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STATUS OF SOME SELECTED MICRONUTRIENTS OF TWO CONTRASTING WETLAND SOILS IN SOUTHERN NIGERIA

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Abstract: Wetlands are essential for the biosphere's life support systems, but they are suffering severe degradation due to increased human activity. The chemical properties of these soils, particularly the availability of essential micronutrients, can significantly impact their ecological function and agricultural sustainability. This study aimed to assess the available (extractable) forms of selected micronutrients in two contrasting wetland soils in southern Nigeria. A total of 54 soil samples were collected from two different sites, Akure and Abakaliki. The samples were analyzed for available Iron (Fe), Zinc (Zn), Copper (Cu), Nickel (Ni), and Manganese (Mn). The results were statistically analyzed using analysis of variance (ANOVA) followed by Tukey's post-hoc test. The wetland soils in Akure showed significantly higher concentrations of available Fe, Zn, Cu, and Mn compared to the soils in Abakaliki. Specifically, the concentrations in Akure were: Fe (104.68 mg/kg), Zn (0.21 mg/kg), Cu (0.40 mg/kg), Ni (0.14 mg/kg), and Mn (0.80 mg/kg). In contrast, the concentrations in Abakaliki were lower: Fe (44.61 mg/kg), Zn (0.05 mg/kg), Cu (0.26 mg/kg), Ni (0.35 mg/kg), and Mn (0.55 mg/kg). The results further indicated that the concentrations of these available micronutrients decreased significantly with increasing soil depth. The study highlights the importance of assessing the bioavailable micronutrient status of wetland soils to better understand their health and guide conservation efforts. These findings provide valuable information for wetland management, emphasizing the need for regular monitoring to maintain their functionality and sustainability for agricultural use.

Keywords: Available micronutrients, Wetland soils, Soil depth, Spatial variability, Southern Nigeria

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1. Introduction

Recently, the use of wetlands for agricultural purposes has risen dramatically in almost every section of the world, particularly in developing countries (McCartney et al., 2010). This is because wetlands provide necessary support and supplement upland soils, where productivity, crop yields, and economic values have dropped drastically due to misuse, incorrect management, soil erosion, and degradation (Ogban et al., 2011). The increase in wetland utilization could also be attributed to global climate change, which poses serious threats to upland cultivation, whereas cropping conditions in wetlands are often more suitable and favorable due to adequate moisture within this ecosystem (Tijani et al., 2012). However, this agricultural intensification can significantly alter wetland soil characteristics. Inland depressions, floodplains, and coastal plains have all been linked to the presence of wetland soils in Nigeria (Fasina, 2005). While wetlands are essential for the biosphere's life support systems, they are suffering severe degradation as a result of increased human activity (Dar et al., 2022).

As anthropogenic activities continue to expand, the disturbance of the earth's ecosystem to generate food and fiber will place a greater demand on soils to supply essential nutrients, including micronutrients. Intensive and continuous cropping for increased yield can significantly deplete soil nutrient pools (Lal, 2001). Land management failure has resulted in a decline in soil physico-chemical and microbiological parameters, which aggravates crop yield reduction and food insecurity (Lal, 2001).

The dynamics of soil micronutrients such as Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), and Nickel (Ni) are of particular importance. These elements, though required in small quantities, are vital for various plant biochemical processes, including chlorophyll synthesis, enzyme activation, and photosynthesis (Alloway, 2008; Marschner, 2011). However, because of their very low abundance, micronutrients are highly sensitive to surrounding environmental factors such as soil pH, organic matter content, and redox potential, which profoundly influence their bioavailability and behavior in ecosystems (N'guessan et al., 2009). Consequently, deficiencies in these elements can limit crop production, while high concentrations or contamination can pose ecological risks, a problem of growing global concern due to their multiple sources and diverse effects on ecosystems (Sheppard et al., 2009).

To understand the soil's inherent capacity to supply these elements to crops and to contribute to the demand for eradicating hunger by 2030 through sustainable food production, studies on the transformation and dynamics of available micronutrients within soil layers across a landscape are deemed essential (United Nations, 2012). Hence, this study aimed to assess and compare the available micronutrient status of two contrasting wetland soils in the southern region of Nigeria, providing a baseline for their sustainable management.

2. Materials and Methods

2.1. Experimental Sites Description

The research was conducted on wetland (Fadama) soils in two different sites in Nigeria, Akure and Abakaliki, in the upland rainforest and derived savannah agro-ecological zones respectively.

2.2. Akure Site

Akure is located in Ondo State, in the southwestern part of Nigeria; lies in the rainforest belt of the tropics between geographical coordinates of 07°15'N and 05°12'E and an altitude of roughly 376.58 meters. The study was carried out at three distinct locations of fadama soil within the Akure metropolis, each of the locations were 100 meters apart. Akure which is a rainforest agro-ecological zone with a flat topography has a bimodal rainfall pattern with wet and dry seasons varying from 1150 to 2550 mm. The two distinct season come up between November and March and between March and November respectively with double maxima rainfall occurring in July and September. The dry season is characterized with high temperature. The coldest months are December and January, with temperatures reaching 34 °C and an annual mean temperature of around 25 °C and the soils in Akure are typically alfisols.

2.3. Abakaliki Site

Abakaliki metropolis on the other hand is the capital of Ebonyi state in South-Eastern region of Nigeria with geographical coordinates of 06°04'N and 08°65'E in the derived savannah zone. The soils in Abakaliki are typically ultisols. Abakaliki has a surface area of around 5670 square kilometers and a population of approximately 141,438 people (NPC, 2006). The location has a rather high temperature range of 27 °C to 31 °C. The rainfall pattern is bimodal (April-July) and (September-November) with an August break. Three wetland soils were located in Abakaliki. These locations are characterized by hydrophytic vegetation, and hydric soils with water at or near the surface for most of the growing season. The soils are saturated long enough to support plants that grow well in wet environment such as rice and vegetables.

2.4. Soil Sampling Procedures

A reconnaissance tour was performed to the study sites in order to identify and choose research sites. The study site's altitudinal range and geographical coordinates were determined using a Global Positioning System (GPS). The soil samples were collected during the dry season at three depths of 0-15 cm, 15-30 cm, and 30-45 cm, respectively, from an established three wetland soils for each study site in Akure and Abakaliki. A total of 54 soil samples using soil auger and other relevant tools were collected. These collected soil samples were air-dried, carefully crushed to decrease heterogeneity, then put through a 2 mm sieve to obtain fine earth separates. Soil samples were collected for each location within the sites at three soil depths of 0–15 cm, 15–30 cm and 30–45 cm respectively. Each location's samples were labeled and preserved in polythene bags before being brought to the University laboratory for proper soil examination.

2.5. Micronutrients Laboratory Analysis

A representative sample of each of the soil samples collected was analyzed for available (extractable) micronutrients. The concentrations of Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), and Nickel (Ni) were determined using the 0.1 M Hydrochloric Acid (HCl) extraction method as described by Ojo-Atere et al. (2011). Following this procedure, 5 grams of each 2 mm sieved air-dried soil sample were weighed into a 100 ml plastic container. Then, 50 ml of 0.1M HCl was added. The mixture was shaken for 30 minutes and subsequently filtered using Whatman No. 42 filter paper. The concentration of the micronutrients in the filtrate was determined using an Atomic Absorption Spectrophotometer (AAS).

2.6. Statistical Analysis

Soil data were subjected to analysis of variance (ANOVA). For statistically different parameters ($P<0.05$), means were separated using Tukey's Test at 5 % probability (Genç and Soysal, 2018).

3. Results

3.1. Main Effects of Sites on Selected Micronutrients in Two Contrasting Wetland Soils

There was a significant difference between the two sites. This indicates that the Akure and Abakaliki sites had significant effects on the concentration of the available (extractable) forms of the selected micronutrients in the two contrasting wetland soils of southern Nigeria. According to the results from (Figure 1), Akure soil had higher concentrations of available Fe, Zn, Cu, Ni, and Mn with values 104.68 mg/kg, 0.21 mg/kg, 0.40 mg/kg, 0.14 mg/kg, and 0.80 mg/kg, respectively, compared to Abakaliki soil with values 44.61 mg/kg, 0.05 mg/kg, 0.26 mg/kg, 0.35 mg/kg, and 0.55 mg/kg, respectively.

3.2. Main Effects of Locations on Selected Micronutrients in Two Contrasting Wetland Soils

Data collected on the effects of locations on soil micronutrients are given in (Figure 2). There were significant differences in soil micronutrient status amongst the three different locations. Fe, Zn and Ni were significantly (P<0.05) higher in location C than in location A and location B. in contrast, location B recorded significantly higher amounts of Cu than location A and location C. However, location A was found to be significantly higher with Mn than location B and location C respectively.

3.3. Main Effects of Depths on Selected Micronutrients in Two Contrasting Wetland Soils

There were significant differences in soil micronutrients status as affected by soil depth (Figure 3). All selected micronutrients decreased in order of increasing soil depth.

3.4. Interaction Effect of Sites By Locations on Selected Micronutrients

There were significant interaction effects between sites and locations on the different soil micronutrients as seen in (Figure 4). The significant interaction effects observed were both in magnitude and direction of response. For example selected micronutrients such as Fe, Zn and Cu respectively was higher at location A, location B and location C in Akure than in Abakaliki, but a reverse trend occurred at Abakaliki where Ni and Mn were in the three locations except in Akure, at location A where Mn is higher. Fe was found to be significantly the highest at Akure, location C, whereas it was lowest at Abakaliki in location C. At location C in Akure, Zn was found to be significantly higher than that recorded for Abakaliki in location C where the lowest Zn was found. The significantly highest amount of Cu was recorded in Akure at location C in Abakaliki and lowest was observed in Akure at location C. For Mn, Akure at location A recorded the highest amount of Mn while the lowest was observed in Abakaliki location B.

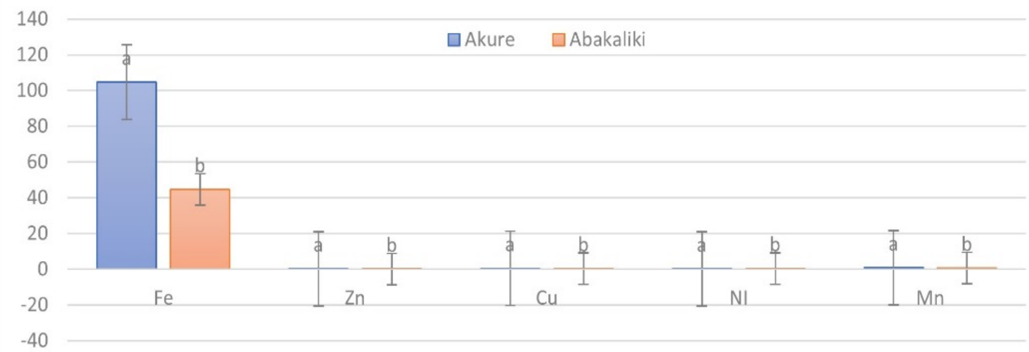

Figure 1. Main effect of sites on some selected micronutrients of two contrasting wetland soils in southern Nigeria.

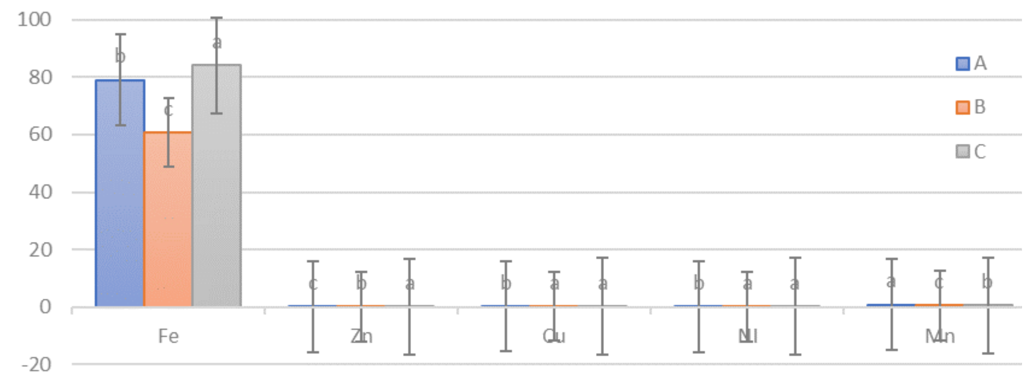

Figure 2. Main effect of locations on some selected micronutrients of two contrasting wetland soil in southern Nigeria.

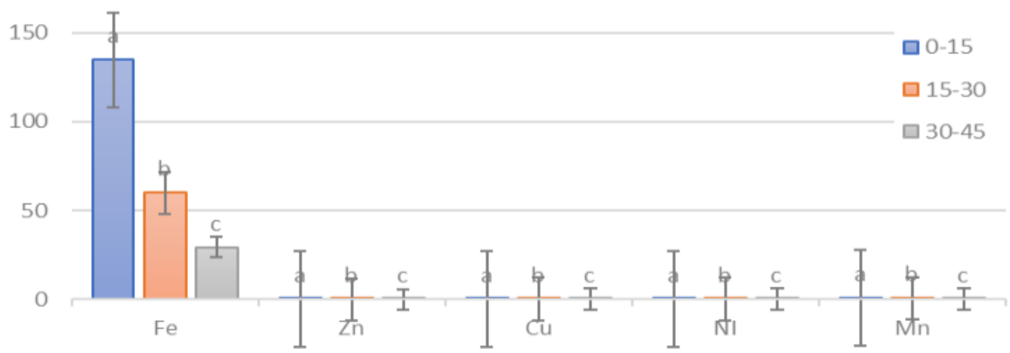

Figure 3. Main effect of depths on some selected micronutrients of two contrasting wetland soil in southern Nigeria.

3.5. Interaction Effect of Sites By Depths on The Selected Micronutrients

There were significant variations amongst sites by soil depths interaction effects on the selected micronutrients (Figure 5). The significant and diverse interaction effects recorded were both in magnitude and direction of response. All the micronutrients: Fe, Zn, Cu, Ni and Mn respectively were found to be significantly the highest at 0-15 cm soil depth in Akure and it was equally observed that the micronutrients parameters decreased with increasing depths at the Akure site, except for Fe where there was irregularity in the trend of movement. The same trend observed in Akure site was observed in Abakaliki site, where Fe, Zn, Cu and Mn decreased with increasing depths and were significantly highest at 0-15 cm soil depth respectively, but Ni was significantly the highest at 30-45 cm soil depth.

3.6. Interaction Effect of Locations By Depths on Some Selected Micronutrients

There were significant locations by soil depth interaction effects on selected micronutrients status as given in (Figure 6). The significantly highest Fe, Zn, Cu, Ni and Mn respectively were recorded at 0-15 cm soil depth in each of the locations. The results indicates that micronutrients parameters for each location decreased with depths.

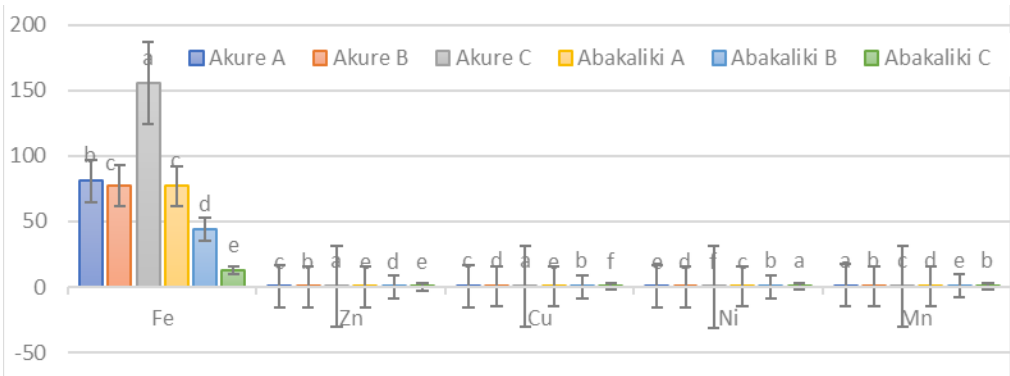

Figure 4. Interaction effect of sites by locations on some selected micronutrients of two contrasting wetland soil in southern Nigeria.

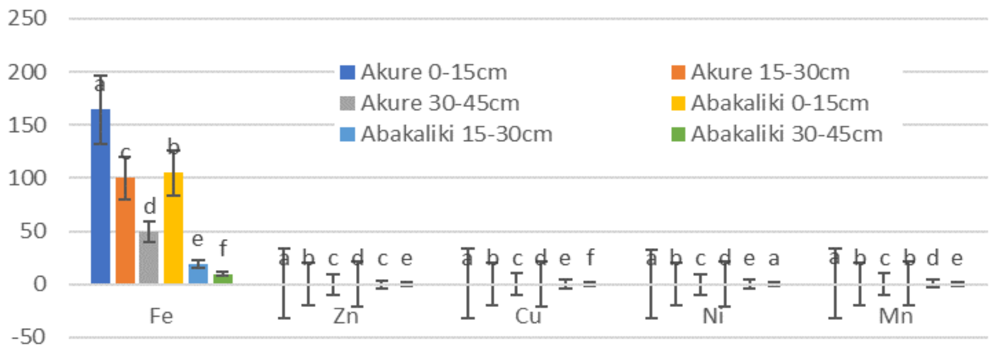

Figure 5. Interaction effect of sites by depths on some selected micronutrients of two contrasting wetland soil in southern Nigeria.

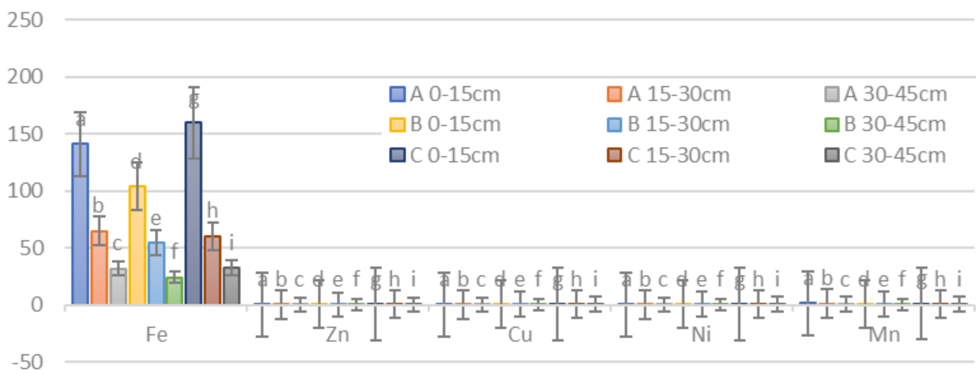

Figure 6. Interaction effect of sites by depths on some selected micronutrients of two contrasting wetland soil in southern Nigeria.

Table 1. Mean concentrations of selected available micronutrients as influenced by site, location, and depth in two contrasting wetland soils in southern Nigeria

Source of Variation	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Mn (mg/kg)
Site					
Akure	104.68 a	0.21 a	0.40 a	0.14 b	0.80 a
Abakaliki	44.61 b	0.05 b	0.26 b	0.35 a	0.55 b
Mean	74.65	0.13	0.33	0.25	0.68
Location					
A	79.08 b	0.07 c	0.31 b	0.21 b	0.90 a
B	60.78 c	0.11 b	0.34 a	0.26 a	0.53 c
C	84.08 a	0.21 a	0.32 a	0.26 a	0.58 b
Mean	74.65	0.13	0.32	0.24	0.67
Depth					
0-15 cm	134.65 a	0.28 a	0.42 a	0.33 a	1.02 a
15-30 cm	59.89 b	0.07 b	0.29 b	0.23 b	0.63 b
30-45 cm	29.39 c	0.04 c	0.27 c	0.17 c	0.37 c
Mean	74.64	0.13	0.33	0.24	0.67
P(F-Test)					
Site(s)	*	*	*	*	*
Location	*	*	*	*	*
Depth	*	*	*	*	*
Site × Location	*	*	*	*	*
Site × Depth	*	*	*	*	*
Location × Depth	*	*	*	*	*
Site×Location×Depth	*	*	*	*	*

Tukey's Test at p≤ 0.05 shows that means followed by the same letter are not significantly different from one another, NS= not significant, *= significant.

3.7. Interaction Effect of Sites By Location By Soil Depths on Selected Micronutrients

The results of three-way analysis of variance as presented in Table 1 indicate that there were significant interaction effect of sites by locations by soil depths on all the selected soil micronutrients status. According to the results in the table, Akure site recorded higher amounts of Fe, Zn, Cu, Ni and Mn respectively than that of Abakaliki site. Also, location C was observed to have higher values of Fe, Zn, Cu and Ni except for Mn where the highest amount of Mn was fpound to be significantly highest at location A. More so, as for depths, Fe, Zn, Cu, Ni and Mn respectively, were all found to be significantly highest at depth 0-15 cm.

4. Discussion

Analysis of available soil nutrients is crucial as it plays a pivotal role in determining the actual nutrient supply for crops and their suitability for cultivation. Several studies have emphasized the importance of these bioavailable nutrients for optimal plant growth and development (Alloway et al., 2008). Zinc (Zn) is required for chlorophyll function and aids in photosynthesis (Marschner, 2011). Copper (Cu) serves as a cofactor for numerous enzymes engaged in critical plant activities and participates in electron transfer within respiratory and photosynthetic systems. Copper is also required for the production and proper functioning of chlorophyll (Marschner, 2011). Manganese (Mn) participates in photosynthesis, is a component of antioxidant enzymes, and increases the uptake and utilization of other critical minerals (Marschner, 2011). Iron (Fe), which is required for the formation of chlorophyll, is also involved in a variety of enzymatic activities as well as the absorption and transport of other nutrients (Marschner, 2011).

The analysis of the available concentrations of these micronutrients including Iron (Fe), zinc (Zn), copper (Cu), nickel (Ni), and manganese (Mn) in soil samples from Akure and Abakaliki revealed significant variations. In Akure, the concentrations of available Fe, Zn, Cu, Ni, and Mn varied significantly among the different soil depths (0-15 cm, 15-30 cm, and 30-45 cm) and locations (A, B, and C). Similar variations were observed in Abakaliki across the different soil depths and locations. When comparing the two sites, it appears that the concentrations of all plant-available micronutrients determined are higher in soil samples collected from Akure than from Abakaliki. This could be a result of the fact that soils in Akure are generally formed from the weathering of igneous and metamorphic rocks that are rich in iron and aluminum oxides. They are mostly referred to as lateritic soils (Ogundele et al., 2021) and contain micronutrients like zinc, copper, and manganese which can be more readily released into available forms. According to (Olawuyi, 2018), Abakaliki soils, on the other hand, are formed from sedimentary rocks that are typically lower in available micronutrients.

Analysis of soil depth is also important as it plays a crucial role in determining the growth and productivity of crops. The depth of the soil profile has a direct impact on the availability of important nutrients, water retention capacity, and root development, all of which are critical for good crop growth (Brady and Weil, 2020). The availability of nutrients to plants is one important factor impacted by soil depth. Different nutrients are distributed unevenly across the soil profile, with some concentrating in the topsoil and others deeper in the subsoil (Brady and Weil, 2020). The topsoil, typically the top 0-30 cm, is high in organic matter and nutrients, making it a perfect habitat for root growth and nutrient uptake. According to our findings, the depth of 0-15 cm had the highest concentrations of available micronutrients, and these available micronutrients declined with depth. This could be because organic matter concentrations are higher at the 0-15 cm depth. Organic matter, when decomposed, can release micronutrients into the soil in plant-available forms (Oldfield et al., 2019); also, as you go deeper into the soil, organic matter decreases, which is why the lowest concentrations of available micronutrients were reported at 30-45 cm.

The variations revealed in the concentration of these available minerals analyzed in Akure and Abakaliki locations have implications for crop suitability and can influence the selection of crops for cultivation. Considering the specific available nutrient requirements of different plant species is essential for maximizing crop productivity and ensuring nutrient adequacy.

5. Conclusion

This study assessed the available forms of essential micronutrients Iron (Fe), Zinc (Zn), Copper (Cu), Nickel (Ni), and Manganese (Mn) in the wetland (Fadama) soils of Akure and Abakaliki in southern Nigeria. The status of these available micronutrients varied significantly between the two locations. The wetland soils in Akure were found to have a higher concentration of most available micronutrients compared to the wetland soils in Abakaliki. Specifically, the concentrations of available Fe, Zn, Cu, Ni, and Mn were higher in the Akure soils, with values of 104.68 mg/kg, 0.21 mg/kg, 0.40 mg/kg, 0.14 mg/kg, and 0.80 mg/kg, respectively. In contrast, the Abakaliki soils had lower concentrations, with values of 44.61 mg/kg, 0.05 mg/kg, 0.26 mg/kg, 0.35 mg/kg, and 0.55 mg/kg, respectively.

Significant variations were also observed based on sampling locations within these sites and with soil depth. A consistent trend was found where the concentrations of these plant-available micronutrients decreased significantly with increasing depth, being highest in the topsoil (0-15 cm). This indicates that the wetland soils in Akure possess a greater inherent capacity to supply these essential elements to plants, suggesting better soil health and fertility for sustaining agricultural productivity under current conditions.

Based on the findings, it is suggested that additional research be conducted to assess the impact of specific land use practices on the availability of these micronutrients in wetland soils. Further investigation is also needed to determine the underlying causes of the disparities in available micronutrient characteristics, which could be linked to parent material, land use methods, vegetation cover, hydrological patterns, and soil management approaches.

For agricultural practitioners, we recommend that the availability of these nutrients be specifically assessed prior to cultivation in these contrasted wetland soils. Such assessments can provide accurate information on the soil's fertility status and aid in the development of targeted nutrient management strategies, such as tailored fertilizer applications, to optimize crop productivity and ensure sustainable agricultural practices in these vital ecosystems.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	O.E.J.	I.U.E.	K.O.L.
C	50	30	20
D	100		
S		100	
DCP	50	40	10
DAI	100		
L	60	30	10
W	50	40	10
CR		100	
SR		100	
PM	100		
FA	50	40	10

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

Acknowledgment

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