Assessment of status and distribution of available micronutrients in soils under different land uses of savannah North Central Region of Nigeria

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Abstract

This study examines the availability of micronutrients under different land uses: natural vegetation, tree plantations (orange and cashew) and arable crops (maize and guinea corn). Available zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) were analysed in one hundred and fifty (150) randomly selected soil samples. Iron at the topsoil and subsoil under tree plantations and natural vegetation was rated marginal, under arable crops it was marginal at topsoil and deficient at subsoil. Available Mn and Zn at the topsoil and subsoil was adequate under all the land uses, with the exception of maize which fell under marginal ranking at topsoil. Copper was rated deficient under arable crops and orange, marginal under cashew, while natural vegetation was marginal at subsoil and adequate at topsoil. The results revealed that arable crops unlike tree plantations statistically differed on all occasions when their mean scores were compared with those of the natural vegetation. Copper-enriched inorganic fertilizers should be used by farmers. Monitoring of soil nutrients should be carried out regularly, in order to improve upon sustainable farming.

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Keywords: Fertilizers, land uses, micronutrients, soil depth, rating

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Introduction

Man needs food for survival, and the production of food is dependent on an essential natural resource ─ soil. For soil to be a good medium for growth of plants, it has to supply adequate macronutrients and micronutrients. Macronutrients (nitrogen, phosphorus, potassium, magnesium and calcium) are elements needed by plants in the large amounts while micronutrients (boron, chlorine, copper, iron, manganese, molybdenum and zinc) are needed in very small quantities (Foth & Ellis, 1997; Food and Agriculture Organization (FAO), 2012; Jimoh, et al., 2015).

Micronutrients deficiency is known to adversely affect plant development, quality and quantity (Imtiaz et al., 2010). Deficiency of iron in soil reduces chloroplast protein, leads to interveinal yellowing of leaves ─ due to the lack of chlorophyll ─ and in extreme cases cessation of cell division occurs, leading to stunted leaf growth (White, 2006). Manganese deficiencies in soil is responsible for chlorosis in the interveinal tissue of younger leaves. In addition, quality and quantity of crop decline in soils that are deficient in Mn, because of low fertility of pollen (Miller, n.d; Tavakoli et al., 2014). When zinc is deficient in soil, stunted growth, interveinal chlorosis, impairment in chlorophyll production occur (Tilahun, 2007; Imtiaz et al., 2010; Marschner, 2012; Rutkowska et al., 2014; Zhou, 2017). Copper deficiencies in soil leads to twisted leaf tips, light overall chlorosis and loss of turgor in young leaves (Esu, 1991; Marschner, 2012; Rutkowska et al., 2014; Butzen,2017).

Kryzanowski et al. (1988) developed one of the most widely used soil micronutrients classification scheme. Three classes of soils wereidentified in the classification scheme: deficient, marginal and adequate. Copper, manganese, iron and zinc are classified as adequate when they are >1.0 mg/kg, > 2.0mg/kg, >4.0mg/kg and >1.0mg/kg respectively. Soils with micronutrients that fall within the adequate range produce optimally, while those with lower values are termed marginal or deficient; and these would need nutrient application for improved yield.

As the global population increases so does the demand and need for food and this has led to an increased pressure on soil nutrients. The area of fertile soil is increasingly under pressure due to continuous cultivation, consequently intensifying degradation. Currently, 46% of the world's land is considered to be degraded (FAO, 2012; Aminu, 2014).

Agriculture is a major economic activity in Nigeria, with about 20 million of its inhabitants engaging in cropping from 2007 to 2009 and the number keeps increasing every year (National Bureau of Statistics, 2010). Invariably associated with this is continuous cropping and pressure on soil nutrients (Yusufu, 2017). To improve the yield of crops, there is growing dependence on inorganic fertilizer, and in Nigeria, the common ones are NPK fertilizers (Ibrahim et al., 2011, cited in Jimoh et al., 2015). These fertilizers supply macronutrient, nitrogen (N), phosphorus (P) and potassium (K) to plants. It is assumed that with the fertilizing practices, the level of micronutrients was adequate and that the problem of micronutrient deficiencies was not a major problem. However, there are indications from developing countries that micronutrient deficiency in soil is rampant. In many West African regions, several trace-element deficiencies have been reported (FAO, 1982; Lombin,1985; Foth and Ellis, 1997). In addition, the deficiency is expected to become more heightened as more people, who are into cropping; are embracing intensive continuous cultivation and this will consequently hinder the optimal growth of plants and agricultural sustainability (Jimoh et al., 2015; Yusufu, 2017).

The knowledge of the quality and fertility of soil is essential in the agricultural sector, as it helps farmers and policy makers know the right management practises to adopt, fertilizer type to choose and decisions to make to help improve the general health of soils (Yusufu, 2017). Studies of micronutrient have been carried out in many parts of the northern region of the Guinea savannah zone of Nigeria; the results showed Zn and Cu deficiencies in some of the soils (Oyinlola & Chude, 2010; Oluwadare et al., 2013; Jimoh et al., 2015). Lafia region falls within the southern region of the Guinea savannah zone; where research on soil nutrients are spare; particularly studies of micronutrients under different land uses (e.g, Opaluwa et al., 2012; Abiola &Medugu, 2016; Abubakar, et al., 2019).

Therefore, the objectives of this study are to: (i) determine the status of four essential micronutrients including zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) in Lafia Local Government Area (LGA) of Nasarawa state under different land uses; (ii) categorize the status of the four essential micronutrients for cropping purpose; and (iii) compare the micronutrients in land uses under continuous cultivation with those of natural vegetation, to ascertain the impact of cultivation on the nutrients.

Study Area and Methodology

The Savannah of Northcentral Nigeria is made up of six states, namely: Benue, Kogi, Kwara, Nasarawa, Niger and Plateau. The place chosen for the study in the region is Lafia Local Government Area in Nasarawa state, an area associated with extensive farming practices. It is located between latitudes 8^{o} 20$^{'}$ and 8^{o} 38$^{'}$N and between longitudes 8^{o} 20$^{'}$ and 8^{o} 40$^{'}$E (Figure 1). Its land area is 2,797.5sq.km. The area is characterized by dry and wet seasons, which typifies a tropical continental climate. November to middle of April marks the dry season, while from middle of April to October rainfalls marking the wet season (Audu, Abubakar, Ojoye, Muhammed & Mohammed, 2018).

Tropical ferruginous soils make up the major soil units found in Lafia Local Government Area. The parent material for the soils are from basement complex and sedimentary formations in the area. Laterite crust occurs extensively on the basement complex rocks while hydromorphic soils are common along river Benue trough and flood plains of major rivers (Lyam, 2000).

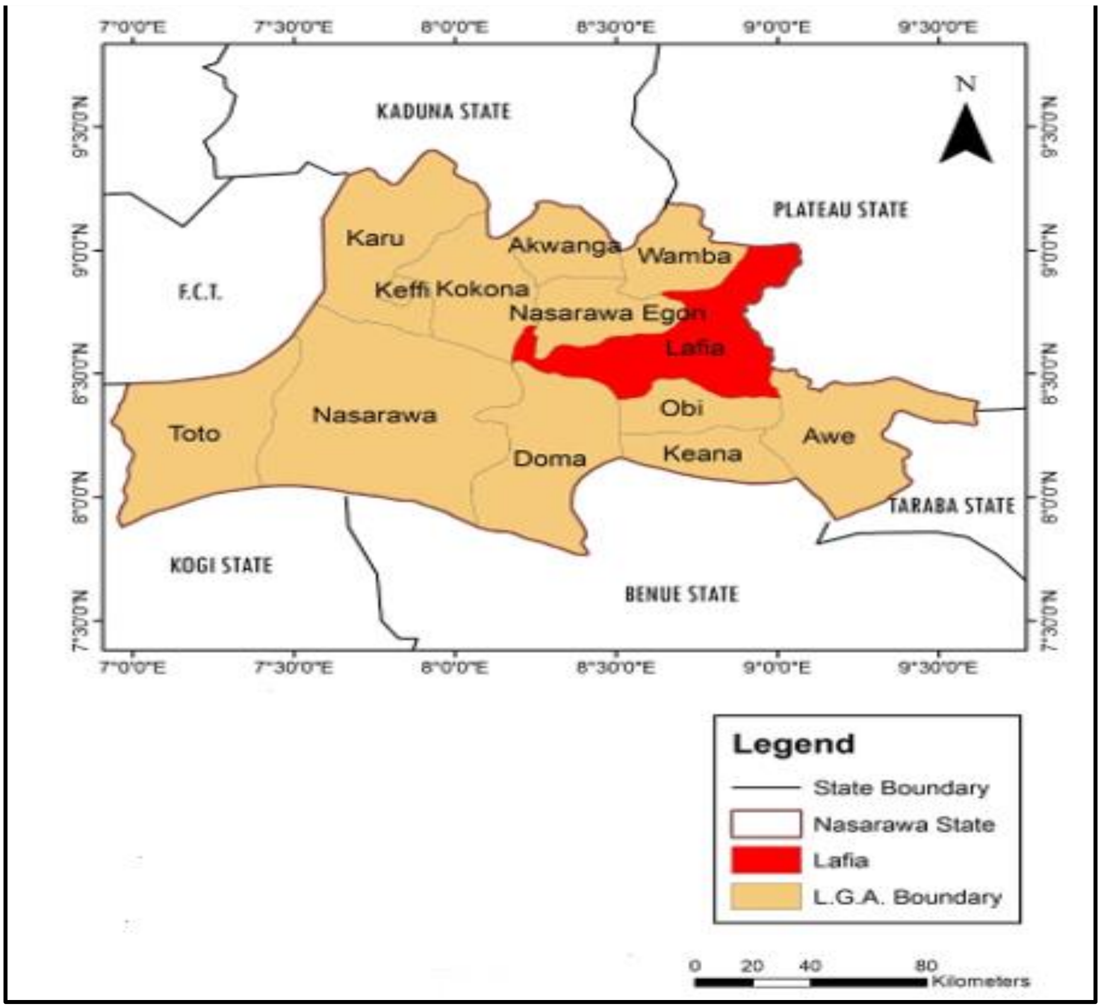

Figure 1: The Study Area
Source: Adapted from the Administrative Map of Nasarawa State

From the two geological formations: basement complex rocks and sedimentary formations in the study area; the areas sampled was on the basement complex rock formation. Thus, the soils belong to the same parent material and are the same morphologically, and their characteristics before use were similar. The choice of land use for the study was natural vegetation and cultivated fields which are planted trees (orange and cashew) and arable crops (maize and guinea corn).

The selection of the soil samples within the study sites was from well-drained areas, which occur on upper slopes, this was done in order to have samples from similar topography. To remove the catenary effect, study sites were confined to the upper slope positions of the catena, on flat locations where the slope angle was not up to 2º. Thus, the sample plots were exposed to about the same degree of nutrient loss. The choice of sample plots from areas of similar geology helped to minimize the problem of inherent variability of soil properties.

The sample plots were measured out as quadrat size of 30m by 30m (900m^2); using a field layout method of 3, 4 and 5 as advocated by Akinsanmi (1981) in laying the quadrats. Lengths of 3m and a width of 4m were measured on the field; this gave a hypotenuse of 5m so that a perfect right angle triangle was obtained in laying out quadrats. A straight line was then taken from right angle so that quadrats are laid out in straight lines. Thereafter, within the quadrat grids of 5m by 5m were then pegged which produced 36 grids per quadrat.

Three quadrats each were measured out under orange, cashew, maize, guinea corn and natural vegetation systems, giving fifteen quadrats for all. Five (5) samples from topsoil (0-20cm) and five from subsoil (20-45cm) were selected randomly from the intersect of the grids within each quadrants, making 10 samples per quadrant for each vegetal type. A total of 150 soil samples were collected in all from the study area (see Table 1); with the aid of a core sampler.

Table 1: Number of Samples Selected from 3 Quadrats A, B, C for Each Soil Management System in the Study Area

Vegetal type	Topsoil Quadrat A	Topsoil Quadrat B	Topsoil Quadrat C	Total topsoil	Subsoil Quadrat A	Subsoil Quadrat B	Subsoil Quadrat C	Total Subsoil
Cashew	5	5	5	15	5	5	5	15
Orange	5	5	5	15	5	5	5	15
Maize	5	5	5	15	5	5	5	15
Guinea corn	5	5	5	15	5	5	5	15
Natural vegetation	5	5	5	15	5	5	5	15
Total Samples				75 Topsoil				75 Subsoil

Laboratory Analysis

The test of the micronutrients in the soil samples was carried out at the Nasarawa State University Agronomic Research Laboratory, where the soil samples were air dried and sieved through a 2mm diameter sieve, put into polythene bags that were assigned laboratory numbers for proper identification. Using standard laboratory procedures, iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were extracted by 0.1M HCl solution (Osiname et al., 1973**)** and their values determined by atomic absorption spectrophotometry (AAS) with flame atomization.

Statistical Analysis

Statistical Package for Social Scientists (SPSS 16.0) software was used to analyze the data collected. Descriptive analysis of the micronutrients values for the different land uses was presented using range and mean. The mean values were used to categorize the available micronutrients into different rating as deficient, marginal or adequate. To ascertain the impact of the continuous cultivation on the micronutrients; One Sample t-test, an inferential analysis, was conducted. The t-test was used to determine if there were statistically significant differences in the mean scores of micronutrients in cultivated fields when compared with the values of the natural vegetation in the study area. The test variables were the land uses under continuous cultivation while the mean scores for natural vegetation was used as the test values. When the sig. value (p – value) is < 0.05, the mean difference is judged significantly different. Conversely, when a sig. value (p - value) is > 0.05 the mean value is deemed not significantly different.

Results and Discussion

Iron (Fe)

Generally, the values of Fe in the study area showed higher content of Fe at the topsoil compared with the subsoil, indicating a decrease in Fe as depth increased (see Table 2). Based on the ratings of Fe by Kryzanowski et al. (1988), Fe values < 2mg/kg are deficient, 2 mg/kg - 4 mg/kg are marginal and > 4 mg/kg are adequate. Using this rating scheme, the topsoil was rated as having marginal Fe. While the Fe content at the subsoil under the arable crops (maize and guinea corn), fell below the critical values 2 mg/kg; and the tree crops (cashew and orange) and the natural vegetation had marginal ratings. Iron at the topsoil is paramount, as it is the Fe at the topsoil that is required for crop growth and development, these being marginal values, crop yield could likely be mildly affected.

Table 2: Descriptive Statistics of Micronutrients Values in Lafia Region, Nigeria

		Fe^{2+}mg/kg		Mn^{2+} mg/kg		Zn^{2+} mg/kg		Cu^{2+} mg/kg	
Land use	Soil Depth	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Natural Vegetation	Topsoil	3.3 - 3.7	3.5	1.2 -2.0	1.7	0.9 -1.6	1.4	1.2 - 1.6	1.3
	Subsoil	2.1 -2.6	2.5	1.7 -2.5	2.1	1.2 -1.8	1.6	0.5 - 0.7	0.6
Cashew	Topsoil	2.8 -3.0	2.9	1.4 -2.4	2.0	1.2 -1.6	1.4	0.4 - 0.6	0.5
	Subsoil	2.1 -2.5	2.3	1.6 -2.9	2.3	1.0 -1.9	1.5	0.1 -0.4	0.5
Orange	Topsoil	2.4 -2.6	2.5	2.2 -3.5	2.5	1.1 -1.7	1.3	0.1 -0.7	0.2
	Subsoil	1.9 -2.1	2.0	2.2 -3.2	2.9	0.9 -1.9	1.4	0.1 - 0.4	0.2
Maize	Topsoil	2.1- 2.5	2.3	2.0 -3.3	2.8	0.8 -1.1	0.8	0.1 - 0.3	0.2
	Subsoil	1.7 -2.1	1.9	3.1 -4.0	3.5	0.6 -1.3	1.0	0.1 - 0.3	0.2
Guinea Corn	Topsoil	2.1 -2.5	2.3	2.1 -3.0	2.6	0.9 -1.3	1.1	0.1 - 0.3	0.2
	Subsoil	1.4 -1.9	1.7	2.9 -3.5	3.2	1.0-1.8	1.2	0.1- 0.3	0.2

The results of studies carried out in some other regions of Nigeria presents a dissimilar outcome as Fe was found to be adequate in the Calabar- tropical rainforest region (Kingsley et al., 2019) and in Zaria- northern Guinea savannah region (Jimoh et al., 2015). The value of Fe in the study area, which has been categorized as marginal at the topsoil and deficient in some samples at the subsoil could be attributed to the low level of organic matter and CEC, which Yusufu (2017) opines is prevalent in Lafia Local Government Area.

Table 3: T-Test Results for Different Land Uses in Lafia Region, Nigeria

	Fe^{2+}mg/kg		Mn^{2+} mg/kg		Zn^{2+} mg/kg		Cu^{2+} mg/kg	
Land Uses	t	P value	t	P value	t	P value	t	P value
Cashew Topsoil	-33.388	.000	4.150	.001	.865	.402	-39.111	.000
Orange Topsoil	-54.668	.000	8.896	.000	-1.680	.115	-23.919	.000
Maize Topsoil	-27.414	.000	9.869	.000	-20.593	.000	-53.010	.000
Guinea Corn Topsoil	-34.632	.000	10.380	.000	-8.084	.000	-53.010	.000
Cashew Subsoil	-5.611	.000	.576	.573	-1.772	.098	-12.250	.000
Orange Subsoil	-27.884	.000	10.587	.000	-2.373	.032	-13.100	.000
Maize Subsoil	-19.215	.000	31.068	.000	-8.021	.000	-19.717	.000
Guinea Corn Subsoil	-20.923	.000	14.150	.000	-5.626	.000	-19.717	.000

The mean values of Fe under natural vegetation when compared with those of land uses used for continuous cropping in the study area, shows there were variances. The result of the t-test shows that the differences in the mean values were significant at both topsoil and subsoil, at $p < 0.001$, for land used to cultivate both arable and tree crops (see Table 3).

Manganese (Mn)

The result of Mn in the study area as presented in Table 2 shows values for both topsoil and subsoil. The mean values of Mn varied from topsoil (1.7 mg/kg to 2.8 mg/kg) to the subsoil (2.1 mg/kg to 3.5 mg/kg), with increased depth resulting in increased values. Kryzanowski et al. (1988) rates Mn in soil: <1mg/kg as deficient and > 1 mg/kg as adequate. At both topsoil and subsoil in the study area, Mn was rated as adequate based on Kryzanowski et al. (1988) ratings. The status of Mn is adequate for crop production- both arable and tree crops- , and crop yields are not in danger of being reduced.

Yusufu (2017) categorized the soils in Lafia, which is the same study area, as being moderately to slightly acidic (pH 4.8 -6.6), thus, the results of Mn in the area could be attributed to this fact, as FAO (1982) opines that it is unlikely for Mn to be deficient in acidic soils. The study area showed an increased in the content of Mn with increased depth; a similar pattern was recorded in Cross River State- Nigeria (Kingsley et al., 2019) and in Bauchi- Nigeria (Ephraim, 2012; Hassan & Ogbonnaya, 2016). The common denominator in all these studies carried out within Nigeria from north to the south is that Mn deficiency was not prevalent.

There were significant differences in the mean scores of Mn under all the cultivated land uses at both topsoil and subsoil when compared with those of the natural vegetation ($p < 0.005$), except cashew ($p = .573$) which showed no significant difference at the subsoil (see Table 3).

Zinc (Zn)

The mean values of Zn in the soils varied across the five selected land uses in the study area (see Table 2). Generally, across all the land uses, the values at the subsoil were slightly higher than what was observed at the topsoil. The values of Zn under the natural vegetation was higher than the cultivated land uses (tree crops and arable crops). Kryzanowski et al. (1988) rating scheme shows that when Zn is <0.5mg/kg it is deficient, 0.5 mg/kg -1 mg/kg is rated marginal and > 1 mg/kg is rated adequate. The values of Zn in the study area was rated adequate, using Kryzanowski et al. (1988) rating scheme, at both the topsoil and subsoil for natural vegetation, tree crops (orange and cashew) and guinea corn. Therefore, Zn is sufficient for high yields of tree crops (orange and cashew) and guinea corn in the study area. The only exception was under maize, where the content of Zn was rated marginal at the topsoil.

The relatively lower Zn content under maize in the study area could be attributed to the fact it is a crop that requires high concentration of zinc during crop production as posited by Schulte (2004). Maize production, therefore, could slightly fall below optimal level in the study area.

The outcome of results of studies in other regions of Nigeria showed Zn deficiencies in the soil. In studies carried out by Kparmwang at al. (2008), Mustapha et al.(2011), and Hassan & Ogbonnaya (2016) in localities within the savannah region of the country; and Kingsley et al. (2019) in the study carried out in the Cross River State, an area in the forest region of Nigeria; the mean values of Zn were considerably lower (<0.5 mg/kg).

Table 3 shows the mean values of Zn in the study area for the tree plantations (cashew and orange) at the topsoil was not significantly different from the mean value of natural vegetation. However, the reverse was observed for arable crops (maize and guinea corn), as their mean values significantly differed when compared with those of the natural vegetation at $p < 0.05$. At the subsoil, the mean values of all the land uses under continuous cropping were significantly different from those of natural vegetation, except land use under cashew. The results are indications that uptake of Zn by arable crops during crop growth, is giving rise to a relatively faster depletion of the nutrient from the soil.

Copper (Cu)

Kryzanowski et al. (1988) categorizes available soil Cu levels: values <0.5 mg/kg is rated, as deficient, 0.5-1 mg/kg is marginal and >1 mg/kg is rated adequate. Soils under orange, maize and guinea corn in the study area were found to be deficient in Cu at both topsoil and subsoil levels, based on Kryzanowski et al. (1988) rating scheme. Cashew had marginal rating at both the topsoil and subsoil. Only natural vegetation had adequate Cu, but that was only at the topsoil as the subsoil had marginal rating. The recorded level of Cu poses a danger for crop production, particularly arable crops.

The findings in this work where the value of copper decreased with soil depth, corroborates what Reuther (1957) postulates, that the subsoil may contain slightly less copper than the topsoil. Similar to results found in the study area, the study undertaken in the southern region of Nigeria by Kingsley et al. (2019) shows the mean values obtained from soil samples in their study were all <0.5 mg/kg an indication of Cu deficiency in the soils. A different outcome was observed by Jimoh et al. (2015) in the study carried in Zaria (a locality within the northern Guinea savanna region of Nigeria) where the mean values of Cu was above > 2mg/kg.

At both topsoil and subsoil in the study area there was significant difference in the mean values of Cu for all the land used for continuous cropping ($p < 0.001$) when compared to the mean values of the natural vegetation (see Table 3). An indication of the impact of nutrient loss through continuous cropping and crop harvesting in the study area.

Conclusion and Recommendations

Because of the importance of micronutrients to crop production, the status of four essential micronutrients: zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) were examined in the soils samples taken from five land uses in the study area. Variance were observed in the micronutrients values across all the land uses. Natural vegetation presented comparatively higher mean values in three (Fe, Zn and Cu) out of the four micronutrients at both topsoil and subsoil, when compared to other land uses in the study area. Significant differences were observed between mean scores of arable crops and those of the natural vegetation on all occasions. On the other hand, the mean difference between tree plantations and the natural vegetation were not significant in all instances. An indication that while continuous cultivation could have led to depletion of available micronutrients, the depletion through nutrient uptake was relatively higher under land uses used for arable crops.

The inadequacy of Cu is widespread in the study area, as it was rated deficient under all the land uses used for cultivation except under cashew. The deficiency could be addressed by application of inorganic fertilizers that has Cu incorporated. The use of inorganic fertilizers rich in copper sulfate and copper oxide by farmers would increase the copper level in the soil.

Continuous monitoring of soil micronutrient by researchers and agricultural agencies is essential, if the study area is to remain viable for intensive cultivation. In addition, as the consumption of crops that are affected by micronutrient deficiencies is linked to an array of morbidities, research is needed in the testing of the micronutrients in the fruits: cashew, orange and in the grains of the crops: maize and guinea corn.

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