Horizon Differences in Micronutrient Contents of Soils of the Coastal Plain Sands in Imo State, South-East Nigeria, Micronutrient Contents of Pedons formed under Coastal Plain Sands

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Abstract

Horizon differences in soils influence ability of crops to obtain nutrients and indeed support other uses. The study aimed at investigating the micronutrient (Cu, Mn, Fe, Zn) contents of horizons of two different pedons which lies on similar parent material (Coastal plain sand) in Imo State. Random survey technique guided by the geologic map of the area was used in siting one profile pits on each of the locations. The profile pits were described; and identification and delineation of horizon boundaries were accomplished using FAO guidelines before actual sample collection for laboratory analyses. Soil data were subjected to coefficient of variation (CV) analysis. The results of the micronutrients indicated range values of 0.02- 0.36 mg kg^{-1} for Mn, 36.6-108 mg kg^{-1} for Fe, 0.091-0.256 mg kg^{-1} for Cu and 0.205-0.774 mg kg^{-1} for Zn in pedon 1. In pedon 2, the ranges were 0.13-1.09 mg kg^{-1} for Mn, 19-50.6 mg kg^{-1}for Fe, 0.143-0.613 mg kg^{-1} for Cu and 0.22- 0.962 mg kg^{-1} for Zn respectively. The values of Zn, Cu and Mn were below the critical limits recommended for arable crop production. However, Fe concentration was generally high in all the horizons and was above the critical level recommended. Hence, the soils were surplus in iron but deficient in Cu, Mn and Zn. It is therefore recommended that agronomic requirements should consider these essential edaphic attributes in the study area.

Key words: Coefficient of variation, Critical level, Horizon, Nutrient, Profile pit

Introduction

Micronutrients assessment has been on the forefront of recent researches with findings that indicated increase in their deficiency. Information on variations of soil micronutrient with soil depth will enable potential land users to appreciate its behavior on various soil types, so that they can be managed appropriately to derive optimum crop productivity. Several researchers have reported on level of micronutrients on soils of the basement complex rocks (Kparmwang et al., 1995, 1998; Oyinlola and Chude, 2010) and also on sedimentary soils (Kparmwang and Malgwi, 1997). Also, Rengel, (2007) and Alloway, (2008) have observed that millions of hectares of arable land in the world are micronutrients deficient. Many of these deficiencies are in relation with increased demands of available forms of micronutrients by rapidly growing crops.

The essential need for micronutrients must always be considered as these makes enormous contribution toward the plant and microbial growth. The excess of micronutrients in the soil brings about nutrient antagonizum, inhibition in plant uptake of some major nutrients, pollution of the ground water etc. The original geologic substrate and subsequent geochemical and pedogenic regimes determine total levels of micronutrients in soils (Jiang et al., 2009). Micronutrient availability to plants can be measured in direct uptake experiments, or estimated with techniques that correlate quantities of micronutrients extracted chemically from soils (Kabata-Pendias, 2001). The minerals present in the pedosphere or lithosphere determines the rate of replenishment of micronutrients which takes place in the soil. The study of micronutrients in respect soil horizons will enable land users to determine its leaching rate, horizons with higher concentration and land-use practices that are suitable for an area. Dar, (2004) reported that there is need for monitoring the micronutrient status through analysis of soils and plant tissues in fields.

However, understanding the variations of soil profile characteristics as it relates to micronutrient status is essential for pedosphere sustainability and proper nutrient balance as required by plants. Also, information on the profile distribution of micronutrient will facilitate decisions on method/rate of fertilizer application and guide to other soil management practices which will enhance the entire ecosystem. The aim of this study is to determine horizon differences in micronutrients (Fe, Mn, Cu, and Zn) content of soils underlain by coastal plain sand.

Materials and Methods

Study Area

The study was carried out in Egbema in Owerri agricultural zone of Imo State, South-east Nigeria, located between Latitudes 5° 33' N and 5° 58' N and longitude 6° 50' E and 6° 59' E. It has a humid tropical climate with an average annual rainfall ranging between 1750 mm and 2500 mm, annual temperature ranging between 24 °C and 31°C and high relative humidity (above 80 %) during the rainy season (NIMET, 2015). Soils of the area are derived from Coastal Plain Sand (Benin Formation) and Alluvium deposit. The original vegetation of the Egbema was tropical rainforest (FDALR, 1985). The rainforest has however been destroyed adversely through anthropogenic activities and replaced largely with oil palm bush.

Soil Sampling and Laboratory Analysis

A previous study of the sites was conducted in the early 2015; and this was followed by field sampling. Two sites (location) were randomly selected from 4 major locations that made up the sampling area. One profile pit was dug in each location. The study sites and profile pits were geo-referenced with the aid of a hand held Global Positioning System (GPS) receiver. The profile pits were described using FAO, (2006) guidelines. Delineation of horizon boundaries was accomplished before actual sample collection for laboratory analyses and samples were collected according to horizons. Ten bulked soil samples (5 per pedon) collected were air-dried, gently crushed and passed through 2 mm sieve to obtain fine earth separates. The processed soil samples were analyzed for soil physic-chemical properties as follows particle size distribution by hydrometer method, moisture content by gravimetric method, bulk density by core method, pH (H_2O) by glass electrode pH meter in a soil water ratio 1:2.5, organic carbon by wet digestion method, total nitrogen by micro Kjeldal method, available phosphorus by Bray ll method, exchangeable bases were extracted with ammonium acetate as calcium and magnesium were determined by ethylene diamineatra acetic acid titration method while potassium and sodium were estimated by flame photometer, exchangeable acidity by leaching the soil with 1N KCl and titrating with 0.05N NaOH (Soil Survey Staff, 2010). The trace elements (Zn, Mn, Fe, Cu) contents of the soils were extracted as supernatant using dithionite-citrate bicarbonate Onyeonwu (2000) and Atomic Absorption Spectrophotometer (AAS) (Buck Scientific model 210 VGP USA) was used to determine the amount of the individual trace element in soil solution.

Data Analysis

The variability of soil properties within the horizons of the profiles was measured by estimating coefficient of variation (CV). The coefficient of variation was ranked according to the procedure of Wilding (1985) where CV < 15% = low variation, CV >15 < 35% = moderate variation, CV > 35 % = high variation. Correlation analysis was conducted to detect the functional relationships among soil variables.

Results and Discussion

Physical and Chemical properties of soil

The results of the physical properties showed sand particle size recorded mean of 361.6 g kg^{-1} in pedon 2 and 797.6 g kg^{-1} in pedon 1. The distribution of sand down the profile showed low variation (CV < 15 %) (Table 1) revealing horizons are homogeneity. In pedon 1, the AB horizon recorded the highest level of sand particle size which indicated irregular distribution of sand down the profile. The average clay content ranged from 173.6 g kg^{-1} to 473.6 g kg^{-1}. The highest quantity of clay was recorded at the argillic horizon (Bt_1) of pedon 2. However, the Bt_1 (illuvial horizon) of the two pedons contained more clay compared to the surface horizons of the pedons. This agreed with findings of (Udoh *et al.*, 2008; Chikezie *et al.*, 2009) that illuviation of clay particles increases its amount at the subsurface horizons. This is as a result of lessivage which is encouraged by intense rainfall, that promotes leaching of silicate down the profile pits and enrich the surface horizon with Fe and Al oxides which supports the formation of kaolinitic clay type.

Silt/clay ratios ranged from 0.04 - 0.45 in pedon 1 and 0.29 - 0.59 in pedon 2. Silt/clay ratio is an important criterion used in the classification of tropical soil. It is also used in the evaluation of clay migration, stage of weathering and age of parent material and soils (Nwaka, 1990; Yakubu and Ojanuga, 2013). The more highly weathered a soil is, the lower the silt fraction. Therefore, soils with silt/clay ratio of less than 0.15 are regarded as highly weathered soils (Van Wambeke, 1962). The result shows that the studied pedons have silt/clay ratio above 0.15 which indicates that the soils are relatively young with high degree of weathering potential. Such soil may lack adsorptive capacity for basic plant nutrients and may be susceptible to erosion menace.

Bulk density values ranged from 1.02 – 1.59 g cm^{-3} in pedon 1 and 0.98 – 1.45 g cm^{-3} in pedon 2, respectively. The results of the coefficient of variation showed moderate variation (16.7 %) in pedon 1 and low variation (13.7 %) in pedon 2. The rate of variations in the bulk density values of the different horizons of the pedons could be attributed to intense rainfall, clay migration and other pedogenic processes.

Table 1: *Soil physical properties of the studied locations.*

Horizon	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Silt/Clay	TC	BD (g cm^{-3})	TP (%)	MC (%)
				Pedon 1				
A	849.6	32.8	117.6	0.28	LS	1.02	60.2	56.3
AB	869.6	32.8	97.6	0.34	LS	1.21	52.7	62.8
Bt1	669.6	12.8	317.6	0.04	SCL	1.38	46.1	70.3
Bt2	829.6	52.8	117.6	0.45	SL	1.46	42.9	82.2
Bt3	769.6	12.8	217.6	0.058	SCL	1.59	37.9	95.6
Mean	**797.6**	**28.8**	**173.6**	**0.234**		**1.33**	**48.0**	**73.4**
CV	**10.1**	**58.1**	**53.7**	**76.8**		**16.7**	**18.1**	**21.4**
				Pedon 2				
AP	429.6	212.8	357.6	0.59	CL	0.98	61.7	56.8
AB	429.6	132.8	437.6	0.37	C	1.26	50.7	92.2
Bt_1	289.6	152.8	557.6	0.27	C	1.29	49.6	104.5
Bt2	329.6	152.8	517.6	0.29	C	1.33	48.1	126.2
Bt3	329.6	172.8	497.6	0.34	C	1.45	43	143.1
Mean	**361.6**	**164.8**	**473.6**	**0.37**		**1.26**	**50.6**	**104.6**
CV	**17.8**	**18.4**	**16.5**	**34.4**		**13.7**	**13.6**	**31.7**

TC= textural class, LS= loamy sand, SL= sandy loam, SCL= sandy clay loam, CL= clayey loam, C= clay, BD= bulk density, TP= total porosity, MC= moisture content, CV = coefficient of variation, <15 %= low variability, 15 ≤ 35 % = moderate variability, >35 %= high variability

Soil pH ranged between strongly acidic (5.06 - 5.35) in pedon 1 and strongly-moderately acidic (5.14 - 5.98) in pedon 2. However, the argillic horizons of pedon 2 were less acidic (moderately acidic) compared to other horizons of the two pedons. The acidic nature of the pedons is in line with the findings of (Onweremadu *et al*., 2011; Ahukaemere *et al.,* 2016) that soils underlain by coastal plain sand are mostly acidic. Soil organic carbon ranged from 1.29 – 5.39 g kg^{-1} in pedon 1 and 1.42 – 8.58 g kg^{-1} in pedon 2. The organic carbon level of the studied site was low according to the rating of Esu, (1991) on soils of southern Nigeria. The highest level of organic carbon (5.39 g kg^{-1}) was recorded in the surface horizon (A) while the least value was recorded in the Bt_3 horizon contained in pedon 1. However, the AB horizon of pedon 2 had the highest amount of organic carbon compared to other horizons of the pedons. High coefficient of variation was recorded in both pedons. This could be a reflection of organic matter deposit, rate of mineralization, residue removal and soil forming processes taking place in the soil. Several authors (Ahukaemere *et al.,* 2016; Osujieke *et al.,* 2016) have made similar findings on soils of southeastern Nigeria.

Manganese (Mn)

The result (Table 2) indicated that with the exception of the Ap horizon in pedon 2, the manganese contents of the horizons of both pedons were below the critical level (1 – 4 mg kg^{-1}) reported by (Sims and Johnson, 1991; Esu, 1991). Available Mn ranged from 0.02 – 0.35 mg kg^{-1} in pedon 1 and 0.13 – 1.09 mg kg^{-1} in pedon 2, respectively. The values obtained were lower than the range 3.12 – 5.88 mg kg^{-1} reported by Verma *et al*. (2005) of Mn in alluvial plain and the range 5.96 - 13.74 mg kg-1 reported by Mulima *et al.* (2015) for soils of Geidan northeast, Nigeria. The available Mn showed high variation (CV = 98.9 %, 57.6 %) in the pedons investigated. The Ap horizon of pedon 2 with the least organic carbon content had the highest value of Mn (1.09 mg kg^{-1}). However, Rengel, (2007) reported that organic residue effects the immediate and potential availability of manganese in soil. Available Mn contents of the pedons did not follow specific trend of decrease down the profile. This is contrary to findings of Sangwan and Singh (1993) that reported irregular pattern of increase in available Mn content with soil depth.

Zinc (Zn)

The available zinc (Zn) varied from 0.20 - 0.77 mg kg^{-1} with mean value of 0.37 mg kg^{-1} in pedon 1 and 0.22 – 0.96 mg kg^{-1} with mean value of 0.66 mg kg^{-1} in pedon 2 (Table 2). The result also indicated that with exception of Bt_2 horizon (0.77 mg kg^{-1}), all the other horizons in pedon 1 were found in deficient range by considering 0.6 mg kg^{-1} as the critical limit of zinc suggested by Lindsay and Norvel (1978). Also, only Bt_2 and Bt_3 horizon in pedon 2 were found in deficient range with values (0.22 mg kg^{-1}, 0.51 mg kg^{-1}) lower than the critical limit. Available Zn had no specific trend of increase and decrease with soil depth in pedon 1 and pedon 2, respectively. However, as Zn decreases with depths, its implication here is that plants may not have a Zn ‟store “in the lower surface. This is in line with the findings of Mustapha *et al.* (2011) in soils of Gombe, Nigeria. Zinc also recorded high coefficient of variation (65.5 %, 44.71 %) in both pedons. The high variation of available Zn between and among the horizons of both pedons agreed with the findings of Jobbage and Jackson, (2001) that leaching could transport micronutrient from one soil horizon to another. The studied soils show that pedon 2 has more level of available Zn over pedon 1 which could be as a result of soil pH and texture. Hence, coarse textured soils are more likely to be Zn deficient than fine textured soils while decrease in soil pH reduces Zn availability.

Iron (Fe)

Available Fe ranged from 36.6 – 108 mg kg^{-1} and 19 - 50.6 mg kg^{-1} in pedons 1 and 2, respectively. The iron content of the two pedons as shown in Table 2 were above the critical levels of 2.5 – 5.8 mg kg^{-1} (Deb and Sakal, 2002) and > 4.5 mg kg^{-1} (Kparmwang *et al.*, 2000). None of the horizons were found in deficient range by considering these critical limits. Fe distributed irregularly down the pit in all the pedons. The highest level of available Fe content was recorded at the Bt_1 horizon of pedon 1 and Bt_2 horizon of pedon 2, respectively.

Table 2: *Soil chemical properties of the studied locations.*

Horizon	pH	OC	TN	Av. P	Ca	Mg	K	Na	Al	H	ECEC	Mn	Fe	Cu	Zn
	(H_2O)	→ g/kg	←	(mg/kg)	⟶	⟶	cmol/kg	⟵	⟵	⟵	⟵	⟶	mg/kg	⟵	⟵
								Pedon 1							
A	5.21	5.39	0.58	13.51	2.67	2.2	0.011	0.002	1.36	0.40	6.643	0.35	47.3	0.091	0.205
AB	5.54	5.19	0.55	13.37	0.18	0.4	0.019	0.007	0.00	0.48	1.086	0.05	48.0	0.256	0.435
Bt_1	5.06	2.39	0.25	7.20	4.67	2.9	0.015	0.002	2.64	0.56	10.787	0.10	36.6	0.099	0.204
Bt_2	5.35	1.39	0.15	6.44	2.50	1.8	0.015	0.004	0.00	0.48	4.799	0.02	108.0	0.142	0.774
Bt_3	5.14	1.29	0.19	4.34	1.83	1.7	0.011	0.009	1.92	0.24	5.710	0.02	55.1	0.164	0.244
Mean	**5.26**	**3.13**	**0.34**	**8.97**	**2.37**	**1.80**	**0.01**	**0.01**	**1.18**	**0.43**	**5.81**	**0.11**	**59.00**	**0.150**	**0.37**
CV (%)	**3.60**	**64.50**	**59.60**	**46.90**	**68.30**	**50.8**	**23.60**	**64.90**	**99.0**	**28.1**	**60.18**	**98.9**	**47.80**	**44.10**	**65.5**
								Pedon 2							
A_P	5.20	1.42	1.47	2.17	2.83	4.0	0.017	0.003	8.84	1.32	17.010	1.09	24.5	0.524	0.768
AB	5.33	8.58	0.89	2.38	4.67	3.4	0.022	0.033	10.04	0.40	18.565	0.43	44.0	0.546	0.962
Bt_1	5.81	3.19	0.33	5.53	3.33	3.2	0.012	0.002	10.96	1.80	19.304	0.76	31.0	0.613	0.825
Bt_2	5.14	2.39	0.20	2.52	5.50	2.6	0.016	0.002	10.36	2.57	21.048	0.13	19.0	0.143	0.220
Bt_3	5.98	2.99	0.31	4.69	0.08	4.2	0.016	0.063	12.80	1.50	18.659	0.83	50.6	0.539	0.512
Mean	**5.49**	**3.71**	**0.64**	**3.46**	**3.28**	**3.48**	**0.02**	**0.02**	**10.60**	**1.52**	**18.92**	**0.65**	**33.8**	**0.473**	**0.66**
CV (%)	**6.92**	**75.53**	**83.81**	**44.60**	**63.4**	**18.4**	**21.6**	**91.9**	**13.7**	**51.8**	**7.71**	**57.60**	**39.10**	**39.71**	**44.71**

OC = Organic carbon, TN = Total nitrogen, Ca = Calcium, Mg = Magnesium, K = potassium, Na = Sodium, Al = Aluminum, H = Hydrogen, ECEC = Effective cation exchange capacity, Mn = Manganese, Fe = Iron, Cu = copper, Zn = Zinc

The amount of available Fe in these soils could be due to the acid conditions of the soils resulting from leaching of most basic cation due to intense rainfall. Available Fe poses no fertility problem in the soils studied. However, Biwe, (2012) reported that the presence of Fe in high concentration in soils could lead to its precipitation and accumulation and upon complex chemical reactions lead to the formation of laterite. This could further lead to restriction of root penetration due to indurations formed as a result of alternate drying and wetting of the soils.

Table 3: *Relationship between micronutrient contents with soil physicochemical properties.*

Soil properties	Cu	Fe	Mn	Zn
Al	0.73**	-0.58	0.74**	0.31
Av.P	-0.32	0.28	-0.45	-0.24
BD	-0.47	0.51	-0.57	-0.43
Ca	-0.16	-0.37	-0.12	0.00
Clay	0.58**	-0.64	0.59	0.16
ECEC	0.59*	-0.61	0.65	0.26
H	0.24	-0.56	0.41	-0.09
K	0.24	-0.09	0.08	0.37
MC	0.19	-0.09	0.13	-0.15
Mg	0.64	-0.39	0.81	0.35
Na	0.48	0.08	0.36	0.17
OC	0.40	-0.14	0.00	0.43
pH(H_2O)	0.65	0.09	0.47	0.37
Sand	-0.67**	0.63	-0.72	-0.27
TN	0.55	-0.37	0.64*	0.52
TP	0.46	-0.59	0.56	0.42

and = significant at 0.05 and 0.01 probability levels, respectively. OC = Organic carbon, TN = Total nitrogen, Ca = Calcium, Mg = Magnesium, K = potassium, Na = Sodium, Al = Aluminum, H = Hydrogen, ECEC = Effective cation exchange capacity, Mn = Manganese, Fe = Iron, Cu = copper, Zn = Zinc,*

Copper (Cu)

The available copper (Cu) varied from 0.10 - 0.3 mg kg^{-1} with mean value of 0.15 mg kg^{-1} in pedon 1 and 0.1 – 0.6 mg kg^{-1} with mean value of 0.47 mg kg^{-1} in pedon 2 (Table 2). In pedon 1, with exception of AB horizon (0.25 mg kg^{-1}), all the other horizons were found in deficient range by considering 0.20 mg kg^{-1} as the critical limit of Cu suggested by (Lindsay and Norvel, 1978; Rhue and Kidder, 1983). Also, in pedon 2, only Bt_2 horizon was found in deficient range with value (0.14 mg kg^{-1}) lower than the critical limit. The available Cu recorded were below the range (1 – 3 mg kg^{-1}) reported by Deb and Sakal, (2002) as the critical level while, Tisdale *et al*. (2003) recommended critical value of 1.0 – 2.0 mg kg^{-1} for Cu. Hence, Cu availability in the surface horizon falls below the critical limit, it is imperative to supplement it for sustainable crop production. This is in concurrence with the findings of Mustapha *et al.* (2011) in soils of Akko in northeast Nigeria. The distribution of copper increased down the profile in irregular pattern with the highest concentration in AB horizon in pedon 1 and Bt_1 horizon in pedon 2. Copper availability showed high variation (39.7 %, 44.1 %) in both pedons. The variation agreed with the works of Jiang *et al*. (2006) which attributed it to anthropogenic disturbance, leaching and topsoil accumulation of nutrients.

Interaction between Soil Properties and Micronutrients

The correlation between the soil micronutrients and some soil physico-chemical properties are presented in Table 3. Though not significant, soil bulk density correlated negatively (r = -0.47, r = -0.57, r = -0.43) with Cu, Mn and Zn. Non significant but positive correlation (r = 0.28) was observed between bulk density and Fe. Clay had significant positive correlation (r = 0.58, p = 0.05) with Cu, negative correlation (r= -0.64) with Fe and positive correlation (r= 0.59, r= 0.16) with Mn and Zn (Table 3). The significant relationship between clay and Cu conformed to the findings of (Sadiq *et al.*, 2008; Oyinlola and Chude, 2010) that clay is of significant important in the availability of Cu. Organic carbon had positive correlation (r = 0.40, r= 0.43) with Cu and Zn but correlated negatively (r= -0.14) with Fe and correlated neutrally (0.00) with Mn. The soil pH(H_2O) correlated positively but non-significantly (r = 0.65, r= 0.09, r= 0.47, r= 0.37) with Cu, Fe, Mn and Zn. The relationship indicates that pH did not significantly influence their availability in the soils. This is in conformity with the findings of Kparmwang *et al.* (2000) in the sedimentary soils. Sims and Johnson (1991) reported that the availability of trace element in the soil is affected by pH and texture. Also, these results obtained from the study conformed to the report of Debs and Sakal (2002) and Tisdale *et al.*, (2003) that the availability of most micronutrients in soils depend on soil pH, OC content and adsorptive surfaces. However, the positive correlation implies that increase in one soil property increases the other while, negative correlation implies that increase in one soil property decreases the other and vice versa.

Conclusion

The results of the study revealed that the soils were generally acidic, low in exchangeable cations, organic carbon and total nitrogen contents. Generally, micronutrient values with the exception of Fe recorded in the study were below critical levels. The relationship between soil properties and micronutrients showed the relevance and impact of these soil properties on the availability of micronutrients. For sustainable soil optimum productivity, micronutrient fertilizers (copper, manganese and zinc) and organic matter application should be applied by farmers within and around the environment of the study area for quality and profitable crop production.

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