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Free Oxide Status and Distribution in Soils of some Economic Palms in selected areas of Delta State, Nigeria

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Abstract

The status and distribution of free oxides in soils of selected economic palms such as Coconut, Oil and Raphia palms in some areas of Delta state (Owah-Abbi, Agbor, Asaba, Bomadi, Sapele, Ughelli and Warri), Nigeria. Composite top and subsurface soil samples were randomly obtained at two soil depths of 0 - 45 cm and 45 - 90 cm from the various locations; air dried, sieved through a 2-mm sieve and analyzed for physical and chemical properties. The acid-ammonium oxalate and dithionite-citrate-bicarbonate methods were used to extract the free oxides from the samples. Free oxides obtained from both extractants were compared. Results indicated that crystalline forms of Fe oxide (Fe_d) were higher than the amorphous forms (Fe_o) in all the locations and generally increased with increased soil depth except in Sapele soils where it slightly decreased with depth. There was evidence of a co-migration of Fe_d with clay in some of the locations. The active Fe ratio Fe_o/Fe_d values were fairly constant throughout the locations and decreased with increasing soil depth indicating the presence of purely crystalline Fe oxide. The high amounts of the crystalline forms in these soils ranging from 110.00 mg/kg to 337.50 mg/kg in the surface soils to 121.90 mg/kg to 559.00 mg/kg in the sub surface soils indicated a possible formation of plinthites and concretions in the rooting depth. This study has shown that some of the locations of Delta state could become unsuitable for the cultivation of economic palms due to the high amounts of free iron oxides that harden irreversibly on exposure. Continuous vegetal cover on the soils of these palms is suggested as a way of reducing the formation of plinthites in the soils of these locations.

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Introduction

Many soils in Nigeria have been reported to contain sesquioxides (oxides of iron, aluminium and manganese) in varying proportions (Ogunkunle and Onansaya, 1992; Agbenin, 2003; Osodeke *et al.*, 2005). The oxides of iron are particularly important owing to their high reactivity in soils such that their percentages have long been used as aids in distinguishing soil types and differentiating soil horizons (Mckeague and Day 1966, Blume and Schwertmann 1969, McKeague *et al.*, 1971b). Some of this iron, which is released during the weathering of iron-bearing parent materials, is precipitated in the soils as poorly crystalline and crystalline iron oxide or hydroxide and oxyhydroxide pigments. The quantity of these alternation products generally increase with soil age. Accordingly, comparisons of percentages of free iron frequently have been used as aids in determining relative ages of soils (Alexander 1974; Ogunsola *et al.*, 1989). In definite terms, free iron refers to the total iron in a soil occurring as reductant-soluble hydrous oxides which are uncombined with layer silicate structures and are either in the form of clay particle coatings, or as discrete particles or possibly in interlayer positions (Ibia, 2001). Free iron oxides contribute to greater soil aggregate stability and are active in phosphate fixation, charge characteristics and ion adsorption.

Two analytical methods are commonly used in estimating percentages of free iron in soils: the acid-ammonium oxalate method first applied to soils by Schwertmann (1964) and the dithionite-citrate-bicarbonate method proposed by Mehra and Jackson (1960). The oxalate extraction is presumed to remove the poorly crystalline iron oxides while the dithionite extraction is presumed to remove finely crystalline iron oxides in addition to the oxalate-soluble fractions (McKeague and Day 1966; McKeague *et al.*, 1971a). The difference between the values obtained by the two methods represents the amount of iron present in definite crystalline forms (Ogunsola *et al.,* 1989) so that with increasing soil age, the crystalline iron oxides increase at the expense of the poorly crystalline forms. This trend is reflected in the ratio of Fe_o to Fe_d (Fe ratio) (Ogunsola *et al.* 1989; Obi *et al.,* 2009). Ideally, the Fe ratio has values less than unity that decrease with increasing soil age (Alexander, 1974).

Free iron content of the basement complex soils of Nigeria have been variously studied (Aghimien *et al.*, 1988; Ogunsola *et al.*, 1989; Obi *et al.* 2009; Oyeyiola and Omueti, 2010). There is however paucity of information on free oxide status of soils formed on coastal plain sand parent material bulk of which support Oil, Coconut and Raphia palms in Southern Nigeria (Aghimien *et al.*, 1988; Osayande *et al.*, 2013).This study was therefore initiated to provide information on free oxide status of soils supporting these economic palms (Oil, Coconut and Raphia palms) in some selected locations of Delta state, Nigeria.

Materials and methods

Study area

This study was carried out in seven locations of Delta state; Abbi, Agbor, Asaba, Bomadi, Sapele, Ughelli and Warri. Delta State is generally low-lying without remarkable hills with a wide coastal belt inter-laced with rivulets and streams which form part of the Niger-Delta. It has two distinct seasons, the rainy season which starts in late March and ends in early November and a short dry season which starts in late November till early March. There is a short break in August. Temperature ranges between 21 ^{0}C to 32 ^{0}C. Rainfall in Delta state has been reported to be in the region of 2300 mm to 3000 mm (Remison, 2004). The vegetation of the sample sites varied from economic palms such as Coconut (*Cocos nucifera* L), Oil palm (*Elaeis guineesis* Jacquin), Raphia palms such as *Raphia hookeri* (the wine palm), *Raphia vinifera* (the bamboo palm), *Raphia regalis* and arable crops such as cassava (*Manihot esculenta*), maize (*Zea mays*) and prominent weeds of the grass family; notable amongst them were *Pennisetum purpureum, Pennisetum pedicelatum, Andropogon gayanus* and *Panicum maximum*

Soil sampling and laboratory analysis

Soil samples were randomly collected at two depths to depict top and sub soils in all the locations, air dried in the laboratory and analyzed as follows: Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Soil organic carbon was determined by the Walkley-Black method (Nelson and Sommer, 1996) Available phosphorus (P) was determined by Bray P-1 method (Anderson and Ingram, 1993). Total nitrogen (N) was determined by macro Kjedahl method (Brookes *et al.*, 1985). Soil pH was determined in a 1:1 soil to water suspension using a pH meter (Hendershot *et al.*, 1993). Exchangeable bases were extracted using NH_4OAC buffered at pH 7.0 (Thomas, 1982). Potassium and sodium were measured by flame photometer while calcium and magnesium were determined using atomic absorption spectrophotometer. The crystalline iron and aluminium oxides designated as Fe_d and Al_d respectively were determined by dithionite-citrate buffered with sodium bicarbonate solution (Mehra and Jackson, 1960). The content of ammonium oxalate soluble iron and aluminium oxides (amorphous oxides) designated as Fe_o and Al_o respectively were determined by Mckeague and Day (1966) method.

Data analysis

Data obtained were analyzed using Genstat statistical software. The coefficient of correlation between some physical and chemical properties and dithionite and oxalate extractable Fe and Al oxides were also determined.

Results

Parent materials and physical properties of the sampled locations

The parent materials and coordinates of the sampled locations are shown in Table 1, while the physical properties defined by the particle size distribution of the soils are shown in Table 2. Three major parent materials were recognized; Alluvium in Abbi, Bomadi and Ughelli, Coastal Plain Sand in Agbor, Asaba and Sapele while Sombreiro / Warri deposits were observed in Warri (Table 1). With respect to the physical properties, sand and silt had the same trend of decreasing with increased soil depth in all the locations while clay increased with increased soil depth (Table 2). Abbi, Agbor, Asaba, Bomadi and Sapele had sandy texture in both their top and sub soils while Ughelli and Warri had sandy loam texture in both top and sub soils (Table 2).

Table 1: Parent materials, coordinates and economic palms found at the sampled locations in Delta State

Location	Parent material	Coordinates		Economic palms in locations of sampling
		Latitudes	Longitudes	
Abbi	Alluvium	5° 42′ N	6° 17′ E	*Raphia hookeri*
Agbor	Coastal plain sand	6° 41′ N	6° 64′ E	*Raphia hookeri* and *Raphia vinifera*
Asaba	Coastal plain sand	6° 11 23′ N	6° 41′ E	*Elaeis guineensis*, Jacquin
Bomadi	Alluvium	5° 76′ N	5° 64′ E	*Raphia hookeri*
Sapele	Coastal plain sand	5° 52′ N	5° 37′ E	*Cocos nucifera* L.
Ughelli	Alluvium	5° 24′ N	5° 57′ E	*Elaeis guineensis* Jacq.
Warri	Sombreiro / Warri deposits	5° 24′ N	5° 11′ E	*Elaeis guineensis* Jacq.

Table 2: Particle size distribution of soils of selected areas of Delta State

Location	Depth (cm)	Sand	Silt (g/kg)	Clay	Textural class
Abbi	0 – 45	865.30	48.70	88.00	Sand
	45 – 90	837.30	30.70	132.00	Sand
LSD (0.05)		17.21	17.91	Ns	
Agbor	0 – 45	848.00	46.00	106.00	Sand
	45 – 90	836.00	27.30	136.00	Sand
LSD (0.05)		5.74	11.74	Ns	
Asaba	0 – 45	844.70	45.30	110.00	Sand
	45 – 90	808.70	34.70	156.70	Sand
LSD (0.05)		17.91	Ns	Ns	
Bomadi	0 – 45	844.70	45.30	110.00	Sand
	45 – 90	808.70	34.70	156.70	Sand
LSD (0.05)		17.91	Ns	Ns	
Sapele	0 – 45	876.70	46.70	76.00	Sand
	45 – 90	840.00	36.00	124.00	Sand
LSD (0.05)		10.34	Ns	Ns	
Ughelli	0 – 45	762.67	42.70	194.70	Sandy loam
	45 – 90	740.67	24.00	235.30	Sandy loam
LSD (0.05)		10.34	10.34	Ns	
Warri	0 – 45	774.00	49.30	176.70	Sandy loam
	45 – 90	745.33	29.30	225.30	Sandy loam
LSD (0.05)		5.74	8.61	Ns	

Chemical properties of soils of the sampled locations

The chemical properties of some of the soils of Delta state are indicated in (Table 3). Agbor, Asaba and Bomadi soils had strong acidity at the top soils but were moderately acid at the sub soils while it was the reverse in Abbi soils with moderately acid top soil but slightly acidic sub soils. Ughelli had soils with moderate acidity at both top and sub soils while Warri soils were slightly alkaline. Soil pH increased with increased soil depth in all the locations. Total nitrogen content decreased significantly with increased soil depth in all the locations while phosphorus decreased significantly with increased soil depth in Agbor, Sapele, Ughelli and Warri soils but decreased with increased soil depth in Abbi and Bomadi soils. Phosphorus in Asaba soils however increased with increased soil depth (Table 3). Potassium increased with increased soil depth in Abbi, Agbor, Asaba, Ughelli and Warri soils while it decreased with increased soil depth in Bomadi and Sapele soils (Table 3). In Abbi, Agbor and Asaba, sodium contents of the soils were the same at both depths, neither decreasing nor increasing with depth while it increased with increased soil depth in Bomadi, Ughelli and Warri. Sodium decreased significantly with increased soil depth in Sapele (Table 3). Calcium increased significantly with increased soil depth in Warri and increased with increased soil depth in Abbi, Agbor, Asaba and Bomadi soils. Calcium however decreased with increased soil depth in Sapele soils. Magnesium increased with increased soil depth in Abbi, Agbor, Asaba, Bomadi and Sapele soils but decreased significantly with increased soil depth in Ughelli and Warri soils. Organic carbon had the same trend as nitrogen in all the locations of decreasing with increased soil depth.

Table 3: Chemical properties of selected areas of Delta State

Location	Depth (cm)	pH (H_2O)	OC ← (g/kg)	N →	P (mg/kg)	Ca ←	Mg	K cmol/kg	Na	CEC →
Abbi	0 – 45	5.82	8.74	0.9	6.38	1.62	0.55	0.35	0.03	2.55
	45 – 90	6.21	4.94	0.76	6.04	1.84	0.59	0.44	0.03	2.90
	LSD (0.05)	Ns	0.69	0.07	Ns	Ns	Ns	Ns	Ns	Ns
Agbor	0 – 45	5.05	7.92	1.17	10.54	0.86	0.38	0.06	0.02	1.32
	45 – 90	5.55	4.55	0.63	5.89	0.97	0.45	0.34	0.02	1.78
	LSD (0.05)	Ns	1.78	0.14	1.56	Ns	Ns	Ns	Ns	Ns
Asaba	0 – 45	5.25	8.90	1.17	5.05	0.80	0.44	0.05	0.02	1.31
	45 – 90	5.53	4.67	0.63	5.88	0.85	0.50	0.07	0.02	1.44
	LSD (0.05)	Ns	1.87	0.14	Ns	Ns	Ns	Ns	Ns	Ns
Bomadi	0 – 45	5.17	10.26	1.46	5.41	0.96	0.47	0.30	0.02	1.75
	45 – 90	5.48	3.16	0.60	4.38	1.02	0.51	0.25	0.03	1.81
	LSD (0.05)	Ns	Ns	0.59	Ns	Ns	Ns	Ns	Ns	Ns
Sapele	0 – 45	6.47	7.65	1.77	4.64	1.80	0.53	0.04	0.03	2.40
	45 – 90	6.53	6.76	1.99	2.88	1.73	0.55	0.03	0.02	2.33
	LSD (0.05)	Ns	0.98	0.21	0.97	Ns	Ns	Ns	0.01	Ns
Ughelli	0 – 45	5.37	16.36	0.96	6.53	0.04	0.98	0.49	0.01	1.52
	45 – 90	5.50	12.07	0.73	5.41	0.08	1.05	0.45	0.02	1.60
	LSD (0.05)	Ns	2.67	0.17	0.95	Ns	Ns	0.04	Ns	Ns
Warri	0 – 45	7.02	7.77	1.81	10.18	3.31	2.52	0.49	1.77	12.09
	45 – 90	7.18	3.64	0.66	5.22	2.61	1.89	0.21	1.64	8.35
	LSD (0.05)	Ns	0.96	0.21	1.05	0.26	0.96	Ns	Ns	1.56

Free oxide Status, distribution and relationship in soils of some economic palms in selected areas of Delta State

The free oxide content of the soils, determined by dithionite and oxalate extraction methods is indicated in (Table 4) while the matrix of correlation showing the relationship between the various forms of the oxides are indicated in Tables 5-11. In Abbi, Agbor, Asaba, Bomadi, Warri and Sapele, dithionite extractable Fe oxides (Fe_d) increased with increased soil depth and decreased with increased soil depth in Sapele soils. Fe_o increased with increased soil depth in all the locations (Table 4). Al_d had the same trend as Fe_d and increased with increased soil depth in Abbi, Agbor, Asaba and Bomadi but decreased with increased depth in Sapele, Ughelli and Warri soils (Table 4). Al_o increased with increased soil depth in Abbi, Agbor, Asaba, Bomadi and Ughelli soils while it decreased with increased soil depth in Sapele and Warri soils (Table 4). Definite crystalline Fe and Al oxides (Fe_d-Fe_o) and Al_d-Al_o respectively had the same trend as Fe_d and Al_d. Fe_o/Fe_d was the same at both depths in Agbor, Asaba, Bomadi but increased with depth in Sapele and Warri soils. It however decreased with depth in Abbi and Ughelli soils. Clay/Fe_d was the same at both depths in Abbi soils but increased with increased soil depth in Agbor and Asaba soils while it increased significantly in Sapele and Warri soils. It decreased significantly with increased soil depth in Bomadi soils. In Ughelli, clay/Fe_d ratio decreased with increased soil depth (Table 4). In Agbor, Asaba and Bomadi Fe_d was positively significantly correlated with Al_d (r = 0.947, $P < 0.01$); Al_o (r = 0.875, $P < 0.05$) and clay (r = 0.970, $P < 0.01$) (Table 5). There was a positively significant correlation between Fe_d and Al_o of Abbi soils (Table 5) There was also a positively significant correlation of Fe_d with clay (Table 5), a trend that was also observed in Agbor soils (Table 6) while Fe_d of Asaba, Sapele and Ughelli soils had no relationship with other soil components (Table 7, 9 and 10). Fe_o had a positively significant correlation with Al_o and clay in Bomadi soils (Table 8). There were however negative significant correlations between Fe_o and organic matter in Bomadi and Warri soils (Tables 8 and 11). Al_d was positively significantly correlated with clay in Agbor and Asaba soils with (r = 0.92, $P < 0.01$) and (r = 0.97, $P < 0.01$) respectively. There were significant and positive correlations between Al_d and silt of Bomadi, Ughelli and Warri soils with (r = 0.91, $P < 0.05$); r = 0.87, $P < 0.05$) and (r = 0.94, $P < 0.05$) respectively (Tables 8, 10 and 11). Positively significant correlations were also obtained between Al_o and silt of Sapele and Warri soils with (r = 0.92, $P < 0.01$) and (r = 0.86, $P < 0.05$) respectively, (Tables 9 and 11) while Al_o was positively significantly correlated with organic matter of Sapele soils with (r = 0.98, $P < 0.01$).

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Table 4: Distribution of dithionite and oxalate extractable Fe and Al Oxides in selected areas of Delta State

Location	Depth (cm)	Fe_d ←	Fe_o	Al_d	Al_o (mg/kg)	Fe_d-Fe_o	Al_d-Al_o →	Fe_o/Fe_d	Clay/Fe_d
Abbi	0 – 45	337.50	1.24	0.92	0.04	336.20	0.88	0.004	0.03
	45 – 90	492.40	1.28	1.15	0.17	491.10	0.98	0.003	0.03
	LSD (0.05)	Ns	Ns	Ns	Ns	21.48	Ns	Ns	Ns
Agbor	0 – 45	377.40	1.87	2.16	0.03	375.50	2.13	0.005	0.02
	45 – 90	408.50	2.04	2.34	0.06	406.40	2.28	0.005	0.03
	LSD (0.05)	Ns	Ns	Ns	Ns	20.21	0.12	Ns	Ns
Asaba	0 – 45	490.00	0.99	2.47	0.03	489.00	2.41	0.002	0.02
	45 – 90	559.00	1.10	3.47	0.05	557.00	3.43	0.002	0.03
	LSD (0.05)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Bomadi	0 – 45	490.00	0.99	2.47	0.03	321.00	0.80	0.004	0.06
	45 – 90	559.00	1.10	3.47	0.05	558.50	0.27	0.004	0.08
	LSD (0.05)	Ns	Ns	Ns	Ns	25.18	Ns	Ns	0.007
Sapele	0 – 45	322.70	1.00	1.84	0.05	321.70	1.80	0.003	0.02
	45 – 90	321.90	1.12	1.66	0.01	320.80	1.65	0.004	0.04
	LSD (0.05)	Ns	Ns	Ns	Ns	Ns	Ns	0.0004	0.008
Ughelli	0 – 45	101.00	0.68	1.53	0.13	100.00	1.52	0.007	0.20
	45 – 90	167.00	0.81	1.38	0.37	166.00	1.35	0.005	0.15
	LSD (0.05)	Ns	Ns	Ns	Ns	Ns	0.08	Ns	Ns
Warri	0 – 45	110.00	0.38	1.03	0.02	109.60	1.00	0.004	1.16
	45 – 90	121.90	0.56	0.76	0.01	121.30	0.76	0.005	0.19
	LSD (0.05)	Ns	Ns	0.18	Ns	Ns	0.16	Ns	0.03

Table 5: Matrix of correlation coefficient of Abbi soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	-0.008	-		
Al_d	0.947**	-0.040	-	
Al_o	0.875*	0.226	0.687	-
Sand	-0.940**	0.131	-0.350	-0.840*
Silt	-0.820*	-0.380	-0.590	-0.650
Clay	0.970**	0.090	0.490	0.830*
Organic matter	-0.980**	-0.150	-0.420	-0.910*

*Correlation significant at 0.05, ** Correlation significant at 0.01

Table 6: Matrix of correlation coefficient of Agbor soils

5	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	-0.076	-		
Al_d	0.733	0.002	-	
Al_o	0.554	0.586	0.660	-
Sand	-0.860*	0.130	-0.960**	-0.650
Silt	-0.950**	0.100	-0.890*	-0.570
Clay	0.930**	-0.120	0.920**	0.600
Organic matter	-0.940**	-0.070	-0.870*	-0.610

*Correlation significant at 0.05, ** Correlation significant at 0.01

Table 7: Matrix of correlation coefficient of Asaba soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	0.068	-		
Al_d	0.760	0.339	-	
Al_o	0.640	0.418	0.771	-
Sand	-0.630	-0.340	-0.980**	-0.740
Silt	-0.710	0.280	-0.590	-0.360
Clay	0.740	0.160	0.970**	0.710
Organic matter	-0.570	-0.390	-0.960**	-0.650

** Correlation significant at 0.01

Table 8: Matrix of correlation coefficient of Bomadi soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	0.910**	-		
Al_d	-0.763	-0.900*	-	
Al_o	0.819*	0.830*	-0.920**	-
Sand	-0.790	-0.880	0.630	-0.660
Silt	-0.740	-0.920*	0.910*	-0.970**
Clay	0.790	0.950**	-0.850*	0.900*
Organic matter	-0.840*	-0.940**	0.780	-0.870*

*Correlation significant at 0.05, ** Correlation significant at 0.01

Table 9: Matrix of correlation coefficient of Sapele soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	0.390	-		
Al_d	0.130	-0.840*	-	
Al_o	0.420	-0.540	0.830*	-
Sand	0.130	-0.690	0.850*	0.950**
Silt	0.380	-0.740	0.750	0.920**
Clay	-0.190	0.650	-0.840*	-0.970**
Organic matter	0.490	-0.430	0.740	0.980**

*Correlation significant at 0.05, ** Correlation significant at 0.01

Table 10: Matrix of correlation coefficient of Ughelli soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	0.640	-		
Al_d	-0.680	-0.408	-	
Al_o	0.460	0.380	-0.790	-
Sand	-0.290	-0.800	0.540	-0.580
Silt	-0.670	-0.090	0.870*	-0.730
Clay	0.930	0.250	-0.920*	0.850*
Organic matter	-0.790	-0.430	0.800	-0.800

*Correlation significant at 0.05

Table 11: Matrix of correlation coefficient of Warri soils

	Fe_d	Fe_o	Al_d	Al_o
Fe_d	-			
Fe_o	0.635	-		
Al_d	-0.451	-0.848*	-	
Al_o	-0.393	0.557	0.890*	-
Sand	-0.720	-0.690	0.810	0.790
Silt	-0.630	-0.750	0.940*	0.860*
Clay	0.690	0.720	-0.850*	-0.820*
Organic matter	-0.640	-0.850*	0.920*	0.760

*Correlation significant at 0.05

Discussion

The soils of the sampled locations are derived from recently deposited materials such as Alluvium in places like Abbi, Bomadi and Ughelli. Asaba, Agbor and Sapele are developed on Coastal plain sands while Warri soils are developed on Sombreiro /Warri deposits. The textural classes are the intrinsic properties of the soil, which are sufficiently permanent and are often used to characterize the soil physical make up (Hillel, 1980). The texture of the soils was predominantly sandy in Abbi, Asaba, Bomadi and Sapele. Osayande *et al.*, (2016) reported that the soils of Abbi, Asaba, Bomadi and Sapele were classified as S1 (Highly suitable) for the cultivation of Coconut and Raphia palms with limitation being the sandy texture of sub-soils and N (not suitable for the cultivation of oil palm). They added that these soils are low with respect to nutrient and water retention. Soil pH is a reflection of soils parent materials and the influence of seasonal variations on chemical properties of soils (Sanchez, 1976). In this study, soils developed on Coastal Plain Sand parent materials had slight acidic top soils, except at Sapele where the soil pH tended towards moderate acidity. This is due to the fact that surface soils of soils derived on Coastal Plain Sand and Alluvium are primarily sand as observed in the texture of the soils of Abbi, Agbor, Asaba, Bomadi and Sapele. Sand textured soils are prone to leaching of exchangeable bases that reduce acidity in soils. Soils of Warri location are neutral which is probably due to the constant inundation with water. This agrees with earlier findings of Oneju (2014). Organic matter as defined by organic carbon was below the critical level of between 20 - 30 g/kg in soils as reported by Enwezor *et al.*, (1989). This could be due to the flat nature of these locations. Flat land surfaces enhance water percolation and are usually free-draining. This encourages organic matter decomposition and mineralization by aerobic microorganisms that are more efficient in the decomposition of plant and animal remains in soils. The mineralization of organic matter in these soils could be responsible for the high nitrate content of some of the soils. Agbor, Asaba, Sapele, Ughelli and Warri soils had high nitrate content. With respect to phosphorus, none of the soils of the locations met the critical level of 10 – 16 mg/kg as reported by Adeoye and Agboola (1985). This may be attributable to the flat nature of the terrain which enhanced microbial activity. Sanchez *et al.*, (1997) observed that the initial loading levels are due largely to microbial uptake, and there is some geochemical adsorption by aluminium and iron minerals in the soil. Though the soils of these locations had adequate magnesium content, within Fayemi and Lombin's (1975) critical value of 0.4 cmol/kg, these soils except Warri were however deficient in calcium being below the critical value of 2.6 cmol/kg as established by Agboola and Corey, (1976). Exchangeable potassium was low, below the critical level of 0.16 – 0.25 cmol/kg as established by Adeoye and Agboola (1985) in Agbor, Asaba and Sapele while the low sodium contents of the soils except Warri could be regarded as adequate.

The Fe_d values are larger than Fe_o values in all the locations indicating that a larger proportion of the oxides are present in the crystalline forms. The correlation of Fe_d with Al_d in Abbi soils indicated a substitution of Fe for Al in Abbi soils. Substitution of Fe by Al has been reported by several workers to occur in soils. (Juo and Maduakor 1974) were the first to observe the substitution of Fe by Al in Nigerian soils by the positive significant correlation of Fe_d with Al_d in the less well drained soils of Southern Nigeria. Pena and Torrent (1984) obtained a positively significant correlation between Fe_d and Al_d and concluded that considerable amount of substitutions of Al for Fe occurred in the Alfisols they studied in Spain. Some of the reasons advanced for this were the seasonal flooding that occurred in those soils. This seasonal flooding is a feature of Abbi soils where the soils are flooded at the peak of the rains (Osayande *et al.*, 2016). The positively significant correlation between Fe_d and Al_o of Abbi soils suggests that Fe_d was closely associated with both the amorphous and the crystalline Al oxides in Abbi soils. The correlation of Fe_d with clay indicated a co-migration of Fe with clay in Abbi soils, a trend that was also observed in Agbor soils. This is buttressed by the fact that both Fe_d and clay increased with increased soil depth in Abbi and Agbor soils. Ogunsola *et al.*, (1989) observed a co-migration of Fe_d with clay with a positively significant correlation of Fe_d with clay, an observation that was buttressed by the increase of Fe_d and clay with depth. In this study, the amorphous iron oxide designated as Fe_o did not associate with organic matter in all the locations. Fe_o had a positively significant correlation with Al_o and clay in Bomadi soils. The positively significant correlation of Fe_o with Al_o in Bomadi soils indicated a close association of amorphous iron and aluminium oxides in these soils while the correlation of Fe_o with clay indicated a close association of the amorphous form of Fe oxide with clay. The association of the amorphous form of Fe oxide with clay was reported by Obi *et al.*, (2009) and Osayande *et al.*, (2013). According to Obi *et al.*, (2009), the amorphous forms of the free oxides are more mobile in soils and easily associate with clay and organic matter while Osayande *et al.*, (2013) obtained a correlation between Fe_o/Fe_d ratio and clay in Upland soils of NIFOR and observed it to be an association of Fe_o with clay, since both components (Fe_o and clay) increased with increased soil depth in Upland soils of NIFOR while Fe_d of the same location decreased with increased soil depth. In this study, the amorphous iron oxide designated as Fe_o did not associate with organic matter in all the locations. There were however negative significant correlations between Fe_o and organic matter in Bomadi and Warri soils. Many researchers have used the Fe_o/Fe_d values to determine the dominance of amorphous or crystalline Fe oxides in soils. (Juo and Maduakor 1974) stated that a decrease of Fe_o/Fe_d with depth indicates the dominance of crystalline Fe oxide. Ogunsola *et al* (1989) used the values of Fe_o/Fe_d to determine the dominance of crystalline iron over amorphous iron oxide. According to Ogunsola *et al.*, (1989), when Fe_o/Fe_d values are low, ranging from 0.08 to 0.36, it indicates that purely crystalline forms of iron dominate. In this study, the purely crystalline Fe oxide can be said to dominate over the amorphous. Osayande *et al.*, (2013) used the Fe_o/Fe_d to distinguish between the poorly drained inland valley soils of NIFOR from the well-drained upland soils. According to Osayande *et al.*, (2013), Fe_o/Fe_d values less than 0.25 at the top and sub soils are regarded as poorly drained while Fe_o/Fe_d values greater than 0.30 are regarded as well drained. Stonehouse and Arnaud (1971) before Osayande *et al.*, (2013) had used the Fe_o/Fe_d to distinguish between well-drained and poorly drained soils. According to Stonehouse and Arnaud (1971), soils with Fe_o/Fe_d ratios of less than 0.35 were classified as being poorly drained, whereas well-drained soils had values greater than 0.35. The Fe_o/Fe_d values could not be used to distinguish between the poorly drained soils from the well-drained soils in this study as the values were fairly constant in all the locations. In Abbi, Agbor, Asaba, Sapele and Warri soils, it could be said that clay movement was dependent on the movement of Fe_d, especially as both components increased with increasing soil depth, except in Sapele where mean Fe_d values at both top and sub soils were 322.7 and 321.9 mg/kg respectively. In Bomadi and Ughelli soils, the clay/Fe_d ratios indicated that iron oxide was partially independent of clay distribution. This is buttressed by the fact that though clay/Fe_d ratio decreased with depth in these two locations, clay on the other hand increased with depth.

Conclusion

Crystalline forms as compared to the amorphous forms dominated the free oxides in soils of these selected locations of Delta state. The high amounts of these crystalline forms in these soils ranging from 110.00 mg/kg to 337.50 mg/kg in the surface soils to 121.90 mg/kg to 559.00 mg/kg in the sub surface soils indicate a possible formation of plinthites and concretions in the rooting depth. Though there is an overwhelming evidence of some economic palms such as Coconut, Oil and Raphia palms in the locations understudy, the evidence of a co-migration of the crystalline Fe oxide with clay suggests an urgent need for the planting of nitrogen fixing cover crops to encourage nitrogen build-up of the top soil, improve the overall cation exchange capacity and enhance water percolation.

References

Adeoye, G.O.and Agboola, A.A. (1985). Critical levels for soil pH, available P, K, Zn and Mg and ear leaf content of P, Cu and Mn in sedimentary soil of Southwestern Nigeria. Fertilizer Research 6: 65-71

Agbenin J. O. (2003). Extractable iron and aluminium effects on phosphate sorption in savanna Alfisol. Soil Sci. Am. J. 67: 589-593

Aghimien A. E., Udo, E. J. and Ataga D. O. (1988). Profile distribution of forms of Iron and Aluminium in the Hydromorphic soils of Southern Nigeria. *Journal of West AfricaScience Association 31*: 57-70.

Agboola, A. A. and Corey, R. B. (1976). Nutrient deficiency survey of maize in Western Nigeria. *Nigerian Journal of Science* 10: 1-13

Alexander E. B. (1974). Extractable iron in relation to soil ash on terraces along the Truckee River. Soil Sci. Soc. Am. Proc. 38: 121-124

Anderson, J.M. and Ingram, J. S. L. (1993). Tropical Soil Biology and Fertility; A

Handbook of Method of Analysis *International Wallingford,* UK, 38-39

Blume, H.P. and Schwertmann, U. (1969). Genetic evaluation of profile distribution of aluminium, iron and manganese oxides. Soil Sci. Am Proc. 34: 438-444

Brookes, P. C.; Landman, A.; Prudes, G. and Jenkenson, D. S. (1985). Chloroform Fumigation and Release of Soil Nitrogen; a rapid extraction method to measure microbial biomass and Nitrogen in Soil. Soil Biology and Biochemistry. 17: 837-842.

Enwezor W. O., Udo, B. J., Usoroh, N. J., Ayotade, K. A., Adepetu, J. A., Chude, V. A. and Udegbe, C. A. (1989). *Fertilizer use and management for crops in Nigeria Series* 2, pp 163.

Fayemi, A.A. and Lombin G. (1975). Critical levels of available magnesium in Western Nigerian soils as estimated under greenhouse comditions. *Agronomy journal* Vol 67: 272-275

Gee, G. W. and Or D. (2002). Particle size distribution. In: Dane, J.H. and Topp, G.C. (eds). Methods of soil Analysis.Part 4.Physical methods. Soil Sci. Soc. Am Book Series No. 5, ASA and SSSA, Madison, W.I. Pp. 255-293

Hendershort, W. H., Lalande, H., Duquette, M. (1993). Soil reaction and exchangeable acidity. In: Carter M.R. (ed). Soil Sampling and methods of soil analysis. Canadian Soc. Soil Sci. Lewis Publishers, London, PP 141-145.

Hillel, D. (1980). Fundamentals of soil physics. New York Academic Press Inc.

Ibia T. O. (2001). Forms of Fe and Al in soil particles of inland Flood Plains of Southeastern Nigeria. Proceeding of the 27th Annual Conference of the Soil Science Society of Nigeria.Pp 165-168.

Juo A. S. R. and Maduakor, H. O. (1974). Forms of pedogenetic distribution of extractable iron and aluminium in selected soils of Nigeria. *Geoderma* 11:167-179

McKeague, J. A.; Brydon, J. E. and Miles N. M. (1971a). Differentiation of forms of extractable iron and aluminium in soils. Soil Sci Soc. Am. Proc. 35: 303-306

Mckeague, J. A. and Day, J. A. (1966). Ammonium oxalate and DCB extraction of Fe and Al.*Canada Journal of Soil Science*. 46: 13-22

McKeague, J. A., Nowland, J. E., Brydon J. E. and Miles, N. M. (1971b). Characterization and classification of five soils from eastern Canada having prominemtly mottled B horizons. *Can J. Soil Sci.* 51: 483-497

Mehra O. P. and Jackson M. L. (1960). Iron Oxides removal from soils and clays. Dithionite-citrate systems Buffered with sodium bicarbonate. Proc.7th Natl. Conf Clays and clay minerals. Pergamon Press, New York pp: 313-327

Nelson, D.W. and Sommer, L.E. (1996).Total carbon, Organic Carbon and Organic Matter. In: Sparks, D.L. (Ed), Methods of Soil Analysis. Part 3. SSSA Book Series No. 5 SSSA Madison, WI, PP: 960-1010

Obi, J. C., Akinbola, G. E. and Anozie H. F. (2009). Distribution of dithionite and oxalate-extractable iron oxides of a catena in the basement complex soils of Southwestern Nigeria. *Nigerian Journal of Soil Science* 19:100-108

Ogunkunle, A. O. and Onansanya, O. S. (1992). Soil landscape relationship in a forest zone in southwestern Nigeria *Samaru J. Agric Research.*, 9:19-33

Ogunsola O. A.; Omueti J. A.; Olade O. and Udo E. J. (1989). Free Oxide status and distribution in soils overlying Limestone areas in Nigeria. *Soil Science* 147 (4): 245-251

Oneju A. A. (2014). Status and distribution of Dithionite and Oxalate extractable Iron and Aluminium oxides in selected soils of Delta state, Nigeria. M.Sc. Unpublished M.Sc. Thesis, Department of Soil Science and land Management, University of Benin, Benin City, Nigeria. 53 pp

Osayande P. E., Orhue E. R., Oviasogie P. O., Oneju A. A. and Edokpayi A. E.(2016). Biophysical properties of selected areas of Delta state and their suitability assessment for coconut, raphia and oil palms cultivation. *Biological and environmental sciences journal for the tropics* 13(1): 95 – 101.

Osayande P. E., Oviasogie P. O., Aisueni N. O., Stephen O., Irhemu P. and Ekebafe M. O. (2013). Assessment of Dithionite and Oxalate Extractable Iron and Aluminium Oxides in Soils Supporting Raphia palms (*Raphia spp)* at NIFOR Main Station. *Nigerian Journal of soil science*. 23 (2): 1-10.

Osodeke, V. E., Nwotiti, I. L. and Nuga, B. O.(2005). Sesquioxides Distribution along a Toposequence in Umudike Area of Southeastern Nigeria. *Electronic Journal of Environmental, Agricultiral and Food Chemistry* 4(6) : 1117-1124.

Oyeyiola J. A. and Omueti J. A. (2010). Sorption Characteristics of phosphorus in some Alfisols of South Western Nigeria. *International journal of soil science*.**2** (1): 1-7

Pena F. and Torrent J. (1984). Relationship between phosphate sorption and iron oxides in Alfisols from a river terrace sequence of mediterranean Spain. *Geoderma,* 33 Elsevier Science Publishers B.V., Amsterdam. PP 78-82

Remison, S. U. (2004). Agriculture as the way. Ambik press, Benin City.73PP

Sanchez P. A. (1976). Properties and management of soils in the tropics. A Wiley Interscience publication. John Wiley and Sons, New York. 605 pp

Sanchez, P. A., Shepherd K.D., Soule M.J., Place F.M., Mokwunye A.U., Buresh R. J., Kwesiga F.R, Izac A.M.N., Ndiritu C.G., and Woomer P.L. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital, P 1 -46. *In* R.J. Buresh *et al.*, (ed). Replenishing soil fertility in Africa. SSSA Spec Publ. 51, SSSA, Madison, WI

Schwertmann, U. (1964). Differenzierung der Eisenoxyde des Bodens durch Extraktion mit Ammoniumoxalat-Losung.Z. Pflanzenernahr. Bodenkd, 105: 194-202

Stonehouse, H. B. and St. Arnaud R. J. (1971). Distribution of iron, clay and extractable iron and aluminium in some Saskatchewan soils. *Can J. Soil Sci.* 51, 283 – 292.

Thomas, G. W. (1982). Exchangeable cations. In: Page A.L. *et al* (eds). Methods of Soil Analysis part 2. *Agron. Monigr* 9. Wisconsin 3rd edition. *ASA* and *SSSA* Madison, pp 159-165.