Journal of Science of Agriculture, Food Technology and the Environment Vol. 20, 2022 *110-142*
Available online: jsafeacademicjournal.com

PHOSPHORUS FORMS AND DISTRIBUTIONS IN SELECTED SOILS OF THE OIL PALM BELT IN YENEGOA, BAYELSA STATE OF NIGERIA

[1*]Nkechika, A., [2]Ogboghodo, A. I., [3]Oviasogie, P.O. [4]Osayande, P. E. and [5]Okonjo, N.P.

[1,3,4,,5] Soils and Land Management Division, Nigeria Institute For Oil Palm Research (NIFOR), P.M.B. 1030, Benin City, Nigeria.

[2] Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin. P.M.B 1154, Benin City, Nigeria.

Email: tonnero20@gmail.com

ABSTRACT

This study was conducted to determine the forms and distribution of phosphorus (P) in some soils in sedimentary soils of the Oil Palm belt in Yenegoa Local Government Area Bayelsa State, Nigeria. A total of thirty one soil samples from six pedons were sampled according to genetic horizons and taken to the laboratory for analysis using standard procedures. Physical and chemical properties were analysed using standard methods. The various phosphorus forms were analysed by sequential fractionations. The texture was dominated by sand. The soils generally was acidic in nature. Total Phosphorus ranged from 5.46 to 49mgkg^{-1} across the slope. Organic Phosphorus (Org-P) formed about 15.07% of total–P. It ranged from 2.46 to 12.49mgkg^{-1} with the highest value of 22.35mgkg^{-1} in pedon OBT$_4$ and decreased within the profiles across the pedons. The inorganic P fraction accounted for 1.30% of total–P. The active P (Ca-P, Al-P and Fe-P) accounted for (0.30 to 45.96) % while Saloid–P, Reductantly soluble P (Occ-P), Occ-Fe and Al-P, and Res-P accounted for 0.11, 0.08, 0.34, and 0.047 % respectively of total inorganic P. Generally, the total and available P-forms were low and distributed moderately. This suggest that Phosphorus requirement varies within the various pedons.

Keywords: Phosphorus forms, distributions, sedimentary materials and Oil Palm.

INTRODUCTION

Phosphorus (P) is an indispensable constituent for plant growth (Sharpley, 2000). It is an essential element of cell membrane, plant heritable materials, and energy storage and transfer systems for chemical reaction in plant cells. Plants absorb P either as the primary monobasic phosphate $H_2PO_4^-$ ions or in smaller amount as the secondary dibasic phosphate, HPO_4^{-2} ions and the phosphate ion, PO_4^{3-} (Coonklin, 2005). In tropical soils, phosphorus availability is highly limited due to the existence of oxides of Aluminium and Iron (Tsado *et al.*, 2002). They react with soluble phosphates found in the soil, forming complexes of low solubility which greatly reduces the amount of available phosphorus (Tsado *et al.,* 2002). Nigerian soils are highly weathered and naturally low in phosphorus (Udo, 1976).The forms of P and the amount in soils a essential for soil Phosphorus management for rich and sustainable crop production (Aduloju *et al.*, 2014). There are reports on the distributions and forms of P in a forest soil profiles in Ibadan, south-west Nigeria and certain forest and savannah soils in some areas in Nigeria (Udo and Ogunwale, 1977).

Oil Palm is regarded as one of the of the economic tree crops that requires a high amount of soil nutrients for optimum growth and productivity (Apori *et al.*, 2020). Phosphorus is among the major soil nutrients (N.P.K and Mg) required by Oil Palm for optimum vegetative growth and higher yield of fresh fruit bunch (FFB) (Apori *et al.,* 2020). Phosphorus forms, distributions and its availability to Oil Palm on a prolong term in such soils becomes necessary.

A sizeable part of southern Nigeria accounts for over 60% of the country’s mangrove forest (Akamigbo, 2001).This land is either permanently or seasonally flooded for a considerable period of the year. Aghimien *et al.,* 1988 reported that poorly drained soils are highly reactive with higher ratios than well drained soils. The parent materials of these soils are low in appetite bearing rocks hence low in Phosphorus.These soils have received little attention hence its limited current use. The need to evaluate the content and distribution of the various forms of P in these soils becomes imperative. The objective of this study is to determine the phosphorus forms and distributions in selected soils of the study area.

MATERIALS AND METHODS

Location/Description of the Study Area

The study location lies between longitudes 6^{o}18’ and 6^{o}30’E and latitudes 4^{o}50’ and 4^{o}66’N in the Yenagoa Local Government Area of Bayelsa State, Nigeria. The geology consists mainly of deltaic deposits (Sedimentary parent material) including sands, silts and clays of fresh water flood plane of the Niger Delta. The area lies within the so called “riverine area” which is characteristically a lowland area consisting of levees (crest and slopes) basins and basin swamps. The topography is flat to gentle sloping. The main river is Orashi (Engeni) river, a major tributary of River Niger, which forms the eastern boundary. The area is well dissected by streams, lakes and network of creeks and falls within the fresh water swamp vegetation (Ofomata 1975). Two distinct vegetation typical of the fresh water swamp. These include trees, shrubs, lianas swamp lilies and grasses. Among the common trees are Oil Palm and plantain with some cassava and maize, abura, mahogany, *Kyaga ivorensis*, *Mitragyna ciliata*, *Anthocleista nobilis and Mussanga cecropiodes.*

Fish farming is a major occupation while oil drilling by oil companies is found all over the site.

Rainfall is high and ranged from 3950-4000mm with a bimodal pattern alternating with a very short (about 2 months) or no dry season. The mean temperature is about 26^{o}C. The coolest months are the rainy months of June to September. Relative humidity is high throughout the year and decreases slightly in the dry season. The mean daily relative humidity is in the range of 82-84%. Daily sunshine hours are generally low, ranging from 1.5 hours in September to 6.1 hours in February. Mean annual evapotranspiration is at about 1000mm per annum and evapotranspiration losses are at a maximum in February (about 120mm) and lowest in September (about 70mm) (Oviasogie *et al.*, 2008).

Soil classification

The soils / representative pedons were classified based on the morphological and laboratory analysis of soil properties, following the FAO (FAO 1974) and the USDA soil Taxonomy (Soil Survey Staff, 1993) Systems.

Sample collection

A total of thirty one soil samples from six (6) pedons on each of the physiographic positions (units) namely pedon 1(G_2 Plane on the straight), Pedon 2 (YE_3 Levee on the slope), pedon 3 (YE_7 Summit on a straight slope), pedon 4 (OR_{13} plane on the straight slope) pedon 5 (OBT_4 depression on the concave slope), pedon 6 (UR_6 depression on the convex slope slope). However the number of samples varied depending on the genetic horizons of the pedon .

Laboratory analysis

Soil samples air-dried and processed through 2mm sieved were analysed for:

a**.** Physicochemical properties of the soil

b. Organic P

c. P fractions

d. Total P

The pH of the soils were determined in 1:1 soil- water using the glass electrode pH meter. The soil particle size (Sand, Silt and Clay) were determined by the Bouyoucos (1962) method. Organic carbon of the soil were determined by the Walkey and Black method (1934). The available P in the soils were extracted with Bray P1 solution (Bray and Kurtz, 1945) and Phosphorus in the extracts were determined by the ammonium molybdate blue method (Bray and Kurtz, 1945). Total Nitrogen of the soils were digested for using the modified Kjedahl method (Bremner, 1996) and Nitrogen in the extracts were determined by the indo-phenol blue colorimetric method (Methods of Soil Analysis, 1982). Exchangeable Bases (Na^+, K^+, Ca^{2+}, Mg^{2+}), of the soil were determined by extracting the cation in 1N neutral- ammonium acetate ($1NH_4OAc$) buffered at pH 7. Exchangeable $Ca^{2+}$and Mg^{2+}were by EDTA Titrometry while Na^+ and K^+ were read by Flame photometry method. Exchangeable Acidity (EA) was extracted using 1N KCl determined by titration of the soil solution with 0.5M NaOH (Mclean, 1964). Effective cation exchange capacity was determined by summation of Exchangeable Bases and Exchangeable Acidity (ECEC) (IITA, 1984). Percentage base saturation (PBS) was calculated as the percentage of basic cations of ECEC (Jaiswal, 2003).

Phosphorus fractionation

The soils were separated into their various phosphate fractions using the method modified by Hedley *et al.* (1982) and Tiessen and Moir (1993) in empirically defined pools of P from the soils. Organic P (Po) in the samples were determined by ignition and unignition method and calculated as the difference between ignition Phosphorus (P_{ig}) and unignition Phosphorus (P_{unig}) ($P_{ig} - P_{unig}$) (Legg and Black 1955). Supernatant were analysed using the ammonium-molybdate colorimetric method concentration of phosphorus in the soils using the spectrophotometer after development of colour (Murphy and Riley, 1962).The inorganic P (Pi) and the total P (Pt) in all the extracts were determined using Murphy and Riley's (1962) method. The procedure for the inorganic phosphorus fractionation is presented schematically in figure 3.

Statistical analysis

Results obtained from the analysis were subjected to simple statistical analyses giving maximum, minimum concentrations, means, standard deviation, coefficient of variation and correlation using GenStat 8 version

RESULTS

Physicochemical properties of soil

Detailed data for the soil physicochemical properties are presented in Table 1. The summarized physicochemical properties of the soils are in Table 2.

The texture of the soils were generally sandy. The highest mean value of 86.43 % for sand were obtained in OR_{13}. Its distribution varied moderately (CV of 26.64 %) in YE_7. Higher values of silt were obtained in Summit on a straight slope. The distribution varied highly (CV of 79.67%) in OBT_4. Highest values for clay were obtained in G_2. Its distribution varied with the highest values of CV 84.57% in Levee on the slope. The soils were generally acidic. The pH of the soils decreases with depth across the physiographic units. The distributions were low in G_2 having CV of 1.14% and did not vary significantly across the slopes. Organic carbon and organic matter were high in surface horizons but decreased within the subsoil across the profiles. OR_{13} and OTB_4 were higher in organic matter. Their distribution varied highly.

Table 1: Physical and chemical properties of the Soils

S/N	PROFILE ID	DEPTH				Cmol/kg							mg/kg			mgkg-1		g/kg	
	PEDON		pH	Al^{3+}	H^+	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	ECEC	BS	N	C	O.M	Avail P	Sand	Silt	Clay
1	G2 (Plain on the straight slope)	0-20	4.50	0.50	0.30	10.64	4.80	0.56	0.58	16.58	17.38	95.54	0.14	17.50	3.02	6.48	558.00	111.00	336.00
		20-70	4.40	0.60	0.50	12.10	4.00	0.46	0.51	17.07	18.17	93.94	0.05	7.10	1.22	5.24	451.00	127.00	416.00
		70-112	4.40	0.80	0.60	12.20	4.00	0.45	0.50	17.15	18.55	92.45	0.05	6.10	1.05	5.20	347.00	117.00	446.00
		112-154	4.38	0.80	0.80	11.56	3.89	0.25	0.46	16.16	17.76	90.99	0.04	3.80	0.59	4.80	377.00	116.00	507.00
		154-192	4.38	0.90	1.10	9.67	2.79	0.38	0.44	13.28	15.28	86.91	0.05	3.00	0.52	4.80	356.00	107.00	526.00
2	YE3(Levee slope)	0-15	4.80	0.70	0.50	7.64	3.30	0.26	0.41	11.61	12.81	90.60	0.09	11.80	3.12	9.22	820.00	116.00	67.00
		15-52	4.40	0.80	0.80	8.10	2.10	0.15	0.42	10.77	12.37	87.07	0.04	9.00	1.55	6.58	817.00	81.00	102.00
		52-105	4.40	0.80	0.50	5.54	3.10	0.18	0.36	9.18	11.48	79.79	0.02	5.10	0.88	6.55	906.00	40.00	54.00
		105-170	4.30	0.90	1.80	5.44	2.00	0.15	0.43	8.02	10.72	74.80	0.02	4.30	0.74	5.59	730.00	66.00	204.00
3	YE7(Summit on a straight slope)	0-15	5.20	1.30	0.50	15.40	2.40	0.28	0.83	18.71	20.71	90.34	0.14	18.90	3.22	10.08	600.00	240.00	150.00
		15-41	5.00	1.40	0.60	8.80	2.00	0.26	0.67	11.73	13.72	85.49	0.06	6.00	1.03	8.40	500.00	300.00	200.00
		41-95	5.10	1.60	1.00	8.20	1.92	0.28	0.58	10.96	13.56	80.82	0.05	65.00	0.86	6.72	807.00	287.00	226.00
		95-150	4.80	1.80	1.10	7.04	1.84	0.21	0.70	9.79	12.69	77.14	0.03	4.80	0.82	5.88	467.00	265.00	268.00
		150-197	4.80	2.80	1.70	8.70	1.76	0.20	0.51	11.17	15.69	71.19	0.03	3.00	0.52	5.88	448.00	259.00	293.00

		0-26	5.00	1.60	0.60	6.38	3.67	0.44	0.42	10.19	13.11	77.72	0.10	15.50	2.67	6.72	927.00	52.00	21.00
		26-37	5.00	1.80	0.60	5.90	3.41	0.14	0.42	9.95	12.35	80.57	0.08	3.30	2.29	7.08	947.00	25.00	28.00
4	**OR_{13}(Plain on the straight slope)**	37-74	4.80	2.00	0.90	4.96	3.16	0.13	0.36	9.21	12.11	76.05	0.05	8.10	1.40	6.73	897.00	57.00	46.00
		74-95	4.80	2.20	1.00	4.38	2.68	0.12	0.33	7.51	10.71	70.12	0.05	6.20	1.07	6.70	892.00	47.00	81.00
		95-120	4.80	2.50	1.00	4.22	1.68	0.10	0.41	6.41	9.90	64.75	0.03	5.10	0.88	9.58	938.00	11.00	51.00
		120-144	4.50	2.50	1.00	3.90	1.68	0.05	0.32	5.95	9.45	62.96	0.02	5.00	0.86	5.88	759.00	70.00	180.00
		144-168	4.51	2.60	1.20	3.68	1.20	0.03	0.32	5.23	9.03	57.91	0.02	4.80	0.83	5.55	710.00	90.00	200.00
5	**OTB_4(Depression on a concave slope)**	0-11	4.50	1.10	1.20	8.08	5.20	0.55	0.72	14.55	16.85	86.40	0.14	16.60	2.86	8.40	707.00	27.00	56.00
		11-47	4.30	1.00	0.80	6.96	4.88	0.29	0.55	12.68	14.57	87.03	0.12	8.50	1.47	6.72	427.00	22.70	346.00
		47-96	4.20	4.10	1.70	7.36	4.72	0.19	0.50	12.77	18.57	68.76	0.05	6.20	1.07	6.72	377.00	77.00	546.00
		96-120	4.00	1.10	0.60	3.76	2.88	0.06	0.48	7.18	8.88	80.85	0.03	3.00	0.52	5.88	377.00	97.00	546.00
6	**UR_6(Depression on the convex slope)**	0-7	4.70	0.80	0.90	8.80	2.40	0.34	0.50	12.04	13.74	87.62	0.14	20.20	3.48	6.72	687.00	240.00	73.00
		7-24	4.50	1.50	1.30	4.08	2.24	0.32	0.48	7.12	9.92	71.77	0.08	10.50	1.98	6.58	537.00	201.00	262.00
		24-40	4.50	1.80	1.50	4.00	2.24	0.22	0.46	6.15	9.81	62.69	0.06	6.70	1.16	6.77	477.00	182.00	351.00
		40-94	4.40	6.70	1.80	3.58	2.08	0.21	0.58	6.45	14.95	43.14	0.05	3.80	0.66	6.72	467.00	157.00	376.00
		94-150	4.30	6.60	1.80	3.58	2.01	0.21	0.44	6.34	14.64	42.62	0.03	3.60	0.62	10.08	458.00	155.00	387.00
		150-175	4.20	6.70	2.30	3.52	2.00	0.12	0.51	6.05	50.05	12.08	0.02	1.60	0.28	8.40	377.00	106.00	517.00

Table 2: Summary results of physical and chemical properties of the Soils.

S/N	PEDON	Stat. Ap	pH	Al^{3+}	H^+	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	ECEC	% BS
				Cmolkg^{-1}								
		Mean	4.41	3.43	0.66	11.23	3.90	0.42	0.50	16.05	20.14	79.54
		Min	4.38	B3.10	0.30	9.67	2.79	0.25	0.44	13.28	18.38	72.25
		Max	4.5	4.10	1.10	12.2	4.8	0.56	0.58	17.15	21.05	82.16
		Range	0.12	1.00	0.80	2.53	2.01	0.31	0.14	3.87	2.67	9.91
		SD	0.05	0.39	0.31	1.07	0.72	0.11	0.05	1.6	1.07	4.13
1	G_2(Plane on straight slope)	CV(%)	1.14	11.28	46.21	9.53	18.43	27.30	10.85	9.96	5.30	5.20
		Mean	4.75	0.80	0.90	6.68	2.63	0.19	0.41	9.90	11.85	83.12
		Min	4.30	0.70	0.50	5.44	2.00	0.15	0.36	8.02	10.72	74.81
		Max	4.80	0.90	1.80	8.10	3.30	0.26	0.43	11.61	12.81	90.63
		Range	0.50	0.20	1.30	2.66	1.30	0.11	0.07	3.59	2.09	15.82
		SD	0.22	0.08	0.62	1.39	0.67	0.05	0.03	1.61	0.93	7.09
2	YE_3**(Levee slope**)	CV(%)	4.96	10.21	68.49	20.77	25.53	28.09	7.68	16.23	7.87	8.53
		Mean	4.78	1.78	0.98	9.63	1.98	0.25	0.66	12.51	15.28	81.18
		Min	4.80	1.3	0.50	7.04	1.76	0.20	0.51	9.79	12.69	71.19
		Max	5.20	2.80	1.70	15.4	2.4	0.28	0.83	18.91	20.71	91.31
		Range	0.40	1.50	1.20	8.36	0.64	0.08	0.32	9.12	8.02	20.12
		SD	0.18	0.60	0.48	3.30	0.25	0.04	0.12	3.65	3.23	7.69
3	YE_7**(Summit on a straight slope)**	CV(%)	5.92	33.80	48.62	34.29	12.56	15.64	18.53	29.14	21.14	9.48
		Mean	4.77	2.171	0.90	4.77	2.50	0.14	0.37	7.88	10.95	70.79
		Min	4.50	1.60	0.60	3.68	1.20	0.03	0.32	5.23	9.03	57.92
		Max	5.00	2.60	1.20	6.38	3.67	0.44	0.42	10.91	13.11	83.22
		Range	0.50	1.00	0.60	2.70	2.47	0.41	0.1	5.68	4.08	25.3
		SD	0.20	0.39	0.22	2.70	0.98	0.14	0.05	2.17	1.58	9.51
4	OR_{13}**(Plain on the straight slope**)	CV(%)	4.27	17.78	24.85	21.47	39.03	94.74	12.77	27.55	14.46	13.43
		Mean	4.25	1.82	1.08	6.54	4.42	0.27	0.56	11.79	14.72	80.75
		Min	4.00	1.00	0.60	3.76	2.88	0.06	0.48	7.18	8.88	68.77
		Max	4.50	4.10	1.70	8.08	5.2	0.55	0.72	14.55	18.57	87.03
		Range	0.50	3.10	1.10	4.32	2.32	0.49	0.24	7.37	9.69	18.26
		SD	0.21	1.52	0.49	1.91	1.05	0.21	0.11	3.19	4.22	8.45
5	OBT_4(**Depression on a concave slope)**	CV(%)	4.99	83 .15	45.18	29.21	23.66	76.18	19.39	27.09	28.69	10.47

S/N	PEDON	Stat. Ap	pH	Al^{3+}	H^{+}	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	ECEC	% BS
				Cmolkg^{-1}								
		Mean	4.48	4.02	1.60	4.59	2.16	0.24	0.48	7.34	13.02	57.12
		Min	4.30	0.80	0.90	3.52	2.00	0.12	0.41	6.05	9.81	34.14
	UR_6**(Depression on the convex slope)**	Max	4.80	0.70	2.30	8.80	2.40	0.34	0.58	12.04	15.05	87.62
		Range	0.50	5.90	1.40	5.28	0.40	0.22	0.17	5.99	5.24	53.48
		SD	0.22	2.92	0.48	5.28	0.16	0.08	0.06	2.33	2.49	21.24
6		CV(%)	4.96	72.73	30.10	45.16	7.31	34.29	12.29	31.78	19.10	37.18

Table 2: Summary results of Physical and chemical Properties of the Soils continues

Stat. Ap: Statistical Apparatus .

***Nkechika *et al.(*2021).**

Table 2: Summary results of Physical and chemical Properties of the Soils continues

S/N	PEDON	Stat. Ap	% N	% C	% OM	mgkg^{-1}Avail P	g/kg SAND	g/kg SILT	g/kg CLAY
		Mean	0.07	7.50	1.28	5.30	417.80	115.60	446.20
1		Min	0.04	3.00	0.52	4.8	347.00	107.00	336.00
	G_2(Plain on straight slope)	Max	0.14	17.50	3.02	6.48	558.00	127.00	526.00
		Range	0.1	14.50	2.5	1.68	211.00	20.00	19.00
		SD	0.04	5.80	1.02	0.69	88.40	7.50	76.00
		CV(%)	63.02	777.60	79.46	13.01	211.60	65.20	170.40
		Mean	0.04	7.60	1.57	6.99	818.30	75.70	106.70
		Min	0.02	4.30	0.74	5.59	730.00	4.00	54.00
		Max	0.09	11.80	3.12	9.22	906.00	116.00	204.00
2	YE_3**(Levee slope)**	Range	0.07	7.50	2.38	3.63	176.00	76.00	150.00
		SD	0.03	3.50	1.09	1.56	719.00	31.70	67.90
		CV(%)	77.74	463.50	69.35	22.32	87.80	418.90	636.30
		Mean	0.06	19.50	1.29	7.39	564.40	270.20	227.40
	YE_7**(Summit on a straight**	Min	0.03	3.00	0.52	5.88	448.00	24.00	150.00
3	**slope)**	Max	0.14	65.00	3.22	10.08	807.00	30.00	293.00
		Range	0.11	62.00	2.7	4.2	359.00	60.00	143.00
		SD	0.05	26.20	1.09	1.821	147.70	23.60	56.30
		CV(%)	73.38	1339.70	84.84	24.64	261.80	87.50	247.70
		Mean	0.05	8.30	1.43	6.89	864.30	50.30	86.70
		Max	0.1	15.50	2.67	9.58	947.00	90.00	20.00
		Min	0.02	4.80	0.83	5.55	71.00	11.00	21.00
		Range	0.08	10.70	1.84	4.04	237.00	79.00	179.00
	OR_{13}**(**Plain on the straight	SD	0.03	4.40	0.75	1.30	93.30	26.50	73.30
4	slope)	CV(%)	61.1	527.60	52.66	18.9	107.90	526.60	845.70

Stat. Ap : Statistical Apparatus.

Table 2: Summary results of Physical and chemical Properties of the Soils continues

S/N	PEDON	Stat. Ap	N (%)	C (%)	OM (%)	mgkg^{-1}Avail P	SAND (g/kg)	SILT (g/kg)	CLAY (g/kg)
5	OBT$_4$ (Depression on a concave slope**)**	Mean	0.08	8.60	1.48	5.207	472.00	107.00	373.50
		Min	0.03	3.00	0.52	4.5	377.00	27.00	56.00
		Max	0.14	16.60	2.86	6.43	707.00	227.00	546.00
		Range	0.11	13.60	2.34	1.93	330.00	20.00	49.00
		SD	0.05	5.80	1.00	0.85	158.40	85.20	231.70
		%CV	62.62	677.10	67.50	16.34	335.70	796.70	620.40
6	UR$_6$**(Depression on the convex slope)**	Mean	0.06	7.70	1.36	7.55	500.50	173.50	327.70
		Min	0.02	1.60	0.28	6.58	377.00	106.00	73.00
		Max	0.14	20.20	3.48	10.08	687.00	24.00	517.00
		Range	0.12	18.60	3.2	3.5	310.00	134.00	444.00
		SD	0.04	6.80	1.19	1.418	104.70	45.70	149.30
		CV(%)	68.22	885.20	87.55	18.79	209.30	263.10	455.60

Stat. Ap: Statistical Apparatus.

***Nkechika *et al.(*2021).**

Results of the P-forms and distributions

Detailed data for the Soil P-forms are presented in Table 3. The results of the P-forms are summarized in Table 4.

Total –P showed a regular increase with depth except in pedon G_2 (Plane on straight slope) where it decreased slightly and later increased. Higher values were obtained in pedons 4 (Plain on the straight slope), pedon 5 (Depression on a concave slope) and UR_6 (Depression on the convex slope), respectively. The distributions varied from little to moderate with the highest CV of 30 % in YE_3 and lowest CV of 1.56 % in OR_{13}. Org-P decrease regularly with depth in all locations. It ranged from 2.46 - 12.49mgkg^{-1}. Highest values were obtained in Depression on a concave slope and Plane on the convex slope respectively. The lowest values were obtained in pedon 2. The distributions varied moderately along the physiographic units except for G_2 and YE_3 respectively. Avail-P showed a regular trend of decrease within depth except in OR_{13}, OBT_4 and UR_6. It was higher in the surface soil and decreased in the subsurface horizon. It was low generally across the mapping units. Its distribution varied slightly across the pedons with CV 24.64 % in levee slope. Saloid-P showed a regular decrease with depth except for depression on a concave slope which increases down with depth. The distributions was uniform across the physiographic units. Aluminium bound Phosphorus (Al-P) showed similar regular trend in increase with depth except in plain on the convex slope with a slight decrease and increase. The distributions varied almost uniformly except in UR_6. Iron-Phosphorus (Fe-P) were found to concentrate more in the underlying horizons across the topographic positions and more in the flood plain and alluvial plain. The distributions varied moderately from one location to another with highest values of CV 35.08 % in YE_7 and the lowest CV of 7.53% in plain on convex slope. Occluded Phosphorus (Occ-P and Redundantly soluble–P) were observed to increase in the surface soil but decreases in the subsurface horizon within and across the profile soil. The highest mean value of 2.05mgkg^{-1}was obtained in OBT_4. The distributions varied widely and highly CV from 5.64 to 92.02 % between the locations. Occluded Iron and Aluminium bound Phosphorus (Occ-Fe and Al-P) distributions showed a particular trend with decrease in depth. The distributions varied slightly across the locations. Calcium held bound Phosphorus (Ca-P) showed a decrease with depth across the pedons. The distributions varied slightly in all the pedons with the highest CV of 28.92 % in levee slope. Residual Phosphorus (Res-P) showed a regular trend of decrease with depth except for pedonsYE$_7$ and OR$_{13}$ (Plain on the straight slope) where it decreased and increased within the profile. The lowest values were obtained on the Plane on convex slope. It varied moderately and highly with the lowest CV of 6.83% in pedon OBT$_4$ and the highest CV of 60.58% in pedon YE$_3$.

Table 3: Results of P-forms and distributions

S/N	PEDONS	DEPTH Cm	Saloid-P	Avail-P	Org-P	Fe-P	Al-P	Ca-P	Occ-P	Occ-Fe and Al-P	Total-P	Residual -P
			→				mg/kg	←				
	G_2	0-20	1.81	6.48	10.86	28.49	15.80	3.80	1.90	3.66	65.13	0.98
1			1.75	6.44	10.84	27.81	16.02	3.79	1.89	3.71	64.98	0.88
2	G_2	20-70	1.30	5.24	7.41	34.83	28.12	3.50	0.80	3.54	74.54	0.75
			1.31	5.22	7.38	34.81	28.12	3.53	0.76	3.52	73.85	0.73
3	G_2	70-112	1.09	5.20	7.28	32.61	18.16	2.80	0.41	2.91	70.65	0.38
			1.12	5.18	7.30	33.01	27.89	2.79	0.43	2.89	71.01	0.35
4	G_2	112-154	1.07	4.80	6.48	37.41	28.16	2.60	0.28	2.88	72.43	0.22
			1.06	4.61	6.46	37.42	28.18	2.58	0.31	2.91	72.35	0.24
5	G_2	154-192	0.91	4.80	5.12	38.50	30.08	2.15	0.31	2.73	72.87	0.28
			0.72	4.83	5.10	38.52	29.97	2.21	0.33	2.69	72.89	0.30
6	YE_3	0-15	1.82	6.20	8.91	35.48	28.25	2.70	1.38	3.11	62.87	1.09
			1.75	6.18	8.89	36.01	28.30	2.70	1.40	3.05	63.01	1.12

7	YE_3	15-52	1.65	4.80	7.25	46.21	32.61	2.48	0.68	2.88	65.81	0.64
			1.63	4.83	7.31	46.18	33.02	2.51	0.71	2.85	66.02	0.62
8	YE_3	52-105	1.08	4.60	6.91	60.70	37.40	1.82	0.39	2.55	104.45	0.26
			1.06	4.61	6.88	61.01	37.20	1.80	0.40	2.62	104.47	0.38
9	YE_3	105-170	1.01	4.28	6.45	71.28	46.81	1.38	0.26	2.38	58.76	1.74
			0.91	4.25	6.51	71.31	47.01	1.40	0.25	2.36	58.78	1.75
10	YE_7	0-15	3.05	10.08	12.41	26.70	26.58	8.26	1.98	7.89	73.98	1.54
			3.11	10.09	12.39	27.01	27.02	8.31	2.01	7.91	73.96	1.52
11	YE_7	15-41	2.80	8.41	11.46	30.81	45.63	8.23	1.68	7.66	77.96	1.48
			2.79	8.42	11.44	31.02	45.63	8.22	1.83	7.72	78.02	1.44
12	YE_7	41-95	2.50	6.72	8.23	40.21	30.18	8.20	1.69	6.98	85.54	0.58
			2.30	6.74	8.20	39.81	30.21	8.18	2.01	7.02	86.02	1.09
13	YE_7	95-150	1.90	5.88	6.13	59.08	38.23	5.68	1.53	6.55	107.09	0.94
			1.88	5.87	6.10	59.06	38.23	5.71	1.55	6.61	106.91	0.96
14	YE_7	150-197	2.01	5.88	5.51	58.13	55.14	5.02	1.08	5.68	96.18	1.08
			1.98	6.08	5.53	58.11	54.98	5.04	1.11	5.71	95.76	1.06

S/N	PEDONS	DEPTH	mg/kg									
		Cm	Saloid-P	Avail-P	Org-P	Fe-P	Al-P	Ca-P	Occ-P	Occ-Fe and Al-P	Total-P	Residual -P
15	OR_{13}	0-26	3.09	6.72	17.80	40.18	29.18	8.12	2.12	8.05	98.21	1.09
			3.05	6.72	17.79	39.89	29.21	8.11	2.12	8.11	99.01	1.07
16	OR_{13}	26-37	3.01	7.08	12.38	48.23	29.29	8.90	2.01	7.25	98.34	0.88
			2.85	6.72	12.36	48.20	29.27	8.85	2.03	7.31	97.96	0.95
17	OR_{13}	37-74	2.80	6.73	9.86	48.48	30.64	7.84	1.86	6.88	98.46	0.91
			2.69	6.75	9.86	49.01	30.63	7.83	1.91	7.01	98.51	0.93
18	OR_{13}	74-95	2.42	6.70	10.13	60.14	35.83	7.51	1.86	8.02	99.58	0.58
			2.40	6.73	10.11	60.12	36.02	7.53	1.91	7.98	99.37	0.64
19	OR_{13}	95-120	1.80	9.58	8.41	78.24	48.91	5.20	1.46	6.88	98.68	1.08
			1.82	9.60	8.43	78.20	49.02	5.15	1.52	6.91	97.99	1.04
20	OR_{13}	120-144	1.50	5.88	7.46	81.09	60.22	4.81	1.38	5.88	101.28	0.62

			1.45	5.86	7.43	80.89	60.19	4.79	1.40	5.91	101.31	0.58
21	OR_{13}	144-168	1.48	5.55	6.58	84.12	71.31	4.68	0.98	6.22	92.09	0.76
			1.50	5.61	5.55	83.97	71.33	4.79	1.02	6.19	92.20	0.81
22	OTB_4	0-11	1.98	6.43	26.38	70.38	44.34	8.10	2.81	8.14	95.89	0.83
			1.96	6.41	26.38	70.41	44.36	8.13	3.02	8.12	96.02	0.83
23	OTB_4	11-47	1.85	5.10	24.51	75.41	62.51	7.50	2.01	7.55	97.96	0.76
			1.87	5.09	24.51	74.99	63.01	7.53	1.98	7.52	98.02	0.71
24	OTB_4	47-96	1.91	4.80	20.81	88.72	68.81	6.81	1.81	7.41	105.09	0.76
			1.93	4.76	20.83	89.02	69.02	6.83	2.03	7.44	105.04	0.74
25	OTB_4	96-120	1.65	4.50	16.23	91.32	68.98	6.38	1.56	5.88	85.09	0.71
			1.62	4.50	16.20	91.18	69.03	6.40	1.61	5.88	84.98	0.70
26	UR_6	0-7	1.48	6.72	28.58	78.19	74.21	4.68	1.28	8.23	85.25	0.72
			1.45	6.73	28.56	77.76	74.23	4.51	1.30	8.19	84.94	0.72
27	UR_6	7-24	1.35	6.58	26.41	78.28	65.38	3.91	1.18	8.14	88.09	0.62
			1.33	6.56	26.40	78.28	65.41	3.90	1.21	8.12	87.98	0.62
28	UR_6	24-40	1.26	6.77	24.35	80.31	68.14	3.54	1.16	7.22	93.89	0.43

			1.27	6.75	24.33	80.33	68.21	3.56	1.16	7.19	94.02	0.44
29	UR_6	40-94	1.27	6.72	20.18	80.71	72.58	3.28	1.15	6.38	110.94	0.41
			1.29	6.74	19.98	80.73	73.03	3.30	1.13	6.41	111.04	0.43
30	UR_6	94-150	1.27	10.08	18.49	80.82	72.61	3.19	1.14	5.11	134.09	0.38
			1.25	10.12	18.51	81.03	73.03	3.21	1.12	5.14	133.98	0.36
31	UR_6	150-175	1.22	8.40	16.09	94.53	73.89	2.85	1.08	6.23	144.01	0.33
			1.19	8.38	16.09	94.48	74.01	2.90	1.06	6.23	143.98	0.36

Table 3: Results P-forms and distributions continues

S/N	PEDON	Stat. Ap	Saloid-P	Avail-P	Org-P	Fe-P	Al-P	Ca-P	Occ-P	Occ-Fe and Al-P	Total-P	Res-P
			← mg/kg →									
1	G_2 (Plane on straight slope)	Mean	1.23	5.3	7.43	34.37	26.06	2.97	0.74	3.14	71.13	0.51
		Min	0.90	4.80	5.12	28.49	15.80	2.15	0.28	2.69	65.13	0.22
		Max	1.81	6.48	10.86	38.5	30.08	3.80	1.90	3.71	74.54	0.98
		Range	0.91	1.68	5.74	10.01	14.28	1.65	1.62	1.02	9.41	0.76
		SD	0.35	0.69	2.12	4.01	5.80	0.67	0.68	0.41	3.63	0.29
		SE	0.16	0.31	0.95	1.79	2.59	0.3	0.30	0.13	1.62	0.09
		CV(%)	28.52	13.01	28.57	11.66	22.25	22.64	92.02	13.01	5.10	56.88
2	YE_3 **(Levee slope)**	Mean	1.39	4.97	7.38	53.42	36.27	2.10	0.68	2.73	71.73	0.95
		Min	1.01	4.28	6.45	35.48	28.25	1.38	0.26	2.36	56.81	0.26
		Max	1.82	6.20	8.91	71.28	46.81	2.70	1.38	3.11	104.45	1.75
		Range	0.81	1.92	2.46	35.80	18.56	1.32	1.12	0.75	47.64	1.49
		SD	0.41	0.85	1.07	15.77	7.96	0.61	0.50	0.29	21.99	0.58
		SE	0.21	0.42	0.54	7.88	3.98	0.30	0.25	0.10	11	0.20
		CV(%)	29.16	17.05	14.52	29.52	21.95	28.92	73.82	10.63	30.66	60.58
3	YE_7 **(Summit on a straight slope)**	Mean	2.45	7.39	8.75	42.99	39.15	7.08	1.6	6.97	80.67	1.17
		Min	1.90	5.88	5.31	26.7	26.58	5.02	1.08	5.68	58.76	0.58
		Max	3.05	10.08	12.41	59.08	55.14	8.26	1.98	7.71	107.09	1.54
		Range	1.15	4.20	6.90	32.38	28.56	3.24	0.09	2.23	48.33	0.96
		SD	0.50	1.82	3.10	15.05	11.59	1.60	0.33	0.84	17.71	0.32
		SE	0.22	0.81	1.39	6.74	5.18	0.71	0.15	0.27	7.92	0.10

CV(%)	20.20	24.64	35.41	35.08	29.59	22.53	20.69	12.03	21.95	27.05

Table 4: Summary of results of P-forms and distributions.

S/N	PEDON	Stat. Ap	Saloid-P	Avail-P	Org-P	Fe-P	Al-P	Ca-P	Occ-P	Occ-Fe and Al-P	Total-P	Res-P
			→ mgkg^{-1} ←									
4	OR_{13} (Plain on the straight slope)	Mean	2.30	6.89	10.37	62.93	43.63	6.72	1.67	7.11	98.68	0.85
		Min	1.48	5.55	6.58	40.18	29.18	4.68	0.98	5.88	96.18	0.58
		Max	3.09	9.58	17.8	84.12	71.31	8.9	2.12	8.11	101.28	1.09
		Range	1.61	4.03	11.22	43.94	42.13	4.22	1.14	2.23	5.1	0.51
		SD	0.7	1.3	3.79	18.09	16.9	1.77	0.41	0.79	1.54	0.19
		SE	0.27	0.49	1.43	6.84	6.39	0.67	0.15	0.22	0.58	0.05
		CV(%)	30.51	18.9	36.54	28.75	38.73	26.28	24.4	11.07	1.56	22.25
5	OBT_4 (Depression on a concave slope)	Mean	1.85	5.21	21.98	81.46	61.16	7.2	2.05	7.24	97.76	0.76
		Min	1.65	4.5	16.23	70.38	44.34	6.38	1.56	5.88	92.09	0.70
		Max	1.98	6.43	26.38	91.32	68.98	8.1	2.81	8.14	105.09	0.83
		Range	0.33	1.93	10.15	20.94	24.64	1.72	1.25	2.26	13	0.13
		SD	0.14	0.85	4.48	10.15	11.61	0.76	0.54	0.89	5.46	0.05
		SE	0.07	0.43	2.24	5.08	5.81	0.38	0.27	0.31	2.73	0.02
		CV(%)	7.69	16.34	20.38	12.47	18.98	10.53	26.51	12.27	5.58	6.83
6	UR_6 (Depression on the convex slope)	Mean	1.31	7.56	22.35	82.14	71.13	3.58	1.17	6.88	99.41	0.49
		Min	1.22	6.58	16.09	78.19	65.38	2.85	1.08	5.11	85.09	0.33
		Max	1.48	10.08	28.58	94.53	74.21	4.68	1.28	8.23	134.09	0.72
		Range	0.26	3.5	12.49	16.34	8.83	1.83	0.2	3.12	49	0.39
		SD	0.09	1.42	4.86	6.18	3.56	0.65	0.07	1.14	19.39	0.14
		SE	0.04	0.58	1.98	2.52	1.45	0.26	0.03	0.33	7.92	0.04
		CV(%)	7.19	18.79	21.74s	7.53	5.01	18.11	5.64	16.62	19.51	29.61

DISCUSSION

The low values of Saloid-P shows that its solubility in the soil solution was slow possibly due to the acidic nature of the soil. The low content of available phosphorus could be as a result of the acidity of these soils (acidic nature). The highest values in the surface soil could be attributed to higher accumulation of surface organic matter content (Samndi, *et al.*,2014). Lowest values relatively in Levee on the Slope could have been pedological processes (weathering due to excessive run off and leaching). The lowest mean values of 5.21 $mgkg^{-1}$ in depression on the concave slope could have resulted from Al^{3+} fixation as a result of poor drainage. Depression on the concave slope and Plane on Convex Slope had a low mean value in available phosphorus relatively possibly due to oxidation by anaerobic conditions, alluvial deposit and ferrolysis in association with organic matter (Javad, 2013).

The relative high Org-P obtained in Depression on the Concave slope and Plane on Convex Slope could be as a result of accumulation of organic matter with retarded decomposition by microbial activities due to aenerobic conditions. The lowest mean values of 7.38$mgkg^{-1}$ were observed in Levee Slope on a sedimentary origin with permanent crops. This could also be as a result of surface run off due to it physiographic position.

The high concentration of Fe-P could be as a result of iron released from iron minerals due to weathering during soil formation and run off. This possibly could also be due to groundwater table fluctuation, leaching and reduction conditions of Fe^{+2} (Zhang and Gong, 2003). According to Javad, (2013),who reported that iron mineral deteriorates in lowlands and coastal plain due to high ground water table and its alternative fluctuation. Also the increase in mean value of Fe- P with depth in pedons OBT_4 and $UR_{6,}$ respectively could also be attributed to the poor drainage conditions of these soils as reflected in their soil colour (coastal plain soils). It could also have been as a result of formation of sesquioxides in the soils (hydromorphic soils) (Aghimien *et al.*, 1988). Fe^{2+} and Mn^{2+} released from their Oxides in reduction conditions could have complexed P in the soil solution within the slopes (Golsefidi, 2001). Hence the increase in Fe-P. The high values obtained somewhat agreed with Aaron *et al*, (2000) who reported that the association of most inorganic P is with the non-crystalline Fe compounds, especially goethite and haematite. The presence of these compounds, coupled with the pH of the soil could be the major factors contributing to the domination of Fe-P in these soils. The high values of Fe-P relative to Aluminium Phosphorus (Al-P) in this study area could suggest that the stability constant of Fe-P in the ligand complexes is also a dominant factor. This observation might be attributed to the ligand complexes and their solubilities. Hence the ease of release of available P in the soil solutions could seem to be hard due to Fe-P fixation. Therefore, its availability is limited. This therefore could justify the need for the use of more P fertilizers in order to maintain the critical level of solution P in soils as suggested by Sanchez (1970).

Aluminium-Phosphorus (Al-P) showed similar regular trend in increase with depth except in pedon UR_6 (plain on convex slope) where there was a slight decrease and increase in the locations studied along the physiographic units with mean values possibly due to groundwater table fluctuation, leaching and reduction conditions (Zhang and Gong, 2003).This findings did not actually follow the report of Aaron *et al.* (2000) that in acids soils, Al^{3+} ion is the dominant ion that will precipitate phosphate and hence be the largest in proportion. Their distribution in these locations could also probably be due to the presence of allophones (Amorphous Al-clay mineral) Mustapha *et al*, (2005). The high value obtained in UR_6 could possibly be as a result of increase in Al ion. The distributions varied almost uniformly except in pedon UR_6 (plain on convex slope) with CV of 5.01.

The decrease with depth across the pedons of Calcium- Phosphorus (Ca-P) could be as a result of the decrease in exchangeable Calcium (Ca^{2+}) with depth. The low values could be as a result of the masking effects of Fe and Al on exchangeable bases in the soil solution, and also due to the fact that it tends to revert to the less soluble of the inorganic forms (Fe and Al) of phosphate in acidic soils (hn/ ydromorphic soils) (Aghimien *et al.*,1988).

The increase in Occluded Phosphorus (Occ-P) in the surface soil could have resulted as an increase in organic complexes is the surface soil. The low values in the subsoil could possibly be an indication of the presence of Fe_2O_3 and Al_2O_3 as reported by Change and Jackson (1957) that soil with high level of Fe_2O_3 and Al_2O_3 have a capacity to Occlud P. Kparmwang (1996) and. Brady (1990) reported that the prolong anaerobic condition may cause most of the reductantly soluble Fe-P relatively available and that Fe in the soil matrix is reduced from Fe^{3+} to Fe^{2+}, making Fe-P complex much more.

Occluded Iron and Aluminium Phosphorus (Occ-Fe and Al-P) decreased in depth with a particular trend. The highest mean values of 7.24 $mgkg^{-1}$ in pedon OBT4 and the lowest 2.73$mgkg^{-1}$ in pedon YE3 could be as a result of deposition due to depression on Concave Slope and run off due to Levee Slope, respectively. The variation with depth did not follow the report of Mustapha and Udom (2005) who reported that the distribution of Occ- Fe-P and Al–P varied as a result of varying degree of Aluminium and Iron compounds in the varying depth. Its presence in these soils could be an indication of Ultisols that are developed from parent materials rich in readily-weatherable Al and Fe (Velbet, 1988) or weathering caused due the formation of free Al and Fe oxides and hydroxides that range from poorly-ordered, fine-textured non-crystalline (amorphous) compounds to highly-structured, coarse-textured crystalline forms. And also that in acid soils, gibbsite (Al) and goethite (Fe) are the most stable crystalline oxides, but a number of soil constituents (e.g organic matter complexes) can inhibit crystallization, favouring the persistence of non-crystalline forms. Hence both types of compounds could sorb Phosphate by the same mechanism, but non-crystalline forms tend to dominate soil sorption reactions because of their larger surface area/mass ratios (Schwertmann and Taylor 1977). Therefore, it could be hypothesized that concentration of non-crystalline Al and Fe and concurrently P sorption, could be greatest in near-surface mineral horizons of these soils possibly because of the inhibitory effect of organic matter on crystallization of Al and Fe oxides and hydroxides (Parfitt and Smart 1978).The increase in total–P with depth could also have resulted mainly from the increase in Fe-P and Al-P with depth. Higher mean values of 98.68, 97.76 and 99.41 $mgkg^{-1}$ in OR_{13}, OBT_4 and UR_6 respectively. The soil residual P was very low. This is an indication that the Phosphorus replenishing capacity of these soils was low.

CONCLUSION AND RECOMENDATIONS

Conclusion

The various forms of Phosphorus were generally low in the P reserve relatively. Their distributions however, were not consistent. Generally, their distributions varied from one location to another along the toposequence. This variability could probably be due to the toposequence characteristics of the soils suggesting that Phosphorus requirement varies with the position of slopes in the various pedons.

Recommendations

It will be recommended that agronomic practices such as the use of cover crops and mulching that will improve and retain soil nutrients be carried out along with phosphorus fractionation studies and systemic evaluation of fertilizer before application in soils formed along the slopes.

REFERENCES

Aaron, J.M., Edward A.G. and Oliver, A.C. (2000). Redox control of phosphorus pools in Hawai in Montana forest soils. *Geodama*, 102:219-237.

Aduloju , M.O., Abdulmumini, A. A. (2014). Distribution of organic and available forms of Phosphorus and micronutrients in the soils of toposequence in Mokwa, Niger State, Nigeria. *Proceedings of the International Soil Tillage Research Organisation (ISTRO)* Nigeria symposium, Akure 3: 6.

Aghimien, E.A., Udo, E. J and Ataga.O. (1988). Profile distribution of forms of Iron and Aluminium in the in the hydromorphic soils of southern Nigeria. *Journal of west African Science Association* **31.** 57-70

Akamigbo, F.O.R. (2001). Survey, classification and land use potentials of wetlands. *Proceedings of 27th Annual Conference of the SoilScience Society of Nigeria*, pp. 1 – 9. Calabar, Nigeria.

Amuyou, U. A.(2015) . Toposequence analysis of soil properties of an agricultural field in the Obudu Mountain slopes, Cross River State-Nigeria. *European Journal of Physical and Agricultural Sciences.* Vol. 3 No. 1,*ISSN 2056-5879.*

Apori, .S.O., Adams, .S., Emmanuel, .H., Mohammed, . M., Murongo , . M., Mark, .K. A. (2020). Evaluation of Soil Fertility Status in Oil Palm plantations in the Western Region of Ghana. *AIMS Agriculture and Food*, 5(4): 938-949

Beck, M. A., and Sanchez, P.A. (1994). Soil phosphorus fraction dynamics during 18 years of cultivation on Typic Paledult. *Soil. Science Society of America. Journal*. 58: 1424–1431.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of soils. *Journal of Agronomy.* 54: 464-465.

Bray, R.H. and Kurtz, L.T. (1945). Determination of Total, Organic and

Available Forms of P in Soils, *Soil Science*, 59: 39-45.

Bremner, J.M. (1996). Nitrogen-Total. In: D.L. Sparks (Editor). Methods of Soil Science. Part 3-chemical Methods. Soil Science Society of America. Book Series 5. Madison Wisconsin, USA. Pp. 1085-1122.

Chang, S.C. and Jackson, M.L. (1958). Soil phosphorus fractions in some represent active soils. *Journal of Soil Science* 9: 109 – 119.

Coonklin, A.R. (2005). Introduction to Soil Chemistry: Analysis and Instrumentation. Ist Ed., John wiley and sons, New York.

F.A.O, (1974) . *Soil map of the world*. The legend. Food and Agricultural organization of the United Nations, Rome.

Fasina, A.S. (2005). Properties and classification of some selected Wetland soils in Ado Ekiti, Southwest Nigeria. *Applied Tropical Agriculture*. Vol 10 (2): 76-82.

Golsefidi, T.H. (2001). Genesis, classification and suitability evaluation of wetland soils for rice cultivation on different landforms in Guilan province, Northern Iran. Isfahan Thesis PhD. University of Technology. Pp. 485.

Hedley, M. J., Stewart, J.W.B., & Chauhan, B.S. (1982). Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. *Soil Science Society of American Journal*. 46 : 970-976,

IITA (1984). *Soil and Plant Analysis : Study guide for agricultural laboratory directions and technologist working in tropical regions (D.A. Tel. and M . Hagarty edits)*. Pp. 278.

Jaiswal, P.C. (2003). *Soil Plant and Water Analysis*. Kalyani Publishers Ludhina, New Delhi Norda Hyderabab, India. Pp. 1-399.

Javad, S.M. 2013: The effect of toposequence on physical and chemical characteristics of paddy soils of Guilan province, Northern Iron, Rasht. *African journal of Agricultural Research.* Vol 8 (18): 1975-1982.

Legg J.O. and Black C.A. (1955). Determination of Organic Phosphorus in Soils II. Ignition . *Soil Science Society of America Proceedings* 19: 139-143.

Mclean, F.O. 1964: Aluminium. In: Black, C.A. (ed.), Methods of soil analysis, Part 2. 9: 978 – 998. ASA. Madison, WI.

Methods of Soil Analysis. (1982). *Soil Science. Society of American Journal*. Pp. 643-693. 2nd Edition.

Murphy, J. and Riley, J.P.A.(1962). Modified simple solution method for the determination of phosphates in natural waters. Analysis. Chim. Acta, 27: 31-36.

Mustapha, S. and Udom, G.N. (2005). Capability and suitability evaluations of fadama soils for selected crops in the Nigerian Sudan Savanna. *Global Journal. Agricultural. Science.* 4: 119-124.

Nkechika, A., Ogboghodo, A. I., Oviasogie, P.O and S. Ovie. (2021). Effects of toposequence on the physicohemical properties of some results available to Oil palm in Yenegoa, Bayelsa State of Nigeria. *Journal of the Science of Agriculture Food Technology and the Environment.* 2: 54-60

Ofomata, G.E.K. (1975). (Ed.). Nigeria in maps: Eastern States. Ethiope Publishing House. Midwest Mass Comm. Corp. Benin City, Nigeria.

Oviasogie, P. O., Aghimien, A. E. and Ndiokwere, C. L. (2008). Fractionation of Ni and V in wetland soils and their distribution in Tissues of the Oil palm. *Journal of Chemical Society of Nigeria.*2: 113 - 123.

Pan, G., Wu, L., Li, L., Zhang, X., Gong, W., Wood, Y., (2008). Organic Carbon stratification and size distribution of the three typical paddy soils from Taihu Lake Region, china. *Journal of Environmental. Science*. vol : 20 (4) pp 456-463.

Parfitt, R.L. and Smart, R. (1978). The mechanism of sulphate adsorption on iron oxides. *Soil Science Society of American Journal*. 42:48-50.

Samndi, M. A and Mahmud, A. T . (2014) . Distribution of Potassium Forms along a Hillslope Positions of Newer Basalt on the Jos Plateau Nigeria. *International Journal of Soil Science* . 9 : 90 -100.

Sanchez, P.A., Palm, C.A., and Boul, S.W. (2003). Fertility capacity soil classification: A tool to help assess soil quality in the tropics. *Geoderma* 114: 157 -185.

Schwertmann U and Taylor R .M. (1977). Iron oxides. Chap 5 In: Dixon IB and Weed SB (Eds) Minerals in Soil

Environments. *Soil Science Society of America.* Madison, WI. **P**p 145-180.

Sharpley, A.N. (2000). Agriculture and phosphorus management: The Chesa peak Bay. CR Press, Boca Raton, FL.

Tiessen, H. and Cole, J. (1984) . Path ways of Phosphorus Transformations in Soils of Differing Pedogenesis . *Soil Science Society of American Journal* . 48: 853.

Tiessen, H., Chacon, P. and Cuevas, E. (1994). Phosphorus and nitrogen status in soils and vegetation along a toposequence of tropical rainforest on the Upper Rio Negro. *Ecologia* 99: 145–150.

Tsado, .P.A.,Osunde, O.A., Igwe, .C.A., Adeboye, .M.K.A. and Lawal, B.A.(2002). Phosphorus sorption characteristic of some selected soil of the Nigeria Guinea Savanna. *International Agricultural science*. 2: 613-618.

Udo, E.J. (1976). Forms and distribution of phosphorous in three Nigerian soil profiles along a toposequence. *Tropical Agriculture (Trinidad).* 54: 149-156.

Udo, E.J. and Ogunwale, J.A. (1977). Phosphorous fractions in selected Nigerian soils. *Soil Science Society of America Journal.* 41:1114-1146.

Velbet, M.A. (1988).Weathering processes. Chapter 6 In: Swank WT and Crossley DA (Eds) Forest Hydrology and Ecology at Coweeta. *Ecological Studies* 66: 93—102.

Zhang, G.L., Gong, Z.T. (2003). Pedogenic evolution of paddy soils in different soil landscapes. *Geoderma* 115: 15-29.

APPENDIX 1

Brief Description of Profile

S/N	PROFILE ID	DEPTH	TEXTURE	COLOUR	ELEVATION (CM)	PHYSIOGRAPHIC POSITION	PARENT MATERIAL	DRAINAGE	LAND USE	REMARK
1	PESON-G2	0-20	SCL	Greyish brown (10YR 5/2)	200	Plain on Straight slope	Sedimentary Origin	Imperfect	Rain forest Arable farming	Presence of surface Stones, rock Outcrops moderately developed structure
		20-70	SCL	Greyish brown (10YR 5/2						
		70-112	SCL	Greyish brown 10YR 5/2) moist						
		112-154	C	Brown (10YR 5/3) Moist						
		154-192	C	Brown (10YR 5/3) Moist						

2	PEDON YE3	0-15	LS	Dark Yellowish Brown (10YR 3/4) Moist						
		15-52	LS	Brown (10YR 5/3) moist						
		52-105	S	Dark yellowish Brown (10YR 5/4) moist						
		105 - 170	SL	Dark grey (10YR 4/1) Moist	218	Levee slope	Sedimentary alluvium	Imperfect	Permanent crops	Presence of surface stones , rock outcrops well developed structure

S/N	PROFILE ID	DEPTH	TEXTURE	COLOUR	ELEVATION (CM)	PHYSIOGRAPHIC POSITION	PARENT MATERIAL	DRAINAGE	LAND USE	REMARK
3	PESON YE7	0-15	SL	Dark yellowish (10 YR 4/5) moist	200	Summit on a straight slope	Sedimentary alluvium	Fairly well drained	Permanent Crop (oil palm)	resence of surface stones, rock outcrops moderately well developed structure
		15-41	L	Greywish brown (10 YR 5/2) moist						
		41-95	CL	Greyish brown (10 YR 5/1) Moist						
		95-150	CL	Reddish yellow						

		150-197	SL	7.5YR 6/8) moist						
4	OR13	0-26	LS	Dark Yellowish brown (10YR 3/6)	200	Plain on Straight Slope	sedimentary, Racant Deltaic deposit	family well drained	FALLOW	Presence of surface stones, rock outcrops structure is mainly single grain. A sandy soil profile
		26-37	S	Dark yellowish (10YR 3/6)mosit						
		37-74	SL	Brown (10YR 4/6) mosit Dark yellowish						
		74-95	SL	brown (10YR 4/4) moist Dark yellowish						
		95-120	S	brown (10YR 4/4) moist Very pale						
		120 -144	SL	brown (10YR 7/4) moist Dark yellowish						
				brown (10YR4/4) mosit						

APPENDIX 1: continues

		144-168	S	Very pale brown (10YR 7/4) moist						

APPENDIX 1: continues

S/N	PROFILE ID	DEPTH CM	TEXTURE	COLOUR	ELEVATION (CM)	PHYSIOGRAPHIC POSTION	PARENT MATERIAL	DRAINAGE	LAND USE	REMARK
5	OTB4	0-11	CL	Grey (2.5YR 5/10) moist	120	depression on a concave slope	Sedimentary, swarmp allurium	imperfect	Swampy and fallow	weakly moderately well developed structure seepage water at 120cm
		11-47	C	Light brownwish Grey (10YR 6/2) moist						
		47-96	C	Grey (10YR 5/1 moist						
		96-120		Grey (10YR 5/1) moist						
		96-120		Grey (10YR 5/1) moist						
6	UR6	0-7		Moist	200		Sedimentary swamp alluvium	flood plain	Fallow	with 7cm depth, weekly
		7-24								

		24-40	SCL	light yellowish Brown (2.5YR 6/4) most						development structure
		24-40	C	Light brownish Grey (2.5YR 6/2) Moist		Depression on the convex slope				
		40-94	C	Light brownish Grey (2.5 YR 6/2						
		94-150	C	Light brownish Grey (10YR 6/2)						
		150-175	SCL	Grey (10YR 6/1)						

***Nkechika *et al.(*2021).**