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Micronutrient Status and Distribution of Some Community Lands Earmarked for Agricultural Intensification in Bayelsa State for Food Security

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ABSTRACT: *Improved agricultural production requires balanced nutrients. In spite of Bayelsa State's intention to increase its' agricultural base, little or no information is available on the soils micronutrient status. This study evaluated the status and distribution of Fe, Mn, Zn and Cu in some communities earmarked for agricultural intensification. Sample collection was guided by horizon differentiation. Micronutrients distribution variation was evaluated using coefficient of variation. Iron concentration varied from 41-91 mg/kg in Elemebiri (ELM) soils with moderate %CV (16, 17 and 28 for ELM1, ELM2 and ELM3) and 34-92 mg/kg in Trofani (TFN) soils with moderate to high %CV (30, 20 and 33 for TFN1, TFN2 and TFN3), respectively. The Mn values varied from 1.3 – 4.25 mg/kg for Elemebiri soils and 0.34 – 3.8 mg/kg for Trofani soils. The %CV of Mn was high as ELM1, ELM2 and ELM3 recorded 36, 31 and 38 %CV and TFN1, TFN2 and TFN3 87, 56 and 63, respectively. Available Zn varied between 3.48 – 16.56 mg/kg and 0.87 – 18.56 mg/kg in the Elemebiri and Trofani soils, respectively. The %CV for Zn was 32, 26, and 53 for ELM1, ELM2 and ELM3 and 41, 24 and 56 for TFN1, TFN2 and TFN3, respectively. Copper concentration varied between 1.24 – 5.3 mg/kg for Elemebiri soils and 0.75 – 5.7 mg/kg for Trofani soils. The %CV for Cu was 28, 33 and 25 for ELM1, ELM2 and ELM3 and 36, 53 and 43 for TFN1, TFN2 and TFN3, respectively. Though micronutrient status of the soils looks promising, there is need for close monitoring.*

KEYWORDS: micronutrient status, agricultural intensification, food security, Bayelsa State

INTRODUCTION

Micronutrients, though required in relatively small quantities, are very important in the proper functioning of plants and growth as a balance of all the essential nutrients is necessary for normal plant growth for optimum productivity and yield (Zewide and Sherefue, 2021). Higher agricultural productivity not only need balanced use of macro nutrients but also of micronutrients Gabasawa, Ibrahim and Aliyu, (2016). As most micronutrients are associated with enzymatic systems of plants, micronutrient deficiency and toxicity can reduce good crop yield (Tisdale, Nelson, Beaton and Havlin, 2005).

According to Verma *et al.* (2005), the distribution of micronutrient forms vary with parent materials and profile depths. Brady and Weil (2010) reported that the deficiency and toxicity of trace elements are often related to level of these elements in the parent material from which the soils form. The concentration of micronutrients also varies with soil depths. Whereas, Mustapha *et al.* (2011) found higher concentrations of zinc and copper in the topsoil than in subsoil, concentrations of iron and manganese were higher in subsoil than in topsoil, while nickel concentration decreased with soil depth (Ideriah *et al.*, 2013). Havlin *et al.* (2012) reported that soils derived from shale are richer in zinc than soils derived from Sandstone. Several soil properties are known to affect the concentration of bioavailable micronutrients in soils. According to Brady and Weil (2010), soil pH especially in well aerated soils, has a deciding influence on the availability of all the micronutrients except chlorine. Under acid conditions, molybdenum is rendered unavailable, while most trace element cations are freely available, sometimes at toxic level. Except iron, increasing organic matter (OM) content in soils, decreases availability of metallic micronutrients (Havlin *et al.*, 2012). In a study conducted by Oyinlola and Chude (2010), available copper, zinc, manganese and iron had significant positive correlation with clay.

Deficiency of micronutrients have been reported in some Nigerian soils (Akinrinde et al., 2005; Ahukaemere, Osujieke and Ndukwu, 2014). Mustapha, Mamman and Abdulhamid, (2010) opined that micronutrient deficiencies in Nigerian soils was quite rare, owing to the extensive system of agriculture practiced previously which permitted the recuperation of soils; hence, replenishing macro- and micro-nutrients hitherto lost. But with the increasing human and animal population coupled with the nation's drive to attain food sufficiency and security necessitated the abandonment of the traditional extensive agricultural system to a more intensive system (Gabasawa, Ibrahim and Aliyu, 2016), micronutrient deficiency is inevitable. Moreover, the use of new high yielding crop varieties which are more nutrient demanding, and the realization of the concept of balanced nutrition by farmers have unraveled micronutrient deficiencies in some Nigeria Savanna soils (Mustapha and Loks, 2005). Ayele et al. (2014) however, opined that micronutrient deficiencies usually occur because sufficient amounts in the soil are not soluble and hence unavailable to the crop, and not due to insufficient amounts in the soil. In the same vein, Gabasawa, Ibrahim and Aliyu (2016) reported that based on critical values of available nutrients, Fe, Mn, Zn, and Cu were not deficient in the farmlands adjacent Kadawa irrigation station in the Sudan Savannah of Nigeria. But in Bayelsa State, little or no information is available on the micronutrient status of the soils. The drive towards food sufficiency and food security in Bayelsa State has necessitated the establishment of several rice farms in designated areas in the state but the micronutrient status such areas are not known. For effective management of these farms, the macro- and micro- nutrient status need to be known to integrate the appropriate fertility management programme for best performance. This study was conducted to evaluate the status and distribution of Fe, Mn, Zn and Cu in some communities earmarked for agricultural intensification.

MATERIALS AND METHODS

Locations and Description of the Study Area

The study was carried out within Bayelsa State Southern Nigeria and the study locations lie between latitude 05° 22' 03.9" N and 04° 59' 08.9" N and longitude 006° 30' 21.1" E and 006° 06' 54.1" E. The annual rainfall ranges between 2000 to 4000 mm, spread over 8 to 10 months of the year. Relative humidity is comparatively uniform (averaging over 80 %) all over the state due to proximity to the Atlantic Ocean. Temperature is fairly constant with a maximum of 30°C. The natural vegetation is tropical rainforest but much of the original vegetation is presently degraded or altered. Food crop production is carried out on the levee crest, levee slope, flood plain (backslope) and on recent alluvial soils on channels of present active rivers. Levee crest soils, originally were no longer flooded but with the climate change, most levee crest soils are under annual floods. Most levee slope and flood plain soils and alluvial soils in the channels of present active rivers are flooded yearly by the Niger River floods.
The designations of the three study locations are ELM1, ELM2 and ELM3 for Elemebiri, and TFN1, TFN2 and TFN3 for Trofani.

Soil sampling and analyses

One profile pit each was located on the levee crest, levee slope and alluvial soils in the channels of present active rivers in the Elemebiri and Trofani study locations, giving priority to where farming is concentrated. Soil samples were collected based on horizon differentiation. Soil sampling procedures followed methods prescribed in the USDA Soil Taxonomy (Soil Survey Staff, 2006). Soil samples collected were air-dried, crushed and sieved to pass through a 2 mm mesh. Analyses was carried out in the Green River Project Laboratory of the Nigerian Agip Oil Company and Zadell Laboratory, Port Harcourt, Nigeria. Standard laboratory methods were used to determine the physical and chemical properties of the soils as reported in Dickson et al. (2021).

Determination of Available Micronutrients

Available Fe, Mn, Zn and Cu were extracted by the double acid extraction method as described by Udo et al. (2009). In this process, subjecting 5g of soil with 25ml of 0.05 M HCl in 0.125 M H_2SO_4 for 15 minutes. After extraction, Fe, Mn, Zn and Cu were determined using ICE 3300 Atomic Absorption Spectrophotometer.

Statistical Analysis

Data were subjected to descriptive statistics. Significantly different means were separated by using Least Significant Difference (LSD) and Standard Deviation (SD). Coefficient of variation (CV) was used for variability analysis where CV < 15 is classified as less variable, CV between 15 – 35%, classified as moderately variable and CV > 35%, classified as highly variable. (Wilding and Drees, 1983).

RESULTS AND DISCUSSION

Physical properties of the Soils

As the soils are of alluvial origin, silt dominated the soil texture followed by either sand or clay. In terms of textural classification, silt loam dominated most of the soils (Table 1), especially ELM 1, ELM2, TFN1, TFN2 and TFN3. The Elemebiri soil was a mix of sandy loam and loamy sand. An examination of the silt/clay ratio revealed high ratios above unity, indicating that the soils were young and recent. Generally, increase in clay fraction with depth was not noticeable revealing that illuviation as a pedogenic process is not prominent. Even in rear cases where the clay fraction in an upper horizon is higher than that of the immediate horizon below, it was not as a result of clay illuviation, but differences in the amount of clay deposited during the annual flood (Dickson et al., 2021).

Table 1: Physical Properties of the Soils in the Study Area

Elemebiri Soils ELM1

		Mg/Kg				
Horizon	**Depth (cm)**	Sand	Silt	Clay	Silt/clay ratio	Textural Class
Ap	0-8	230	670	100	6.7	Silt loam
Ap2	8-21	200	620	180	3.4	Silt Loam
B1	24-34	150	540	310	1.7	Silty clay loam
B2	34-65	140	560	300	1.9	Silty clay loam
C1	65-90	200	700	100	7	Silt loam
C2	90-118	210	690	100	6.9	Silt loam
C3	118-150	120	730	150	4.9	Silt loam
C4	150-200	240	560	200	2.8	Silt loam

ELM2

Ap	0-11	180	660	160	4.1	Silt loam
Ap2	11-19	220	640	140	4.6	Silt loam
B1	19-32	190	680	130	5.2	Silt loam
B2	32-42	310	570	120	4.8	Silt loam
B3	42-57	280	580	140	4.1	Silt loam
C1	57-88	180	640	180	3.6	Silt loam
C2	88-106	120	720	160	4.5	Silt loam
C3	160-190	240	640	120	5.3	Silt loam

ELM3

A	0-18	780	180	40	4.5	Loamy sand
Ap	18-31	720	240	40	6	Loamy sand
Ap2	31-44	680	280	40	7	Sandy loam
C1	44.68	880	100	20	5	Loamy sand
C2	68-81	780	200	20	10	Loamy sand
C3	81-123	720	180	100	1.8	Sandy loam
C4	123-160	670	210	120	1.8	Sandy loam
C5	160-200	660	190	150	1.3	Sandy loam
Trofani soils			TFN			
Ap	0-14	210	600	190	3.2	Silt loam
A	14-31	210	620	170	3.6	Silt loam
B1	31-55	390	500	110	4.5	Silt loam
B2	55-140	170	660	170	3.9	Silt loam
B3	140-150	110	600	290	2.1	Silty clay loam
C	150-200	130	660	210	3.1	Silt loam
			TFN2			
Ap	0-11	790	170	40	4.3	Loamy sand
Ap2	11-35	150	600	250	2.4	Silt loam
B1	35-44	150	570	280	2	Silty clay loam
B2	44-70	170	600	230	2.6	Silt loam
C1	70-126	310	580	110	5.3	Silt loam
C2	126-200	410	490	100	4.9	Loam
			TFN3			
A	0-13	710	250	40	6.3	Silt loam
Ap1	13-23	710	270	20	14	Silt loam
Ap2	23-38	680	250	70	3.6	Silt loam
C1	38-52	670	250	80	3.1	Silt loam
C2	52-69	540	360	100	3.6	Silt loam
C3	69-83	710	170	120	1.4	Silt loam
C4	83-200	910	80	10	8	Sand

Chemical properties of the Soils

pH of the soils measured in water varied from 5.46 – 6.55 in ELM1, 5.44 – 6.61 in ELM2, 5.31 – 7.00 in ELM3, 5.30 – 5.95 in TFN1, 5.95 – 6.80 in TFN2 and 5.55 – 6.11 in TFN3. Generally, the pH of the soils were moderately acid though a few were high, based on the categorization by FAO (2004). The study area is a high rainfall environment which must have caused leaching loss of a chunk of the basic cations and those lost, replaced by acidic cations as earlier reported by Dickson *et al.* (2021).

Calcium dominated the exchange complex of the soils followed by magnesium. Comparing the values obtained to FAO (2006) ratings, the concentration of exchangeable bases was low. Havlin *et al*. (2012) attributed low concentration of exchangeable bases to leaching loss of basic cations and high acidity. Onweremadu *et al.* (2011) earlier recorded low exchangeable calcium in soils from Coastal Plain sands and Aluvium in Sotheastern Nigeria which they attributed to sandiness of the soils which encouraged leaching loss of calcium.

Except for horizons C5 of ELM3 and A2p of TFN2, the ECEC in all the studied soils were below 6 cmol/kg critical level recommended by Esu (1991) hence were considered low. Though the soils are in an area of high rainfall and leaching loss of nutrients is expected, it is possible that the alluvial materials from which these soils were formed were inherently low in basic cations.

Average organic matter content of the soils, based on FPDD (2012) ratings, was medium except in ELM2 (0.71%) which was below medium. The low to medium organic matter in spite of the dense vegetative cover might be attributed to removal of organic materials through frequent bush burning and high organic matter mineralization. This is further exacerbated by the continuous cultivation with short or no fallowing, abandoning land rotation, hitherto practiced to restore soil fertility.

Generally, total N values were low (FPDD, 2012). Except in ELM3, total N in all the soils were higher in the surface soil layers than the underlying horizons. Since soil total N is closely related to soil organic matter, the low total may be attributed to removal of organic materials through frequent bush burning and high organic matter mineralization which was confirmed by Alemayehu *et al*. (2014) in Ethiopia.

Available P concentration was low to medium, decreasing with increasing soil profile depth. Dickson *et al.* (2021) reported close relationship between soil organic matter and available P in these soils which might be reason for the low available P. Additionally, the low soil P values could be attributed to the acidic nature of the soils and possible fixation by sesquioxides in the soils (Havlin, *et al.,* 2012).

Status of Available Micronutrients in the Soils

Presented in tables 2 and 3 is the concentration of micronutrients (Fe, Mn, Zn and Cu) in the soils. Iron concentration varied from 41-01 mg/kg in Elemebiri soils and 34-92 mg/kg in Trofani soils. Fe concentration in the soils was far higher than 7.0 mg/kg recorded by Uzoho *et al.* (2007) for coastal plain sands of Imo State Nigeria and the critical available level of 4.5 mg/kg by Kparmwang *et al.* (2000) but within the available Fe range of 0 – 233mg/kg reported by Ukeagbu *et al.* (2015) for soils supporting oil palm plantations in the coastal plain sand, Imo State Nigeria. From the recorded results, Fe deficiency is not a likely problem as earlier reported by Kparmwang *et al.* (2000) for acidest soils of warm humid zones of Nigeria. Rather, the likelihood of Fe toxicity

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is possible with the climate change and longer period of flooding being experienced. The %CV of Fe in the soil profiles were 16, 17 and 28 for ELM1, ELM2 and ELM3 in the Elemebiri location and 30, 20 and 33 for TFN1, TFN2 and TFN3 for Traofani soils, respectively. The %CV of Fe in the six profiles examined indicated moderate variability which revealed that Fe was not homogeneously distributed. Dickson *et al.* (2021) recorded variability of morphological, physical and chemical properties of these soils and attributed it to differences in the sources of parent material and degree of hydromorphism which might be the possible reasons.

The Mn values recorded were 1.3 – 4.25 mg/kg for Elemebiri soils and 0.34 – 3.8 mg/kg for Trofani soils and were within the 0.2 – 5 ppm range given by Tisdale et al. (2008) and lower than the 4.9 – 145.6 mg/kg range reported by Ukeagbu *et al.* (2015) for coastal plain sands in Imo State Nigeria. Generally, the concentration of Mn in the surface layers of Elemebiri and Trofani soil profiles was generally higher than what was recorded in the bottom layers. The higher concentration of Mn in the surface layers could be attributed to lower pH values in the surface layers was accompanied by larger amounts of organic matter. The implication of this is that organic matter was responsible for acidification of the profiles through litter decomposition. It is also interesting to note that apart from the regular litter addition, the annual floods also come with organic matter enrichments. Similar to this report, Zaidey *et al.* (2010), recorded higher acidity in the surface layer of soils and attributed the high acidity to contribution by organic matter supplied from the vegetation as all the study sites were covered with trees. Hattori *et al.* (2005) had earlier reported that organic matter and exchangeable Al contributed to the acidity of degraded land under rehabilitation in Sarawak, Malaysia. In confirmation to this, Brady and Weil (2010) opined that in uncultivated profiles, there was somewhat greater concentration of micronutrients in the surface soil, much of which presumably in the organic fraction. Although the elements held in this way were not always readily available to plants, their release through decomposition undoubtedly was an important fertility factor.

The %CV recorded for Elemebiri soils were 36, 31 and 38 for ELM1, ELM2 and ELM3, respectively. In the Trofani soil profiles, %CV values were 87, 56 and 63 for TFN1, TFN2 and TFN3, respectively. Apart from ELM2 which fell within moderate variability, Mn was highly variable in all the other profiles. This probably indicated high impact of differences in the source of the parent materials and hydromorphism.

Available Zn did not take a definite pattern in both Elemebiri and Trofani soils but varied from 3.48 – 16.56 mg/kg and 0.87 – 18.56 mg/kg in the respective soils. A variation in available Zn ranging between 2.46 and 14.00 mg/kg in soils under different land use with similar lithology was recorded in Nigeria by Uzhoho *et al*. (2007) and similarly, Ukeagbu *et al.* (2015) recorded Zn variation in the coastal plain sands of Imo State, Nigeria ranging between 0.3 and 14.00 mg/kg. The values in this study were within the range recorded by the previous authors mentioned indicating that the soils were not deficient in Zn. However, Kparmwang *et al*. (1995) reported Zn

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deficiency for soils of coastal plain sands and in basaltic soils of Northern Guinea savanna in Nigeria. In most cases, Zn concentration was higher in the surface soil layers which could be the result of higher soil acidity. It is obvious that soil acidity in the surface layers were increased through litter decomposition which increased the release and availability of the micronutrients.

Table 2: Chemical properties/Micronutrient concentration of Elemebiri Soils

Horiz.	Depth	pH	percent		Avail P	Exchangeable (cmolkg-1)					Percent				
	Cm		TN	Org. C	Mgkg -1	Ca	Mg	K	Acid.	CEC	BS	Fe	Mn	Zn	Cu
ELM1															
Ap	0-8	5.46	0.25	2.25	18	0.74	0.64	1.65	2.5	5.62	61	50	3.05	15.57	3
Ap2	Aug-21	5.62	0.11	2.24	16	1.26	0.59	0.55	1.5	3.99	62	57	2.9	14.28	3
B1	21-34	5.77	0.08	1.52	9	0.78	0.43	0.53	2.4	4.2	43	48	1.81	9.61	3.2
B2	34-65	5.73	0.09	1.5	10	0.76	0.49	1.42	2	4.74	58	68	1.91	8.47	3.1
C1	65-90	6.55	0.08	1.22	6	0.75	1.22	0.47	1.8	4.31	58	41	1.35	12.94	1.55
C2	90-118	5.72	0.04	0.7	6	1.2	0.1	0.21	1.8	3.39	47	57	1.3	6.7	3.4
C3	118-150	5.85	0.06	0.71	5	1.22	0.16	0.18	2.4	4.04	41	63	1.42	8.48	1.65
C4	150-200+	5.86	0.05	1.07	3	0.71	0.49	0.72	1.4	3.39	59	62	1.57	7.23	3.6
Mean		5.82	0.09	1.40	9.12	0.93	0.52	0.72	1.98	4.21	53.62	55.75	1.91	10.41	2.81
%CV		5	70	432	59	27	67	75	0.214	17	15	16	36	33	28
ELM2															
Ap	0-11	5.44	0.09	1.03	16	1.95	0.09	0.43	1.7	4.27	69	41	3.56	11.95	2.3
Ap2	Nov-19	5.74	0.01	0.21	17	0.8	0.09	0.62	0.9	2.44	63	60	2.5	9.54	3.2
B1	19-32	6.61	0.02	0.26	14	0.8	0.76	0.58	2.1	4.31	52	64	2.39	14.85	3.65
B2	32-42	6.04	0.02	0.16	10	0.85	0.79	0.66	2.7	5.07	52	65	1.69	16.17	2.95
B3	42-57	6.07	0.01	0.11	7	0.84	0.13	0.44	2.3	3.77	47	42	1.8	13.39	1.25
B4	57-88	5.74	0.02	0.12	8	0.9	0.48	0.7	1.5	3.66	65	53	1.94	16.56	4.7

C1	88-106	6.15	0.03	0.16	6	0.63	0.43	0.18	1.7	2.99	51	51	1.72	8.74	2.9
C2	106-190+	6.18	0.03	0.14	7	0.85	0.36	0.26	0.7	2.21	73	55	1.6	8.66	3
Mean		6.00	0.03	0.27	10.63	0.95	0.39	0.48	1.70	3.59	59.0	53.8	2.15	12.48	2.99
%CV		6	90	113	42	43	72	39	40	27	16	17	31	26	33
ELM3															
A	0-18	5.52	0.03	0.84	15	0.73	0.45	0.45	1.2	2.9	66	62	4.25	11.34	1.9
Ap1	18-31	7	0.06	0.78	18	0.84	0.97	0.58	1.9	4.37	62	42	3.01	6.75	4.8
Ap2	31-44	6.15	0.04	0.82	9	0.72	0.76	0.18	1.2	2.92	65	53	2.22	4.09	2.25
C1	44-68	5.95	0.02	0.53	9	0.72	0.08	0.12	0.5	1.49	76	42	1.8	6.42	3.1
C2	68-81	5.98	0.04	0.56	10	0.56	0.22	0.33	1	2.14	59	78	2.41	3.48	250
C3	81-123	5.79	0.07	0.56	6	0.87	0.08	0.27	1.8	3.1	53	53	2	9.66	4.95
C4	123-160	5.86	0.05	0.59	7	1.2	0.43	0.52	2.8	5.63	46	91	1.56	17.98	4.2
C5	160-200+	5.31	0.04	0.57	5	1.28	0.74	1.81	2.2	6.11	68	62	1.6	12.72	5.3
Mean		5.945	0.044	0.656	9.875	0.865	0.466	0.533	1.575	3.583	61.875	60.375	2.356	9.055	34.563
%CV		8	37	20	45	291	71	101	47	46	15	28	38	54	251

Table 3: Chemical properties/Micronutrient concentration of Trofani Soils

Horiz.	Depth	pH	Percent		Avail P	Exchangeable (cmolkg-1)					percent				
	Cm		TN	Org. C	Mgkg-1	Ca	Mg	K	Acid.	CEC	BS	Fe	Mn	Zn	Cu
TFN1															
Ap	0-14	5.64	0.13	1.6	12	0.75	0.12	0.15	1.8	2.89	38	54	2.39	5.41	2.8
A	14-31	5.75	0.06	0.45	8	0.78	0.42	0.65	2.1	3.62	53	49	3.42	15.86	2.4
B1	31-55	5.88	0.03	0.24	4	0.78	0.98	0.26	2.3	4.37	47	34	0.58	6.52	3.8
B2	55-140	5.95	0.02	0.21	11	0.75	0.32	0.62	1.9	3.66	48	79	0.86	9.17	5.7
B3	140-150	5.86	0.04	0.68	5	0.56	0.22	0.16	5.4	6.37	15	77	0.49	9.55	3.4
C	150-200+	5.3	0.04	1.04	16	0.77	0.2	0.61	2	4.45	37	76	0.63	14.26	2.55
Mean		5.73	0.05	0.70	9.33	0.73	0.38	0.41	2.6	4.22	39.66	61.5	1.39	10.12	3.44

%CV		4	75	76	49	12	83	59	53	28	34	30	87	41	36
TFN2															
Ap	0-11	6.16	0.06	1.28	17	0.75	0.12	0.15	1.8	2.89	38	45	1.53	6.33	2.6
A2p	Nov-35	6.15	0.05	0.59	10	1.83	0.89	0.14	3.3	6.21	47	40	0.74	11.84	0.75
B1	35-44	5.98	0.03	0.35	15	1.22	0.32	0.53	2.6	4.75	45	61	0.65	8.79	3.1
B2	44-70	6.8	0.03	0.31	5	0.89	0.4	1.88	1.8	5.04	64	39	0.8	6.43	4.8
C1	70-126	6.4	0.02	0.19	15	0.78	0.66	0.28	1	2.79	64	46	0.45	7.9	5.3
C2	126-200+	6.15	0.02	0.21	2	1.83	0.48	0.28	0.8	3.44	77	60	0.34	8.74	2.4
Mean		6.273	0.035	0.488	10.66 7	1.217	0.478	0.543	1.883	4.187	55.833	48.500	0.752	8.338	3.158
%CV		4.635	46.94 8	84.65 5	57.07 7	41.383	56.259	123.270	50.307	32.626	26.503	19.980	55.783	24.280	52.928
TFN3															
A	0-13	5.74	0.1	1.2	15	1.24	0.93	0.46	1.8	4.52	60	49	3.8	11.34	5.1
Ap1	13-23	5.98	0.06	0.72	10	0.8	0.68	0.51	1.6	3.66	56	55	2.26	7.2	5.3
Ap2	23-38	5.55	0.05	0.55	3	0.75	0.34	0.94	1.7	3.8	55	92	1.2	9.53	4.1
C1	38-52	6.06	0.03	0.3	9	0.74	0.34	0.5	1.4	3.05	54	75	0.92	8.88	3.9
C2	52-69	5.98	0.06	0.68	5	0.95	1.01	0.63	2	4.67	57	66	1.29	15.99	2.59
C3	69-83	6.11	0.03	0.32	4	0.78	0.06	0.19	4.6	5.7	19	83	1.21	0.87	3.4
C4	83-200+	5.79	0.01	0.08	10	0.74	0.53	0.88	1	3.92	57	30	0.95	18.52	0.85
Mean		5.89	0.05	0.55	8.00	0.86	0.56	0.59	2.01	4.19	51.14	64.29	1.66	10.33	3.61
%CV		3	60	67	53	21	61	44	59	21	28	33	62	56	43

Okoli *et al.* (2017) reported non even distribution of Zn in soil profiles of different parent materials in Imo State, Southeastern Nigeria. In this study, the percent coefficient of variability of the Elenebiri soil profiles were 32, 26, and 53 for ELM1, ELM2 and ELM3 while for Trofani soils, it was 41, 24 and 56 for TFN1, TFN2 and TFN3, respectively. The variability was moderate to high which further emphasize the high impact of differences in the source of the parent material.

Copper concentration varied from 1.24 – 5.3 mg/kg for Elemebiri soils and 0.75 – 5.7 mg/kg for Trofani soils. An important source of the trace elements is organic matter which goes into several complex combinations with organic matter forming organic colloids. Organic matter is largely responsible for both storage and release of nutrient ions in tropical soils especially in low activity clays dominated ultisols (Asadu, 2013). Brady and Weil (2010) earlier reported that copper, especially is held tightly by organic matter- so much so that its availability can be very low in organic soils. Ahukaemere *et al.* (2014) reported available copper in organic matter paddy soils of Abia State, Southeastern Nigeria, in the range of 0.05 – 0.25 mg/kg while Okoli *et al.* (2017) recorded 0.281 – 3.202 mg/kg for soils of different parent materials in Imo State. Ukeagbu *et al.*

(2015), on the other hand, recorded 0 – 1.5 mg/kg Cu in the soils of the coastal plain of Imo state, Nigeria. Tisdale *et al* (2005) rated Cu concentration in soils of the savanna with the following values: 0-2.5, low, 2.6-4.5, medium and ›4.5 mg/kg, high. Using the values reported by the three groups of authors as basis for comparison, the concentration of Cu recorded for the soils were high but within the medium to high ratings of Tisdale and colleagues.

The percent coefficient of variability of the Elenebiri soil profiles were 28, 33 and 25 for ELM1, ELM2 and ELM3 and for Trofani soils, 36, 53 and 43 for TFN1, TFN2 and TFN3, respectively. As observed for the other micronutrients, the medium to high copper variability could be traced to impact of differences in the source of the parent materials.

CONCLUSION

The Elemebiri and Trofani soils are some of the proposed sites on which rice farming is to be intensified in Bayelsa State. The soils under consideration had sufficient iron, manganese, zinc and copper for crop production given previously recorded available micronutrient levels as they were above the critical levels reported. Though deficiency of these nutrients are not expected, serious monitoring must be carried out to ensure that rice production is not negatively affected because insufficiency of any of these nutrients as micronutrient deficiencies have been reported previously in other soils because sufficient amounts in the soil are not soluble.

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