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ORIGINAL RESEARCH ARTICLE

Assessment of Micronutrient Status in Soils Derived from Three Parent Materials on the Jos Plateau, Nigeria

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ABSTRACT

Parent materials play significant roles in determining the resultant characteristics of various soils. However, not much information is available on their micronutrient status of soil of the Jos Plateau. Hence, the objective of this study was to assess plant available Cu, Zn, Mn and B in soils derived from migmatite, granite gneiss and biotite granite parent materials on the Jos Plateau. Seven profile pits were dug in each geologic unit and soil samples obtained using guidelines in the soil survey manual. Available Cu, Zn, and Mn in soil samples were determined using the 0.1 M HCl extraction method and data collected was subjected to one-way analysis of variance. The results indicated that there were significantly higher contents of available Cu in the A horizon for soil derived from migmatite than in those over biotite granite or granite gneiss. Mean available Cu contents in the A horizon were 1.61 (± 0.35), 1.7125 (± 0.96), and 3.33 mg/kg (± 0.16) for granite gneiss, biotite granite and migmatite respectively; whereas for the B horizon mean contents were 2.06 (± 0.40), 2.98 (± 1.31), and 4.13 mg/kg (± 1.93) for granite gneiss, biotite granite and migmatite respectively. Generally, there were no significant differences in distribution of Mn, Zn and B among the geologic units. Implying that soils derived from migmatite, granite gneiss and biotite granite seems to behave similarly in contents of available Cu, Mn, Zn and B. Also, soil particle size had a significant moderate relationship with Cu and may influence its distribution in these soils.

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KEYWORDS

Boron, Copper, Manganese, Micronutrients, Zinc, Jos Plateau.

INTRODUCTION

The Jos Plateau is a highland region and lies within the northern Guinea Savanna vegetation zone (Figure 1). However open grasslands and farms have replaced the original savannah forest (Owonubi, 2017). The area is characterized by a mixed farming system. The average land holding size in the study area is about 2.36ha per household (Thapa and Yila, 2010). Farmers are practicing rain-fed and irrigated farming, with livestock as integral component. Rainfed farming is practiced in the uplands, characterized by food crops such as maize, bean, guinea corn, sweet potato, millet, groundnuts and rice. Traditionally, dry season irrigated farming, locally known as fadama is practiced along riverbanks (Adepetu, 1985; Pasquini et al, 2004). Despite the agricultural importance of these soils, there is dearth of information on the properties of these soils in general, and on the micronutrients contents of the soils in particular. Intensive agricultural activities in addition to high erosional processes in the study area have made it imperative to investigate status of soil micronutrients in the study area. Constraints to crop production and erosional processes on the Jos Plateau have been documented by Olowolafe and Nyagba (1999), Olowolafe and Dung (1999) and Owonubi (2017).

Assessment of the concentration of soil micronutrients can give an indication of the fertility status of soils. Schulte and Kelling (1999a) noted that available Cu is held mainly on the surface of clay minerals or in association with organic matter, furthermore, soil organic matter and pH were reported to influence its distribution and availability. Similarly, Soil texture, pH, phosphorus, and moisture conditions were reported to be primary factors affecting Zn availability in soils (Schulte, 2004). On the other hand, Schulte and Kelling (1999b) reported that temporary waterlogged conditions result in manganese toxicity whereas prolonged wet conditions are favorable for the occurrence of manganese deficiency.

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Soil organic matter is the major source of boron in soils. As a result, soils low in organic matter are deficient in boron more than soils high in organic matter (Voss, 1998). The relationship between soil characteristics and parent materials have been underscored by Jenny (1994). Furthermore, the term soil parent material has been defined by various researchers from similar perspectives. Jenny (1994) defined parent material as the initial state of the soil system. Parent material from which the soil has developed influences several soil characteristics inclusive of soil fertility status.

The objective of this study therefore is to assess the concentration of plant available copper, Zinc, Manganese, and Boron micronutrients, in soils derived from granite gneiss, biotite granite and magmatic parent materials on the Jos Platea.

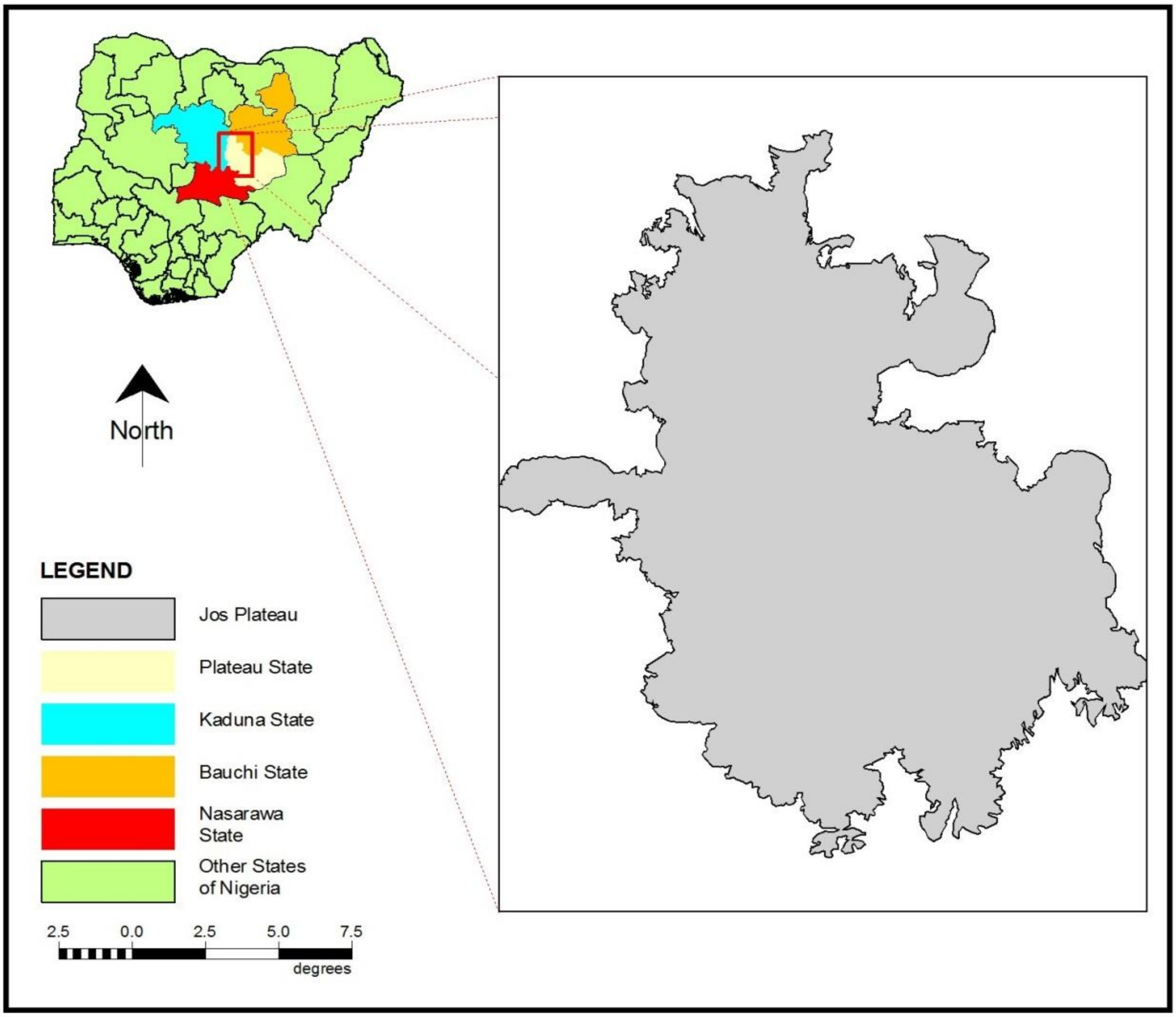

Figure 1: Location of the Jos Plateau (Source: Owonubi, 2017).

MATERIALS AND METHODS

The land systems map of the Jos Plateau at a scale of 1: 250, 000 (Directorate of Overseas surveys, 1977) was used to identify three parent material: granite gneiss, biotite granite and migmatite within the Jos Plateau. Seven profile pits were dug in each geologic stratum at random and soil samples were collected using guidelines provided in the soil survey manual (Soil Survey Division Staff, 1993). Available Cu, Zn, and Mn were determined using the 0.1 M HCl extraction method as described by IITA (1979). A Pye Unicam model Sp 192 atomic absorption spectrometer atomic absorption spectrometer was used to determine the Cu, Zn, and Mn in the extract. Available boron in soil was determined colorimetrically after extraction with hot water. Soil pH was determined in 0.01M CaCl2 solution at a 1:2.5 soil/water or solution ratio as described by McLean (1982). Soil pH was read with a a Pye Unicam model 290MK pH meter. The hydrometer method as described by Gee and Bauder (1986) was used to determine particle size distribution.

The method of Van de Knijff *et al*., (2000) was used to determine geometric mean weight diameter of the primary soil particles (Dg) was determined using Equation 1 as described by for sand, silt and clay particle size class, A is the maximum diameter (mm), B is the minimum diameter and f is the corresponding mass fraction.

$$Dg = \exp\sum f.ln\left(\frac{A-B}{2}\right) \qquad \text{Equation 1}$$

STATISTICAL ANALYSIS

Descriptive statistics involving mean, standard deviation and 95% confidence intervals were used to analyze data generated from the study. Furthermore, one -way analysis of variance involving the Fisher's test of significance was used to compare the concentration of available micronutrients (Cu, Zn, Mn, and B) in soils derived from granite gneiss, biotite granite and migmatite parent materials. Correlation analysis was also performed to examine if there was any relationship between soil particle size distribution and the micro-nutrients. Furthermore, correlation analysis was performed between micronutrients and soil texture. This was achieved by ranking and coding soil texture classes as follows: sands (1), loamy sands (2), sandy loams (3), fine sandy loam (4), very fine sandy loam (5), loam (6), silt loam (7), silt (8), sandy clay loam (9), silty clay loam (10), clay loam (11), sandy clay (12), silty clay (13), and clay (14).

RESULTS AND DISCUSSION

Soil Particle Size Distribution and Soil reaction

Soils derived from biotite granite are mostly sandy clay to loam in texture, while the magmatic soil textures are generally sandy loam to sandy clay loam and sandy loam to sandy clay loam. Also, soil textures over granite gneiss are sandy loam to sandy clay loam and sandy clay to loam in the surface and subsurface soils (Owonubi, 2017). The 95% Confidence Interval for Mean clay content in the A horizon of these soils generally ranged from 10.83 to 16.77%. Mean clay content (Table 1) in the B horizon was 24.67, 24.00 and 21.50% respectively for soils derived from granite gneiss, biotite granite and migmatite. Nonetheless the 95% confidence interval for mean generally ranged from 16.93 to 28.70% in the B horizon. The 95% confidence interval for mean pH in the soils generally ranged from 4.32 to 5.73 indicating that the A horizons are extremely to moderately acid in reaction. Clay content in the A horizons are within the range reported by Owonubi (2008) for some basement complex soils in the Nigerian guinea savanna but clay content in the B horizons are considerably lower than that reported for the soils (mean content: 31 to 42%). This lower clay content in the B horizons could be credited to lower degree of weathering in the soils.

Furthermore, the 95% confidence interval for mean pH in the soils generally ranged from 4.18 to 5.63 implying that the B horizons are extremely to moderately acid in reaction. The acidic nature of the basement complex rocks from which the soils were derived and leaching of basic cations out of the profile could be responsible for the low pH observed in the soils (Olowolafe, 2002; Fasina and Adeyanju, 2006). Consequently, as was noted by Brady and Weil (1999), low pH conditions tend to increase the availability of Cu, Zn, Mn, and B in soils.

Table 1: Particle size distribution of soils derived from granite gneiss, biotite granite and migmatite

Landform	Profile	Horizon	Depth	Clay	Silt	Sand	Texture	Dg
GRANITE GNEISS								
Crest	1	A	0-9	14	4	82	SL	0.3353
		R	nd	nd	nd	nd	nd	nd
Upper foot slope	2	A	0-12	14	10	72	SL	0.2687
		B	12-30	22	16	62	SCL	0.1239
		BC	>30	24	16	60	SCL	0.1079
Middle foot slope	3	A1	0-7	12	22	66	SL	0.1988
		A2	7-20	12	18	70	SL	0.2303
		BW1	20-40	18	20	62	SL	0.1411
		BW2	40-57	18	22	60	SL	0.1311
		BW3	57-72	24	16	60	SCL	0.1079
		BW4	72-107	24	18	58	SCL	0.1002
		BC	>107	20	14	66	SL	0.1532

Table 1: continued

Landform	Profile	Horizon	Depth	Clay	Silt	Sand	Texture	Dg
BIOTITE GRANITE								
Upper foot slope	4	Ap	0-10	14	28	58	SL	0.1388
		A2	10-30	20	34	46	L	0.0735
		Bw1	30-70	24	34	42	L	0.0557
		Bw2	70-89	24	40	36	L	0.0447
		BC	89-125	34	24	42	CL	0.0402
Middle foot slope	5	Ap	0-15	10	10	80	LS	0.3549
		A2	15-27	14	12	74	SL	0.2499
		Bw1	27-61	18	16	66	SL	0.1635
		Bw2	61-90	24	14	62	SCL	0.1161
		Bw3	>90	16	18	66	SL	0.1745
MIGMATITE								
Upper foot slope	6	Ap	0-7	22	8	70	SCL	0.1662
		Aw	7-38	24	4	72	SCL	0.1676
		B1	38-65	20	8	72	SCL	0.1909
		Bt2	65-81	24	14	62	SCL	0.1161
Lower foot slope	7	Aw1	0-21	22	12	66	SCL	0.1435
		Bt1	21-57	22	12	66	SCL	0.1435
		Bt2	57-73	28	10	62	SCL	0.1019

Note: Depth in cm; clay, sand and silt are documented in percent, S = SAND; C = CLAY; L = LOAM; nd = not determined (rock layer); Dg = Geometric mean weight diameter of the primary soil particles with units in millimeters.

Copper and Manganese

The profile distribution of available copper and manganese is presented in Table 2 and shows an irregular trend with depth. Mean available copper contents in the A horizon were 1.6075 (± 0.34529), 1.7125 (± 0.96209), and 3.3333mg/kg (± 0.15822) for granite gneiss, biotite granite and migmatite respectively; whereas for the B horizon mean contents were 2.0629 (± 0.39504), 2.9817 (± 1.3130), and 4.1250mg/kg (± 1.9344) for granite gneiss, biotite granite and migmatite respectively. Contents of available copper in the B horizon were higher than in the A horizon across geologic units. This could be attributed to higher levels of clay in the B horizon compared to the A horizon resulting in greater adsorption of copper cations on the surface of clay minerals in the B horizon (Schulte and Kelling, 1999a). Nevertheless, available copper contents were rated high for the soils (Buchholz, 2004). In comparison, the available copper contents were much lower than that reported for European Union soils (ESDC, 2019), but fell within the range (nil to 3.76 mg/kg) documented for some basement complex derived plinthic soils (Yaro et al., 2007). Also presented in Table 3, is a significant moderate positive correlation (r = 0.51) between Cu and soil texture and a significant moderate negative correlation (r = -0.54) between Cu and Dg. Implying that in these soils particle size distribution has a significant influence on the distribution of available copper and that finer textured soils are more likely to have higher copper contents than coarsely textured soils.

Furthermore, available manganese contents in soils among geologic units were statistically similar ($P > 0.05$). Mean available Mn contents in the A horizon were 36.3975 (± 15.6804), 33.8000 (± 21.3039), and 40.4767mg/kg (± 24.4216) for granite gneiss, biotite granite and migmatite respectively; whereas for the B horizon mean contents were 16.6029 (± 6.9821), 23.1967 (± 10.8021), and 17.1900mg/kg (± 12.3765) for granite gneiss, biotite granite and migmatite respectively. Contents of available Mn in the A horizon were higher than in the B horizon across geologic units probably due to its association with organic matter; nevertheless, available Mn contents were rated high for the soils (Buchholz, 2004). Furthermore, the available Mn contents in these soils were to a great extent higher than the range (2.80 - 19.00; mean: 9.2mg/kg) documented by Oyinlola and Chude (2010) for the surface soils of some Alfisols derived from basement complex rocks. In contrast, Mn contents were much lower than that reported by Patel et al. (2015) for Central Indian soils (range: 205 – 2800 mg/kg, mean: 1178 ± 119 mg/kg).

Table 2: Micronutrient elements in soils derived from granite gneiss, biotite granite and migmatite

Geology	Slope position	Profile	Horizon	Depth*	Cu	Mn	Zn	B
Granite Gneiss	Crest	1	A	0-10	1.37	17.54	8.07	0.88
	Upper foot slope	2	A	0-12	1.27	36.80	17.48	0.71
			B	12-30	1.69	12.74	6.39	0.71
			BC	>30	1.69	9.76	14.13	0.70
	Middle foot slope	3	A1	0-7	1.79	55.91	7.29	0.75
			A2	7-20	2.00	35.34	11.16	0.70
			BW1	20-40	2.84	30.84	4.84	0.58
			BW2	40-57	2.00	19.28	5.10	0.60
			BW3	57-72	2.11	14.70	11.03	0.60
			BW4	72-107	1.90	12.45	9.10	0.54
			BC	>107	2.21	16.45	17.74	0.56
Biotite granite	Upper slope	4	Ap	0-10	2.95	63.54	11.42	0.66
			A2	10-30	2.00	34.91	17.23	0.82
			Bw1	30-70	3.89	37.45	15.16	0.72
			Bw2	70-89	3.16	18.64	12.71	0.64
			BC	89-125	5.04	36.43	3.42	1.31
	Middle slope	5	Ap	0-15	0.95	18.34	2.90	0.99
			A2	15-27	0.95	18.41	26.52	0.88
			Bw1	27-61	1.79	17.32	6.39	0.73
			Bw2	61-90	1.69	16.16	7.03	0.90
			Bw3	>90	2.32	13.18	17.48	0.85
Migmatite	Upper foot slope	6	Ap	0-7	3.16	55.55	18.00	1.06
			Aw	7-38	3.37	53.58	14.00	0.87
			B1	38-65	2.84	32.80	43.55	0.70
			Bt2	65-81	2.84	21.46	10.65	0.88
	Lower foot slope	7	Aw1	0-21	3.47	12.30	13.87	0.96
			Bt1	21-57	3.89	7.36	11.29	1.04
			Bt2	57-73	6.93	7.14	9.23	0.81

Note: * = units in cm, units of Cu, Mn, Zn and B is mg/kg, profile 1 is an Entisol with one horizon and a rock layer below it.

Zinc and Boron

The profile distribution of available zinc and boron is shown in Table 2 and shows an irregular trend with depth. There was no significant difference (P>0.05) in available soil contents among geologic units. Mean available zinc contents in the A horizon were 11.0000 (± 4.6320), 14.5175 (± 9.9328), and 15.2900mg/kg (± 2.3478) for granite gneiss, biotite granite and migmatite respectively; whereas for the B horizon mean contents were 9.7614 (± 4.867), 10.3650 (± 5.5546), and 18.6800mg/kg (± 16.6023) for granite gneiss, biotite granite and migmatite respectively. Moreover, available Zn contents were rated high for the soils (Buchholz, 2004). Besides, the available zinc contents are to a great extent higher than that documented (range: 1.80 – 10.5; mean: 4.2mg/kg) by Oyinlola and Chude (2010) for the surface soils of some basement complex derived Alf sols. The values are also much higher than that reported Patel et al. (2015) for selected Central Indian soils.

Table 3: Correlation analysis between particle size distribution and micronutrients across geologic units

	Cu	Mn	Zn	B
Clay	0.665	-0.208	-0.075	0.257
	0.000	0.288	0.705	0.187
Silt	0.100	0.166	-0.165	-0.258
	0.612	0.398	0.400	0.185
Sand	-0.404	-0.039	0.164	0.087
	0.033	0.842	0.403	0.660
Dg	-0.535	0.051	0.093	0.097
	0.003	0.796	0.637	0.624
Texture code	0.507	-0.154	0.090	0.349
	0.006	0.435	0.650	0.069

Cell Contents
Pearson correlation
P-Value

Additionally, available boron contents in the soils among geologic units were statistically similar (p >0.05). Mean available boron contents in the A horizon were 0.7600 (± 0.0829), 0.8375 (± 0.1377), and 0.9633mg/kg (± 0.0950) for granite gneiss, biotite granite and migmatite respectively. However, these values are low when compared to the ratings developed by Sutradhar et al. (2016). Boron contents were generally higher in the A-horizons compared to the B-horizon most likely due to influence of organic matter as noted by Sutradhar et al. (2016). Similar Boron contents were obtained by Mustapha and Fagam (2007) for some basement complex derived soils.

CONCLUSION

There were no significant differences in distribution of micronutrients among the geologic units in most cases. Implying that soils derived from migmatite, granite gneiss and biotite granite seems to behave similarly in contents of available Cu, Mn, Zn and B. Optimum levels of the micro elements were observed in the soils studied except for boron. This could be due to sufficient quantities in the parent materials and favorable soil conditions for their release. Furthermore, this study also has shown that soil particle size could be a major factor affecting distribution of available copper in these soils. However, there is a need for further detailed soil study to be conducted in the Jos Plateau area; to obtain more information on the micronutrient status of the soils.

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