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Micronutrient distribution in soils of Ethiope region of Delta State, Nigeria

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ABSTRACT

Investigation was carried out in Ethiope Region of Delta state, Nigeria to evaluate the distribution of micronutrients contents of oxisols. Ten farming communities were purposely selected in the region, and a total of 60 composite samples were collected with the aid of augers at a depth of 0 - 30 cm. The samples were air-dried at room temperature, sieved with 2 mm sieve mess before subjecting to laboratory analysis following standard procedures to determine the selected soil micronutrients (Fe, Cu, Mn, Zn). Data obtained were analyzed with descriptive statistics and analysis of variance while the least significance difference (LSD) at 5 % probability level was used to separate means. The relationship among nutrient parameters was shown with correlation analysis Results obtained indicated that the soils were moderate to slightly acidic, low in organic carbon and total nitrogen with medium contents of available P. Iron and Mn were found to be above the critical limits for crop production. At the same time, Cu and Zn were generally low. The high level of Fe might be a potential environmental problem upon complex reactions that will result in plinthite and hard pan formation that can restrict rooting and causing infiltration problem in the region. From the findings, it is advisable to apply organic fertilizers to boost the fertility of the soil and probably prevent plinthic layers development.

1.0. Introduction

Micronutrients are essential elements needed by plants in small quantity for growth and reproduction. These elements (Fe, Cu, Mn, Zn, etc) play significant roles in carbohydrate metabolism, protein biosynthesis and gene expression through involvement in enzymic systems (Oluwadare et al., 2013). They are needed for physiological and reproductive functions that improve growth and yield of crops (Chidanandappa et al., 2008 and Thomas et al., 2018). Studies have shown micronutrients deficiency to be a significant constraint of soil productivity (Onwudike et al., 2016) in Nigeria. As a result of this, many farm lands is deficient in a micronutrient, and the symptoms are increasing in the country that led the declining crop yield and incidence of reduction in infectious disease resistance (Thomas et al., 2018). The increasing deficiency symptom has prompted researches that will enable farmers to know the nutrient behaviour and management option appropriate for optimum crop productivity in the region (Ahukaemere et al., 2017). Assessment of the micronutrients will address the fertility problem and consequently help in making sound agricultural policies that will promote sustainable development. Ethiope East region in Delta State, Nigeria, lands are put into agricultural uses and oil exploration activities without no soil fertility maintenance; as a result information on micronutrient status is not known (Mustapha & Loks, 2005; Onwudike et al., 2016).

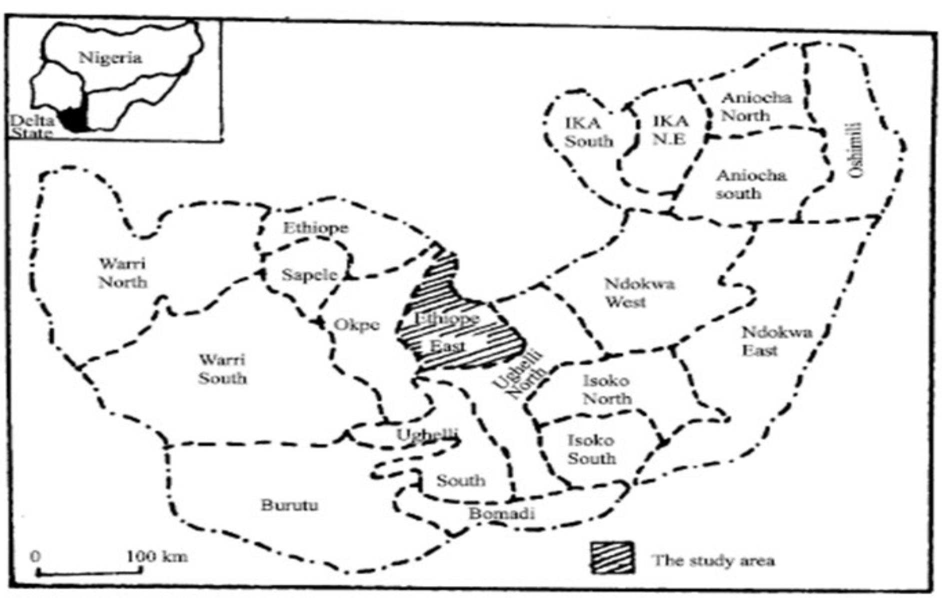
Attempt to increase food production for the increasing population and also provide raw materials for our industries have subjected agricultural lands in Nigeria to intensive uses resulting in deforestation (Onwudike et al., 2016). This has changed the soil chemical properties with time and micronutrients inclusive probably due to top soil removal by erosion and organic matter depletion (IFPRI, 2010). Unfortunately, when fertilizers are applied to replenish the lost nutrient attentions are only given to the significant elements (NPK) forgetting the fact that weathering, leaching and crop removal also deplete micronutrient in the soil (Voncir et al., 2008 & Ibrahim et al., 2011). More also, the introduction of improving variety and management practices which increases crop yield also places more significant stress on soil micronutrient supplying powers in most farms in Nigeria (Onwudike et al., 2015). Despite this, much emphasis has not been entirely placed on the micronutrients assessment making information on its status to be scanty, most notably in Ethiope region, Delta State, Nigeria.

Soil micronutrient can be enhanced through continuous assessment of its contents to integrate appropriate management option, but this was not the case in this region. There is little research work on micronutrients distribution in the soil of the Ethiope region. The understanding of soil variability of micronutrient is critical for proper nutrient management. If the information on soil micronutrients distribution is known, it will enhance agriculturist and farmers' decisions on the type and rate of fertilizer to apply (Ahukaemere et al., 2017). With a focus on food self-sustainability by Nigeria government, information on micronutrient distribution will be an added advantage. The content of available micronutrients in the soil profile is essential for understanding soil fertility management (Kingsley et al., 2019). Sustainable crop production requires a good understanding of soil fertility to develop appropriate nutrient management policy (Gebeyaw, 2015), understanding the distribution of micronutrient will help in the management of soil fertility. With little or no information on micronutrient distribution of agricultural soils in Ethiope region of Delta State, Nigeria, it is imperative to investigate the micronutrients distribution of the region. Hence, the current study focused on the assessment of micronutrients distribution in Ethiope region of Delta State, Nigeria.

2.0. Materials and Methods

2.1. Local Description of study areas

The study was conducted in Ethiope region of Delta State, Nigeria, and the region was named after River Ethiope in a lowland area close to Sapele. The region is made of two local government areas (Ethiope East and Ethiope West), and the primary income source of the people was farming. Ten communities were purposely chosen from the region, five in each local government area (Boboroku, Ekpan, Jesse, Oghara, Ugbenu, Mosogar, Okpara, Oria, Igun and Uruoka). Ethiope East lies within geographical co-ordinates of 5°41'16.76" N 5°59'2.90" E with a population of 200,792 and a land area of 380 km2. In comparison, Ethiope West lies within co-ordinates of 5°55'11.86" N 5° 43'45.80" E (Figure 1), with an area of 536 km² and a population of 203,592 at the 2006 census. The soils of the Ethiope region have a crude oil deposit that is undergoing continuous exploration and exploitation. Records of Federal Meteorological Survey depict the region with high temperature and rainfall that is favourable for the cultivation of different crops with vegetation that is predominantly evergreen. The climate is typical to that of the tropical region and humid in most parts of the year with high relative humidity that varies between 50% and 75%. Soil fertility maintenance is through fertilizer application, though, without proper documentation.



Figures in parentheses are standard deviations

2.2. Field Study and laboratory analysis

In each selected community, nine composite soil samples were randomly taken at the depths of 0 – 30 cm. Soil samples collected were air-dried, crushed with pestle and mortar and sieved with 2 mm sieve to remove particles greater than 2 mm, and the soil was subjected to laboratory analyses. The pH, total nitrogen, organic carbon content, available phosphorus, manganese, Iron, Copper and Zinc according to the methods described by Udo & Ogunwale (1986).

2.3. Statistical analyses

Data generated were subjected to descriptive statistics and analysis of variance (ANOVA) while the least significance difference (LSD) at 5 % probability level was used to separate means. Correlation analysis was used to show the relationship among nutrient parameters with SAS software version 9.0.

3.0. Results

3.1. Selected soil properties of the Ethiope region

Soil pH of the Ethiope region ranged between 5.77±0.176 and 6.77±0.067 and was found that 40 percent of the soils samples analyzed were moderately acidic while 60 % were slightly acidic (Table 1). The communities with the moderate acidic condition were Boboroku, Jesse, Oghara and Ugbene while other communities were slightly acid. Organic carbon varied between 2.10±0.115 in Uruoka and 3.32±0.197 at Igun. Generally, soil organic carbon was low in the region. Total nitrogen concentration ranged from 0.20±0.021 to 0.58±0.165 g/kg (Oria – Ugbenu, respectively). This shows that nitrogen content in the region is low. Phosphorus content ranged from 11.13±1.495 in Igun to 19.0±1.069 mg/kg in Ekpan-Ovu, which is moderate.

3.2. Micronutrient distribution of Ethiope Region

Soil manganese contents ranged from 6.7±3.94 mg kg-1 in Mosogar to 39.7±16.180 mg kg-1 in Uruoka and this is low (Table 2). Iron content ranged between 162.7±5.487 mg kg-1 in Igun to 425±3.512 mg kg-1 in Boboroku, which is high. The concentration of copper in the soils of the region varied from 0.77±0.023 mg kg-1 in Oria to 1.85±0.178 mg/kg in Oghara soils, it was low while zinc ranged from 0.36±0.036 mg kg-1 at Oghara and Boboroku to 1.89±0912 mg kg-1.

Table 1 Major soil fertility parameters of Ethiope region

Community	pH (H_2O)	Organic carbon	Total nitrogen	Avai. Phosphorus
		--------------------g/kg--------------		------Mg/kg--------
Boboroku	5.77±0.176c	2.35±0.087bc	0.25±0.022bc	15.6±1.255abcd
Ekpan-Ovu	6.30±0.115ab	2.97±0.426ab	0.27±0.023bc	19.0±1.069a
Igun	6.37±0.088a	3.32±0.197a	0.43±0.069ab	11.13±1.495d
Jesse	5.60±0.058c	2.21±0.166c	0.22±0.023c	12.35±1.82cd
Mosogar	6.77±0.067ab	2.55±0.230bc	0.23±0.028c	12.43±1.162cd
Oghara	5,87±0.186c	2.37±0.119bc	0.27±0.020bc	15.47±1.963abcd
Okpara	6.41±0.145a	2.73±0.203abc	0.29±0.085bc	18.47±1.426ab
Oria	6.37±0.167a	2.13±0.422c	0.20±0.021c	15.90±1.332ab
Ugbenu	5.97±0.033c	3.02±0.201ab	0.58±0.165a	14.53±1.938bcd
Uruoka	6.37±0.176a	2.10±0.115c	0.26±0.009bc	16.901.353ab

3.3 Nutrient variability of Ethiope Region

Soil pH values were less variable in all the communities investigated, that is, less than 15 % (Table 3). Seventy percent of soil organic matter in the area was less variable while 20 % moderately variable (Ekpan-Ovu and Mosogar) and 10 % was highly variably (Oria). Total nitrogen was less variable in four communities, moderately variable in five communities while it was highly variable in one community. Available phosphorus was less and moderately variable in the region investigated. Out of the ten communities evaluated, manganese was less and moderately variable in two communities each while it was highly variable in six communities. Iron was less variable in all the communities investigated except in Okpara, which was moderately variable. Three communities were less variable in copper content, and six communities were moderately variable while one community was highly variable in copper content. Low zinc variability was recorded in two communities and in four communities, moderate variability was found while high variability was recorded in the remaining communities.

Table 2 Micronutrient distribution of Ethiope region

Community	Manganese	Iron	Cupper	Zinc
	--------------------	Mg/kg	--------------------	
Boboroku	21.0±3.182abc	425.0±3.512a	1.61±0.201ab	0.36±0.038b
Ekpan-Ovu	13.8±1.141c	174.7±9.262c	1.43±0.026ab	1.06±0.258b
Igun	37.3±7.778ab	162.7±5.487c	1.09±0.168bc	0.42±0.012b
Jesse	20.1±4.11bc	429.3±16.91a	1.62±0.112ab	0.58±0.073b
Mosogar	6.7±3.94c	409.0±28.7a	1.44±0.228ab	0.56±0.034b
Oghara	14.1±2.730c	396.3±3.712a	1.85±0.178a	0.36±0.036b
Okpara	22.0±1.821abc	190.3±30.88c	1.36±0.137ab	18.2±17.23a
Oria	18.9±1.91bc	190.0±14.47c	0.77±0.023c	1.25±0.154b
Ugbenu	21.5±6.080abc	164.0±10.79c	1.25±0.194bc	1.03±0.272b
Uruoka	39.7±16.180a	294.3±15.377b	1.57±0.350ab	1.89±0.912b

3.4.Soil properties correlation matrix of the region

Soil organic matter and the nutrient elements investigated were weakly but positively associated with soil except for Fe and Zn, which were negatively associated (Table 4). Total nitrogen was positively associated with organic carbon, but available phosphorus was negatively associated. Manganese and zinc were positively associated with organic carbon, while Fe and Cu negatively associated. Available P, Fe and Cu negatively associated with total nitrogen while Mn and Zn positively but weakly associated. Three out of the 4 micronutrients evaluated weakly but positively associated with Available P while Fe negatively associated. Iron negatively associated with Mn while Cu and Zn positively but weakly associated with Mn. Copper positively associated with Fe while Zinc negatively associated with Fe, and Cu negatively associated with Zn.

Table 3 Percentage nutrient variability of Ethiope region

Community	pH	OC.	TN	P	Mn	Fe	Cu	Zn
Boboroku	5.3	6.4	14.9	14.0	26.2	1.4	21.6	18.3
Ekpan-Ovu	3.1	24.8	14.8	9.7	14.4	9.2	3.2	42.1
Igun	2.4	10.3	27.9	23.3	36.1	5.8	26.8	5.0
Jesse	1.8	13.0	18.7	25.6	35.4	6.8	12.0	22.0
Mosogar	1.8	15.6	21.1	16.2	102.3	12.2	27.4	10.4
Oghara	5.5	8.7	12.8	22.0	33.5	1.6	16.7	17.3
Okpara	3.9	12.8	17.2	13.4	14.3	28.1	17.5	163.6
Oria	4.5	34.3	18.0	14.5	17.5	13.2	5.2	21.4
Ugbenu	1.0	11.5	49.5	23.1	49.1	11.4	26.9	45.8
Uruoka	4.8	9.5	6.0	13.9	70.5	9.0	38.5	83.5

3.5. Correlation coefficient between selected soil properties and manganese, iron, copper and zinc

All the micronutrients evaluated showed a positive relation with soil pH, organic carbon, total nitrogen and available P (Table 5). Manganese strongly related while Fe was weakly related to the selected soil properties. Copper had a strong relationship with the selected soil properties except available P. Zinc had a weak relationship with the soil properties except for total nitrogen which it had a strong healthy relationship.

Table 4 Correlation matrix of soil properties in Ethiope region

	pH	OC.	TN	P	Mn	Fe	Cu	Zn
pH	1.0000	0.09300	0.00418	0.28473	0.18135	-0.57095	-0.25188	0.32139
		0.6250	0.9825	0.1273	0.3375	0.0010	0.1793	0.0833
OC.		1.0000	0.50873	-0.01853	0.02499	-0.45828	-0.29100	0.18340
			0.0041	0.9226	0.8957	0.0109	0.1187	0.3320
TN			1.0000	-0.29205	0.10894	-0.38576	-0.25597	0.02105
				0.1173	0.5666	0.0353	0.1722	0.9121
P				1.0000	0.05524	-0.23360	0.13324	0.35825
					0.7719	0.2141	0.4827	0.0519
Mn					1.0000	-0.19791	0.23731	0.00469
						0.2945	0.2067	0.9804
Fe						1.0000	0.51647	-0.23397
							0.0035	0.2134
Cu							1.0000	-0.14173
								0.4550
Zn								1.0000

Table 5 Correlation coefficients between soil zinc fractions and some selected soils properties

Major nutrient parameters	Micronutrient			
	Manganese	Iron	Cupper	Zinc
Soil pH	0.6869	0.0153	0.9815	0.2711
Organic carbon	0.7492	0.1827	0.9915	0.4742
Total nitrogen	0.7721	0.1207	0.7811	0.7511
Available phosphorus	0.6197	0.0661	0.0797	0.1122

4.0. Discussion

Soil pH is a vital soil determinant that controls the availability of micronutrients (Yadav, 2011). The pH values found in this study are in moderately to the slight range, and this could result from the increasing availability of micronutrients that will consequently improve soil fertility (Sha'Ato et al., 2012 & Orhue et al., 2015). Nutrient elements solubility increases at moderate to slightly acid soil, especially metals, and this enhance adsorption than precipitation and complexation reactions (Johnson & Petras (1998) and Thomas et al., 2018). Though, adsorption can decrease with lowering pH due to competition between protons and toxic metals exchange sites in soil colloids. Aluminium and Mn are toxic in acidic soils, and this causes a reduction in its availability to crop. At high pH, nutrient elements are generally low because most micronutrients are not soluble (Rieuwertset et al., 2006 & Thomas et al., 2018). Also, at high pH, divalent forms of micronutrients could be oxidized to trivalent and tetravalent forms which are not available to crops due to insolubility increasing the concentration in soil (Yadav, 2011). It was noted by Modaihsh (1997) that at low pH, the nutrient elements are mostly soluble, resulting in problems of toxicity and at high pH, solubility reduces leading to poor nutrient status. But this was not the case because most nutrients were soluble at the range of the pH values found in this study (Rieuwertset et al., 2006)

The organic matter and total nitrogen status found in soils of the region were low (FFD, 2012) indicating the soils were deficient in both parameters. Total nitrogen was highest in Ugbenu soils, probably due to the higher levels of soil organic matter. The medium levels of available P found in the region fall within the critical range of 7-20 mg/kg given by FFD (2012). However, this medium-ranged can be improved for optimum crop production. The range of available P recorded could be due to soil pH level (Moderately to slightly acidic) could that prevent P complexed with aluminium (Shobayo et al., 2013).

The manganese concentrations were irregular across the region (Onyekwere et al., 2017) though rated high, according to FFD (2012) indicating it is above the critical limit of <3 mg/kg. This result corresponded with the findings by Tena & Beyene (2011) and Kingsley et al. (2019) who pointed out that amount Mn is generally high in the tropical soils. The lower Zn concentration in the region apart from Okpara soil may occur probably due to the acidic nature of the region that could induce Zn adsorption. According to Thomas et al. (2018), increase soil pH lower solubility of Zn and consequently increasing its adsorption by soil colloidal properties negatively charged. It was also reported that adsorption of zinc is favoured by organic matter, so the low organic matter of the region can lead to poor its distribution (Thomas et al., 2018). Low organic matter could lead to poor formation of organic zinc complexes which act as buffer zones in the soil for zinc (Udom et al., 2004). The low concentration of Zn will require fertilization for optimum crop production (Bassirani et al., 2011). The positive correlation of total zinc with pH is an indication of zinc availability, though in small concentration.

The Fe in soils was above the recommended critical limits of 2.5 mgkg-1 for crop production and generally high, an indication that deficiency of Fe will not occur in the Ethiope region (Mulima et al., 2018). In a related finding, Mengel & Geurtzen (1986) and Biwe (2012) reported that Fe deficiencies are not common in acid soils because it is soluble under acid condition. Though, some researchers pointed out that high concentration of Fe can cause its precipitation and accumulation that can lead to the formation of Plinthite upon complex reactions (Ephraim, 2012 & Sha'Ato et al., 2012). This upon alternate wetting and drying could irreversibly form hard indurated material which could restrict root penetration and drainage (Ephraim, 2012 & Orhue et al., 2015). The high Fe concentration can result in the formation of complexes that could lead to infiltration and drainage challenges (Mustapha et al., 2011 & Ahukaemere et al., 2017). Copper distribution was generally low to medium so a deficiency of the element could be predicted in the nearest future. This is contrary to the opinion of Lombin (1983) that available Cu in Nigeria soils are optimum for crop production, and it will pose no fertility treatments. In a related development, Havlin et al. (2012) reported copper to be firmly bound to soil organic carbon that could also decrease copper avail-ability.

Available Fe and Cu correlated negatively with pH, organic carbon and total nitrogen, indicating an increase of these parameters will result to decrease in the concentration of available Fe and Cu. This could affect the availability of micronutrients in the soils (Okoli et al., 2017). A positive relationship between soil organic carbon and the micronutrients observed according to (Verma et al., 2005 & Onwudike et al., 2017) could be attributed to the chelating agent of organic carbon which improves water and nutrients holding capacity of the soil.

5.0. Conclusion

Results found in the Ethiope Region showed that the soils were generally moderately to slightly acidic and low in organic carbon and total nitrogen while available P was moderate. The soils contained Mn and Fe above the critical levels for crop production and can be categorized to be high; however, Cu and Zn found were generally low. The high Fe content might cause or be a potential environmental problem upon complex reactions resulting in the formation of plinthite, leading to hard pan formation restricting root penetration. In contrast, the low Cu and Zn content need fertilization. Because of the findings, it is recommended for sustainable crop production to be achieved; there is a need for organic matter application to increase soil fertility soil and reduce the possibility of developing plinthic horizon.

References

Ahukaemere, C. M., Osujieke, D.N., Ndukwu, B. N., 2017. 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. Bulgarian Journal of Soil Science 2(2):112-

Bassirani, N. Abolhassani, M., Galavi, M., 2011. Distribution of Available Micronutrients as related to the soil characteristics of Hissar; Haryana (India). Africa Journal of Agricultural Research, 6(18), 4239-4242.

Biwe, E.R., 2012. Status and distribution of available micronutrients along a toposequence at Gubi Bauchi North-Eastern Nigeria. International Resources Journal of Agricultural Science. 2(10): 436 – 439.

Chidanandappa, H. M., Khan, H., Chikkaramappa, T., Shivaprakash, B. L., 2008. Forms and distribution of zinc in soils under mulberry (Morus indica L.) of multivoltine seed area in Karnataka. Journal of Agricultural Science 42: 26-32.

Ephraim, R.B., 2012. Status and distribution of available micronutrients along a toposequence at Gubi Bauchi North-Eastern Nigeria. International Research Journal of Agricultural Science and Soil Science 2(10):436-439

FFD (Federal Fertilizer Department) 2012. Federal Ministry of Agriculture and Rural Development (Vol. 15, No. 2, pp. 1049-1058). Abuja, Nigeria.

Gebeyaw T. Y., 2015. Assessment of micronutrient status in different land use soils in Maybar lake watershed of Albuko District, South Wello Zone, North Ethiopia. Global Journal of Crop, Soil Science and Plant Breeding, 3 (1): 143-150.

Havlin, J. L., Beaton, J. D., Tisdale, S. L., Nel-son, W. L., 2012. Soil fertility and fertilizers: An introduction to nutrient management.7th edition. PHI Private Limited, New Del-hi-110001.Pp 513.

Ibrahim, A. K., Usman, A., Abubakar, B., Aminu, U. H., 2011. Extractable micronutrients status in relation to other soil properties in Billiri Local Government Area. Journal of Soil Science and Environmental Management, Vol. 3(10): 282-285

IFPRI (International Food Policy Research Institute) 2010. Fertilizer and Soil Fertility In: Potential in Ethiopia Constraints and Opportunities for Enhancing the System. Working Paper July, 2010.

Johnson, C. E., Petras, R. J., 1998. Distribution of zinc and lead fractions within a forest spodosol. Soil Science Society America Journal, 62, 782-789. https://doi.org/10.2136/sssaj1998.03615995006200030035x

Kingsley, J., Ayito, E. O., Akpan-Idiok, A. U., Effiom, O. D., 2019. Status and distribution of soil available micronutrients along a hillslope at Ekpri Ibami in Akamkpa Local Government Area of Cross River State, Nigeria. African Journal of Agricultural Research 14(1): 40-45

Lombin, G., 1985. Evaluation of the micronutrient fertility of Nigeria's semi-arid savannah soils: boron and molybdenum. Soil science and Plant Nutrition 31 (1): 13-25,

Mengel, K., Geustren, G., 1986. Iron Chlororis and the cause of Chlorosis. Journal of Plant Nutrition, 9, 161–173.

Modaihsh, A. S., 1997. Foliar application of chelated and non-chelated metals for supplying micronutrients to wheat grown on calcareous soil. Experimental Agriculture 33(2), 237-345. https://doi.org/10.1017/S001447979700001X

Mulima, I. M., Ismaila, M., Daya, D. D., Talha, I. Z., Abba Mani, F., 2018. Evaluation of available micro nutrients status of sandy loam soils of Gujba, Yobe State, Nigeria. Journal of Agricultural Science and Practice 3(5): 113-120

Mustapha, S., Loks, N.A., 2005. Distribution of available zinc, copper, iron and manganese in the fadama soils from two distinct agroecological zones in Bauchi State. Nigeria Journal of Environmental Science 9(2): 22-28.

Oluwadare, D.A., Voncir, N., Mustapha, S., Mohammed, G.U., 2013. Evaluation and Enhancement of Available Micronutrients Status of Cultivated Soil of Nigeria Guinea Savanna Using Organic and Inorganic Amendments. Journal of Agriculture and Veterinary Science 3 (5): 62-68

Okoli, N. H., Uzoho, B. U., Onweremadu, E. U., Ahukaemere, C. M., Osisi, A. F., Aliba, E.O., 2017. Status of available micronutrients in soil profiles of different parent materials in Imo State, Southeastern, Nigeria. Nigeria Journal of Soil Science 27: 40-52

Onwudike, S. U., Agbani, L., Ihem, E., Onyegbule, U., 2017. Influence of Land Use Types on Soil Properties and Micronutrient Concentrations on Soils of Similar Lithology in Owerri, Southeastern Nigeria. MAYFEB Journal of Agricultural Science 4 1-9

Onwudike, S. U., Ihem, E.E., Irokwe, I.F., Onwuso, G., 2015. Variability in the Physico-chemical Properties of Soils of Similar Lithology in Three Land Use Types in Ahiazu Mbaise, Imo State Nigeria. Journal of Agriculture and Crops 1(3): 38-43.

Onwudike, S. U., Onweremadu, E. U., Ihem, E. E., Agim, L.C., Osisi, A. F., Osuaku, S. K., Azuh, P. O., 2016.

Evaluation of Micronutrient Status of Soils under Three Land Use Types in Oyigbo, River State, Nigeria. Futo Journal Series (FUTOJNLS) 2(1): 32 - 40

Onyekwere, I.N., Ethan, S., Adiele, J.G., Mbe, J.O., Nwokoro, C.C., 2017. Micronutrients Characterization of Soils of Basalt Parent Material in Ikom, Cross River State Nigeria for Sustainable Crop Production. Direct Research Journal of Agriculture and Food Science (DRJAFS) 5(10):348-352.

Orhue, E. R., Ekuase, H. O., Atere, O. O., Eze, U. E., 2015. Status of some plant nutrients of basement complex soils in derived savanna in Edo State, Nigeria. Nigerian Journal of Agriculture, Food and Environment 11(1):33-37

Sha'Ato, R., Ajayi, S. O., Ojanuga, A. G., 2012. Total and extractable copper, iron, manganese and zinc in major agricultural soils in the Lower Benue Valley, Central Nigeria and the concept of extractant efficiency. Nigerian Journal of Chemical Research 17:59-81

Rieuwerts, J. S., Ashmore, M. R., Farago, M. E., Thornton, I., 2006. The influence of soil characteristics on the extractability of Cd, Pb and Zn in upland and moorland soils. Science Total Environment, 366, 864-875. https://doi.org/10.1016/j.scitotenv.2005.08.023

Shobayo, A. R., Raji, B. A. Malgwi, W. B., Odunze, A. C., 2013. Classification of soils developed on gneisses and schists in the Northern Guinea savanna of Nigeria. Nigerian Journal of Soils and Environmental Research 11: 86-93

Tena, W.S., Beyene, T., 2011. Identification of growth-limiting nutrient(s) in alfisols: Soil Physico-chemical properties, nutrient concentrations and biomass yield of maize. American Journal of Plant Nutrition and Fertilizer Technology 1:23-35.

Thomas, E. Y., Omueti, J. A. I., Adebisi, A. A., 2018. Distribution of Zinc in Selected Benchmark Soils of South Western Nigeria. Journal of Agricultural Science 10(2): 271-280

Udo, E. J., Ogunwale, J. A., 1986. Laboratory manual for analysis of soil, plant and water samples (2nd ed., p. 174).

Udom, B. E., Mbagwu, J. S. C., Adesodun, J. K., Agbimn, N. N., 2004. Distribution of Zn, Cd, Cu and Pb in a tropical Ultisol after long term disposal of sewage sludge. Environment International, 30, 467-470. https://doi.org/10.1016/j.envint.2003.09.004

Verma, V. K., Setia, R. K., Sharma, P. I., Charanjit, S., Kumar. A., 2005. Pedospheric Variations in Distribution of DPTA – extractable Micronutrients in Soils Developed on Different Physiographic Units in Central Parts of Punjab, India International Journal Agriculture and Biology 7(2): 243 – 246.

Voncir, N., Mustapha, S., Tenebe, V.A., Kumo, A.L., Kushwaha, S., 2008. Content and Profile Distribution of Extractable Zinc (Zn) and Some Physicochemical Properties of Soil Along a Toposequence at Bauchi, Northern Guinea Savanna of Nigeria. International Journal of Soil Science 3: 62-68.

Yadav, B. K., 2011. Micronutrient Status of Soils under Legume Crops in Arid Region of Western Rajasthan, India. Academic Journal of Plant Sciences 4 (3): 94-97.