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Micronutrient status of grain size fractions in soils of land uses in Mbano, Southeastern, Nigeria

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ABSTRACT

Micronutrient status in grain size fractions provides information on the active soil fraction and the ability for stabilization against microbial decomposition. Total, available, exchangeable and water-soluble Fe, Zn,Cu and Mn in bulk and grain size soil fractions were evaluated in three landuse types (Cassava, Cashew and Oil palm) in Ehime Mbano, Southeastern, Nigeria. Also, selected soil properties (pH, O.M, ECEC, clay, silt, Ca and P) were correlated with bulk soil micronutrients using correlation analysis. Equally, micronutrient in grain size soil fractions was regressed with bulk soil contents using regression analysis. Total, available, exchangeable and water-soluble micronutrients ranged from 1389.08-2350.06, 75.07-166.61, 73.43-163.45 and 1.64-8.04 (Fe), 12.93-21.88, 3.08-3.22, 2.31-2.56 and 0.62-0.77 (Zn), 0.39-4.11, 0.21-0.64, 0.12-0.37 and 0.09-0.27 (Cu) and 127.62-215.96, 27.06-28.25, 19.80-21.94 and 5.85-7.26 mg kg^{-1} (Mn) respectively. Whereas, total and available Fe, Mn and Zn, exchangeable Fe and all Cu were significantly (LSD 0.05) higher in Oil palm, exchangeable Mn and Zn and water-soluble Mn and Zn were higher in cashew and cassava landuse types respectively. Also most bulk soil micronutrients were significantly ($P < 0.05$) correlated with soil pH, O.M, sand, silt and clay but not with C.E.C and exchangeable Ca. Equally, micronutrient distribution varied amongst grain size soil fractions with most distinctly higher in Oil palm land use. Furthermore, averaged over land use types, clay size fraction was more enriched with most micronutrients. Finally, more than 95% of bulk soil micronutrients could be accounted for by the grain size soils fractions and with the contribution of each grain fraction being equal.

1.0 Introduction

Conflicting reports exist concerning micronutrient status of agricultural soils worldwide, with the tropics and indeed Nigerian soils indicating widespread deficiencies (Oyinla and Chude, 2010; Hassan and Ogbonnaya, 2016). These deficiencies have been ascribed to low nutrient content in the soil mineralogy, intense weathering, leaching, adsorption by soil constituents, increased use of micronutrient fertilizers and apathy towards the application of organic amendments (Onwudike *et al*., 2017; Bhaskar *et al*., 2017). It also includes the transformation from fallow or shifting cultivation practices to continuous cultivation, increased irrigation and cropping intensity as well as the use of improved crop varieties with high demands on soil nutrients (Oguike and Mbagwu, 2009; Oyinla and Chude, 2010). Micronutrients are essential elements that are required in trace amounts and play significant roles in most enzymatic and redox processes in plants (Hassan and Ogbonnaya, 2016). Depending on their ionic charges, they fall into micronutrient cations (Cu, Fe, Mn and Zn) and anions (Cl, B, Mo etc) (Havlin *et al*., 2012) with the former often forming complexes with soil organic matter (Begum *et al*., 2016). Assessment of soil micronutrient status is necessary for its efficient and sustained management. Soil micronutrients exist in different chemical forms with varying availability (Filgueiras *et al*., 2002; Adiele *et al*., 2015) and includes operationally defined pools such as the solution, exchangeable, carbonate bound, Fe/Mn bound, organic matter bound, structural and the residual fractions (Aydinalp, 2009; Ideriah *et al*., 2013). Solution and exchangeable pools are soluble, mobile and available and constitute the portion often extracted in evaluating soil micronutrient availability (Oyinla and Chude, 2010). They are the fraction quickly lost through leaching, runoff, erosion and uptake by crops and microbes (Okoli *et al*., 2016). Total soil micronutrient provides information about the overall soil status and as such of little value in the assessment of the soil fertility status (Onyekwere *et al*., 2017). Available micronutrient status indicates the potential behaviour or bioavailability of metals and useful in geo-environmental studies for risk assessment (Ideriah *et al*., 2013). Information concerning total and available micronutrient status is essential in estimating the soil supplying capacity and bioavailability for crop production.

In Nigeria, food production lags population growth and efforts at addressing this trend involved an intensification of crop production in different landuse types. Since crops take up varying amounts of nutrients, soil micronutrient status may vary with land use types (Onwudike *et al*., 2017; Motuma and Chimdi, 2018). For instance, it has been noted that total Zn and Cu increased in cultivated relative to uncultivated soils in Turkey (Aydinalp *et al*., 2009) and available Zn accumulated in the forest than cultivated Ethiopian lands (Motuma and Chimdi, 2018). In a study of some Southeastern Nigerian soils, Uzoho *et al*. (2007) reported increased available Fe and Mn and depressed Zn in fallow and forests than continuously cultivated soils and the accumulation of available Zn in an industrial site, oil palm plantation, cassava, cocoyam and bamboo land uses than others. Onwudike *et al*. (2016) obtained high available Fe and Cu under oil palm, Mn and Zn under plantain plantation than pineapple orchard in soils of similar lithology in Owerri, Southeastern, Nigeria. The differences amongst land could be ascribed to changes in soil physicochemical and biological properties (Uzoho *et al*., 2007; Onwudike *et al*., 2017; Motuma and Chimdi, 2018) or alteration in the distribution and chemical forms of micronutrients due to soil organic matter, pH, clay and submergence (Dhaliwal *et al*., 2009). It has been noted that soil micronutrients increases with S.O.M but decreases with the pH (Nath, 2013). Also, available Fe, Cu, Mn and Zn have been reported to increase with soil texture, O.M, C.E.C and pH (Bhaskar *et al*., 2017). Equally, a significant correlation has been indicated between available Zn and Mn with silt, Fe, Cu, Mn and Zn with clay, Cu and Mn with pH and Fe, Cu and Mn with O.C (Oyinlola and Chude, 2010). Furthermore, Aydinalp *et al*. (2009) obtained a positive correlation between total Zn with O.M and pH and a negative relationship between Cu and C.E.C. Others included a significant correlation between total and available Cu, Fe, Mn and Zn with O.C (Dhaliwal *et al*., 2009).

Most studies on micronutrient status involve the use of bulk soils with limited use of the grain size fractions. However, few available information on soil grain size fractions involved the accumulation of boron in silt fractions of some semi-arid soils of Tunisian (Tlili *et al*., 2019). Others included that with different nutrients and involved increased carbohydrate accumulation in the sand (Spaccini *et al*., 2001) and clay (Solomon *et al*. 2000), K in clay size fraction of soils developed over talc in Ejigbo, Kogi state, Nigeria (Ajibade and Ogunwale, 2012), silt fraction in floodplain soils of Southeastern, Nigeria (Igwe *et al*., 2008) and the sand fraction of coastal and Iranian soils (Najafi-Ghiri and Abtahi *et al*., 2013), heavy metals on clay fraction of soils of varying land uses in Iran (Sayadi *et al*., 2016) and P in clay fractions of low-land soils of Egbema, Southeastern Nigeria (Uzoho, 2018).The differences with particle size soil fractions have been attributed to variations in soil surface area (Sayedi *et al*., 2016; Tlili *et al*., 2019) and soil organic matter (Najafi-Ghiri and Abtahi, 2013). It has been reported that the finer the soil particles, the higher the surface area (Spaccini *et al*., 2001; Sayadi *et al*., 2016; Tlili *et al*., 2019). Thus, inventory of micronutrients in grain size soil fractions will help determine soil active fraction and ability of nutrient stabilization against microbial decomposition.

Although, micronutrient status of varying landuse types in Nigeria have been studied (Oyinla and Chude, 2010; Hassan and Ogbonnaya, 2016; Onyekwere *et al*., 2017; Onwudike *et al*., 2017), information concerning the status in grain size soil fractions appears to be limited. The objective of this study was therefore, to determine the grain size distribution of micronutrients in soils of selected land uses in Ehime, Mbano, Southeastern, Nigeria.

2.0 Materials and Methods

2.1 Study Location

The study location was Ehime-Mbano in the humid rainforest agroecological zone of Southeastern, Nigeria. Mbano lies between Latitudes 5^0 39^1 and 5^0 42^0 N and Longitudes 7^0 18^1 and 7^0 22^1 E on an elevation of 124 metres above sea level. Its mean annual rainfall ranges from 2200 -3000 mm, with a bimodal distribution pattern that peaks in July and September and a short dry spell, the August break in August. Its mean daily temperature ranges from $26\text{-}30^0$C and mean annual relative humidity from 85-88% (IPEDC, 2006). The soil type was Kandic Paleuduct (USDA, 2004) derived from Coastal Plain Sands (Orajiaka, 1975). Study sites included three land uses; Cashew, Cassava and Oil palm, with the cashew consisting of a thirty years old cashew plantation that has received N.P.K fertilizers at various growth stages, the Oil palm, a twenty-five years old Oil palm plantation fertilized with urea and muriate of potash at various stages while the cassava land use was a less than two years old cassava farm fertilized with N.P.K 10:10:17: 3 Mg fertilizers. Main economic activities of the area included farming, trading, quarrying and artisanry.

2.2 Sample Collection and Preparations

Surface (0-15 cm) soil samples were collected from ten spots of each land use, making a total of thirty samples. The soil samples were air-dried, ground and sieved using a 2 mm diameter sieve and the fine earth soil fractions stored ready for laboratory analysis. Also, subsamples of the fine earth soil fractions were fractionated into sand (<0.002 mm), silt (0.002-0.02 mm) and clay (0.02-2.0 mm) fractions using the method described by Sequaris and Lewandowski (2003).

2.3 Laboratory Analysis

Fine earth (< 2 mm) bulk soil subsamples of were analyzed for particle fractions (Gee and Or 2002), organic carbon (Nelson and Sommers, 1996) and the value converted to organic matter by multiplication using a factor of 1.72, exchangeable cations after extraction with 1N NH_40Ac (Thomas 1996), available P (Olson and Sommers, 1982) and pH in 1:2.5 soil/water ratio using glass electrode of the pH meter. Also, total micronutrient (Fe, Cu, Mn and Zn) in bulk and grain size soil fractions were determined after extracted with 30% of H_20_2 and 0.5 M HCl on an A.A.S Model 650 (Page *et al*., 1982). Equally, water-soluble and exchangeable micronutrient fractions in bulk and particle size soil fractions were sequentially extracted using the method described by Salbu *et al*. (1998).

2.4 Calculations

2.4.1 Micronutrient Availability

Available micronutrients in both bulk and particle size soil fractions were calculated by summation of the water-soluble and exchangeable fractions.

2.4.2 Enrichment Factors

Micronutrient enrichment factors in the various particle size fractions were obtained by dividing the particle size fractions with bulk soil contents.

2.5 Statistical Analysis

Data generated for total, available, exchangeable and water-soluble micronutrients in bulk and particle size soil fractions as well as the correction factors were subjected to analysis of variance (ANOVA) and means separated using L.S.D at 5% probability level. Also, the correlation between soil properties and micronutrient in bulk soil was determined using correlation analysis. In contrast, the relationship between bulk and particle size soil micronutrients was determined using simple linear multiple regression analysis. All analyses were conducted using the Genstat statistical package (Buyse 2004).

3.0 Results and Discussion

3.1 Soil Characterization

Sand dominated the soil fractions with the texture mostly sandy ascribable to the nature of the parent material which is Coastal Plain Sands (Table 1). A similar observation has been reported by others (Uzoho *et al*., 2007; Udoh *et al*., 2013; Oviasagie and Oko-Oboh, 2013). Soils were acidic with a pH range of 5.23-5.93 attributable to intense base leaching from high tropical rainfall. Soil organic matter varied as 2.86, 2.17 and 2.89 g kg^{-1} for cassava, cashew and oil palm respectively and below critical limits (15.0-20.g kg^{-1}) for southeastern Nigeria soils (Enwezor *et al*., 1990) or low using the rating proposed by Adaikwu *et al*. (2013). The low organic matter content could be due to rapid mineralization from high temperature and moisture or bush burning (Oviasagie and Oko-Obog, 2013. Available phosphorus ranged from 1.33-2.45 mg kg^{-1} and low relative to the critical limit of 8-12 mg kg^{-1} for tropical soils (Enwezor *et al*., 1990). Soil ECEC varied between 1.87-8.69 cmol kg^{-1} and low following a scale of < 6cmol kg^{-1}(low), 6-12 cmol kg^{-1} (medium) and > 12 cmol kg^{-1} (high) proposed by Adepetu *et al*. (1979). Generally, the soils were coarse-textured, acidic, low in organic matter and fertility consistent with Ultisols of Southeastern, Nigeria (Enwezor *et al*., 1990).

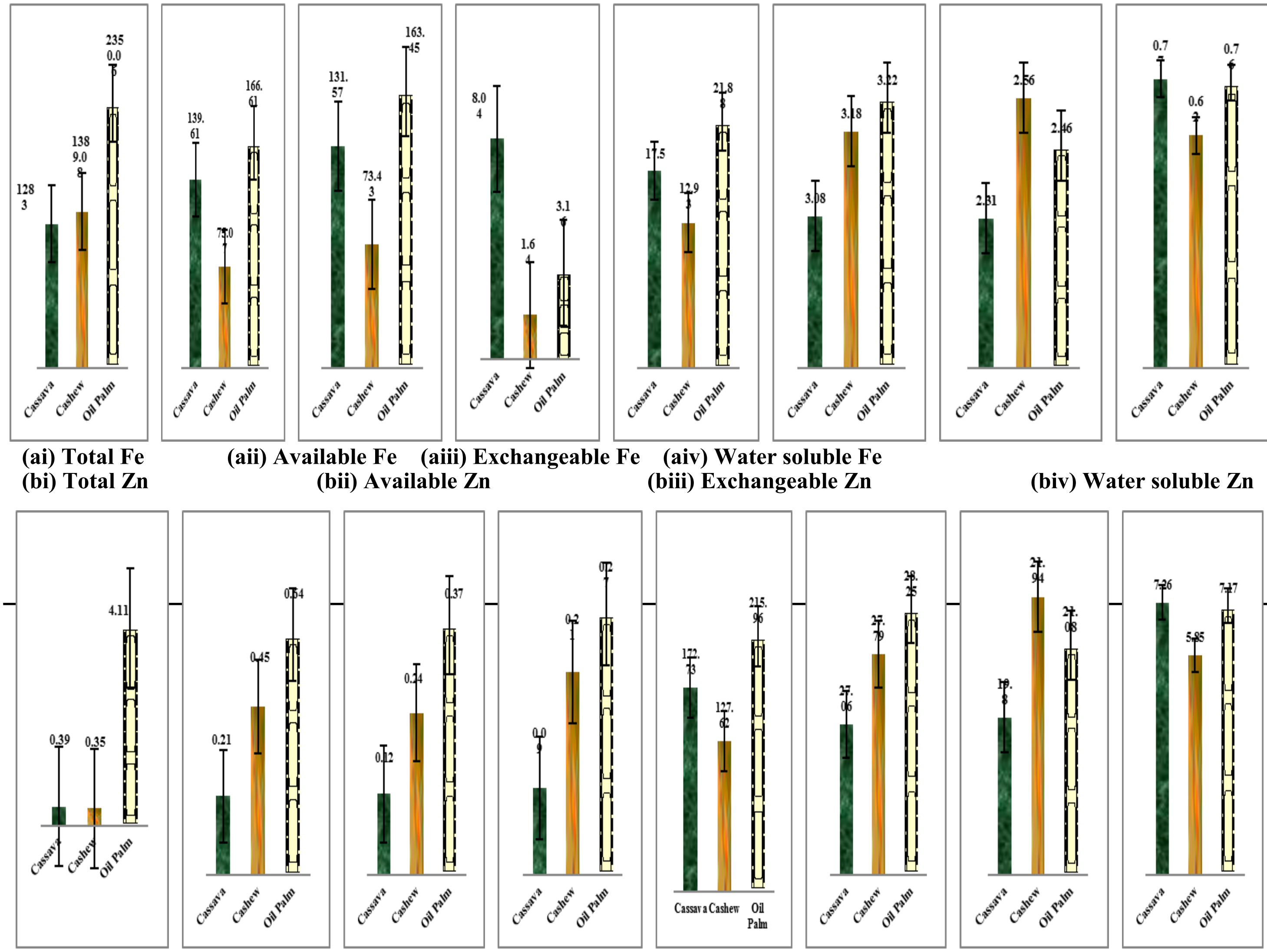
3.2 Soil Micronutrients

Total, available, exchangeable and water-soluble micronutrients ranged from 1389.08-2350.06 (1674.05), 75.07-166.61 (127.10), 73.43-163.45(122.82) and 1.64-8.04 (4.28) (Fe), 12.93-21.88 (17.44), 3.08-3.22 (3.16), 2.31-2.56 (2.44) and 0.62-0.77 (0.72) (Zn), 0.39-4.11 (1.62), 0.21-0.64 (0.43), 0.12-0.37 (0.24) and 0.09-0.27 (0.19) (Cu) and127.62-215.96 (172.10), 27.06-28.25 (27.70), 19.80-21.94 (20.94) and 5.85-7.26 (8.27) mg kg^{-1} (Mn) in bulk soil (Fig 1). Available Fe, Zn, Cu and Mn constituted 7.59, 18.12, 26.54 and 16.10 % of mean respective total contents while exchangeable and water-soluble fractions were 96.63 and 3.37 (Fe), 77.22 and 22.78 (Zn), 55.81 and 44.19 (Cu) and 75.60 and 29.85% (Mn) of the mean available fractions. Ranges of total Fe, Mn, Zn and Cu in the soils were low compared to background soil values of 50,000-300,000 (24.492.97), 200-2000 (792.92), 10-300 (65.17) and 2-100 (27.18 mg kg^{-1}) for Fe, Mn, Zn and Cu respectively (Isirimah *et al*., 2004; Mahmoulabadi *et al*., 2015), soils of varying land use systems in Punjab (Dhaliwal *et al*., 2009), rice-growing hydric soils of India (Bhaskar *et al*., 2017) and soils of lower Benue valley, Central Nigeria (Sha Ato *et al*. 2012). Also, besides Mn, total Fe, Zn, Cu were low compared to soils of Abraka, Nigeria (Akporhonor and Agbaire, 2009) and with only Fe low relative to soils of varying land uses in Bangladesh (Begum *et al*., 2009). Equally, ranges of available micronutrients were high relative to paddy soils of Abia state, Southeastern, Nigeria (Ahukaemere *et al*., 2014) and soils on a toposequence in Akamkpa, Cross River State (Kingsley *et al*., 2019).

Furthermore, besides available Fe, ranges of Mn, Zn and Cu were low compared to aquic brown soils of China (Jiang *et al*., 2009) while mean available Fe, Mn and Zn but Cu were high relative to some mountainous soils of Tanzanian (Meliyo *et al*., 2015). Also, the mean available Fe and Zn were low, while Mn and Cu were high compared to some Nigerian soils (Biwe, 2012). In general, mean available Fe and Zn were above critical limits of 4.50 and 0.80 mg kg^{-1} respectively (Lindsay and Norvel, 1978), Mn (1.00 mg kg^{-1}) (Udoh *et al*., 2006) and Cu (0.20 mg kg^{-1})(Sims and Johnson 1991). Water-soluble and exchangeable micronutrients constituted the available fractions, with the former lower due to leaching, crop and microbial uptake (Okoli *et al*., 2016). Amongst land uses, total and available Fe, Mn and Zn, exchangeable Fe and all Cu were significantly (LSD 0.05) higher in Oil palm while exchangeable and water-soluble Mn and Zn were in cashew and cassava land uses respectively**.** Superiority in the micronutrient content of Oil palm could be due to its low

Table 1. Selected Physical and Chemical Properties of Soils of various land uses

Parameters	Units	Land use Types		
		Cassava	Cashew	Oil Palm
pH (H_20)		5.93	5.23	5.61
Organic matter	g kg^{-1}	2.86	2.17	2.89
Available P	mg kg^{-1}	2.45	1.33	1.69
Exchangeable Ca	Cmol(+) kg^{-1}	1.56	3.52	1.4
Exchangeable Mg	Cmol(+) kg^{-1}	1.53	4.79	0.27
Exchangeable K	Cmol(+) kg^{-1}	0.04	0.05	0.03
Exchangeable Na	Cmol(+) kg^{-1}	0.01	0.01	0.01
TEA	Cmol(+) kg^{-1}	0.04	0.32	0.16
ECEC	Cmol(+) kg^{-1}	3.18	8.69	1.87
Base Saturation	%	98.7	96.3	91.4
Sand	g kg^{-1}	798.00	848.00	868.00
Silt	g kg^{-1}	24.00	14.00	34.00
Clay	g kg^{-1}	178.00	138.00	98.00
Textural Class		Sandy Loam	Loamy Sand	Sand



(ai) Total Fe (aii) Available Fe (aiii) Exchangeable Fe (aiv) Water soluble Fe
(bi) Total Zn (bii) Available Zn (biii) Exchangeable Zn (biv) Water soluble Zn

(ci) Total Cu (cii) Available Cu (ciii) Exchangeable Cu (civ)Water soluble Cu
(di) Total Mn (dii) Available Mn (diii) Exchangeable Mn (div) Water soluble Mn

Fig 1. Micronutrient Concentrations in Soils of different Landuses

pH since the higher the acidity, the greater its concentration (Havlin *et al*., 2012). Relationships between soil properties and the micronutrients (Table 2) indicated a significantly ($P < 0.05$) correlation between organic matter and soil pH with most micronutrients exception being exchangeable Fe and all (total, available, exchangeable and water-soluble) Cu. It has been reported that total and available Fe, Mn, Zn and Cu correlates distinctly with soil O.M and pH (Aydinalp *et al*., 2009; Dhaliwal *et al*., 2009; Bhaskar *et al*., 2017). Nath (2013) obtained increased micronutrients with O.M but not soil pH. Also, there was a distinct correlation between silt contents and the micronutrients exception being available Zn and Cu, exchangeable Zn and Mn and water-soluble Cu and Fe. In contrast, clay content was seriously related with available Zn and Mn and water-soluble Fe and Mn. It has been noted from a study of some Nigerian soils that available micronutrients (Fe, Mn, Zn and Cu) were significantly correlated with clay while available Zn and Mn were with silt (Oyinlola and Chude, 2010). Equally, contrary to the severe observed relationship between ECEC and micronutrients (Bhaskar *et al*., 2017), there were no such relationships between the micronutrients with ECEC and exchangeable Ca in the soils studied.

In Tables 3, 4 and 5 are shown micronutrient distributions in grain size soil fractions, enrichment factors and the relationship between grain size and bulk soil micronutrient contents respectively. Mean total Fe (1344.32), Zn (10.06), Cu (1.23) and Mn (99.26), available Cu (0.20) and water-soluble Zn (0.26) and Cu (0.12) (Table 3) were high in silt, available Fe (77.60), Zn (1.36) and Mn (11.99), exchangeable Fe (79.52), Zn (1.12) and Mn (9.60) and water-soluble Fe (3.09) in clay and only water-soluble Mn (2.48 mg kg^{-1}) in sand fraction. Accumulations of most micronutrients in soil grain size fractions were distinctly higher in Oil palm than the other land. Irrespective of land use types, micronutrient (total, available, exchangeable and water-soluble) distribution in both bulk and grain size fractions decreased as Fe > Mn > Zn > Cu signifying the superiority of iron probable due to the dominance of iron oxide in clay mineralogy of tropical soils (Uzoho *et al*., 2007). Also, averaged over land use types, enrichment factor was higher in clay than other soil fractions (Table 4) and suggesting the ability of clay to retain more nutrients from microbial degradation. High enrichment of the clay fraction has been reported in related

Table 2. Simple Correlation between Micronutrients and Soil Properties

Soil Properties	pH	OM	ECEC	Clay	Silt	Sand	P	Exch. Ca
Total Fe	0.66*	0.75**	-0.14ns	0.05	0.89**	0.75**	0.33ns	0.04ns
Total Zn	0.83**	0.94**	-0.25ns	0.38ns	0.97**	0.80**	0.70**	-0.09ns
Total Cu	0.24ns	0.44ns	-0.50ns	0.39ns	0.81**	0.32ns	0.04ns	-0.35ns
Total Mn	0.83**	0.94**	-0.25ns	0.38ns	0.97**	0.80**	0.70**	-0.09ns
Available Fe	0.75**	0.91**	-0.45ns	0.34ns	0.98**	0.66*	0.75**	-0.30ns
Available Zn	0.97**	0.89**	0.38ns	0.70**	0.62ns	1.00**	0.67*	0.52ns
Available Cu	0.45ns	0.48ns	0.12ns	0.16ns	0.62ns	0.65*	-0.03ns	0.27ns
Available Mn	0.97**	0.90**	0.37ns	0.70**	0.63ns	1.00**	0.68*	0.51ns
Exchangeable Fe	0.74**	0.90**	0.44ns	0.31ns	0.99**	0.66*	0.72*	-0.29ns
Exchangeable Zn	0.94**	0.84**	0.47ns	0.67*	0.55ns	0.99**	0.60ns	0.60ns
Exchangeable Cu	0.45ns	0.50ns	0.04ns	0.18ns	0.67*	0.63ns	-0.01ns	0.20ns
Exchangeable Mn	0.94**	0.84**	-0.47ns	0.67*	0.55ns	0.99**	0.60ns	0.60ns
Water-Soluble Fe	0.54ns	0.61ns	-0.32ns	0.73**	0.40ns	0.27ns	0.92**	-0.31ns
Water-Soluble Zn	0.98**	0.99**	0.05ns	0.71**	0.80**	0.92**	0.86**	0.19ns
Water-Soluble Cu	0.45ns	0.44ns	0.22ns	0.13ns	0.55ns	0.66*	-0.07ns	0.37ns
Water-Soluble Mn	0.98**	0.99**	0.05ns	0.71**	0.80**	0.92**	0.86**	0.19ns

Table 3. Micronutrient Concentration in Grain Size Fraction of Various Landuses (mgkg-1)

Land use	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
		Total			Available			Exchangeable			Water Soluble	
	Fe											
Cassava	131.55	562.53	673.00	3.17	62.12	83.47	3.03	61.94	75.22	0.14	0.18	8.25
Cashew	61.26	1110	308.53	0.74	19.31	59.82	0.57	18.22	59.33	0.17	1.09	0.49
Oil Palm	134.25	2360.42	10.05	6.12	81.91	89.52	5.96	79.22	89.00	0.16	2.69	0.52
LSD 0.05	**31.27**	**696.36**	**250.88**	**2.04**	**24.18**	**11.86**	**2.04**	**23.76**	**11.22**	**0.01**	**0.96**	**3.38**
	Zn											
Cassava	1.81	10.23	6.61	1.11	0.96	1.21	0.85	0.61	1.00	0.26	0.35	0.21
Cashew	1.14	6.79	5.84	0.50	1.02	1.87	0.26	0.84	1.63	0.24	0.18	0.24
Oil Palm	3.49	13.15	6.68	0.83	1.60	1.01	0.54	1.35	0.73	0.29	0.25	0.28
LSD 0.05	**0.92**	**2.41**	**0.35**	**0.23**	**0.27**	**0.34**	**0.22**	**0.29**	**0.35**	**0.02**	**0.06**	**0.03**
	Cu											
Cassava	0.10	0.11	0.21	0.08	0.05	0.11	0.06	0.03	0.04	0.02	0.03	0.07
Cashew	0.11	0.12	0.14	0.19	0.33	0.18	0.07	0.08	0.11	0.12	0.25	0.07
Oil Palm	0.24	3.46	0.67	0.21	0.21	0.26	0.15	0.13	0.11	0.06	0.08	0.15
LSD 0.05	**0.06**	**1.46**	**0.22**	**0.05**	**0.11**	**0.06**	**0.04**	**0.04**	**0.03**	**0.04**	**0.09**	**0.04**
	Mn											
Cassava	17.87	100.97	65.24	9.76	8.44	10.64	7.28	5.23	8.57	2.45	3.30	1.98
Cashew	11.25	67.02	57.64	4.40	8.97	16.44	2.28	7.20	13.97	2.26	1.70	2.26
Oil Palm	34.45	129.79	65.93	7.30	14.06	8.88	4.73	11.57	6.26	2.73	2.36	2.64
LSD 0.05	**9.03**	**23.74**	**3.48**	**2.03**	**2.35**	**2.99**	**1.89**	**2.45**	**2.99**	**0.18**	**0.61**	**0.25**

Table 4. Enrichment Factor of Micronutrients in Size Fractions of various Landuses ($mgkg^{-1}$)

Land use	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
		Total		Available			Exchangeable			Water Soluble		
	Fe											
Cassava	0.10	0.44	0.52	0.02	0.44	0.60	0.02	0.48	0.57	0.02	0.18	1.02
Cashew	0.04	0.80	0.22	0.01	0.26	0.80	0.01	0.25	0.81	0.10	0.66	0.30
Oil Palm	0.06	1.00	0.004	0.04	0.49	0.54	0.04	0.48	0.54	0.05	0.85	0.16
LSD 0.05	**0.02**	**0.21**	**0.20**	**0.01**	**0.09**	**0.10**	**0.01**	**0.10**	**0.11**	**0.03**	**0.26**	**0.35**
	Zn											
Cassava	0.10	0.58	0.38	0.36	0.31	0.39	0.36	0.26	0.43	0.34	0.45	0.27
Cashew	0.09	0.53	0.45	0.16	0.32	0.59	0.10	0.33	0.64	0.39	0.29	0.39
Oil Palm	0.16	0.6	0.31	0.26	0.50	0.31	0.17	0.42	0.3	0.38	0.33	0.37
LSD 0.05	**0.03**	**0.03**	**0.05**	**0.08**	**0.08**	**0.11**	**0.10**	**0.06**	**0.13**	**0.02**	**0.06**	**0.049**
	Cu											
Cassava	0.26	0.28	0.54	0.38	0.24	0.52	0.50	0.25	0.33	0.22	0.33	0.78
Cashew	0.31	0.34	0.40	0.42	0.73	0.40	0.29	0.33	0.46	0.57	1.19	0.33
Oil Palm	0.36	0.84	0.16	0.33	0.33	0.41	0.41	0.35	0.30	0.22	0.30	0.56
LSD 0.05	**0.04**	**0.23**	**0.15**	**0.034**	**0.20**	**0.05**	**0.08**	**0.04**	**0.06**	**0.15**	**0.38**	**0.17**
	Mn											
Cassava	0.10	0.58	0.38	0.36	0.31	0.39	0.37	0.26	0.43	0.34	0.45	0.27
Cashew	0.09	0.53	0.45	0.16	0.32	0.59	0.10	0.33	0.64	0.39	0.29	0.39
Oil Palm	0.16	0.60	0.31	0.26	0.50	0.31	0.22	0.55	0.30	0.38	0.33	0.37
LSD 0.05	**0.03**	**0.03**	**0.05**	**0.08**	**0.08**	**0.11**	**0.10**	**0.11**	**0.13**	**0.02**	**0.06**	**0.05**

Table 5.Relationship Between Micronutrient in Grain Size Particles and Bulk Soils of Varying Landuses

Parameters	Regression Equation
Total Fe	$Y(t_{Fe})$ = 0.006 + 0.93 tFe sand + 0.94 tFe silt + 0.94 tFe clay
Available Fe	$Y_{(aFe)}$ = 0.003 + 0.97 aFe sand + 0.93 aFe silt + 0.94 aFe clay
Exchangeable Fe	$Y_{(eFe)}$ = 0.006 + 0.94 eFe sand + 0.94 eFe silt + 0.94 Fe clay
Water soluble Fe	$Y_{(wFe)}$ = 0.003 + 0.96 wFe sand + 0.94 wFe silt + 0.94 wFe clay
Total Zn	$Y_{(tZn)}$ = 0.003 + 0.95 tZn sand + 0.93 tZn silt + 0.95 tZn clay
Available Zn	$Y_{(aZn)}$ = 0.00012 + 0.95 aZn sand + 0.92 aZn silt + 0.94 aZn clay
Exchangeable Zn	Y(eZn) = 0.009 + 0.95 eZn sand + 0.94 eZn silt + 0.94 eZn clay
Water-soluble Zn	$Y_{(wZn)}$ = 0.003 + 0.81 wZn sand + 0.98 wZn silt + 1.00 wZn clay
Total Cu	$Y_{(tCu)}$ = 1.07 tCu sand - 0.95 tCu silt + 0.87 tCu clay - 0.003
Available Cu	$Y_{(aCu) =}$ 6.72 aCu sand - 1.40 aCu silt - 1.64 aCu clay- 0.07
Exchangeable Cu	$Y_{(eCu)}$ = 0.003 + 0.89 eCu sand + 1.19 eCu silt + 0.72 eCu clay
Water-soluble Cu	$Y_{(wCu)}$ = 2.87 wCu sand - 0.79 wCu silt + 1.18 wCu clay - 0.021
Total Mn	$Y_{(tMn)}$ = 0.95 tMn sand + 0.93 tMn silt + 0.95 tMn clay - 0.004
Available Mn	$Y_{(aMn)}$ = 0.96 aMn sand + 0.92 aMn silt + 0.93 aMn clay -0.0001
Exchangeable Mn	$Y_{(eMn)}$ = 0.016 + 0.95 eMn sand + 0.93 eMn silt + 0.94 eMn clay
Water-soluble Mn	$Y_{(wMn)}$ = 0.048 + 3.92 wMn sand + 1.19 wMn silt + 1.65 wMn clay

t = total, a = available, e = exchangeable and w = water soluble

studies for carbohydrates (Solomon *et al*. 2000), K (Ajibade and Ogunwale, 2012), heavy metals (Sayadi *et al*., 2016) and P (Uzoho, 2018). The high clay enrichment could be due to its large surface area (Spaccini *et al*., 2001; Sayadi *et al*., 2016; Tlili *et al*., 2019). Relationships between micronutrient contents of grain size and bulk soil showed that more than 95% of bulk soil contents was due to grain size concentrations and with the contribution of each size fraction being uniform as indicated by their coefficients (Table 5). Uzoho *et al*. (2019) obtained less than 50% of bulk soil sesquioxides due to the grain size fractions of soils of southeastern, Nigeria and with silt fraction contributing more than others.

4.0 Conclusions

Forms of micronutrients (Fe, Mn, Zn and Cu) decreased as total > available > exchangeable > water-soluble with the nutrients being an increasing order of Cu < Zn < Mn < Fe, averaged over forms. Also, amongst land use types, accumulation of most micronutrients was significantly (LSD 0.05) higher in Oil palm than others. Equally, the available status of all micronutrients was above critical limits and thus not likely to impede crop nutrition. Most bulk soil micronutrients correlated significantly ($P < 0.05$) with some soil properties, especially pH, O.M, ECEC, Ca, P, clay and silt. Grain size nutrient concentrations varied, with the clay size fraction more enriched, averaged over land use types. Furthermore, micronutrients in grain size fractions accounted for more than 95% of the bulk soil and with the contribution of each size fraction being uniform.

Declarations of interest: none

References

Adaikwu A.O. and Ali, A., 2013. Assessment of some soil quality in Benue State. Nigerian Journal of Soil Science 23(2):66-75.

Adepetu, J.A., Adebayo, A.A, Aduayi, E.A. and Alofe, G.O., 1979. A Preliminary Survey of Fertility status of Soils in Ondo state under traditional cultivation. Ife Journal of Agriculture 1:134-149

Adiele, J.O., Egesie, C, Nwaogu, A.S, Kahyar, S.S and A.O.Ano., 2015. Available Iron Distribution in Nigeria—A Review. Journalof Soil Science and Environmental Management,6 (4): 68-79

Ahukaemere, C.M, Nwopara, U.N., Ekpenyong, O.S., 2014. Profile Distribution of Selected Essential Micronutrients in Paddy Soils of Abia State, Southeastern, Nigeria. Nigerian Journal of Soil Science 24:158-166

Ajiboye, A.G and A.J. Ogunwale 2012. Forms and distribution of potassium in particle size fractions on talc overburden soils in Nigeria. Agronomy and Soil Science, 1-12

Akporhonor, E.E., and Agbaire, P.O., 2009. Physiochemical properties and micronutrients status of farmland soils in Abraka, Nigeria African J. Pure and Appl. Chemistry, 3 (7):131-134

Aydinalp, C., 2009. Concentration and Speciation of Cu, Ni, Pb and Zn in Cultivated and uncultivated soils. Bulgarian Journal of Agricultural Science, 15 (2): 129-134

Begum, K, Jahan, I., Rahman, M.H., Chowdhury, M.S. Elahi, S.F., 2009. Status of some Micronutrients in Different Soils of Gazipur District as Related to Soil Properties and Land Type. Bangladesh Journal of Science and Industrial Research. 44(4): 425-430

Begum, A, Faruque, H.M.D., Parveen, Z., 2016. Distribution of Zinc Fractions in Relation to Properties of some Soils of Bangladesh. Dhaka University Journal of Biological Science. 25 (1): 19-25

Biwe, E.R., 2012. Status and distribution of available micronutrients along a toposequence at Gubi, Bauchi, North-Eastern Nigeria. International Research Journal Agricultural Science and Soil Science 2(10): 436-439.

Bhaskar, B.P., Tiwari, G., Prasad, J., 2017. Influence on Profile Distribution of Total and DTPA-Extractable Micronutrients in Rice growing hydric soils of Majuli river island, Assam India. Spanish Journal of Soil Science 7 (1): 59-85

Buysse, W., Stern, R., and Coe, R. 2004., Genstat Discovery Edition for everyday use. Nairobi, Kenya, 2004. 114 pp.

Dhaliwal, S.S., Sharma, B.D., Bijay, S., 2009. Micronutrient Status of different Land Use Systems in Relation to Soil Quality and Sustainability under different Watersheds in Submontaneous Tract of Punjab. Annals of Arid Zone 48 (2): 103-112

Enwezor, W.O., Udo, E.J. Ayotade, K.A. Adepetu, J.A., Chude, V. O., (Eds.) 1990. A review of soil and fertilizer use in Nigeria. In FPDD. Literature review on soil fertility investigations in Nigeria (Five Volumes). Federal Ministry of Agriculture and Natural Resources, Lagos. 281 pp

Gee, G.W. and D. Or,. 2002. Particle size analysis. In: Dane, J. H. and G.C. Topp (Eds) part 4. Methods of Soil Analysis, Physical Methods. Soil Science Society America. Book Series 5, A.S.A and SSSA, Madison, Wisconsin. pp255 – 293.

Hassan, A.M and Ogbonnaya, C. S., 2016. Status and distribution of available micronutrient in Udic Kanhaplustults of Bauchi local government area, Bauchi state School Journal of Agriculture and Veterinary Science 3(3):257-261

Havlin, J.L., Beaton, J.D. Tisdale, S.L. and Nelson, W.L., (Eds.) 2012. Soil Fertility and Fertilizers. An Introduction to Nutrient Management.7th ed. PHI Private Limited, New Delhi- 110001. pp513.

Ideriah T.J.K., Ikpe, F.N and Nwanjoku, F.N., 2013. Distribution and Speciation of Heavy Metals in Crude Oil Contaminated Soils from Niger Delta, Nigeria. World Environment 2013, 3(1): 18-28

Igwe, C.A., Zarei, M. and Stqhr, K., 2008. Factors affecting potassium status of flood plain soils, eastern Nigeria. Archives of Agronomy and Soil Science 54(3): 309-319

IPEDC (Imo State Planning and Economic Development Commission) 2006. Imo state of Nigeria statistical year book. Published by Imo State Planning and Economic Development Commission, State Secretariat, Portharcourtroad, 282pp.

Isirimah, N.O., Dickinson, A.A. and Igwe, C., 2004. Soil Acidity and Soil Management. In Introductory Soil Chemistry and Biology for agriculture and Biotechnology. Pp 103-113

Jiang, Y., Zhang, G., Zhou, D., Qin, Y., Liang, W.J., 2009. Profile Distribution of Micronutrients in an Aquic Brown Soil as Affected by Land Use. Journal of Plant, Soil and Environment, 55(11): 468 – 476

Kingsley, J., Esther, A., Akpan-Idiok, O.A.U. Effiom, O.D., 2019. Status and distribution of soil available micronutrients along a hillslope at Ekpri Ibami in Akamkpa Local Government Area of Cross River State, Nigeria. African Journal of Agricultural Research, 14(1): 40-45,

Lindsay, W.L. and Norvell, W.A., 1978. Development of a DTPA Soil Test for Zinc, Iron Manganese and Copper. Soil Science. Society of American Journal, 42: 421-428

Meliyo, J.L, Massawei, B.H.J., Brabers, L., Msanya, B.M., Kimaro, D.N. Mulungu, L.S. Kihupi, N.I. Deckers, J.A. Gulinck, H. Leirs H., 2015. Status and variability of soil micronutrients with landforms in the plague focus of western Usambara mountains, Tanzania," International Journal of Plant and Soil Science 4(4): 389–403

Mahmoudabadi, E., Sarmadiani, F., Nazary, R.M., 2015. Spatial distribution of soil heavy metals in different land uses of an industrial area of Tehran (Iran). International Journal of Environmental Science Technology. 12:3283–3298

Motuma, K and Chimdi, A., 2018. Availability of Boron, Sulfur and Zinc and Status of other Selected Soil Properties Under Acidic Soils of Different Land Use Types: The Case of WayuTuka District, East Wollega Zone. American-Eurasian Journal of Agriculture and Environmental Sciences 18 (1): 17-22.

Nath, T.N., 2013. The Status of Micronutrients (Mn, Fe, Cu, Zn) in Tea Plantations in Dibrugarh district of Assam, India. International Research Journal of Environment Sciences 2 (6): 25-30

Najafi-Ghiri, M. and Abtahi, A., 2013. Potassium fixation in soil size fractions of Arid Soils. Soil and Water Resources 8(2):49-55.

Nelson, D.W and Sommers, L.E., 1996. Total Carbon, Organic Carbon, and Organic Matter In: Sparks D. L., Page A. L., Helmke P. A., Loeppert R. H., Soltanpour P. N.,TabatabaiM.A., Johnston C. T, Sumner M. E. (Eds.). Methods of soil analysis. Part 3. Chemical methods, Soil Science Society of America Book Series: 5. Soil Science Society of America Madison, U.S.A., 961

Oguike, P.C. and Mbagwu, J.S.C., 2009. Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. World Journal of Agricultural. Science, 5: 63-69.

Okoli, N.H, Uzoho, B.U., Onweremadu, E.U., Nkwopara, U.N. and Irokwe, I.F., 2016. Zinc Fractionation of Soils of different Parent Materials and their Relationship with some Soil Properties. Malaysian Journal of Soil Science 20: 49-66

Olsen, S.R and Sommers, L.E., 1982. Phosphorus In Methods of Soil Analysis. Part 2. Edited by A.L.Page, R.H.Miller and D.R.Keeney. Madison W.I, American Society of Agronomy. Pp 1572.

Onwudike, S.U., Onweremadu, E.U., Ihem, E.E., Agim, L.C., Osisi, A.F., Osuaku, S.K., Azuh, P.O., 2016. Evaluation of Micronutrient Status of Soils under Three Land Use Types in Oyigbo, River State, Nigeria. FUTO Journal Series (FUTOJNLS), 2(1): 32 – 40

Onwudike, S.U., Agbani, L. Ihem, E. and Onyegbule, U., 2017. Influence of Land use Types on Soil Properties and Micronutrients Concentration on Soils of Similar Lithology in Owerri, Southeastern, Nigeria. Mayeb Journal of Agricultural Science 4:1-9

Oyinla, E.Y and Chude, V. O., 2010. Status of Available Micronutrients of the Basement Complex Rock – derived Alfisols in Northern Nigeria Savanna. Tropical and Subtropical Agroecosystems, 12 (2010): 229 – 237

Onyekwere, I.N, Ethan, S., Adiele J.G, Mbe J.O, Nwokoro C.C., 2017. Micronutrients Characterization of Soils of Basalt Parent Material in Ikom, Cross River State Nigeria for Sustainable Crop Production. Direct Research Journal of Agriculture and Food Science (DRJAFS) 5 (10): 348-352

Orajaka, S.O., 1975. Geology in: Nigeria in Maps: Eastern States (G.E.K. Ofomata, Eds.) Ethiopia Publishers: Benin City, Nigeria. 5-7.

Oviasagie, P.O and Oko-Oboh, E., 2013. Fertility Status of Soils obtained from Coastal Plain Sands and Inland Transition Formations. Nigerian Journal of Soil Science 23(1): 188-196

Page, A.L., Miller, R.H. and Keeney, D.R., 1982. Methods of Soil Analysis. Part 2, 2nd edition. A.S.A, Madison, Wisconsin, U.S.A

Salbu, B., Krekling, T. and Oughton, D.H., 1998. Characterization of radioactive particles in the environment. Analyst. 123: 843-849

Sayadi, M.H and Sayadi, M.R.G., 2016. Grain size fraction of heavy metals in soil and their relationship with land use. Proceedings of the International Academy of Ecology and Environmental Sciences, 2017, 7(1): 1-11

Sh'Ato, R., Ajayi, S. O. and Ojanuga, A.G., 2012. Total and extractable copper, iron, manganese and zinc in dominant agricultural soils in the Lower Benue Valley, Central Nigeria and the concept of extractant efficiency. Nigerian Journal of Chemical Research 17: 59-82

Séquaris, J.M. and Lewandowski, H., 2003. Physicochemical characterization of potential colloids from agricultural topsoils, Colloid Surface Analysis 217: 93–99.

Sims, J. T and Johnson, G.V., 1991. Micronutrient soil tests. pp. 427-476. J.J. Mortvedt, F.R. Cox, L.M. Shuman and R.M (Eds.). *In*: Micronutrients in Agriculture, 2nd Ed. Soil Science Society of America. Books Series No. 4.

Solomon, D.J, Lehmann, J., Zech, W., 2000. Land use Effects on Soil Organic Matter Properties of Chromic Luvisol in Semi-arid Northern Tanzania: Carbon, Nitrogen, Lignin and Carbohydrates. Agriculture, Ecosystem and Environments 78:203-213

Spaccini, A, Zena. C. A, Igwe. C, Mbagwu, J.S.C and Piccolo, A., 2001. Carbohydrate in Water Stable Aggregates and Particle Size Fractions of Forested and Cultivated Soils of two Contrasting Tropical Ecosystems. Biochemistry 53:1-22.

Thomas G.W., 1996. Soil pH and soil acidity. Sparks *et al*. (Ed.). Method of soil analysis, Part 3, Chemical methods, SSSA Book Series No 5, SSSA and A.S.A, Madison, 475-490

Tlili, A., Dridi, I., Attaya, R., Gueddari, M., 2019. Boron Characterization, Distribution in Particle-Size Fractions, and Its Adsorption-Desorption Process in a Semiarid Tunisian Soil Hindawi Journal of Chemistry 2019: 1-8

Udo, B. U., Edem, S.O., Udom, G.N. and Ndaeyo, N.U. 2006. Chemical characteristics of wetland soils in Akwa Ibom State. Nigerian Journal of Agricultural Technology. 13: 1–12.

Udoh B.T, Ogunkule, A.O, Akpan, U. S, 2013. Fertility capability classification of Acid Sands (Soils) as Influenced by parent materials in Akwa Ibom State. Nigerian Journal of Soil Science, 23 (1):56–66

United State Department of Agriculture (USDA) 2004. Soil survey laboratory methods manual, Soil survey investigation report No. 42, Version 4.0, USDA-NCRS, Lincoln, N.E

Uzoho, B.U., Oti, N.N., Ngwuta, A., 2007. Fertility status under land use types on soils of similar lithology. Journal of American Science 3(4): 20-29.

Uzoho, B.U., 2018. Phosphorus Concentrations in Grain Size Fractions of Low-Land Soils of Egbema, Southeastern Nigeria. London Journal of Research in Science: Natural and Formal 11(1): 55-62.

Uzoho, B.U, Okoli, N.H and Ekwugha, E.U., 2019. Impact of Texture on Sesquioxide Distribution in Southeastern Nigerian Soils. Internation Journal of Environment 8 (1):43-58