluble-P	
					mg/kg					
					Depth (cm)					
Landuse	*(0-30)*	*(31-180)*	*(0-30)*	*(31-180)*	*(0-30)*	*(31-180)*	*(0-30)*	*(31-180)*	*(0-30)*	*(31-180)*
Cultivated arable land	4.26	6.92	10.24	7.65	35.00	40.10	33.60	28.50	8.01	10.23
Uncultivated fallow land	6.87	6.05	5.37	6.68	36.20	27.40	42.40	37.70	9.24	7.24
LSD	2.03		3.01		Ns		Ns		ns	

ns = not significant, surface = 0-30 cm, subsurface = 30-180 cm

Table 5: Relationship between the Soil Properties and Phosphorus Forms

%OC	1												
%sand	0.185	-0.987***	1										
%silt	0.445***	-0.593***	0.457***	1									
Avai_P	0.257	-0.073	0.144	-0.323	-0.823***	1							
Ca	0.723***	0.072	-0.094	0.071	-0.511***	-0.634***	1						
Ca_P	0.386*	-0.041	0.106	-0.307	-0.726***	0.970***	-0.729***	1					
Fe_P	0.21	-0.307	0.31	0.148	0.131	0.378*	-0.485***	-0.364*	1				
Labile_P	0.295	-0.316	0.357*	-0.044	0.235	-0.109	-0.123	-0.133	-0.142	1			
Mg	0.767***	0.393**	-0.388*	-0.236	-0.617***	-0.423***	0.778***	0.428***	-0.360*	-0.562***	1		
TEA	-0.42	-0.195	0.186	0.148	0.413**	-0.464***	0.822***	-0.488***	-0.664***	0.045	0.606***		
WS_P	0.742***	0.074	0.043	-0.630***	0.286	0.222	0.430***	0.054	-0.219	0.146	0.326	1	
k	-0.12	-0.15	0.058	0.543***	-0.716***	-0.571***	0.326	-0.497***	-0.208	-0.514***	0.414**	-0.455**	1
pH	0.061	0.091	0.033	-0.675***	-0.624***	0.711***	-0.470***	0.719***	-0.172	0.215	-0.276	0.441***	-0.530***
	%OC	%clay	%sand	%silt	Al_P	Avai_P	Ca	Ca_P	Fe_P	Labile_P	Mg	WS_P	k

Avail-P=Available P, Ca=Calcium, Ca-P=Calcium-P, Fe-P=Iron-P, TEA=Total exchangeable acidity, WS-P=water soluble P, *,,*** =5%, 1%, and 0.1% levels of probability**