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EFFECT OF LAND USE AND SOIL DEPTH ON SOIL PHOSPHORUS FRACTIONS

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ABSTRACT

The aims of the experiments were to determine the effect of land use and soil depths on soil phosphorus fractions. Soil samples were taken systematically from dug profile pits at 0-20, 20-40 and 40-60 cm. Soil samples were characterised and P fractionation analyses were done in triplicates using standard procedures. Data generated were analysed using Statistical Analyses System (SAS) software. Results indicated that soil P forms are in the order of abundance: available P > Al and Fe P > residual P > Ca P > labile P. Total P content of the soil is concentrated at the 0-20 cm soil depth. The values of the soil total P in order of abundance among the land uses is: fadama farm > fallow land > oil palm plantation > agroforestry > plantain plantation > cassava farm. Fadama soil had the highest amount of the soil P forms while either of cassava farm soil and plantain plantation soil had the least values. There is the accumulation of soil P forms at 40-60 cm depth in fadama farm. The negative nutrient balance and the sandy texture of cassava and plantain is probably responsible for the low P forms. Soil P forms are positively correlated.

INTRODUCTION

Since the primary source of phosphorus in terrestrial ecosystems is the weathering of minerals, the dynamics of P in soil and maintenance of its adequate supply are important for sustainability of native and managed agricultural ecosystem. Phosphorus exists in both inorganic and organic forms, different forms of P exists in different amounts and proportions depending on the inherent soil condition imposed by parent material geochemistry, soil development stage and management practices. The nature and distribution of P in soils provided useful information needed for improved management of P fertility.

One of the important considerations in the evaluation of fertility level of soils is the determination of P status. Phosphorus can occur in soil in variety of forms and the quantity of each is dependent upon the particular mineralogical and ionic environment (Ayodele and Agboola, 1981). Phosphorus fractionation provides an effective approach for investigating soil P availability and P transformation in soil and the likelihood of its transport.

Several studies have been carried out on the amount and distribution of P in soil profile, Allen and Mallarino; 2006), but reports on profile distribution of P fractionation in in different land use in Nigerian soils are scarce. Therefore, the objective of this study is to investigate the effect of different land use and soil depth distribution of phosphorus fractions.

MATERIALS AND METHODS

Description of the land use sites

Agroforestry arboretum ***c***onsist of tree species as *Treculia africana, Acacia nilotica, Tectona grandis, and Gmelina arborea*, it was established in 1990. Degraded land (short fallow of 2-3 years) had secondary natural regrowth of about 4years with herbaceous shrubs, few trees and grasses (*Panicum maximum*). Fadama (lowland) had existed for about 11years with shrubs and grasses, it is also used for the cultivation of dry season vegetables, lowland rice, and pepper. Oil palm plantation was established in late 2007, and planted to oil palm and sometimes intercropped with maize. Plantain plantation was established and grown to plantain alone since 2007. Cassava farm was grown to cassava since 2011, adjoining land is used for soil and gravel mining.

Soil collection

Soil samples were taken systematically from soil profiles of different land uses (Table 1) at the Federal University of Agriculture, Abeokuta Nigeria. The sampling depths were 0-20, 20-40 and 40-60 cm. The geographical locations of the land used are also shown in Table 1.

Soil characterisation

The soil samples were taken to the laboratory where they were air-dried at room temperature, crushed and sieved to pass through 2mm sieve ready for analysis. All soil samples were subjected to physico-chemical analyses. The soil samples were analyzed for: particle size by the hydrometer method; soil pH in water using a glass electrode; organic carbon by the wet dichromate method.

Phosphorus fractionation

A portion of the sieved samples of P was subjected to a simplified five-step sequential extraction procedure (Tchienkoua *et al*., 2010). Five gram of the air dried and sieved soil was weighed and poured into a well labelled 120 ml extraction bottles (with the use of a weighing balance) and 40 ml of successive extractants were added. The extractants were added sequentially in the following order: (a) (0.03M NH_4F in 0.025N HCl), (b) 0.5 M $NaHCO_3$, (c) 0.1 M NaOH, (d) 0.5 M HCl, (e) 2M H_2SO_4. The different P form extracted are available, labile, Al and Fe bound, calcium bound and residual P, respectively. After each extraction, the filtered solution contain extractable fraction of phosphorus from which 1 ml of each sample was pipette into a test-tube and 3 ml of both ascorbic acid and molybdate reagent were added and left for about an hour to fully develop color after which it was read in a spectrophotometer at 880 nm wavelength.

Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) using the Statistical Analysis System package (SAS, 1999). Significance treatment means were separated using Duncan Multiple Range Test (DMRT). Correlation and regression analyses were also done to estimate the relationship and quantify their magnitude among the soil phosphorus fractions using the same software

RESULTS AND DISCUSSION

The properties of the top soil of the experimental land use types are shown in Table 1.

The pH of the soil ranged from 5.0 to 6.8. The pH of the soils from plantain plantation, and cassava farm was more acidic than soils from other land uses. Soil from agroforestry land use seems to be the most basic in reaction followed by oil palm plantation soil. Generally, the soil reaction is close to neutral in the soils and acidic in plantain and cassava soils. However, for optimal performance of the crops being grown, there is the need for soil liming to increase the pH of the soil and hence soil nutrient availability. Soil organic carbon (SOC) content of the soils indicated that the soil OC decreased with soil depth. The SOC of the soil from oil palm plantation, plantain plantation, agroforestry plantation, and the fadama seems similar and higher than other land uses particularly between the first 40 cm soil depth. Soil from cassava farm is very poor in SOC. The distribution of the SOC of the soils from the land uses reflected the type and density of the vegetation cover. The biomass return to the soil from the agroforestry plantation, plantain and oil palm is higher than that from the other land uses. Cassava farm is predominantly sandy with very little ability to hold nutrient or organic material and this could have encouraged the leaching of basic cations. This is perhaps the reason for the use of the adjoining sites for sand mining. The SOC of the soils was also seen to correlate with the soil clay content. Fadama soil, is a lowland soil that could have received organic materials eroded from upper slope. However, the decomposition of organic material under a poorly drained soil as in the fadama soil is expected to be low. The clay content of the soils was higher at lower depths. The soils are classified as Alfisol except fadama soil that is an Inceptisol. The soil textural class suggests that the soil of the different land use examined were predominantly sandy in the surface layers. It thus implies that the soils would be well drained in the surface, and may have poor water and nutrient holding capacity.

The distribution of the P forms across soil depth is shown in Table 2. It is clear that soil available P (Bray 1 P), labile P (NaHCO3-P) and Al and Fe P (NaOH-P) are all concentrated at 40-60 cm soil depth while the least values are recorded at the top soil (0-20cm). The values recorded at the last soil layer were similar to that from the 0-20 cm (for Bray 1P and NaOH P) but significantly higher than the soil P fractions at 20-40 cm. On the other hand, Ca bound P and the residual P are higher at 0-20 cm soil depth, followed by the values at the 40-60 cm depth but least at 20-40 cm depth. The aggregates of the soil P forms (total P) show that the P distribution is in the order of abundance: 0-20 cm = 40-60 cm > 20-40 cm. The distribution of the P forms with soil depths shows an erratic trend, however, large proportion of the available P is deposited at 40 60 cm depth. Since the values reported are the aggregates from different land use, some of the component land use could have influenced the value.

In Table 3, soil from the fadama had significantly higher amount of available P compared with other land uses. This was closely followed by the values from agroforestry soil, though these values were not significantly different from the value from oil palm plantation soil. They were higher than the values from fallowed land, cassava farm and plantain plantation. Available P has been reported to be the highest form of P in most soils and is also reported as the major sink for P applied to soils (Gichangi, *et al.* 2010). The trend observed in labile P was slightly different. Here, Fadama soil still had the significantly higher values compared with other land uses, but cassava farm soil was superior in values compared with other land uses. The difference was statistically significant. Agroforestry soil, oil palm plantation soil had similar values, though lower than the value from fallowed land. The least value was recorded in plantain plantation soil. The lowest values for Al and Fe bound P were observed in soil from cassava farm, agroforestry and plantain plantation. Soil from the fallow land had value significantly higher than that from oil palm plantation while fadama soil had the highest value. Fadama soil and fallow soil had the highest amount of Ca P, followed by the values from agroforestry, oil palm and plantain soils. The lowest values were recorded in soil from cassava farm. The trend observed in residual P is similar to that observed in NaOH extractable P. Trend in the values of the soil total P in order of abundance among the land uses were: fadama farm > fallow land > oil palm plantation > agroforestry > plantain plantation > cassava farm. Araújo et al. (1993) and Araújo et al. (2003) have reported that all soil P fractions were plant-available, including the residual fraction, but with different relative intensities (Galvão and Salcedo, 2009). The consistent higher values observed in the fadama soil indicated that the soil is superior in terms of P fluxes and amount than other land use. The topographic location of the land use (valley bottom) could have put it at a vantage position to have deposits of P from varied sources deposited through erosion. This is perhaps the reason for the continual use of fadama for all year cropping with minimal fertilizer use. The trend of values for other land uses are erratic, however, agroforestry and fallow land seems to be better than other land uses. This could be due to the large foliage of different tree species being returned to the soil surface in the agroforestry arboretum and the leaves of shrubs and leguminous fallow species in the fallow land. Oil palm soil also had marginal values of the P forms compared with the trio earlier mentioned. The low value could be probably due to 'nutrient export' from the oil palm seeds used for palm oil. High amount of nutrient including phosphorus in the seeds and the low biomass return and poor fertilization programme practiced in the farm will eventually result into a negative nutrient balance in the farm enterprise. Cassava farm and plantain farm were the poorest in P forms. This is attributable to very sandy and porous nature of cassava soil which will hinder nutrient holding. Leaching of soil P is also expected to be high in the soil. Plantains are known to be heavy feeders on soil nutrients and hence needed high fertilization to replenish the lost nutrients from the harvested fruits. This was hardly achieved in the farm under study; the net effect is the gross reduction in the amount of soil fertility indicators as shown in the very low soil P forms.

The interaction of soil depth and land use on the P forms is shown in Table 4. The results were similar to those reported earlier. The Tables shows that soil from the fadama and agroforestry had significantly higher values at different soil depths compared with other interactions for available P, labile P and Al and Fe P. There seems to be the depositions of the P form at the fadama soil at 40 – 60 cm depth (same for agroforestry soil in available P). Some of the values were not significantly higher than those from 0-20 cm depth. Plantain and cassava farm also had the lowest amount of the soil P forms irrespective of the soil depths. The reason for the deposition of forms of soil P at lower depth of the fadama had earlier been explained.

The correlation coefficients shown in Table 5 indicate that all the P forms are closely related. The relationships between the P forms are positive and significant. However, the highest correlation was found between NaOH P and H_2SO_4 P ($r=0.75$; $p<0.001$). The contributions of each of the P forms to the total P are expectedly high and significant. An attempt to quantify the relationship amongst the soil P forms is presented as Table 6. The available pool of soil P is determined by the relative amounts of labile and residual P. Generally, the equations in the Table reveal that the influence of the soil P forms on each other is positive. The highest coefficient of determination was recorded in equation relating residual P as a function of NaOH extractable, NaHCO3 and HCl extractable P forms.

CONCLUSIONS

Soil phosphorus fractions are affected by soil land use types, and the soil texture. Soil total P are concentrated at the 0-20 cm depth while the P forms are in the order of abundance available P > Al and Fe P > residual P > Ca P > labile P. Fadama soil had the highest amount of the soil P forms while either of cassava farm soil and plantain plantation soil had the least values.

Table 1: Some selected characteristics of the top soil of the experimental sites

Land use/GPS location	Soil depth (cm)	pH (H_20)	O.C. (%)	Clay (%)	Texture
Oil palm plantation	0-20	6.8	2.35	8.8	loamy sand
N07.2701º E003.4128º	20-40	6.2	2.03	10.8	loamy sand
	40-60	5.9	0.34	14.8	loamy sand
Plantain plantation	0-20	5.3	3.83	10.8	loamy sand
N07.2876º E003.4022º	20-40	5.3	2.01	20.8	sandy clay loam
	40-60	5.0	2.01	20.8	sandy clay loam
Agroforestry plantation	0-20	6.0	3.73	8.8	loamy sandy
N07.0733^0 E003.4484^0	20-40	6.2	2.01	12.8	loamy sandy
	40-60	6.1	0.62	20.8	sandy clay loam
Cassava	0 – 20	5.2	0.33	6.0	Sand
N 07.24388º, E 003.46198º	20 – 40	5.6	0.05	7.0	Sand
	40 – 60	5.1	0.22	5.0	Sand
Degraded	0 – 20	6.20	1.96	5.40	Loamy sand
N 07.23803º, E 003.44531º	20 – 40	5.90	0.76	15.40	Sandy loam
	40 – 60	6.20	0.52	11.40	Sandy loam
Fadama	0 – 20	5.90	2.89	8.80	Loamy sand
N 07.2273º, E 003.4484 º	20 – 40	5.50	2.73	6.80	Loamy sand
	40 – 60	6.40	2.27	14.87	Loamy sand

Table 2. Effect of soil depth on soil phosphorus fractions (mg kg^{-1}) (Mean values across land use)

Depth (cm)	Bray1 P	$NaHCO_3$ P	NaOH P	HCl P	H_2SO_4 P	Total P
0-20	41.33a	2.58b	15.49a	10.08a	13.07a	82.55a
20-40	38.50b	1.65c	8.32b	2.29b	9.03b	59.80b
40-60	41.45a	2.96a	17.28a	2.96b	12.35a	77.00a

Table 3. Effect of land use on soil phosphorus fractions (mg kg^{-1}) (Mean values across soil depths)

Land use	Bray1 P	$NaHCO_3$ P	NaOH P	HCl P	H_2SO_4 P	Total P
Fadama	45.43a	7.89a	29.65a	11.38a	24.86a	119.21a
Agroforestry	41.69b	0.87de	4.11d	3.11b	7.04c	56.82cd
Oil palm	39.96bc	0.51e	14.76c	2.49b	6.61c	64.35c
Fallowed	39.14cd	1.62c	24.51b	9.28a	17.21b	91.76b
Cassava	38.66cd	2.41b	3.62d	1.72b	6.56c	52.99d
Plantain	37.70d	1.10d	5.52d	2.67b	6.60c	53.59d

Table 4. Effect of soil depth and land use interaction on soil phosphorus fractions (mg kg^{-1})

Land use	Depth	Bray1 P	$NaHCO_3$ P	NaOH P	HCl P	H_2SO_4 P	Total P
Fadama	0-20	48.49a	7.24b	39.76a	27.04a	36.85a	159.39a
Fadama	20-40	38.65bc	4.23c	12.19defg	1.65b	6.66de	63.40efgh
Fadama	40-60	49.12a	12.21a	36.99ab	5.44b	31.04a	134.81b
Agroforestry	0-20	39.28bc	0.76gh	3.49i	3.02b	6.38de	52.94fgh
Agroforestry	20-40	38.56bc	1.11fg	1.62i	3.00b	6.50de	50.82h
Agroforestry	40-60	47.21a	0.71gh	7.22efghi	3.28b	8.25cde	66.68efg
Oil palm	0-20	41.44b	0.70gh	11.67defgh	1.93b	6.36e	62.11efgh
Oil palm	20-40	39.31bc	0.26h	14.44de	2.61b	6.40de	63.04efgh
Oil palm	40-60	39.13bc	0.56gh	18.17d	2.94b	7.05de	67.87ef
Fallowed	0-20	40.99b	2.65d	29.47c	24.05a	15.70bc	112.88c
Fallowed	20-40	38.43bc	0.63gh	14.22def	2.13b	21.45b	76.87de
Fallowed	40-60	37.99bc	1.57f	29.82bc	1.66b	14.46bcd	85.52d
Cassava	0-20	39.40bc	2.44d	3.62i	1.72b	6.58de	53.77fgh
Cassava	20-40	38.51bc	2.41de	2.83i	1.72b	6.48de	51.97gh
Cassava	40-60	38.06bc	2.37de	4.42hi	1.72b	6.61de	53.20fgh
Plantain	0-20	38.38bc	1.68ef	4.90ghi	2.68b	6.52de	54.17fgh
Plantain	20-40	37.53c	1.28fg	4.59hi	2.62b	6.65de	52.68fgh
Plantain	40-60	37.19c	0.33h	7.05fghi	2.70b	6.63de	53.91fgh

Table 5. Correlation coefficient among soil P forms

	Bray1 P	$NaHCO_3$ P	NaOH P	HCl P	H_2SO_4 P
$NaHCO_3$ P	0.62***				
NaOH P	0.57***	0.61***			
HCl P	0.46***	0.35***	0.61***		
H_2SO_4 P	0.64***	0.66***	0.75***	0.64***	
Total P	0.73***	0.71***	0.91***	0.78***	0.91***

*** significant at 0.1 % probability

Table 6. Regression equations among soil P forms

Dependent variable	Independent variables	Coefficient of Determination (R^2)
Bray1 P (a)	= 37.33 + 0.49 b + 0.17 e	0.48
$NaHCO_3$ P (b)	= - 9.06 + 0.13 e + 0.25 a	0.51
NaOH P (c)	= 2.86 + 0.39 d + 0.56 e + 1.00 b	0.62
HCl P (d)	= 0.66 + 0.50 e	0.41
H_2SO_4 P (e)	= 2.87 + 1.11 b + 0.29 c + 0.39 d	0.69

Where: Bray1 P= (a), $NaHCO_3$ P = (b), NaOH P = (c), HCl P = (d), H_2SO_4 P = (e)

REFERENCES

Allen B. L., and Mallarino A. P. 2006. Relationships between extractable soil phosphorus and phosphorus saturation after long-term fertilizer or manure application. Soil Science Society America Journal, 70:454–463.

Araújo MSB, Salcedo IH, and Sampaio EV. 1993. Efeito de fertilizações fosfatadas anuais em solos cultivados com cana-de-açúcar. II. Formas disponíveis e efeito residual do P acumulado. R Bras Ci Solo 17:397-403.

Araújo MSB, Schaefer CER, and Sampaio EV. 2003. Plant phosphorus availability in Latosols and Luvisols from northeastern semi-arid Brazil. Communication in Soil Science and Plant Analysis 34:407-425.

Ayodele, O.J. and Agboola A.A. 1981. Evaluation of phosphorus fixation capacity of tropical savannah soils of western Nigeria. Soil Science America Journal, 45:462-464.

Galvão SRS, and Salcedo IH. 2009. Soil phosphorus fractions in sandy soils amended with cattle manure for long periods. R Bras Ci Solo 33:613-622.

Gichangi EM, Mnkeni PNS, and Brookes PC. 2010. Goat manure application improves phosphate fertilizer effectiveness through enhanced biological cycling of phosphorus. Soil Science and Plant Nutrition 56:853-860.

SAS Institute 1999. The SAS system for Windows. Release 8.0. SAS Inst., Cary, NC.

Tchienkoua, Zech W, and Sanginga N. 2010. Inorganic Phosphorus fractions dynamics following Phosphorus application on maize in Acid soils. American-Eurasian Journal of Agriculture and Environmental Science 8 (6): 793-800.