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Total and Available Micronutrient Status in Soils of Derived Savanna Ecology of Oyo State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author POO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author DO managed the analyses of the study including the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The potentially available and total micronutrient status in soils of derived savanna ecology of Oyo State, Nigeria were assessed and compared with standard critical values in soils. Soil samples were collected from a land measuring 285m^2 on a line transect with the aid of a stainless soil auger. The sampling depths were 0 -15 cm, 15 – 30 cm, 30 – 45 cm and 45 – 60 cm respectively. The Physico-chemical properties and micronutrient content of the soil were determined using standard methods. The mobility factor of the micronutrients revealed the following trends Zn > Fe > Mn > Cu. In all, the concentration of Mn was relatively constant irrespective of the soil depth. This study revealed that the micronutrients (Fe, Mn, Zn, and Cu) were adequate and well supplied in the soils of the area, and therefore, deficiencies of the elements are quite unlikely. Generally, the soils contained Fe, Mn, Zn, and Cu above the critical level for crop production. The application of organic matter would help to improve the overall fertility of the soil. Activities that hastens up mineralization of organic materials should be minimized in managing soil health for optimum nutrient availability. Soil testing is recommended before fertilizer use to prevent nutrient imbalance or toxicity.

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Keywords: Micronutrients; derived savanna; physicochemical properties; GPS.

1. INTRODUCTION

Soil plays a dominant role in determining the sustainable productivity of an agro-ecosystem. Sustainable productivity of soils mainly depends upon its ability to supply the essential nutrients to the growing plants. A major constraint to the sustainability, productivity, and stability of soils is the deficiency of micronutrients [1]. Micronutrients (also known as trace elements) are essential nutrient elements required by plants in exceedingly small quantities for growth and development. This contrasts with macronutrients, which constitute a relatively larger percentage of plant weight. They include iron, zinc, copper, boron, manganese, molybdenum, and chlorine. The micronutrient content of soils depends upon the soil types, parent material, soil pH, organic matter, clay content, amount of exchangeable bases, and phosphate [2,3].

Optimum plant growth and crop yield depend not only on the total amount of nutrients present in the soil at a particular time but also on their availability which in turn is controlled by physicochemical properties like soil texture, organic carbon, calcium carbonate, cation exchange capacity, pH and electrical conductivity of the soil [1]. Uptake of micronutrients is influenced by the presence of major nutrients due to either negative or positive interactions [4].

The concentration of an element in the soil can be divided into total and available, which is a fraction of the total content that is potentially available to plants. In most cases, much of the total content of an element will not be available for immediate uptake by plants. The available concentration of an element in the soil is an estimate of the fraction of that element, which is present as either free ions, soluble complexes, or in readily desorbable forms [5,6].

Derived savanna is a vegetation type that is characterized by the presence of fire-tolerant and fire-sensitive trees with appreciable occurrence of grasses and is co-inhabited by forest and savanna species [7]. The principle of limiting factors states that the level of crop production cannot exceed the limiting amount for essential plant growth factor. An adequate supply of nutrients, including micronutrients, is a plant growth factor. A knowledge about the status and distribution of micronutrients is essential for successful and sustainable agricultural enterprise, particularly crop production.

This study was undertaken to determine the potentially available and total micronutrient status in soils of derived savanna ecology of Oyo state and to compare values obtained with standard critical values in soils.It was aimed at providing information about the micronutrient statusof soils of the study area with a view to knowing the extent of productivity.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is located at Ighoho within Oorelope Local Government Area of the northern fringes of Oyo State, South-Western Nigeria. The State is enclosed within latitude N08^{0}51’18.3’’ and E003^{0}43’32.1’’. The site is significantly positioned at the top of the valley with an elevation ranging from 139.8 - 150.7m above sea level. It falls within the derived savanna region of Oyo State, Nigeria. Climate is characterized by seasonal rainfall, high temperature, and moderate to high relative humidity. It has two distinct seasons of rainy and dry periods in a year with an annual rainfall range from 856 – 1350mm.

2.2 Soil Sampling and Analysis

Soil samples were obtained from the land measuring 285m^2 on a line transect with the aid of a stainless soil auger. The soil samples were collected by making a composite of three core per sampled points on the line transect. The samples were obtained from predetermined depths of 0 – 15 cm, 15 – 30 cm, 30 – 45 cm and 45 – 60 cm, placed in a labelled polythene bag, and thereafter transferred to the laboratory for processing and analysis. All sample points were geo-referenced using the geographical positioning equipment (e-trex). In the laboratory, the soils were air-dried, crushed in a porcelain mortar and sieved through a 2 mm sieve prior to analysis. Soil pH was determined in water in a soil/solution ratio of 1:1 according to Folsenet al. [8], Organic carbon by Walkey and Black wet digestion method [9], Total Nitrogen by micro-Kjedhal method and NH_4-N calorimetrically, Available phosphorus was determined by the Bray and Kurtzmethod [10], Particle size distribution by the hydrometer method [11], Cation exchange capacity was estimated by summing up all the exchangeable bases with exchangeable acidity [12].

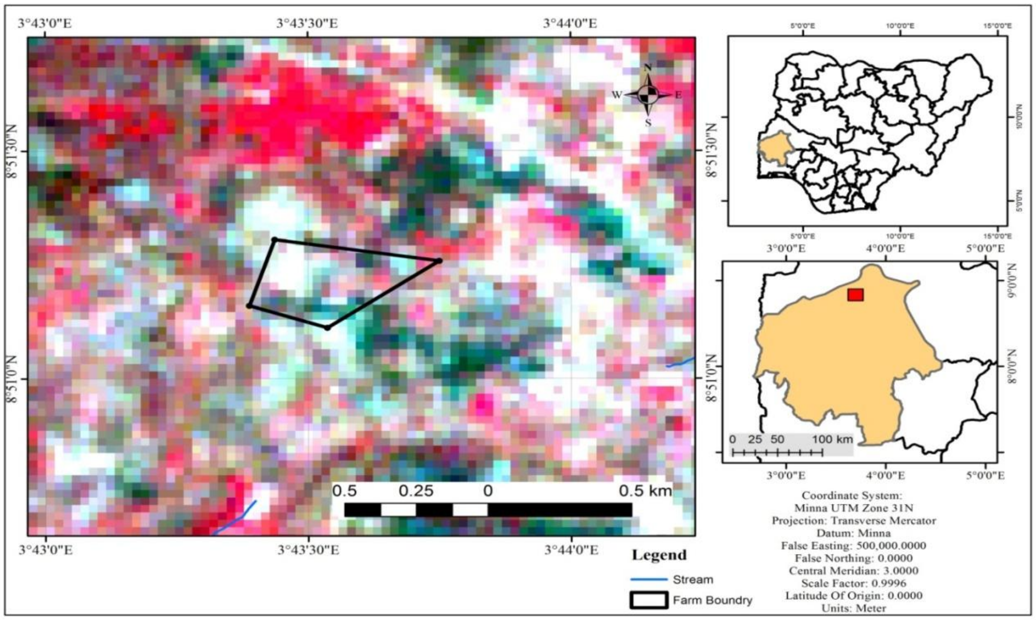

Fig. 1. Map showing study area in Oyo State Nigeria

2.3 Determination of Available Micronutrients in the Soil

1g of soil sample was introduced into the digesting tubes following the addition of 40 ml concentrated HNO_3. The samples were placed in the digester for 8hr at 96^0C with intermittent stirring [13]. Upon complete digestion preceding the observation of white fumes, the samples were allowed to cool, filtered into 100 ml volumetric flasks using Whatman no 42 filter paper. The samples were made to the 100ml mark on the volumetric flask using distilled de-ionized water. The concentration of Fe, Mn, Cu and Zn in the supernatant solution was determined using atomic absorption spectrophotometer Buck scientific method GVP 210. All samples were analysed in duplicates.

2.4 Data Analysis

The mobility factor of the micronutrients was calculated as follows:

Concentration of $\frac{avalaiblemicronutrient}{totalmicronutrient}\ X\ 100\%$

The data was subjected to a one – way ANOVA using the SPSS version 20.0 software. Statistical significance of difference was obtained at 95% confidence interval. During the determination of each analytes, the first samples were analyzed and spiked with referenced standards of known concentrations and also analyzed. The % recoveries were calculated from the concentrations of the measured sample spikes and expected sample spikes. In all the analysis, the percentage recoveries of all analytes determined ranged from 89–92%. The first samples of each analytes were determined in duplicates and the Relative Percent Difference (RPD) were calculated. The RPD of repeat analysis ranged from 4.2–6.7%.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of the Soil Samples

Some relevant soil Physico-chemical properties are presented in Table 1. The textural class of the soils in the study area are mainly loamy sand to sandy loam. The pH ranged from 5.0–6.6, indicating slightly acidic properties. Total organic carbon ranged from 0.10–0.51%. Total N ranged from 0.003–0.03%, Available phosphorus ranged from 6.21–8.7 mg/kg while CEC ranged from 2.5 – 5.84 meq/100 g.

Table 1. Selected physico-chemical properties of the soil samples

Sample ID/Depth	Coordinate	pH	EC.	T.O.C	O.M	N	P	Ca	Mg	Na	K	C.E.C	Sand	Silt	Clay
(cm)			(µS/cm)	←	(%)	→	(mg/kg)	←	meq/100g		→		(%)		
GBH$_1$0-15	N08^{0}51’06.7”	6.3	30	0.42	0.72	0.03	7.1	3.09	1.04	0.43	0.1	4.66	82	11.9	6.1
GBH$_1$15-30	E003^{0}43’32.1”	5.9	20	0.39	0.67	0.25	9.22	3.11	0.57	0.31	0.08	4.07	81.5	9.4	9.1
GBH$_1$30-45		6.2	20	0.38	0.66	0.02	6.51	2.08	0.08	0.34	0.08	2.58	80.5	10.9	9.5
GBH$_1$45-60		5.9	10	0.1	0.17	0.01	9.29	2.4	0.88	0.41	0.06	3.75	80.5	9.9	9.6
GBH$_2$0-15	N08^{0}51’09.6”	5.7	30	0.51	0.88	0.33	6.21	3.04	1.6	0.34	0.09	5.07	83.5	10.9	5.6
GBH$_2$15-30	E003^{0}43’29.8”	5.9	20	0.77	1.33	0.05	12.57	3.12	0.16	0.3	0.08	3.66	82.5	9.9	7.6
GBH$_2$30-45		6.3	10	0.13	0.22	0.01	14.37	4.24	1.36	0.24	0.06	5.9	82.5	10.9	6.6
GBH$_2$45-60		6.4	10	0.54	0.93	0.03	18.81	2.48	1.68	0.34	0.04	4.54	81.5	10.9	7.6
GBH$_3$0-15	N08^{0}51’11.5”	5.9	40	0.51	0.86	0.03	7.18	3.28	1.12	0.41	0.11	4.92	79.5	10.9	9.6
GBH$_3$15-30	E003^{0}43’28.2”	5.7	20	0.38	0.66	0.02	8.42	3.76	0.48	0.4	0.08	4.72	80.5	11.4	8.1
GBH$_3$30-45		5.6	30	0.32	0.55	0.01	5.24	3.52	1.84	0.39	0.09	5.84	80.5	10.9	8.6
GBH$_3$45-60		5.3	30	0.13	0.22	0.02	19.71	4.08	0.48	0.41	0.07	5.04	80	11.4	8.6
GBH$_4$0-15	N08^{0}51’15.9”	5.3	40	0.32	0.55	0.02	7.17	3.76	0.08	0.4	0.09	4.33	80	12.4	7.6
GBH$_4$15-30	E003^{0}43’27.6”	5	30	0.13	0.22	0.01	7.2	2.56	0.96	0.41	0.08	4.01	79.5	9.9	10.6
GBH$_4$30-45		5.2	40	0.35	0.61	0.02	8.18	3.28	2.16	0.3	0.06	5.8	77.5	11.9	10.5
GBH$_4$45-60		5.3	40	0.29	0.5	0.02	3.17	3.12	1.52	0.21	0.06	4.91	77.5	11.9	10.6
GBH$_5$0-15	N08^{0}51’18.9”	5.9	50	0.29	0.5	0.02	8.75	4.08	0.4	0.31	0.08	4.87	83.5	11.9	4.6
GBH$_5$15-30	E003^{0}43’26.2”	6.3	40	0.29	0.5	0.02	10.46	3.04	0.08	0.21	0.07	3.4	86.5	8.4	5.1
GBH$_5$30-45		6.6	30	0.26	0.45	0.02	23.12	2.08	0.56	0.31	0.07	3.02	84.5	10.4	5.1
GBH$_5$45-60		5.9	60	0.22	0.38	0.01	18.57	3.36	0.8	0.2	0.04	4.4	84.5	9.9	5.6

Key: pH = hydrogen ion concentration (soil reaction), EC = Electrical conductivity, N = Total Nitrogen, OM = Organic Matter, TOC = Total Organic Carbon, P = Available Phosphorus, exchangeable cations of Na = Sodium, Ca = Calcium, Mg = Magnesium, K = Potassium, CEC = Cation Exchange Capacity

3.2 Micronutrient Status

3.2.1 Iron (Fe)

Total Fe content in the soil ranged from 309.30 – 491.20 mg/kg, 334.30 – 654.30 mg/kg, 382.70 – 726.30 mg/kg and 382.80 – 669.40 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively with mean values of 412.80 mg/kg, 506.54 mg/kg, 556.66 mg/kg and 540.48 mg/kg. The values for available Fe ranged from 123.70 – 196.50 mg/kg, 133.70 – 258.10 mg/kg, 153.10 – 290.50 mg/kg and 153.10 – 67.50 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively. Fig 2a shows the mean values for the available Fe. The values obtained were above the critical limits for Fe as outlined by Lindsay and Norvell [14], and Esu [15]. Thus, the soil is sufficient in available Fe. Although excessive concentration of Fe in the soil could result in precipitation and accumulation and upon complex reaction lead to formation of laterite. This, when dried, could irreversibly form hard indurated materials (ironstone), which may restrict root penetration and drainage. Mustapha et al. [16] had a similar observation. Adiele et al. [17], in their review, agree with these findings.

3.2.2 Manganese (Mn)

Total Mn in the soil ranged from 18.90 – 36.30 mg/kg, 18.60 – 37.90 mg/kg, 5.64 – 56.70 mg/kg and 19.30 – 52.30 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively with mean values of 29.08 mg/kg, 30.42 mg/kg, 32.37 mg/kg and 32.22 mg/kg. The available Mn ranged from 6.10 – 11.80 mg/kg, 6.00 – 12.30 mg/kg, 1.80 – 18.40 mg/kg and 6.30 – 17.00 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 - 45 cm and 45 – 60 cm depths respectively. Themean values for the available Mn are shown in Fig 2b. Available Mn content fell within the medium and high critical limits for interpreting soil nutrients as outlined by Lindsay and Norvell [14] and Esu [15]. This implies that the soils contain sufficient Mn for successful crop production. It is also above the critical limits reported by Sims and Johnson [18]. Surface soils had more Mn content when compared with sub-surface soils. According to Mustapha et al. [16], high Mn content in the soil could lead to the formation of complexes, which may result in serious drainage and infiltration problems. Available Mn inthe soils of the study area is not a limiting factor to successful crop production.

3.2.3 Zinc (Zn)

Total Zn content in the soil ranged from 45.10 – 89.50 mg/kg, 23.90 – 74.50 mg/kg, 30.70 – 84.40 mg/kg and 26.60 – 49.20 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively with mean values of 69.58 mg/kg, 52.90 mg/kg, 47.78 mg/kg and 38.08 mg/kg. The available Zn ranged from 12.40 – 24.20 mg/kg, 14.30 – 20.10 mg/kg, 13.20 – 18.50 mg/kg and 9.46 – 24.60 mg/kg at the 0 -15 cm, 15 – 30 cm, 30-45 cm and 45–60 cm depths respectively. The mean values for the available Zn are shown in Fig 2c. The values obtained were above the critical limit as outlined by Lindsay and Norvell, [14] and Esu [15]. The concentration of Zn had a decreasing trend as the depth increases. Zinc had earlier been reported to be generally of low mobility in soils [19] and has a tendency of being adsorbed on clay-sized particles [20]. Its implication here is that plants may not have a Zn storedin the lower surface. This agrees with the findings of Mulima et al. [21].

3.2.4 Copper (Cu)

Total Cu content in the soil ranged from 3.83 – 8.84 mg/kg, 2.28 – 8.14 mg/kg, 4.36 – 9.32 mg/kg and 5.34 –9.32 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively with mean values of 6.24 mg/kg, 5.34 mg/kg, 7.13 mg/kg and 7.18 mg/kg. The available Cu ranged from 0.87 – 2.58 mg/kg, 0.38 – 2.81 mg/kg, 1.12 – 2.16 mg/kg and 1.47 – 2.07 mg/kg at the 0 -15 cm, 15 – 30 cm, 30 -45 cm and 45 – 60 cm depths respectively. The mean values for the available Zn are shown in Fig 2d. These values indicate that Cu is adequate in the soil since it exceeds the critical limits outlined by Lindsay and Norvell [14] and Esu [15]. Cu was more in the sub-surface soils than the surface soils. This supports the findings of Udo et al. [22]; Manggoel et al.[23]; Ilori and Shittu [24]. There is thus a tendency for downward movement and accumulation of Cu in the subsurface soils.

The mobility factor of the micronutrients revealed the following trends Zn > Fe > Mn > Cu. In all, the concentration of Mn was relatively constant irrespective of the soil depth.

Table 2. Concentration of (mg/kg) of selected total micronutrients in the soils

Sample ID/Depth (cm)	Coordinate	Fe	Mn	Zn	Cu
$GBH_1$0-15	N08^{0}51'06.7"	491.2	20.4	71.6	8.13
$GBH_1$15-30	E003^{0}43'32.1"	645.3	35.1	23.9	6.42
$GBH_1$30-45		674.3	56.7	31.4	7.75
$GBH_1$45-60		669.4	52.3	27.3	8.31
$GBH_2$0-15	N08^{0}51'09.6"	465.6	36.3	68.2	4.85
$GBH_2$15-30	E003^{0}43'29.8"	562.3	23.1	74.5	3.31
$GBH_2$30-45		523.1	27.3	60.3	5.52
$GBH_2$45-60		541.8	26.6	41.8	6.25
$GBH_3$0-15	N08^{0}51'11.5"	376.5	35.3	73.5	8.84
$GBH_3$15-30	E003^{0}43'28.2"	442.7	37.9	64.2	6.57
$GBH_3$30-45		476.9	5.64	84.4	8.73
$GBH_3$45-60		455.7	34.1	45.5	9.32
$GBH_4$0-15	N08^{0}51'15.9"	309.3	34.5	89.5	5.57
$GBH_4$15-30	E003^{0}43'27.6"	334.3	18.6	42.7	8.14
$GBH_4$30-45		382.7	29.3	32.1	9.32
$GBH_4$45-60		382.8	19.3	49.2	6.69
$GBH_5$0-15	N08^{0}51'18.9"	421.4	18.9	45.1	3.83
$GBH_5$15-30	E003^{0}43'26.2"	539.1	37.4	59.2	2.28
$GBH_5$30-45		726.3	42.9	30.7	4.36
$GBH_5$45-60		652.7	28.8	26.6	5.34

Table 3. Concentration (Mg/kg) of selected available micronutrients in the soils

Sample ID/Depth (cm)	Coordinate	Fe	Mn	Zn	Cu
$GBH_1$0-15	N08^{0}51’06.7”	196.5	6.6	24.2	2.38
$GBH_1$15-30	E003^{0}43’32.1”	258.1	11.4	`19.6	2.12
$GBH_1$30-45		269.7	18.4	17.3	1.64
$GBH_1$45-60		267.8	17	17.7	2.07
$GBH_2$0-15	N08^{0}51’09.6”	186.2	11.8	18.5	2.58
$GBH_2$15-30	E003^{0}43’29.8”	224.9	7.5	16.3	1.98
$GBH_2$30-45		209.2	8.9	15.9	2.16
$GBH_2$45-60		216.7	8.6	24.6	2.07
$GBH_3$0-15	N08^{0}51’11.5”	150.4	11.5	13.8	1.14
$GBH_3$15-30	E003^{0}43’28.2”	177.1	12.3	20.1	2.81
$GBH_3$30-45		190.8	1.8	14.4	1.12
$GBH_3$45-60		182.3	11.1	9.46	1.95
$GBH_4$0-15	N08^{0}51’15.9”	123.7	11.2	18.1	1.39
$GBH_4$15-30	E003^{0}43’27.6”	133.7	6	14.3	2.21
$GBH_4$30-45		153.1	9.5	18.5	2.14
$GBH_4$45-60		153.1	6.3	13.7	1.55
$GBH_5$0-15	N08^{0}51’18.9”	168.6	6.1	12.4	0.87
$GBH_5$15-30	E003^{0}43’26.2”	215.6	12.2	14.4	0.38
$GBH_5$30-45		290.5	13.9	`13.2	1.15
$GBH_5$45-60		261.1	9.4	13.6	1.47

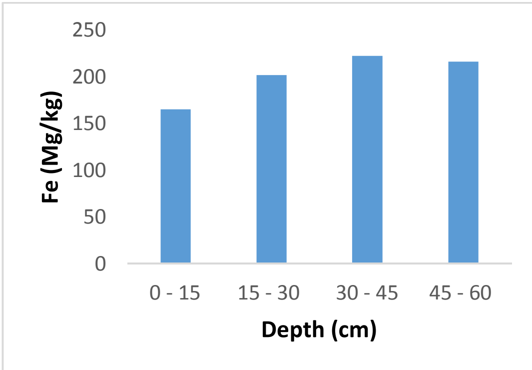

Fig. 2a. Mean of available Fe across depth in all locations

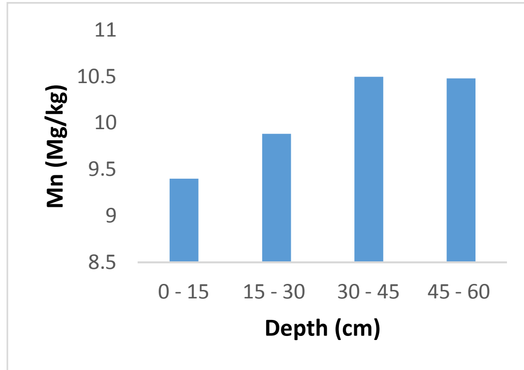

Fig. 2b. Mean of available Mn across depths in all Locations

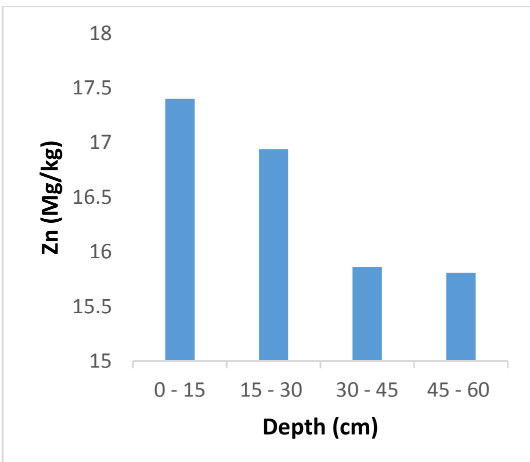

Fig. 2c. Mean of available Zn across depths in all locations

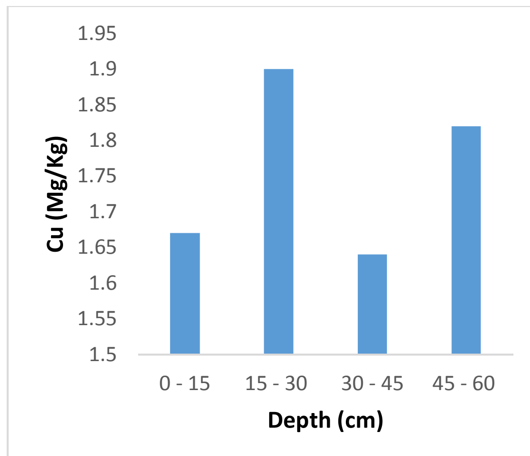

Fig. 2d. Mean of available Cu across depths in all locations

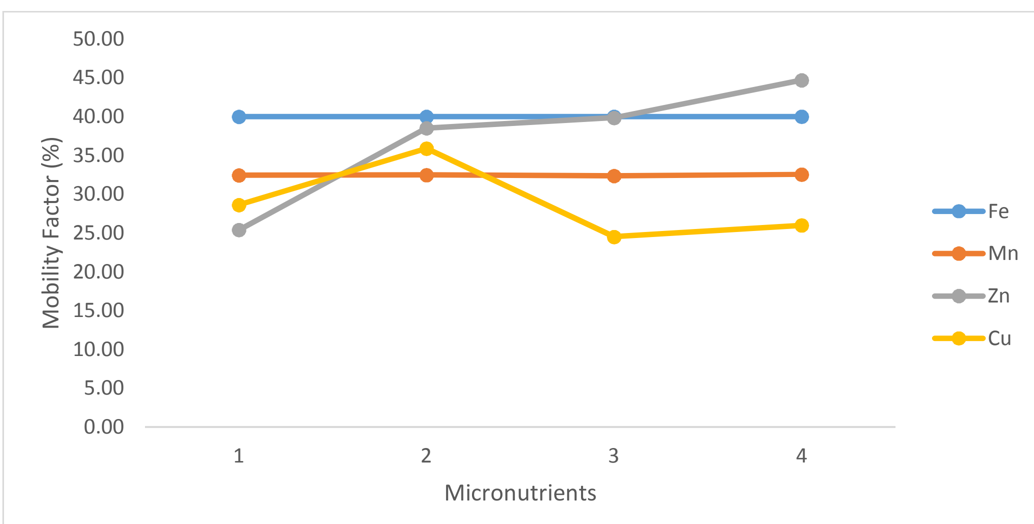

Fig. 3. Mobility factor (%) of micronutrients in the study area

4. CONCLUSION

This work provides information about the micronutrient status in the soils of derived savanna ecology of Oyo State, Nigeria. The study has shown that the micronutrients (Fe, Mn, Zn, and Cu) were adequate and well supplied in the soils of the area, and therefore, deficiencies of the elements are quite unlikely. Generally, the soils contained Fe, Mn, Zn, and Cu above the critical level for crop production. The application of organic matter would help to improve the overall fertility of the soil. Activities that hasten up the mineralization of organic materials should be minimized in managing soil health for optimum nutrient availability. Soil testing is recommended before fertilizer use to prevent nutrient imbalance or toxicity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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