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Status and distribution of soil available micronutrients along a hillslope at Ekpri Ibami in Akamkpa Local Government Area of Cross River State, Nigeria

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A field study of the status and distribution of available soil micronutrients along a hillslope of Ekpri Ibami was carried out on a 50 ha land. The aim of the study is to evaluate the micronutrient status and distribution and their relationship with some selected soil properties. A total of 16 soil samples were collected from each pedogenic horizons of four profile pits dug along a hillslope classified as upper slope, middle slope, lower slope and valley bottom. The micronutrients determined in the laboratory were iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) while the soil properties determined were particle size distribution (sand, silt, and clay), pH and organic carbon. The result obtained showed that the soils of Ekpri Ibami are characterized by sandy loam texture with sand= 706.9 g/kg, silt = 93.6 g/kg and clay = 199.5 g/kg. Soil reaction showed that the soils are strongly acidic (5.1) with low organic content (0.73 g/kg). The result of the soil micronutrients indicates that Fe content was high (5 mg/kg) in all the slope positions; copper was rated medium (0.2-2.0 mg/kg); zinc was rated low (0.8 mg/kg) at upper slope and lower slope while the middle slope and valley bottom were rated medium (0.81-2.0 mg/kg); manganese was rated medium (1.1-5.0 mg/kg) in all the slope positions. The results indicate that the sand particles, pH, and organic are the main soil properties which influences availability of micronutrients in the soil due to their significant relationships. The significant correlation among the studied available micronutrients points to the fact that, their abundance and release to plant is controlled by similar factors. The soils will not require supplementary application of Fe rich fertilizer since they are above critical limits of arable production but a complementary supply of copper, zinc, and manganese fertilizers are strongly recommended to enhancing the soil fertility status of the area.

Key words: Micronutrients, hillslope, soil productivity, food production, sustainability.

INTRODUDTION

Micronutrients are important elements that are assimilated by plants in trace amount. In as much as the element are required by the plant in small quantities, vital plant metabolism are impaired or limited if the elements are unavailable thus leading to plant growth dysfunctionality and reduced yield. This also could lead to poor soil fertility status that wholly determines crop productivity level. Furthermore, iron (Fe), manganese (MN)

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Figure 1. Location map of the study area.

manganese (Mn), copper (Cu) and zinc (Zn) are positively charged micronutrients which form complexes with different enzymes and other organic compound functional groups; Zn cofactor more than 100 enzymes (Shenkin, 2006). These elements are also important in gene display, breakdown of proteins, nuclear acids, growth substance, chlorophyll and secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance and so on (Rengel, 2003; Gao et al., 2008).

The focus on food security and sustainable crop production by the government of Federal Republic of Nigeria through the Ministry of Agriculture and Rural Development by the use of up to date information of nutrient status of soils has become of utmost concern. The status and distribution of available micronutrients within a soil profile system along a land scape has been considered essential for the understanding of the soil inherent ability to sustain an adequate amount or supply of these elements to crop so as to meet the demand of zero hunger by 2030 through sustainable food production (United Nation, 2012).

Several researchers have championed the importance of assessing the soil micronutrient status (Chaudar et al., 2012; Ibrahim et al., 2011; Mustapha et al., 2011) and also its quantities through geostatistical calculations (Garima et al., 2015). This study therefore aimed to evaluate the status and distribution of available Fe, Mn, Cu and Zn in soil profiles along a hillslope at Akamkpa Local Government Area of Cross River State.

MATERIALS AND METHODS

Study location

Cross River State is on a latitude of 6°10'2" N and longitude of 8°39'36" E of the Greenwich meridian. The study was at Ekpri Ibami area which lies between latitudes 05°18'53" and longitude 08°13'25" at an elevation of 82 to 111 m above sea level located in the tropical sub-humid environment, within Akamkpa Local Government Area of southern Cross River State (Figure 1).

Climatic condition of the study area

The study area experiences humid tropical climate with distinct wet and dry seasons. Rainfall ranges between 1500 and 3500 mm per annum while the relative humidity was between 80 and 90%. The mean annual temperature is between 25.4 and 27.5°C (NIMET, 2015). Rainfall, relative humidity, temperature and sunshine data for the study area were adapted from Calabar weather station of the Nigerian Meteorological Agency since the study area (Akamkpa)

Table 1. Physicochemical of properties of Agricultural land of Ekpri Ibami.

Soil parameter	Range	Mean
Sand (g/kg)	496.4-875.2	706.9
Silt (g/kg)	29.6-143.6	93.6
Clay (g/kg)	80-380	199.5
Textural class	Sandy loam	-
pH (H_2O)	3.9-5.1	5.1
OC gkg^{-1}	0.04-2.59	0.73

falls within 100 km range of this synoptic station as recommended by Afangide et al. (2010).

Geologic formation

The basement complex rocks occupy about 10,000 km^2 in Southeast Nigeria (Ekwueme et al., 1990), out of which about 40% is found in Cross River State which makes up the Oban-Obudu massif and, a continuation of the African-pan Basement Complex of the Cameroun highlands. The characteristics of the material reflect the processes that form the underlying and the influence of the environment where they occurred.

Vegetation and land use

Southern Cross River State falls within the tropical rainforest climatic zone. According to FDALR (1990), the vegetation of the study area is predominantly secondary forest re-growth. Annual crops identified consist of *Zea mays*, *Manihot* species, *Oryza sativa*, *Musa* species, *Dioscorea* species, and perennial crops such as *Carica papaya*, *Elaeis guineensis*, *Hevea brasiliensis* and *Irvingia gabonensis*. Dominant trees, climbers, and shrubs such as *Daniella oliveri, Ficus* species*, Khaya senegalensis, Laxifora* species*, Combretum* species*, Alcohornea* species*, Andropogon* species*,* and *Digitaria* species, are scattered almost evenly while African bamboo trees grow wildly near the streams and lowland areas.

Sampling method

The study was carried out on a 50 ha (500,000 m^2) land. Four (4) profile pits were dug along the hillslope of Ekpri Ibami representing upper slope, middle slope, lower slope and valley bottom geomorphic positions labeled as I, II, III and IV, respectively. Soil samples were collected from each identified and described pedogenic horizons of the four profile pits making a total of sixteen samples and transported to the laboratory for analysis.

Laboratory analysis

Particle size distribution was determined using the hydrometer method as described by Bouyoucos (1957). Soil pH was determined in 1:1 soil water suspension with a glass electrode pH meter. Organic carbon was determined by the wet oxidation method of Walkley and Black (1934). The extractable micronutrients: Zn, Cu, Fe and Mn, were extracted using 0.1 M HCl solution (Osiname et al., 1973) and determined on an atomic absorption spectrophotometer at a specific wavelength.

Statistical analysis

The result was subjected to discrete statistics and a Pearson correlation coefficient was used to show the relationships between micronutrients and some selected soil properties.

RESULTS AND DISCUSSION

The results of the laboratory analysis are shown in Tables 1 and 2.

Physicochemical properties of soils of Ekpri Ibami hillslope

The particle size distribution of soils of Ekpri Ibami hillslope showed that sand content ranged from 496.4 to 875.2 g/kg, silt from 29.6 to 143.6 g/kg and clay from 80 to 380 g/kg with mean values of 706.9, 93.6 and 199.5 g/kg, respectively. This suggests that the soils are coarsed-textured, covering 70.6% of the agricultural land and may be faced with the problem of water and nutrient adsorption for plants. This could be attributed to the parent material from which the soils originate from (Akamigbo, 1984). The soil pH ranged from 3.9 to 5.1 with a mean value of 5.1 and rated as strongly acidic (<5.5) based on the rating suggested by Karltun et al. (2013). This pH value of the soils has been established not to support some plant nutrients, thus not optimally available to plants for uptake, plus this range of pH is not compatible to plant root growth (Tisdale et al., 2003). Accordingly, the organic carbon content of the soils ranged from 0.04 to 2.59 gkg^{-1} with a mean value of 0.73 gkg^{-1}. Status of the organic carbon was totally low when compared with the rating provided by Adaikwu et al. (2013).

Status and distributions of micronutrients

Available iron (Fe)

The DTPA extractable iron content in the soils ranged from 69.5 to 109 $mgkg^{-1}$ (mean 92.8 $mgkg^{-1}$), 84.7 to 180.9 $mgkg^{-1}$ (128.1 $mgkg^{-1}$), 42.57 to 111.16 $mgkg^{-1}$ (mean 87.75 $mgkg^{-1}$) and 103.71 to 142.32 $mgkg^{-1}$ (116.69 $mgkg^{-1}$) for upper slope, middle slope, lower slope and valley bottom, respectively (Table 2). The result obtained showed that the iron content of the soils

Table 2. Profile distribution of extractable micronutrient.

PEDON No.	Depth (cm)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
UPPER SLOPE PEDON I	**N05˚ 19’ 16.84” ; E008˚ 13’ 36.1” ; 108 m ASL**				
Ap	0-17	94.5	0.32	0.30	2.38
Bt1	17-62	98.2	0.22	0.38	3.16
BC	62-122	69.5	0.29	0.21	2.04
Crt	122-200	109	0.36	1.47	2.23
	Mean	92.8	0.30	0.59	2.45
	CV	18.0	19.90	100.13	20.05
MIDDLE SLOPE PEDON II	**N05˚ 19’ 25.3” ; E008˚ 13’ 35.7” ; 108 m ASL**				
Ap	0-16	180.9	0.23	1.03	2.02
Bt1	16-65	145.5	0.27	1.10	2.37
Bt2	65-112	84.7	0.43	0.69	2.70
Cr	112-200	101.3	0.37	0.46	3.47
	Mean	128.1	0.33	0.82	2.64
	CV	34.0	28.14	36.52	23.45
LOWER SLOPE PEDON III	**N05˚ 19' 11.3" ; E008˚ 13' 36.8" ; 102 m ASL**				
Ap	0-8	99.03	0.32	0.42	1.08
Bt1	0-53	42.57	0.45	1.07	2.04
Bt2	53-114	98.25	0.26	0.63	1.06
Crt	114-200	111.16	0.34	0.66	2.67
	Mean	87.75	0.34	0.70	1.71
	CV	34.98	23.16	39.11	45.85
VALLEY BOTTOM PEDON IV	**N05˚ 19' 23.3" ; E008˚ 13' 33.8" ; 102 m ASL**				
Ap	0-19	103.71	0.36	0.57	3.06
Bt1	19-60	106.08	0.23	0.72	3.94
BC	60-124	142.32	0.20	1.06	4.37
Cr	124-200	114.63	0.58	1.26	3.64
	Mean	116.69	0.34	0.90	3.75
	CV	15.19	50.48	34.83	14.67

of Ekpri Ibami hillslope was high (>5.0 $mgkg^{-1}$) when compared with the rating by Esu (1991). The high iron (Fe) content obtained in the soils may be attributed largely to weathering of biotite ($Al_{1.24} Fe_{1.4} H_{1.64} K_{0.98} Mg_{0.71} Na_{0.02} O_{12} Si_{1.36} Ti_{0.16}$) as a result of the geological formation of the study area been basement complex origin. Similarly, it is known that soil parent material has an influence on chemical compositions of soil (Irmak et al., 2007). The result of iron content obtained in soils of Ekpri Ibami under a humid rainforest condition was similar to that of Gubi Bauchi North (44.75 $mgkg^{-1}$) under a Sahel Savannah condition.

The high Fe content in the soil (above the limiting value of 2.5 mg/kg for crop production) connotes that Fe deficiency is not likely for crops grown on these soils. However, the presence of Fe in high concentrations in soils could lead to its precipitation and accumulation and upon complex chemical reactions leading to the formation of phlintite (laterite). This upon alternate wetting and drying could irreversibly yield hard consolidated material (petrophlintite or ironstone) which could restrict root penetration and drainage. This observation is similar to that of Ephraim (2012).

Available copper (Cu)

Table 2 shows that copper (Cu) in the soils ranged from 0.22 to 0.36 mg/kg (mean = 0.30 mg/kg), 0.23 to 0.43 mg/kg (mean = 0.33 mg/kg), 0.26 to 0.45 mg/kg (mean = 0.34 mg/kg), and 0.20 to 0.58 mg/kg (mean = 0.34 mg/kg) for upper slope, middle slope, lower slope and valley bottom, respectively. The result obtained shows that the soils falls within the medium (0.2-2.0 mg/kg) micronutrient fertility rating for copper content as given by Esu (1991). Generally, copper shows an irregular

Table 3. Pearson correlation coefficient (r) between soil properties and micronutrients.

Correlation	Fe	Cu	Zn	Mn	Sand	Silt	Clay	pH	OC
Fe	1								
Cu	-0.410	1							
Zn	0.378**	0.281**	1						
Mn	0.203**	0.026**	0.169**	1					
Sand	0.314**	0.085**	0.018**	0.508**	1				
Silt	-0.345	-0.141	-0.549	-0.156	-0.505	1			
Clay	-0.224	-0.042*	0.190**	-0.518	-0.944	0.192**	1		
pH	0.232**	-0.298	0.015**	0.121**	0.463**	-0.291	-0.415	1	
OC	0.175**	-0.146	-0.020*	-0.012*	0.282**	-0.168	-0.256	0.236**	1

**Correlation is significant at the 0.01 level. *Correlation is significant at the 0.05 level. OC: Organic carbon.

distribution down the profile in all the distinct landscape positions while the highest been obtained at the lower slope and valley bottom; this could be attributed to contribution of surface washed materials deposited.

Available zinc (Zn)

Table 2 shows the result of zinc (Zn) content in the soils. Extractable zinc was rated low based (<0.8 mg/kg) on the critical values of Esu (1991) at the upper slope and valley bottom while the middle slope and valley bottom were rated medium (0.81-2.0 mg/kg). The “low status” soils would require Zn fertilization for a better arable crop production. In general, Zn was observed to follow an irregular increase and decrease pattern with depth in all the landscape positions. Singh and Shukla (1985) and Bassirani et al. (2011) reported similar results, this also conforms to the findings of Ephraim (2012) in soils in Gubi, Bauchi North, Nigeria.

Available manganese (Mn)

Manganese (Mn) content in the soils of Ekpri Ibami ranged from 2.04 to 3.16 mg/kg (mean = 2.45 mg/kg), 2.02 to 3.47 mg/kg (mean = 2.64 mg/kg), 1.06 to 2.67 mg/kg (mean = 1.71 mg/kg) and 3.06 to 4.37 mg/kg (mean = 3.75 mg/kg) at the upper slope, middle slope, lower slope and valley bottom, respectively. The manganese content showed an irregular increase and decrease with depth in all the profiles which is similar with the result obtained by Onyekwere et al. (2017) and Ephraim (2012). According to the rating of Esu (1991), it is rated ‘medium’ in all the horizons of the profile. This suggests that the soils Mn content is above the critical available range of <3 mg/kg reported by Lindsday and Norveil (1978) and >1.0 mg/kg reported by Esu (1991). This finding is in contrast with the report by Haque et al. (2000), Beyene (1982), Dibabe et al. (2007) and Tena and Beyene (2011) who reported that amount of extractable Mn is generally high in the tropical soils and Mn toxicity is even more common than deficiency.

Relationship of available micronutrients with soil properties

Presented in Table 3 is the coefficient of correlation ($p<0.05$ and $p<0.01$) between available micronutrients and some soil physicochemical properties at Ekpri Ibami hillslope. This affirms the study by Brady (1995) who highlighted the significant influence of micronutrients and soil physicochemical properties. As shown in Table 3, iron (Fe) gave a significant correlation with Zn (r = 0.378**), Mn (r = 0.203**), Sand (r = 0.314**), pH (r =0.232**) and Organic carbon (r = 0.175**) at 5% level of significance indicating that as one parameter increases there is also a corresponding increase with the other. Copper (Cu) showed a positive correlation with Zn (r =0.281**), Mn (r = 0.026**) and Sand (r = 0.085**) but gave a negative but significant correlation with clay (r = -0.042*). Zinc (Zn) gave a positive and significant correlation with Mn, sand and clay but a negative significant correlation with organic carbon. While manganese (Mn) gave a positive correlation with sand (r = 0.508**) and pH (r = 0.121**) but a negative significant correlation with organic carbon (r = -0.012*).

Sand gave a positive correlation with pH and organic carbon; silt a positive and significant correlation with clay while pH gave a positive and significant correlation with organic carbon (r = 0.236**). This contradicts the results of Sidhu and Sharma (2010) and Kumar and Babel (2011) who reported that the available micronutrients increased with increase in organic carbon but corresponds with decreased with increase in pH. Tisdale et al. (2003) stated that micronutrients react with soil organic matter to form stable complexes; these micronutrient cations which are bound by organic matter are more available to plants than the inorganic forms. The findings of this study affirms the report of Brady and Weil (2002) and Esu (2010) who stated that the availability of most micronutrients in soils depends on soil organic carbon content.

Conclusion

The status and distributions of available Fe, Cu, Zn and Mn at the hillslope of Ekpri Ibami proposes a complementary supply of copper, zinc and manganese fertilizers and organic manure to sustain food crop production in the studied soil, while iron is not likely to be limited in such soils. The results indicate that the sand particles, pH and organic are the main soil properties which influences availability of micronutrients in the soil due to their significant relationships. The significant correlation among the studied available micronutrients points to the fact that, their abundance and release to plant is controlled by similar factors. So it is recommended that for sustainable food production and availability continuous use of organic materials: farm yard manure and crop residue. Also, the farmers should embrace management practices such as minimal tillage which will in turn improve soil fertility and maintain the availability of micronutrients.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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