ДЕЙСТВИЕ РАЗЛИЧНЫХ ПОЧВЕННЫХ МЕЛИОРАНТОВ НА СВОЙСТВА ПОЧВЫ, ЗАГРЯЗНЕННОЙ СЫРОЙ НЕФТЬЮ, И РАЗВИТИЕ КУКУРУЗЫ

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Влияние различных почвенных мелиорантов на почвы, загрязненные сырой нефтью и выращивание кукурузы было изучено в в Егбема, штата Имо в Нигерии. Эксперимент был заложен в сосудах по полностью рендомизированной схеме в трех повторениях. Были использованы 18 сосудов, в которых поместили по 9 кг почвы. Загрязнение (разлив нефти) имитировали, добавив к почве в каждом сосуде 22,5 г (5 т/га) сырой нефти, за исключением контрольного сосуда (нулевое загрязнение). Всего было 6 вариантов опыта: NPK 20:10:10; измельченная известь ($CaCO_3$); твердый навоз коров (CD); твердый птичий помет (PM), которые вносили одинаково по 13,5 г (3 т/га) исключая варианты контроль (Ct) и неисправленное загрязнение (UP). Процентное содержание органического углерода определяли три раза после мелиорации. В каждый сосуд были высажены по два семени кукурузы (Oba II). В опыте контролировали прорастание, высоту растений, время выметывания метелки, фаза вымётывания пестичных столбиков и урожай. Почва – супесчаная, умеренно высокой пористости. Грансостав не подвержен влиянию загрязнения сырой нефтью; но химические свойства почвы оказались затронутыми. Процентное содержание органического углерода после загрязнения быо высоким, pH снизился, а отношение C/N расширилось. LSD при 5% вероятности, показало, что загрязнение сырой нефтью затрагивает состав основных катионов в почве, особенно магния. Мелиорация, однако, вызвала снижение процентного состава органического углерода, сужение отношения C/N и увеличение содержания основных катионов и pH. Характеристика растений кукурузы в этих исследованиях показала положительное влияние мелиорантов, использованных на загрязненной почве по сравнению с контролем и немелиорированной почвой. Вариант с NPK показал более высокий уровень мелиорации чем другие варианты. Урожай был таким – 47 т/га для NPK, 24 т/га для извести, 20 т/га для навоза, 29 т/га для птичьего помета, затем 20 и 18 т/га для контроля и немелиорированного загрязнения.

***Ключевые слова**: воздействие, почвенный мелиорант, загрязнение сырой нефтью, характеристика, кукуруза.*

IRON, ZINC, COPPER AND MANGANESE AVAILABILITY IN FOUR CONTRASTING HYDROMORPHIC SOILS OF EGBEMA, SOUTH-EASTERN NIGERIA

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Trace elements are particularly sensitive to surrounding environmental condition which influences their availability and behavior in the ecosystem. The study assessed the availability of four trace elements (Mn, Fe, Cu and Zn) in selected wetland soils of Egbema, Imo State, South-Eastern Nigeria. Six composite soil samples (0-30 cm depth) were collected from the different wetlands (Iyiaba, Omanpe, Orashi and Agbo). Soils were generally acidic (5.27-5.64) with low organic carbon (4.4-7.11 g kg^{-1}) and CEC (2.71-5.79 $Cmol+kg^{-1}$). Omanpe wetland soil contained significantly ($p<0.05$) higher quantity of Fe (43.97 $mgkg^{-1}$) compared to other soils investigated. Also, significantly ($p<0.05$) higher quantity of Cu (0.56 $mgkg^{-1}$) was recorded in Orashi wetland compared to other investigated soils.

***Keywords:** ecosystem, hydromorphic soils, trace element, South-eastern Nigeria*

1. Introduction

Wetlands are complex ecosystems that share a number of properties such as saturated soils for at least some part of the year, generally showing distinct hydromorphic features, and supporting plants adapted to water logged conditions [1]. Scanty information about these soils in Nigeria has led to their mismanagement and unsustainable use. The current awareness of the usefulness of wetland soils necessitates the need for effective survey of these soils for sustainable land use. The need for a holistic understanding of the availability of some vital trace elements in wetland soils of South-eastern Nigeria cannot be overemphasized, especially in the light of the devastating soil degradation and food insecurity that now bedevil the region. Micronutrients deficiencies in soils are wide spread in a number of countries including Nigeria [2]. Many trace elements have been classified as essential trace elements required by plants for normal and healthy growth, and include the transition metals manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn), as well as boron (B) and molybdenum (Mo). However, within particular locations, local pedogenic and hydrological factors appeared to influence the total concentration of trace elements in soils and their bioavailability to plants [3]. Frequent and prolonged water saturation of wetland soils give rise to biogeochemical processes different from those occurring in aerated soils due to a decrease or loss of molecular oxygen, whose diffusion in aqueous media is low [2]. Because of their very low abundance, trace elements are particularly sensitive to surrounding environmental conditions, which influence their physico-chemical speciation and their behaviour in the ecosystems [4]. High concentrations or contaminations of trace elements in agricultural soil are becoming an issue of global concern due to their multiple sources, distribution and diverse effect on the ecosystems [5, 6].

Therefore, the evaluation of the concentrations of trace element in soil would be helpful for the sustainable use of arable land and the improvement of human health. In light of this, it was investigated the availability of iron, copper, zinc and manganese in some hydromorphic soils of Egbema, South-eastern Nigeria.

2. Materials and Methods

2.1. Study Area

The investigations were carried out in Nmahu in Egbema Local Government Area of Imo State, South-eastern Nigeria. It is located between Latitudes 5°33'N and 5°58'N and longitude 6°50'E and 6°59'E. It has a humid tropical climate with an average annual rainfall ranging from 1750 to 2500 mm, annual temperature range from 26°C to 31°C and high relative humidity (above 80%) during the rainy season [7]. The study sites were wetlands which include Orashi, Agbo, Omampe and Iyiaba. These sites 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 environments such as rice and vegetables. Soils of the area are derived from coastal plain sand (Benin Formation) and Alluvium deposit. Egbema has typical rainforest vegetation with a variety of plant types. As agriculture and fishing are major socio-economic activities of the area, about 70 % of the total area is used as cultivated land. Slash-and-burn technique has been the major method of land clearing, whereas bush fallow is a soil fertility regeneration practice that has prevailed for over 10 decades, though very few of the farmers use inorganic fertilizers.

2.2. Field Study

A reconnaissance visit was made to the surveyed area prior to the field study. Four wetlands (hydromorphic soils) namely Orashi, Agbo, Omanpe and Iyiaba were randomly selected. Six (6) soil samples (0-30 cm) were collected using soil auger in each of the sites. A total of twenty four (24) soil samples were collected. Undisturbed soil samples for determination of bulk density were collected using core samplers.

2.3. Laboratory Soil Analysis

Bulked soil samples collected were air-dried, gently crushed and passed through 2 mm sieve to obtain fine earth separates. The processed soil samples were analyzed for some physical and chemical properties following procedures outlined by Soil Survey Staff, [8]. The trace elements (Zn, Mn, Fe, Cu) content of the soils were extracted using the procedures of Onyeonwu [9] and Atomic Absorbance Spectrophotometer (AAS) (Buck Scientific model 210 VGP USA) was used to determine the amount of the individual trace element in soil solution.

2.4. Data Analysis

Soil data were subjected to analysis of variance (ANOVA). For statistically different parameters ($p < 0.05$), means were separated using Least Significant Difference (LSD). Correlation analyses were conducted to detect the functional relationships among soil variables.

3. Results and Discussion

3.1. Physical Properties of Soils

Results of the physical properties of the soils are presented in Table 1. Significantly ($p<0.05$) highest sand fraction (796.27gkg^{-1}) was recorded in Omanpe wetland compared to Agbo (736.27 gkg^{-1}), Iyiaba (682.93 gkg^{-1}) and Orashi (382.93 gkg^{-1}). Clay fraction (450.93 gkg^{-1}) was significantly ($p<0.05$) higher in Orashi than other soil groups investigated. Soil texture has earlier been defined as a near permanent attribute of the soil and hardily does it easily change due to land use, management or conservation. The bulk density was at values (mean ≥ 1.21 gcm^{-3} ≤ 1.33 gcm^{-3}) that will allow vigorous growth of plant roots and soil organisms. Significantly ($p<0.05$) highest bulk density (1.31 gcm^{-3}) was recorded in Agbo compared to 1.20, 1.18 and 1.09 gcm^{-3} recorded in Omanpe, Orashi and Iyiaba. Lower values of bulk density of the soils also indicated greater pore space and improved aeration thus creating a good environment for biological activity [10]. Moisture content of the soils ranged from 63.13-149.67gkg^{-1} and was optimum for the performance of most tropical crops. Water availability is reported to be one of the most important environmental parameters controlling plant performance [11].

Table 1

Mean values of the physical properties of soils (n = 24)

Location	Sand	Silt	Clay	Silt/Clay	TC	BD,	TP,	MC,
		g kg^{-1}				g cm^{-3}	%	g kg^{-1}
Iyiaba	682.93	146.13	170.93	1.00	SL	1.09	57.86	131.67
Omanpe	796.27	26.13	177.60	0.22	SL	1.20	53.00	63.13
Orashi	382.93	166.13	450.93	0.41	CL	1.18	54.00	84.50
Agbo	736.27	102.80	160.93	0.64	SL	1.31	56.63	149.67
LSD(0.05)	98.10	40.37	109,00	0.64	-	0.16	11.07	34.43

TC= Textural class, S= Sand, SL= Sandy loam, LS = Loamy sand, BD = Bulk density, TP = Total porosity, MC= Moisture content

3.2. Chemical Properties of Soils

Results of the chemical properties of the soils are shown in Table 2. The pH values of the soils ranged from 5.27 in Omanpe to 5.64 in Agbo. Soil pH is the key factor for the availability of essential plant nutrients [12]. The pH values in water suspension were higher than corresponding values in 1N KCl solution, indicating that all the soils at their natural pHs are negatively charged [13]. Also, the base (KCl) must have precipitated more acidity in the soil solution. Recommendations of fertilizers for controlling proneness of the soils of the location to acidity must be based on the results from the pH in KCl to ensure that reserved acidity in the soil solution will be taken care of.

Table 2

Chemical properties of the soils (n = 24)

location	pH	pH	Av. P	Oc	TN	Ca	Mg	K	Na	TEA	TEB	CEC
	(w)	(KCl)	mgkg-1	gkg-1	gkg-1	Cmolkg-1						
Iyiaba	5.56	5.03	6.21	7.11	0.74	2.66	3.37	0.01	0.01	2.31	6.05	3.23
Omanpe	5.27	4.89	11.36	4.32	0.46	2.51	1.83	0.02	0.003	1.81	4.36	3.29
Orashi	5.45	5.02	3.36	4.4	0.9	3.61	3.53	0.02	0.01	11.12	7.17	5.79
Agbo	5.64	5.09	6.91	6.64	0.69	3.83	2.9	0.016	0.03	4.013	6.77	2.71
LSD(0.05)	0.76	0.57	7.78	12.26	0.86	3.56	1.41	0.01	0.04	2.597	4.76	2.72

OC=organic carbon, Oc= organic carbon, TN=total nitrogen, Av. P=available phosphorus, TEA=total exchangeable acidity, TEB=total exchangeable bases, CEC= Cation exchange capacity.

Organic carbon of the soils were generally low (< 2%) [14]. Esu [15] reported organic carbon value of < 10 gkg^{-1} as low in soils of South-eastern Nigeria. However, Iyiaba wetland recorded highest (7.11 gkg^{-1}) organic carbon compared to other soils (Table 2). Sahrawat [16] suggested that soil organic matter accumulates with time in waterlogged soils due to lack of oxygen and other terminal electron acceptors, like Fe^{2+} and $SO4^{2-}$, resulting in inefficient organic matter oxidation at low Eh values. Organic matter influences the availability and mobility of trace elements in soils either by changing the soil pH or by accumulating the free metal ions (cations) on the large negative charge of the organic matter [17].

Total nitrogen of the soils was also low (< 0.1%) [14] and did not vary among the wetland soils studied. However, the highest mean total nitrogen value (0.90 gkg^{-1}) was recorded in Orashi followed by Iyiaba (0.74 gkg^{-1}), Agbo (0.69 gkg^{-1}) and Omanpe (0.46 gkg^{-1}). These values compares well with the report of Olaleye [18] that N is normally deficient in most wetland soils. The low nitrogen contents of the soils may be associated with leaching coupled with intermittent flooding and drying which are known to favour N loss [19].

Total exchangeable bases and the basic cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) of the soils were low. Mean total exchangeable bases value ranged from 4.36-7.17 $cmol_{+}kg^{-1}$ across the wetlands studied. Exchangeable bases are important properties of soil as they relate information on the soil's ability to sustain plant growth, retain nutrients and buffer acid deposition [20].

Also, CEC of the soils were low. Average CEC values varied from 2.71 to 5.79 $cmol_{+}kg^{-1}$. These values were in line with the values reported by Fasina, [21] in some Nigerian soils. According to Chukwuma *et al.,* [22] and Wu *et al.,* [23] increase in cation exchange capacity decreases Cu and Zn availability in soils due to increased nutrient sorption.

3.3. Micronutrient contents of the Soils

Determined the trace element contents of the varying wetland soils are presented in Figs. 1 and 2. Manganese (Mn) content of the soils was low. Iyiaba wetland contained significantly ($p<0.05$) highest quantity of manganese (1.17 $mgkg^{-1}$) than Orashi (0.76 $mgkg^{-1}$), Omanpe (0.17 $mgkg^{-1}$) and Agbo (0.09 $mgkg^{-1}$). However, the manganese content in Iyiaba wetland was in excess of the critical value (1.0 mg/kg) while those of other wetlands were lower.

Mean iron (Fe) contents of the soils were 23.83 $mgkg^{-1}$ in Iyiaba, 27.73 $mgkg^{-1}$ in Agbo, 33.17 $mgkg^{-1}$ in Orashi and 43.97 $mgkg^{-1}$ in Omanpe. However, mean value (43.97 $mgkg^{-1}$) of available iron in Omanpe was significantly ($P \leq 0.05$) higher than other wetlands investigated. However, these values were extremely high compared to the critical value (3.5 $mgkg^{-1}$) reported by Esu *et al*., [24]. Grybos *et al.,* [25] reported the importance of manganese and iron-oxy-hydroxides as major parameters controlling trace element mobility in wetland soils.

The available zinc (Zn) contents of the soils were 0.23 $mgkg^{-1}$ in Agbo, 0.28 $mgkg^{-1}$ in Omanpe, 0.85 $mgkg^{-1}$ in Orashi and 0.93 $mgkg^{-1}$ in Iyiaba respectively. Except for Iyiaba and Orashi, all the soils had values lower than the zinc critical level (0.5 mg/kg).

With exception of Orashi wetland soils, the mean values of available copper (Cu) across the soils were lower than the critical level (0.2 mg/kg). Orashi wetland contained significantly highest proportion of available copper compared to other wetlands. Copper is adsorbed into the soil, forming an association with organic matter, soil minerals, Fe and Mn oxides, thus making it one of the least mobile of the trace elements [26]. This may explain why low values of available copper were recorded in the surveyed areas.

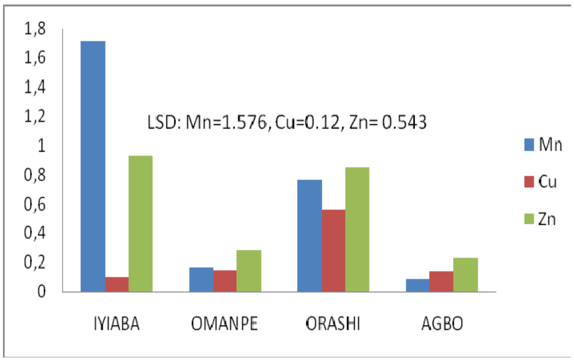

Fig 1. *Distribution of manganese, copper and zinc (mgkg^{-1}) in the soils*

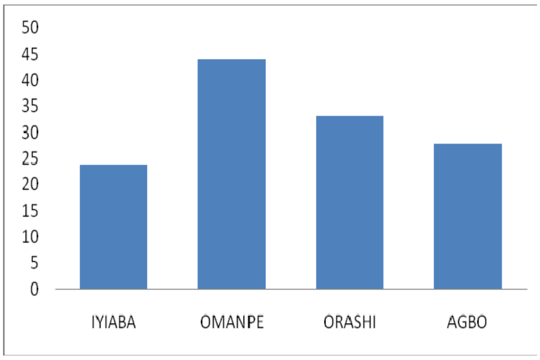

Fig 2. *Distribution of Iron (mgkg^{-1}) in the soils*

3.4. Relationship between Micronutrients and Selected Soil Properties

Determined relationship between each trace element and selected soil properties are presented in Figs 3-6. Thus pH and organic matter content showed negative but non-significant correlation with copper whereas it had positive but significant correlation with clay and CEC (Fig. 3). According to Voss [27], organic matter content decreases copper availability due to strong bonding of copper to organic matter. On the other hand, parameters of organic matter and clay content, CEC and soils pH had positive correlation with manganese and zinc (Figs 4 and 6). However, all the micronutrients had positive, significant correlation with clay fraction and cation exchange capacity of soil. Similar positive significant relationship has been reported to exist between some metals and clay content [28]. The concentrations of iron in soils had negative but significant correlation with parameters of pH and organic matter content (Fig. 5).

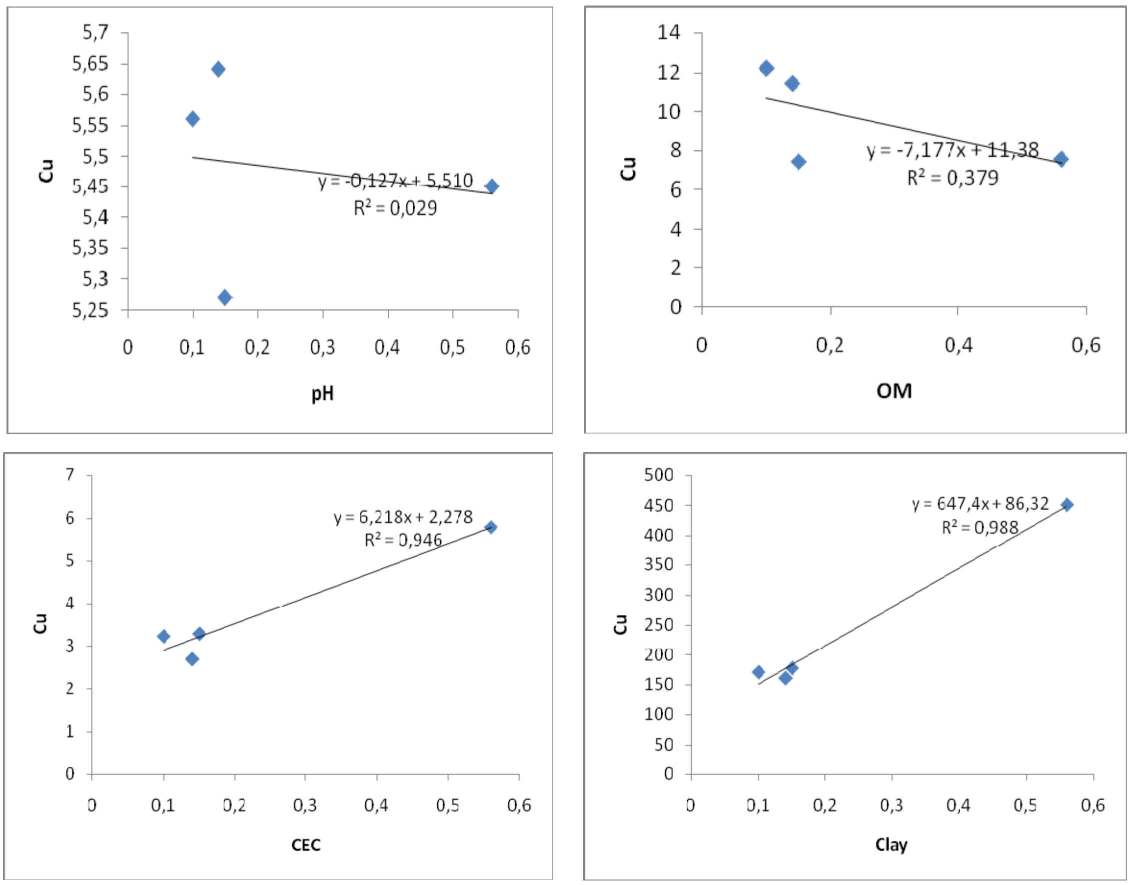

Fig 3. *Relationship between copper (Cu) and some soil properties*

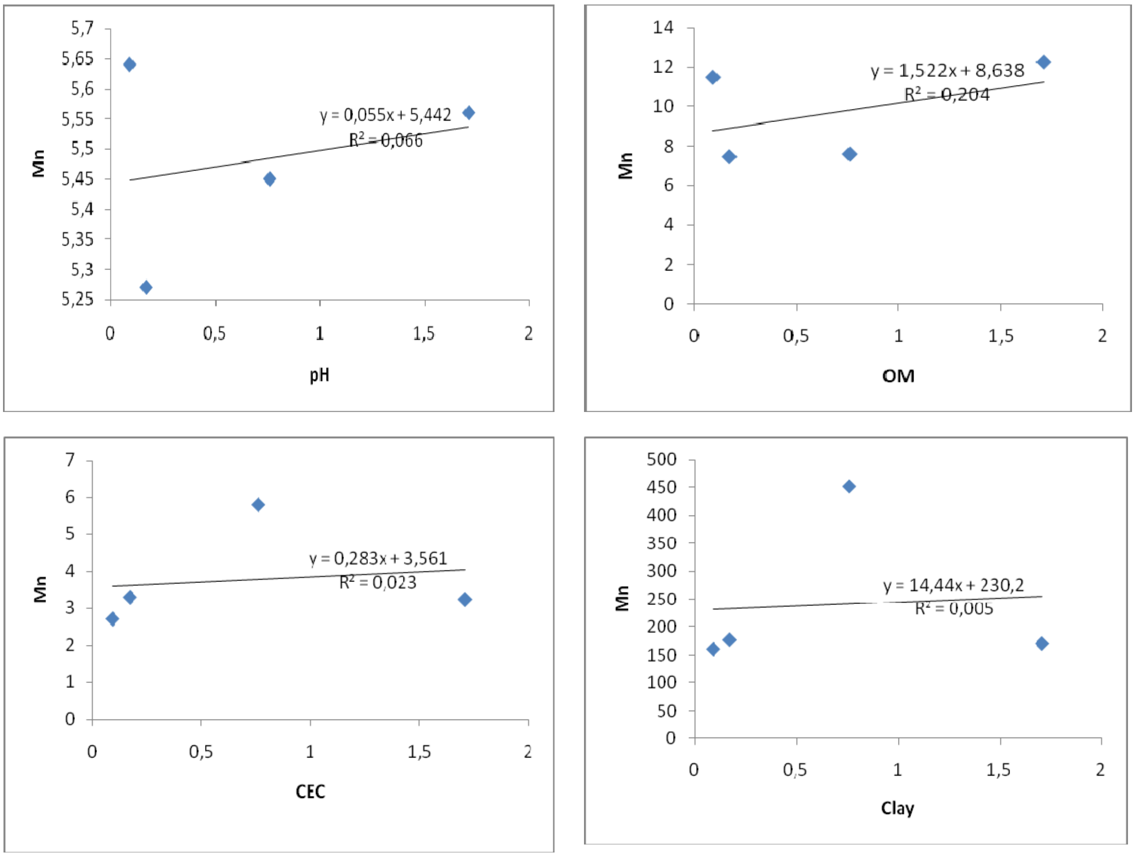

Fig 4. *Relationship between Mn and selected soil properties*

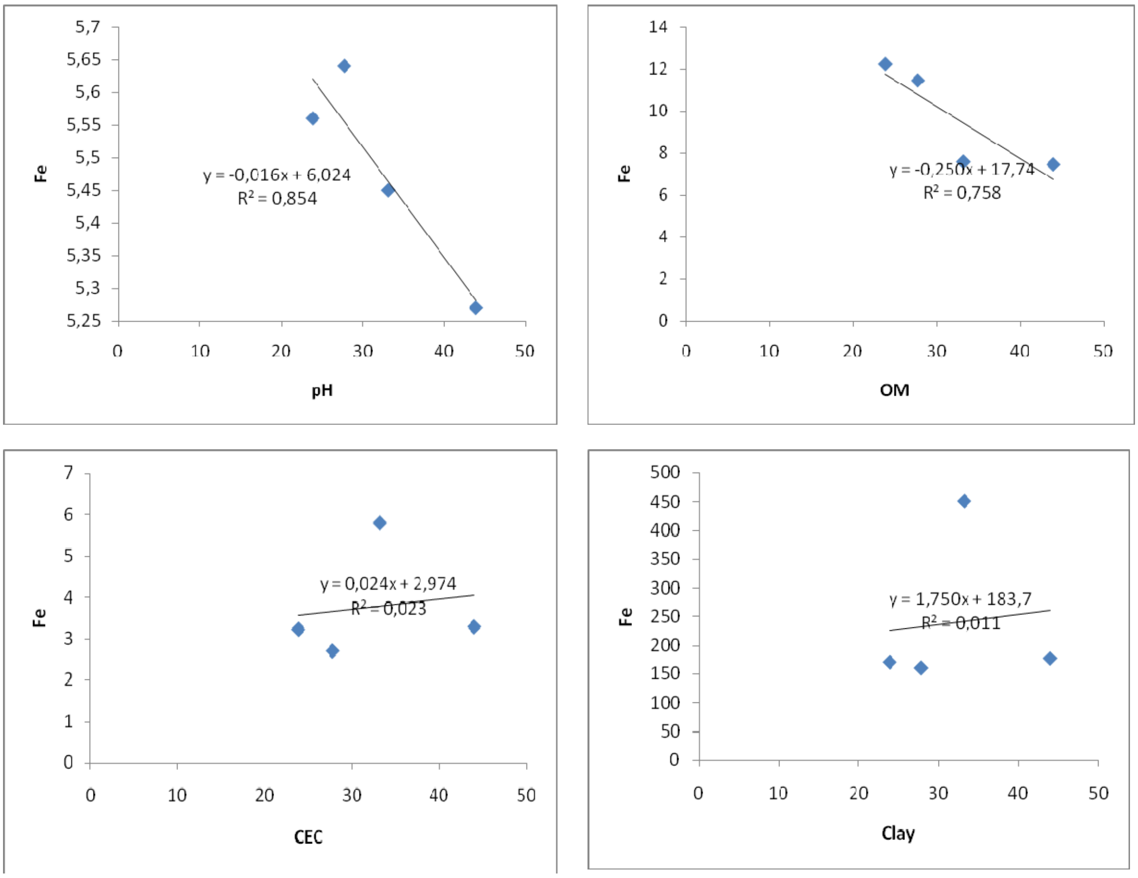

Fig 5*. Relationship between Fe and selected soil properties*

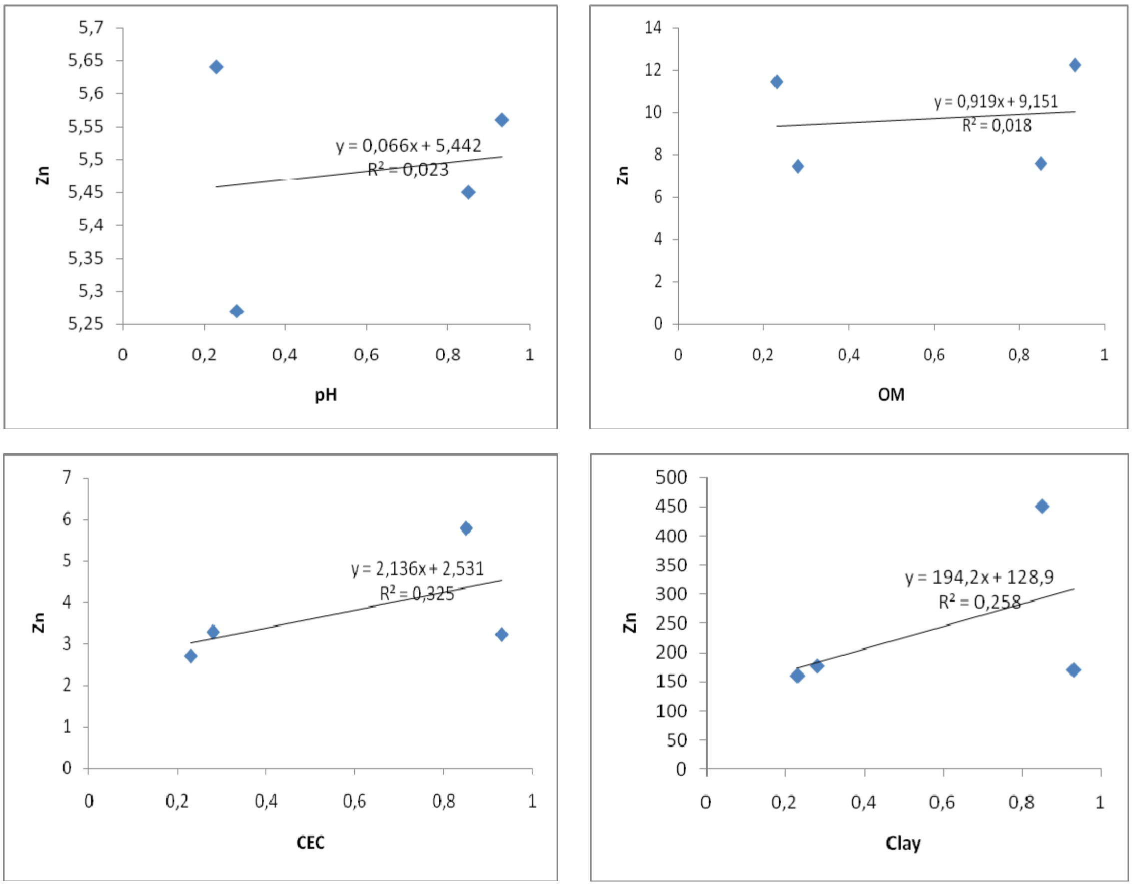

Fig 6. *Relationship between Zn and selected soil properties*

4. Conclusion

The results of the study revealed that the soils were generally acidic, low in exchangeable cations and CEC with low organic carbon and total nitrogen contents. Generally, micronutrient values with the exception of Fe recorded in the study were below critical levels. However, Fe and Cu contents were significantly higher in Omanpe and Orashi compared to other soils. Generally, micronutrients concentration followed decreasing trend of Fe > Mn > Zn > Cu. For optimum soil productivity, micronutrient fertilizer and organic matter application should be adopted .

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НАЛИЧИЕ ЖЕЛЕЗА, ЦИНКА МЕДИ И МАРГАНЦА В ЧЕТЫРЕХ КОНТРАСТНЫХ ГИДРОМОРФНЫХ ПОЧВАХ ЭГБЕМА В ЮГО-ВОСТОЧНОЙ НИГЕРИИ

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Микроэлементы особенно чувствительны к состоянию окружающей среды, которая влияет на их доступность и поведение в экосистеме. В ходе исследования оценивали наличие четырех микроэлементов (Mn, Fe, Cu и Zn) в отдельных болотных почвах Egbema, штат Имо, Юго-Восточной Нигерии. Шесть сложных образцов почвы (0-30 см глубиной) были отобраны на различных болотных угодиях (Iyiaba, Omanpe, Orashi и Agbo). Почвы были, как правило, кислые (pH 5.27-5.64) с низким содержанием органического углерода (4.4-7.11 г/ кг) и CEC (2.71-5.79 Cmol/кг). Заболоченная почва Omanpe содержала значительно ($p < 0{,}05$) большее количество Fe (43.97 mg/kg) по сравнению с другими исследуемыми почвами. Кроме того, было зафиксировано значительно ($p < 0{,}05$) большее количество Cu (0,56 mgkg-1) в заболоченной почве Orashi по сравнению с другими исследуемыми почвами.

Ключевые слова: *екосистема, гидроморфные почвы, микроэлементы, Юго-Восточная Нигерия.*