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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 land use types (Cassava, Cashew and Oil palm) in Ehime Mbano, Southeastern, Nigeria. Also, using correlation analysis, selected soil properties (pH, OM, ECEC, clay, silt, Ca and P) were correlated with bulk soil micronutrients. 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 land use types, respectively. Also, most bulk soil micronutrients were significantly ($P < 0.05$) correlated with soil pH, OM, sand, silt and clay but not with CEC 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 the micronutrient status of agricultural soils worldwide, with the tropics and 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 applying 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, and improved crop varieties with high demands on soil nutrients (Oguike and Mbagwu, 2009; Oyinla and Chude, 2010). Micronutrients are essential elements 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 of little value in assessing the soil fertility status (Onyekwere *et al*., 2017). Available micronutrient status indicates metals' potential behaviour or bioavailability and is helpful in geoenvironmental 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 to address this trend involved intensifying crop production in different land use 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 SOM but decreases with the pH (Nath, 2013). Also, available Fe, Cu, Mn and Zn have been reported to increase with soil texture, OM, CEC 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 OC (Oyinlola and Chude, 2010). Furthermore, Aydinalp *et al*. (2009) obtained a positive correlation between total Zn with OM and pH and a negative relationship between Cu and CEC. Others included a significant correlation between total and available Cu, Fe, Mn and Zn with OC (Dhaliwal *et al*., 2009).

Most studies on micronutrient status involve using bulk soils with limited use of the grain size fractions. However, little available information on soil grain size fractions involved boron accumulation 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 nutrient stabilization against microbial decomposition.

However, the micronutrient status of varying land use 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. Therefore, the objective of this study was 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 agro-ecological 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 26-30^{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 NPK 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 NPK 10:10:17: 3 Mg fertilizers. The 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 were 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 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 micronutrients (Fe, Cu, Mn and Zn) in bulk and grain size soil fractions were determined after extracting 30% of H_20_2 and 0.5 M HCl on an AAS 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 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 and the correction factors were subjected to analysis of variance (ANOVA) and means separated using LSD at 5% probability level. Also, the correlation between soil properties and micronutrients 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 was 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 use 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 use, respectively.

Superiority in the micronutrient content of Oil palm could be due to its low 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 significant ($P < 0.05$) 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 OM and pH (Aydinalp *et al*., 2009; Dhaliwal *et al*., 2009; Bhaskar *et al*., 2017). Nath (2013) obtained increased micronutrients with OM but not soil pH. Also, there was a distinct correlation between silt contents and the micronutrients, the exception being available Zn and Cu, exchangeable Zn and Mn and water-soluble Cu and Fe.

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). In contrast, clay content was seriously related to available Zn and Mn and water-soluble Fe and Mn. 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.

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

		Land use Types		
Parameters	**Units**	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

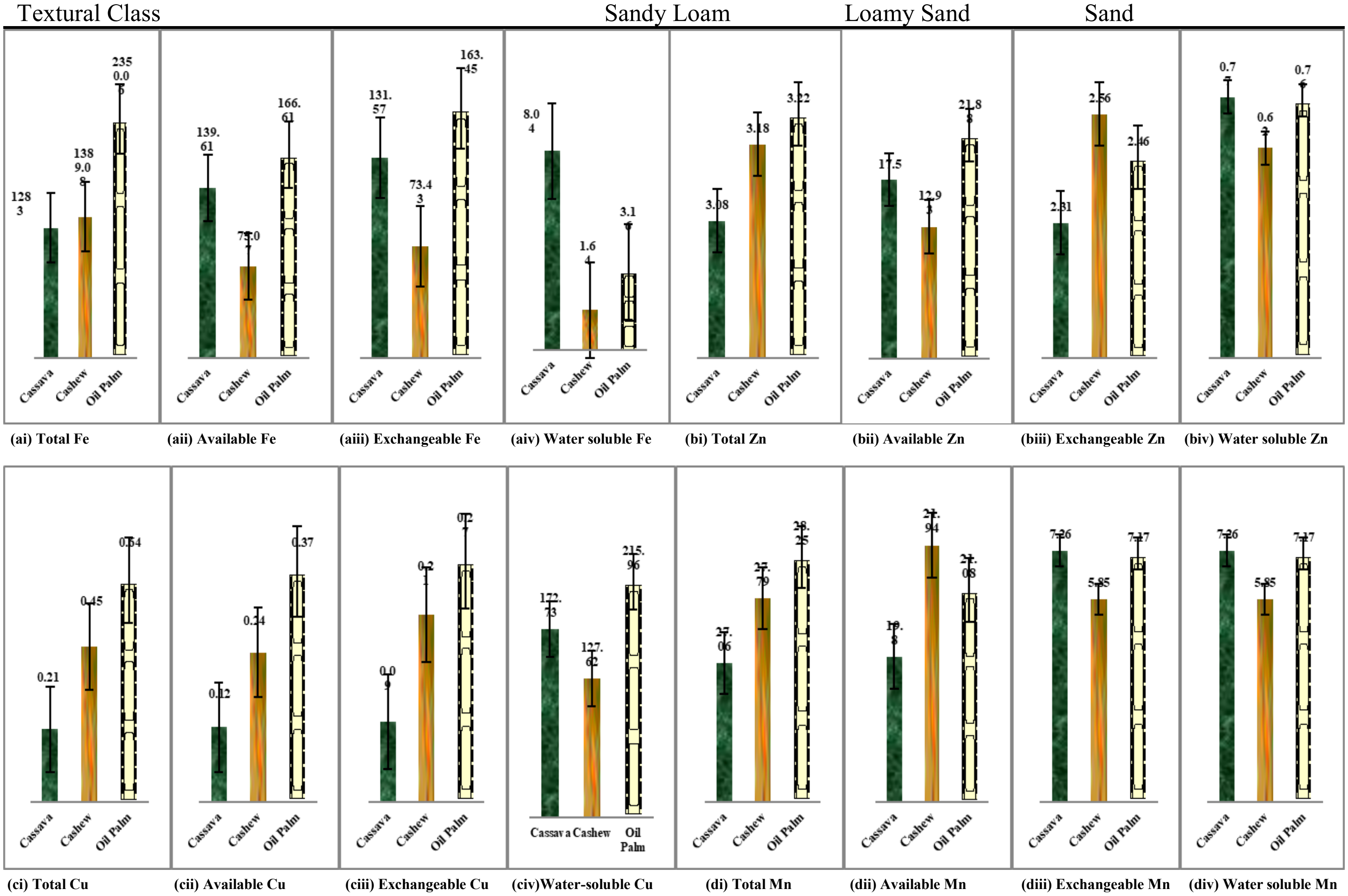

Fig 1. Micronutrient Concentrations in Soils of different Landuses

Tables 3, 4 and 5 show micronutrient distributions in grain size soil fractions, enrichment factors, and the relationship between grain size and bulk soil micronutrient contents. 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 in 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 suggested clay's ability to retain more nutrients from microbial degradation. High enrichment of the clay fraction has been reported in related studies for carbohydrates

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 (mg kg-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	R	R^2	Sig.
Total Fe	$Y(t_{Fe})$ = 0.006 + 0.93 tFe sand + 0.94 tFe silt + 0.94 tFe clay	1.00	1.00	0.00
Available Fe	$Y_{(aFe)}$ = 0.003 + 0.97 aFe sand + 0.93 aFe silt + 0.94 aFe clay	1.00	1.00	0.00
Exchangeable Fe	$Y_{(eFe)}$ = 0.006 + 0.94 eFe sand + 0.94 eFe silt + 0.94 Fe clay	1.00	1.00	0.00
Water soluble Fe	$Y_{(wFe)}$ = 0.003 + 0.96 wFe sand + 0.94 wFe silt + 0.94 wFe clay	0.99	0.98	0.00
Total Zn	$Y_{(tZn)}$ = 0.003 + 0.95 tZn sand + 0.93 tZn silt + 0.95 tZn clay	1.00	1.00	0.00
Available Zn	$Y_{(aZn)}$ = 0.00012 + 0.95 aZn sand + 0.92 aZn silt + 0.94 aZn clay	0.99	0.98	0.00
Exchangeable Zn	Y(eZn) = 0.009 + 0.95 eZn sand + 0.94 eZn silt + 0.94 eZn clay	0.99	0.98	0.00
Water-soluble Zn	$Y_{(wZn)}$ = 0.003 + 0.81 wZn sand + 0.98 wZn silt + 1.00 wZn clay	0.99	0.98	0.00
Total Cu	$Y_{(tCu)}$ = 1.07 tCu sand - 0.95 tCu silt + 0.87 tCu clay - 0.003	0.99	0.98	0.00
Available Cu	$Y_{(aCu) =}$ 6.72 aCu sand - 1.40 aCu silt - 1.64 aCu clay- 0.07	0.99	0.98	0.00
Exchangeable Cu	$Y_{(eCu)}$ = 0.003 + 0.89 eCu sand + 1.19 eCu silt + 0.72 eCu clay	0.99	0.98	0.00
Water-soluble Cu	$Y_{(wCu)}$ = 2.87 wCu sand - 0.79 wCu silt + 1.18 wCu clay - 0.021	0.99	0.98	0.00
Total Mn	$Y_{(tMn)}$ = 0.95 tMn sand + 0.93 tMn silt + 0.95 tMn clay - 0.004	1.00	1.00	0.00
Available Mn	$Y_{(aMn)}$ = 0.96 aMn sand + 0.92 aMn silt + 0.93 aMn clay -0.0001	1.00	1.00	0.00
Exchangeable Mn	$Y_{(eMn)}$ = 0.016 + 0.95 eMn sand + 0.93 eMn silt + 0.94 eMn clay	1.00	1.00	0.00
Water-soluble Mn	$Y_{(wMn)}$ = 0.048 + 3.92 wMn sand + 1.19 wMn silt + 1.65 wMn clay	1.00	1.00	0.00

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

(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, the 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, OM, 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

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