PHOSPHORUS SORPTION CAPACITY OF SOILS OF THREE DIFFERENT PARENT MATERIALS IN ENUGU STATE.

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ABSTRACT

This project explores the phosphorus sorption capacity of soils originating from three distinct parent materials. The study employed laboratory experiments to assess the Physical and Chemical Properties of soils derived from three different parent materials (Sandstone, Shale and alluvium) as well as the P sorption characteristics of these soil types. The routine analysis showed the texture of alluvium to be sand, sandstone to be sandy clay loam (SCL), Shale as clayey loam (CL). The PH of these soils ranged from 5.8-7.3 which was indicated as slightly acidic to slightly alkaline; the value of the Total Nitrogen was low for all the soils. The soils showed significant differences in levels of organic matter(OM) content Using the Adsorption Parameters of the Lagmiur Model results indicate that soils derived from different parent materials exhibit varying P sorption capacities, the alluvium derived soils generally displaying higher sorption capacity compared to sandstone and shale derived soils, with a standard phosphorus requirement of 50.05mg/kg, maximum adsorption of 524, affinity coefficient of 2.43 maximum buffering capacity of 1272 and correlation coefficient of 0.86, These findings have important implications for agriculture and environmental management, as they provide insights into the nutrient retention capabilities of different soil types and can guide sustainable land use practices to mitigate phosphorus runoff and its associated environmental impacts. Understanding the phosphorus sorption capacity of soils derived from different parent materials is crucial for optimizing nutrient management strategies and preserving ecosystem health.

Keywords: phosphorus sorption, parent materials, chemical properties of soils

INTRODUCTION

Soil plays a crucial role in supporting agricultural productivity and ecosystem functioning. Understanding the characteristics and properties of soil is essential for effective land management and sustainable agricultural practices. Among the various soil properties, the sorption capacity of phosphorus, an essential nutrient for plant growth, significantly influences its availability to plants and potential losses through leaching (Shen *et al.* 2001).

Enugu State in Nigeria exhibits diverse parent materials, including shale, sandstone, and alluvium, which may result in variations in the phosphorus sorption characteristics of soils across the region. Understanding these variations and their implications for nutrient management is crucial for promoting sustainable agriculture and optimizing fertilizer use in Enugu State.

Despite the importance of phosphorus sorption characteristics, there is a lack of comprehensive studies investigating the specific sorption behaviours of soils derived from different parent materials in Enugu State. The existing knowledge gaps limit the ability of farmers, researchers, and land managers to make informed decisions regarding soil fertility management and nutrient supplementation. Therefore, there is a need for a systematic investigation to determine the phosphorus sorption capacities and related soil properties of soils derived from different parent materials in Enugu State. Such research will provide valuable insights into the factors influencing phosphorus availability in these soils and guide the development of tailored nutrient management strategies to enhance agricultural productivity while minimizing environmental impacts. By addressing this research gap and gaining a deeper understanding of the phosphorus sorption characteristics of soils in Enugu State, we can contribute to improved soil management practices, optimized fertilizer use, and sustainable agricultural development in the region.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

The study was conducted on some soils of Enugu state in South Eastern Nigeria. Enugu state is situated within latitude $06^0 21^0$N and $06^0 30^0$N and longitudes $07^0 26^0$E and $07^0 37^0$E. Estimated population of Enugu is about 4,267,837 (Census 2006). Presently Enugu State consists of 17 local government areas. It is bordered to the north by Benue state and to the west by Anambra state, to the east by Ebonyi state, and Abia State to the south. The entire area extent is 7,161 sq. kilometers. Soils were collected from Enugu East from soils formed under Alluvium, Nkanu East from soils under shale parent materials, Enugu South from soils of Sandstone, and Nkanu West from soils formed on sandstone parent materials.

Enugu South Local Government Area lies between 6.42^0N and 7.49^0E with land area of about 73.1km square and population of 361,644. Nkanu East Local Government Area lies between $6^0 20$N and $7^0 39$E with a land area of about $441.2km^2$. Vegetation is predominantly savannah grassland with pockets of rainforest. Nkanu West Local Government Area is between $6^0$18N and$7^0$33E with land area of about 202.3 km². Enugu East lies between 6.51^0N and 7.51^0E with estimated population of 160000 people.

TOPOGRAPHY

The topography of Enugu includes major features such as the plateaus, rolling plains and the cuesta. The cuesta is a 500km Along belt which runs from Leru northwards to Idah in kogi State. The Enugu escarpment runs west wards and stands as a divide between the Anambra River Basin to the West and the Cross-River Basin to the east (Offodile,2014).

CLIMATE AND VEGETATION

Enugu state experiences a tropical climate, characterized by two distinct seasons - the rainy season and the dry season. The rainy season usually starts in April and lasts until October, with the highest rainfall occurring between July and September. The dry season, on the other hand, lasts from November to March, with relatively low rainfall. The average annual temperature in the LGA is around 28°C (82°F). The mean annual rainfall of Enugu ranges from 2000-3000mm.

Enugu is dominated by tropical rainforest with derived savannah. The vegetation is rich with some tree species like oil palm, oil bean, breadfruit, pear etc. The major farming system is the mixed cropping. The major arable crops grown include yam, maize, rice, cowpea, cassava and vegetables.

FIELD STUDY

The soil samples for the study were collected from depth of 0-20cm from soils of different parent materials used for arable crop production in Enugu state using soil auger. Soils formed on Alluvium were collected from Enugu East, soils formed on shale parent materials were collected from Nkanu East and soils formed on sandstone parent materials were collected from Enugu South and Nkanu West respectively.

SAMPLE PREPARATION

The soil samples were air dried at room temperature and gently crushed to pass through a 2mm. The sieved samples were placed in neat polybags and properly label before taken to the laboratory for analysis.

METHODOLOGY

There are several methods used in determining the physical and chemical properties of soil:

Phosphorus sorption

3g of soil was weighed into 50ml centrifuge tube containing 30ml of one of the following initial concentrations as KH_2PO_4 in 0.01M in $CaCl_2$: 0,5,10,15,20,25 ppm. 3 drops of toluene were added to each sample to inhibit microbial growth. The tubes were sealed, placed in a shaker and shaken for thirty minutes period daily for 5 days at room temperature. At the end of the equilibrating period (5 days) the samples were centrifuged for fifteen minutes at 1600rpm and filtered. P in the supernatant solution was determined using Murphy and Riley (1962) method. Adsorbed P was calculated based on the different between the initial solution concentration and the final concentration in the filtrate. From the result, adsorption parameters were determined using Lagmuir Model.

measurement of phosphorus adsorption parameter using Lagmuir model.

The lagmuir model is described as

$$\frac{c}{x/m} = \frac{1}{kb} + \frac{c}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where x/m is the amount of phosphorus adsorbed onto the soil per unit mass of soil in Mg/kg P, C is the equilibrium concentration of p in solution mg/kg P. K is the affinity coefficient relating to bonding energy expressed in mg/kg p and b is the adsorption maximum with unit mg/kg p of soil. Both k and b are constants and were obtained from plotting a graph of C/(x/m) versus C. kb and b were obtained from a linear version of equation 1 written as

$$\frac{1}{\frac{x}{m}} = \left(\frac{1}{kb}\right)\frac{1}{c} + \frac{1}{b} \ldots\ldots\ldots\ldots\ldots.(2)$$

Where 1/b is the slope and 1/kb is the intercept

Particle size

Particle size distribution was determined by the hydrometer method of Bouyoucos (1962), and modified by Udo *et al*., (2009).

Calgon was used as the dispersing agent; a soil sample weighing 50g was subjected to dispersion over night with the dispersing agent in a dispersing cup. The hydrometer reading was taken the next day after stirring the content in the dispersing cup and transferring the content to the sedimentation cylinder and subsequent vigorous agitation of the cylinder from end to end while covering the open end of the cylinder with the palm. Hydrometer readings were taken after 40 seconds and 2hours after agitation. Textural class was determined with textural triangle

Soil pH (H_20)

The pH of the soil sample was determined using a 1:2.5 soil water ratio using glass electrode (Udo *et al*.,2009). Ten grams (10g) of soil was weighed into a beaker and 25ml of distilled water was added to the soil. The suspension was stirred occasionally with glass rod for 10minutes and was allowed to stand for about 30minutes. Thereafter the electrode of the pH meter was inserted into the partly settled suspension and the pH of the sample was measured by taking the reading of the pH meter.

Organic carbon and organic matter

Organic carbon was determined by dichromate-oxidation method of Walkley and Black wet oxidation method as outlined by Udo *et al*., (2009). Soil sample was ground using aggregate mortar and passed through a 0.5mm sieve., 0.5g of the ground sample was weighed out into a 250ml conical flask and 5ml of 1N $K_2Cr_20_7$ (potassium dichromate) solution was added accurately into each flask and swirled gently to disperse the soil. Ten (10ml) of concentrated sulphuric acid (H_2S0_4) was added using an automatic pipette directing the stream into the suspension and swirling in other to mix the soil and the reagents. After standing for 30minutes in sheets of asbestos, 50ml of distilled water was added and 2-4 drops of (barium solution) indicator was added before titration with 0.5N ferrous ammonium sulphate solution. The blank was prepared using the same method without soil sample.

The organic carbon was calculated

Organic carbon in soil = $\frac{(Me\ K_2Cr_20_7 - MeFS0_4) \times 0.003 \times 100\ (F)}{\text{Mass of air dried soil to be used}}$

Where F = correction factor

Me = Normality of solution x volume used.

While organic matter was calculated by multiplying organic carbon with Van Bemmelen factor (1.724).

Exchangeable bases

Exchangeable bases (K, Ca, Na, and Mg) were extracted with 1N NH_4OAC buffered at pH 7.0 (Udo *et al*., 2009). Air dried and sieved soil was weighed 2.5 g into a 50ml extraction vessel and 50ml of extraction reagent {(1N NH_4OAC) Ammonium acetate} was added and shaken for two hours on a mechanical shaker. It was immediately filtered and the filtrate was collected for element determination. The amount of Ca and Mg was determined using Ethylene Diamine Tetra-Acetic acid (EDTA) titration method while potassium and sodium were determined by flame photometer.

Available phosphorus

This was determined using Bray 2 method as described by Bray and Kurtz (1945). One gram (1g) of air dried and sieved soil was weighed into a 15ml centrifuge tube and 10ml of the extracting solution (1N NH_4F) was added. This was shaken for one minute on a mechanical shaker and decanted. 5ml of the supernatant was taken with a pipette and put into 20ml test tube then 5ml of distilled water and 2ml of molybdate solution was added and mixed properly. Ten (10ml) of stannous chloride ($SnCl_2H_2O$) was added and mixed again. Available phosphorus was measured using a spectrophotometer.

Total nitrogen

Total nitrogen in the soil sample was determined by the Macro- Kjeldahl method by Bremner (1996) and modified by Udo *et al.,* (2009). Nitrogen in 1g of soil sample was converted to $(NH_4^+)_2SO_4$ by digestion with concentrated sulphuric acid (H_2SO_4). The $NH4^+$ liberated by distillation of the digest with an alkaline solution (NaOH), was determined by titration using a standard HCl.

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Soils Studied

The physical and chemical properties of the soil under study are shown in table 4.1. There were marked differences in the physical and chemical properties of the soils formed on different parent materials in Enugu State. The average percentage sand was high in the alluvium from Enugu south (91%) and Enugu East (90.3%), the shale from Nkanu East had the lowest percentage sand of 24.3% while the soil of the sandstone from Enugu South and Nkanu West had percentage sand of 50.3 and 52.3% respectively. Generally, the soils had high average percentage sand of 62.39 and a low average percentage clay of 22.2%. This observation is in line with the finding of (Okechi *et al.,* 2020) that the soils of the South Eastern Nigeria have high percentage sand with low percentage clay. This might be due to continuous cropping and high clay leaching due to high rainfall within the area. The soils had a pH range of 5.8 to 7.3. This shows that the soils were slightly acidic and some are slightly alkaline. There are no significant different among the means of the available P in the soil studied. The alluvium from Enugu South had available phosphorus of 14.4mg/kg which is below the critical level of 15mg/kg as reported by Osodeke and Ubah (2005) for optimum crop production. The highest available p was found in the shale of Nkanu East with the value of 18.4 mg/kg. There was significant difference among the mean of the total nitrogen. The value of the total nitrogen was low for all the soil ranging from 0.03 to 0.09%. These values were lower than the critical level of 0.15% for optimum production as reported by Adeoye and Agbola (1984). The soils showed significant differences ($p<0.05$) in levels of organic matter. Organic matter contents were low for all the soils. The mean organic matter contents ranged from 0.59 to 1.31% which is below the critical level of 2% for optimum crop production. The low organic carbon could be as a result of high rainfall and temperature prevalent in the area which encourages rapid mineralization of organic matter and subsequent leaching of organic carbon. The level of calcium ranged from 4.40 to 6.40cmol/kg which is above the critical level of 2.0cmol/kg. The soil had low level of potassium for all the soils studied with a mean K level of 0.15cmol/kg which is below the critical level of 0.4cmol/kg required for optimum crop production. Generally, the soil had low organic matter content, low nitrogen content and low effective cation exchange capacity. This is in line with the findings of Enwezor et al.;(1989) who observed that the soils of South Eastern Nigeria are low in organic carbon and exchangeable bases due to high rainfall regime, leaching and acidic nature of the soil parent materials prevalent in the area.

Table 4.1 physical and chemical properties of soil under study

Sample	Sand %	Silt %	Clay %	Texture	pH H_2O	pH kcl	Av.P mg/kg	TN %	OM %	Ca (cmol kg^{-1})	Mg	K	Na	EA	ECEC	BS %
Alluvium E/south	91.3	4.9	3.8	Sand	7.6	6.4	14.4	0.03	0.59	4.40	1.00	0.092	0.086	0.22	5.80	96.21
Shale Nkanu East	24.3	41.1	34.6	CL	6.6	5.8	18.4	0.09	1.76	6.40	2.20	0.220	0.176	1.24	10.24	87.79
Sandstone E/south	50.3	16.1	33.6	SCL	6.9	6.0	16.2	0.04	0.93	5.60	1.60	0.186	0.142	1.08	8.61	87.45
Alluvium E/East	90.3	2.3	7.4	Sand	8.5	7.3	15.2	0.04	0.79	4.60	0.80	0.088	0.080	0.18	5.75	98.60
Sand stone Nkanu west	52.3	17.1	30.6	SCL	6.8	5.9	16.6	0.06	1.31	5.20	1.40	0.180	0.150	1.32	8.30	83.49
Mean	**62.39**	**16.48**	**22.2**		**7.36**	**6.35**	**16.3**	**0.06**	**1.09**	**5.30**	**1.42**	**0.15**	**0.13**	**0.82**	**7.83**	**91.72**
LSD $_{(0.05)}$	22.33	7.12	8.62		NS	NS	NS	0.02	0.39	NS	0.50	0.05	0.04	0.32	2.65	NS

4.2 Standard Phosphorus Requirement of The Soils Studied.

Sorption isotherm for P is the curve which describes the relationship between phosphate take up by a soil surface and the concentration of phosphate remaining in solution, measured after addition of phosphate in a laboratory experiment. It is used to determine the Standard Phosphorus Requirements of soils and therefore useful in p fertilizer recommendation (Osodeke, 1999). The p sorption isotherm presented in figure 1 related the amount of p sorbed by the soil to the concentration of p in equilibrium solution. The curves indicated that p additions were proportional to the amount of p sorbed until when the sorption sites were saturated.

The standard phosphorus requirement (SPR) of the soils were calculated from the p sorption isotherm. The SPR of the soils is the amount of p concentration at 0.2mg/kg as suggested by Fox and Kamprath (1970). There was a significant difference ($p>0.5$) among the Standard phosphorus requirements of the soils of different parent materials.

The Alluvium parent materials showed the highest SPR with value of 50.5 and 48.08 for Enugu south and Enugu East respectively. This might be due to lower organic matter content of the soils derived from alluvium compared to soils of other parent materials. The sandstone parent materials of Nkanu west and Enugu south had SPR of 39.12 and 35.4 respectively. The lowest relative SPR was found in the shale of Nkanu East. This might be because of its higher clay and organic matter content which tends to remain more phosphorus than the porous and sandy soils of Alluvium and Sandstone.

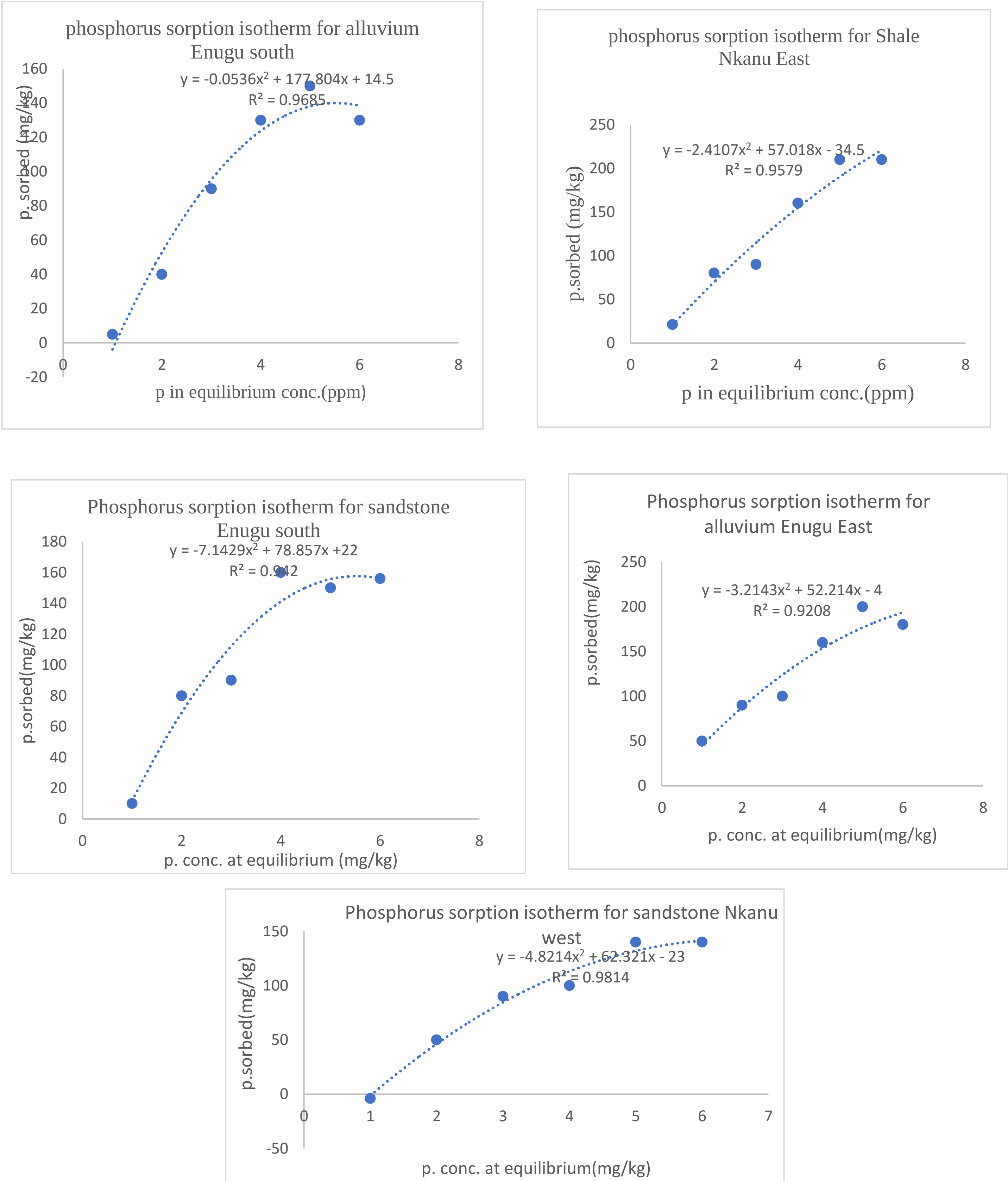

Figure 1: phosphorus sorption isotherm for soils of different parent materials in Enugu State

4.3 phosphorus sorption parameters using the Lagmuir Model

The linear sorption isotherms were obtained by plotting the amount of p in equilibrium concentration over the amount of p sorbed (c/x/m) against the amount of p concentration at equilibrium concentration of C for Lagmuir model. From the lagmuir model the maximum adsorption capacity, affinity coefficient and maximum buffering capacity of the soils were derived. The result (table 4.2) shows that there were significant differences among the sorption parameters of soils studied. The phosphorus soption capacities of the soils ranged from 245 to 524mg/kg with a mean sorption capacity 232mg/kg. The Alluvium parent materials derived from Enugu South had the highest phosphorus sorption capacity/maximum adsorption of 524 while the shale of Nkanu East had the lowest phosphorus sorption capacity of 254mg/kg. The low phosphorus soption observed in the shale may be due to its relatively higher organic matter content. Steven and Cole (1999) reported that organic molecules or anions compete with the phosphate ions at the adsorption sites, thereby blocking the adsorption sites and reducing the amount of p sorbed by the soil. The maximum buffering capacity ranged from 366 to 1272 with a mean buffering capacity of 677mg/kg. The maximum buffering capacity describes the resistance to change in p concentration of soil solution. The maximum buffering capacity measures the ability of the soil to replenish phosphate ion in low concentration. The affinity coefficient of the soils ranges from 1.16 to 2.3 with alluvium from Enugu south having the highest affinity coefficient of 2.42. The affinity coefficient or the adsorption energy expresses the binding energy required to adsorb p. It shows how easily the added p is absorbed or released from the adsorbing surface (Mehdi et al., 2007).

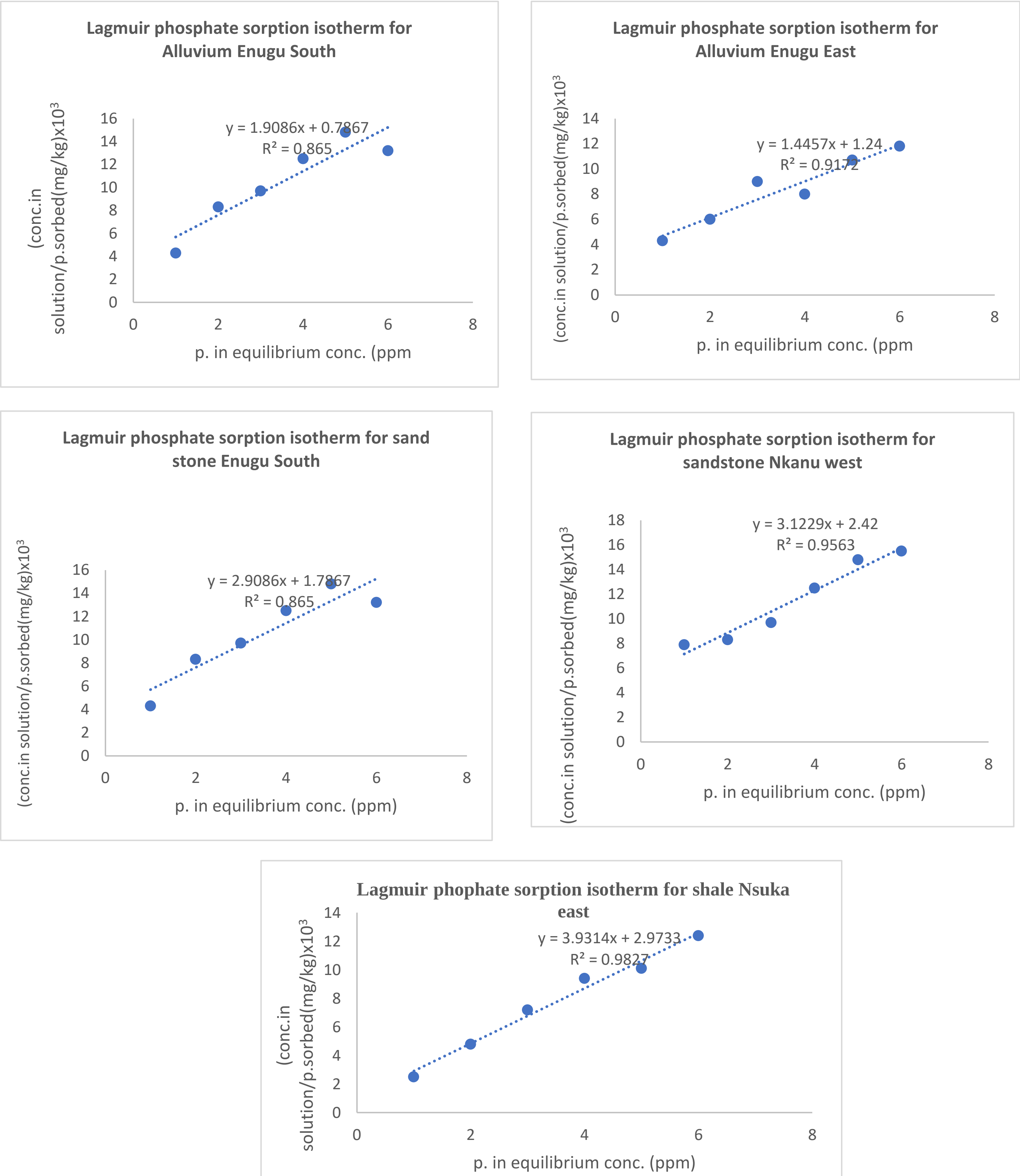

Figure 2: Lagmuir phosphate sorption isotherm for soil of different parent materials in Enugu state

TABLE 4 2. ADSORPTION PARAMETERS OF THE LANGMIUR MODEL

Soils of different parent materials in Enugu State	Standard phosphorus requirement (mg/kg)	Maximum adsorption	Affinity coefficient	Maximum buffering capacity	Correlation coefficient
Alluvium Enugu South	50.05	524	2.43	1272	0.86
Shale Nkanu East	22.4	254	1.32	336	0.98
Sandstone Enugu South	35.4	343	1.63	561	0.86
Alluvium Enugu East	48.08	692	1.16	806	0.91
Sandstone Nkanu West	39.12	320	1.29	413	0.95
Mean	39.01	426.6	1.566	677.6	0.92
LSD $_{(0.05)}$	15.1	231	1.11	223	Ns

CONCLUSION AND RECOMMENDATIONS

This research evaluated the phosphorus sorption capacity of soils of different parent materials in Enugu State. Soil of alluvium, sandstone and shale parent materials were collected from different local government area in Enugu. The available phosphorus ranged from 14.4 to 18.4mg/kg with the alluvium of Enugu East having the lowest available p. Based on the findings, the soils were generally low in organic matter, potassium and nitrogen. The soils of alluvium parent material had the highest phosphorus sorption capacity, maximum buffering capacity and affinity coefficient. This might be due to low organic matter content and high percentage sand found in the alluvium soils. The shale had the lowest sorption capacity and maximum buffering capacity. The standard phosphorus requirement of the shale was also lower than the soils of Alluvium and the sand stone. This shows that the soil of alluvium and sand stone will require more phosphorus than the soils of the shale parent material in the soils studied.

Based on the finding there is need for the application of organic matter content in the soil especially the Alluvium of Enugu south and Enugu East. This will help to improve the fertility of the soil there by adding the needed nitrogen, potassium and other nutrient deficient in the soils. It will also reduce the phosphorus sorption capacity and affinity coefficient of the soils thereby releasing the adsorbed phosphorus, thus making phosphorus available to the soil. There is also need for mulching, liming and use of biochar. These methods have proved to improve the desorption of the adsorbed phosphorus from soils of South eastern Nigeria. Further investigation into the phosphorus dynamics of the soils of Enugu is highly recommended. Other isothermic models of phosphorus study like Freundlich and Temkin should also be used to determine the best fit for the soils of Enugu state. This will give further insight into the phosphorus dynamics of soils of different parent materials in Enugu.

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