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NUTRIENT STATUS AND MANAGEMENT OF SOME HYDROMORPHIC SOILS IN RIVERS STATE, NIGERIA FOR SUSTAINABLE CROP PRODUCTION

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AUTHORS' CONTRIBUTIONS

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ABSTRACT

Nutrient status of some hydromorphic soils in Rivers State were studied for their potentials and probable constraints to crop production. A total of one hundred and twenty surface (0-15 cm) and sub-surface (15-30 cm depth) soil samples obtained from ten locations were subjected to routine laboratory and statistical analysis using standard methods. Random sampling technique was employed in the collection of soil samples. Results revealed that the sand component of the soils which ranged from 117 g/kg to 891 g/kg decreased with increased soil depth. The clay and silt fractions ranged from 24 g/kg to 231 g/kg and 28 g/kg to 701 g/kg respectively. The highest sand content was obtained at 0 – 15 cm topsoil. The results showed that nutrient status of some of the soils were low as revealed by their estimated levels of availability. The soils were acidic in reaction. Mean pH values were 4.2 in the surface soils and 3.7 in the subsurface soils. Total nitrogen, calcium, sodium and electrical conductivity were all less than the critical levels in soils but moderate to high in organic matter, available phosphorus, exchangeable potassium, base saturation and micronutrient (Fe and Mn). The main constraints of these soils to sustainable crop production were therefore, the low chemical fertility (high acidity, low exchangeable Calcium and Nitrogen concentrations). However, short season crops (vegetables) can be grown at subsistence level. Ordinarily, fertilizer and lime could be recommended as measures to increase yield of crops, but these inputs are both unaffordable and unavailable at critical periods. Therefore, the farmers are encouraged to harness cheap resources found on the farms such as mulch and bio-fertilizers, to improve soil nutrient status rather than rely on inputs that are normally not accessible.

Keywords: Nutrient status; hydromorphic soils; sustainable crop production.

1. INTRODUCTION

Hydromorphic soils are characterised by an excess of soil water at least for a short period of time [1]. The soil process which operates under such conditions is called gleying process, and these are induced by water saturation if water and soil temperature allow microbial activity. Hydromorphic soils are geographically characterised by impeded drainage or with a seasonal water table within the rooting zone of the vegetation at least for short periods of time [2, 3]. The soils support a wide range of crops, such as banana, early maize, cocoyam, water leaf, tomatoes, spinach (green), okra, fluted pumpkin and cassava [3].

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The soils support any vegetation that tolerates permanent or period wetness. Hydromorphic soils are increasingly becoming important crop-land for dry and wet season farming. During the wet season, it is a more preferred habitat for growing rice, sugarcane and plantains [4]. During the dry season when the floods recede, the soils particularly those situated in urban areas are used for intensive dry season crop production [5,6]. Farms in such sites provide gainful employment to many people during what would have been a slack season. Therefore, the importance of dry season farming on hydromorphic soils cannot be over emphasized, when one considers the significance of these crops in our diet and economy [7].

Hydromorphic conditions in the soil could be found as a result of the presence of slowly permeable or relatively impermeable layer or fine-grained parent materials; and so results in a perched water table [8, 9]. In addition, frequent incidence of very high intensity rainfall, where rainfall intensity exceeded water infiltration rate could cause water build-up over the land surface constituting a hydraulic head, which initiate over-head flow or run-off [10]. Hydromorphic soils are generally coarse textured, with high acidity, organic matter and nitrogen contents vary from low to moderately high, depending on the intensity of water level and duration of water logging which influence the rate of organic matter degradation. The soils are generally low in exchangeable bases particularly potassium and magnesium especially in the coarse deltaic plain soil of flood plain derivatives of sandstorm plant materials [1,11].

The recent decline in agricultural productivity, fertility due to fall in fallow period consequent of population pressure on land has directed attention to marginal lands, amongst which are the wetlands, poorly drained, waterlogged hydromorphic soils. Following the ban on importation of rice, the potentials of these hydromorphic soils which line the coastal fringes and spill-plains of the major rivers are being exploited for paddy rice production. The occurrence of such soils is widespread but much dispersed in Rivers State area.

It has been reported that the Rivers State of Nigeria constitute a good part of the low resources of the country which are at present, marginally utilized. In order to put the hydromorphic soils of the state to substantial agricultural use, evaluation of the soils nutrient status is necessary. According to Fagbami [12], the sustainability of agricultural production system is predicated on proper land use planning for which assessment of the nutrient potentials of the soils is one of the requirements.

The nutrient potentials of hydromorphic soils are not adequately exploited in south-south Nigeria, River State inclusive. Information on nutrient status of hydromorphic soils of the study area is scarce, yet the need to generate soil nutrient data to improve agricultural production exists. Information of this nature is a prerequisite for better soil management. The objective of this study is to evaluate the nutrient status of some hydromorphic soils in Rivers State, highlight their constituents and suggest ways of managing and utilizing this important ecosystem for sustainable crop production.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was carried out in Rivers State, Nigeria. Rivers State is located within longitude 6^05^0-70^050^0 East of the Greenwich meridian and latitude 5^005^0-06^0 North of the equator. The State occupies the low land area of the Niger Delta with dense and thick tropical rainforest vegetation. It is characterized by high atmospheric (ambient) temperature that ranges between 25^0c to 38^0c. Its climate is characterized by seasonal, variable and heavy rainfall which decreases from 4700mm on the coast to about 1700mm in extreme north. The area experiences bimodal pattern of rainfall from April to July and September to November with a short dry spell known as August Break.

2.2 Field Sampling

Simple random sampling technique was employed in the collection of samples. A total of one hundred and twenty surface (0-15 cm) and subsurface (15-30 cm) soil samples were collected from ten locations and used for the study. In each location (Figs. 1 and 2), six samples (approximately 3kg) were taken from randomly chosen hydromorphic soils at each depth with the use of soil auger, the core samples were bulked, thoroughly mixed to get the composite or representative samples and sub-sampled.

2.3 Sample Preparation

Sub-samples collected were air-dried, ground and sieved with a 2 mm sieve to remove particles greater than 2 mm in diameter. The samples were parcelled in polyethene bags, properly labelled and transported to the laboratory for analysis.

2.4 Laboratory Procedures

The physical and chemical analyses were carried out on the less than 2mm soil fractions.

The soil particle size distribution was determined by the hydrometer method using Sodium hexametaphosphate (calgon) as a dispersant. Soil pH in water was determined by means of the pH meter using soil to liquid ratio 1:2.5, according to Maclean (1982).Total organic carbon TOC was determined by Walkley and Black wet oxidation method as outlined by Nelson and Sommer (1982). The TOC is converted to organic matter using the Van Bemmelen factor of 1.724.

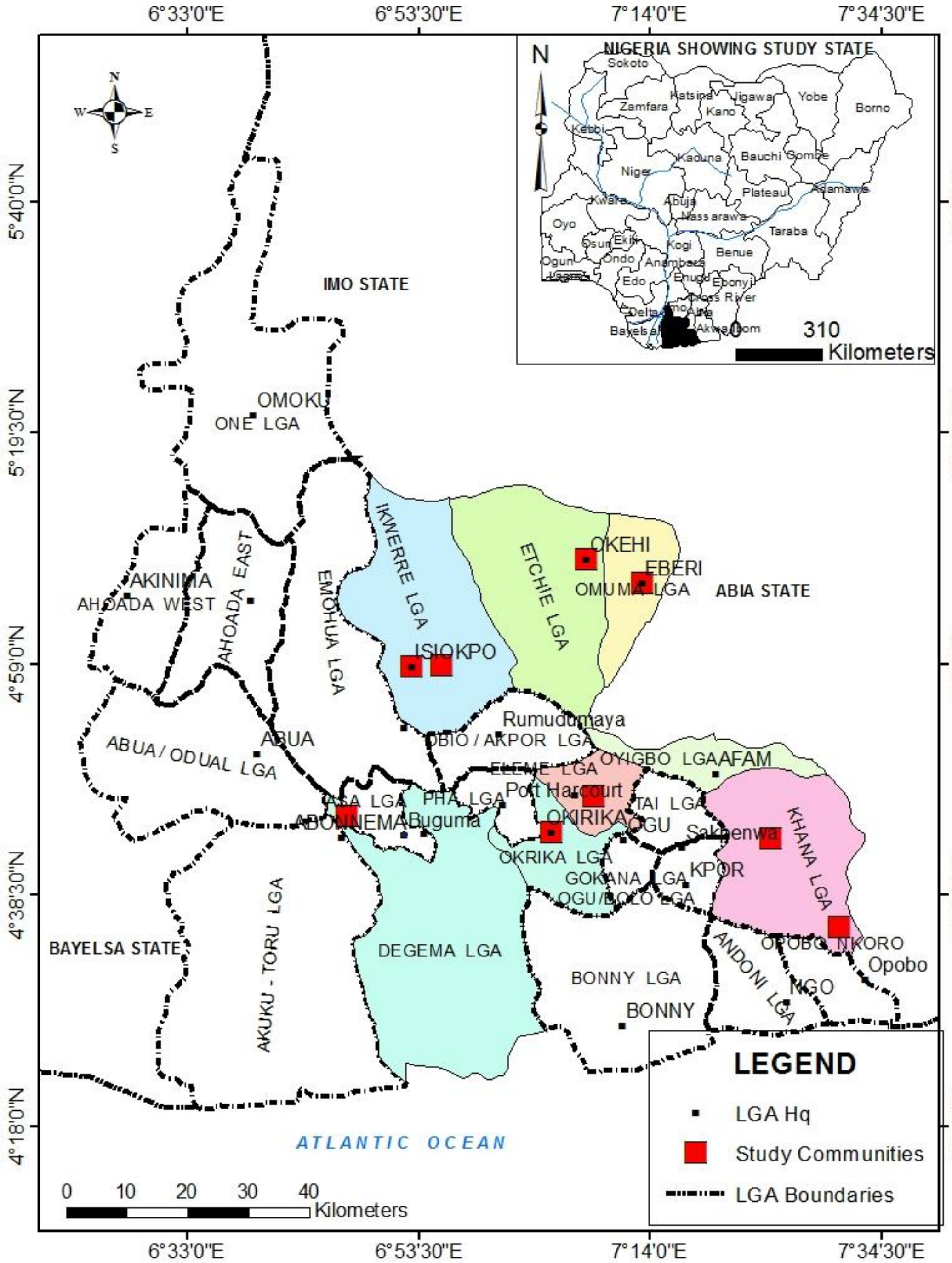

Fig. 1. Map of Rivers State showing the Local Government Areas of study locations

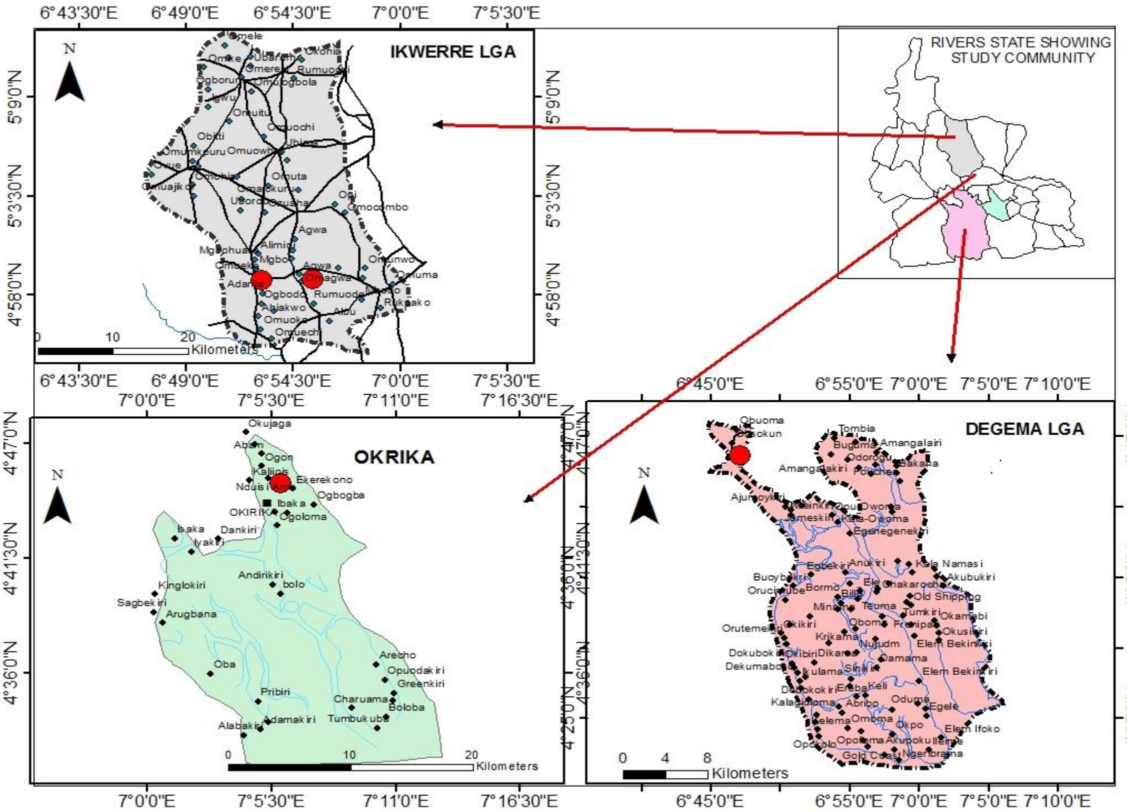

Fig. 2. Map of Ikwerre, Okrika and Degema Local Government Areas indicating sampled locations

Total Nitrogen was determined by Kjeldahl digestion procedures as described by Udo and Oguawale, [13]. Extractable Phosphorus was extracted using Bray and Kurtz II solution (Olsen and Sommer, 1982) and determined by Molybdenum blue method. Exchangeable bases were extracted with neutral normal acetate (NH_4OAc) extraction method. Potassium and Sodium were determined with the Flame photometer while Calcium and Magnesium were done by EDTA complexometric titration method.

Exchangeable acidity was determined in the 1N KCl using 1:10, soil: solution ratio. The amount of exchangeable Hydrogen and Aluminium in the leachate was determined by the titration method as described by Mclean (1982). Effective cation exchange capacity (ECEC) of the soils was determined by summation method of total exchangeable bases TEB and exchange acidity EA.

Base saturation was derived using the formula B.S=$\frac{totalexchangeablebase \times 100}{ECEC}$

Electrical conductivity was determined using the conductivity meter and cell at 1:5 soil: water suspension, to measure electrical resistance. Micronutrient (Mn and Fe): Fe was determined using the spectrometric method as described by Udo *et al*. [13]. Manganese was determined using atomic absorption spectrophometer as described by Praveen, [14].

2.5 Statistical Analyses

Data from laboratory observations were subjected to statistical analysis to determine means, standard deviation and coefficient of variability as outlined by Wilding and Dress, [15] and used in arriving at the inferences.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution and Textural Class of the Soils

The results of particle size distribution; sand, silt and clay content, as well as the textural classes are presented in (Table 1). Sand content ranged from 16.3 to 89.10 with a mean value of 7.52 for surface soils and 11.70 to 79.40 with a mean value of 10.29 for sub surface soils. Silt content ranged from 2.80 to 70.10

Table 1. Particle size distribution and textural class of the hydromorphic soils

S/n	Location	Depth (cm)	clay	silt	sand	Textural class
			←	g/kg	→	
1	**Onne**	0-15	41.0	162.0	797.0	Loamy sand
		15-30	63.0	282.0	654.0	Sandy loam
2	**Degema**	0-15	102.0	701.0	197.0	Silty loam
		15-30	127.0	422.0	471.0	Loam
3	**Kono**	0-15	42.0	69.0	889.0	Sand
		15-30	121.0	316.0	563.0	Sandy loam
4	**Okrika**	0-15	231.0	606.0	163.0	Silty loam
		15-30	160.0	723.0	117.0	Silty loam
5	**Oyigbo**	0-15	177.0	28.0	795.0	Sandy loam
		15-30	163.0	42.0	794.0	Sandy loam
6	**Omuma**	0-15	27.0	358.0	615.0	Sandy loam
		15-30	85.0	428.0	487.0	Loam
7	**Etche**	0-15	42.0	161.0	797.0	Loamy sand
		15-30	61.0	283.0	656.0	Sandy loam
8	**Omagwa**	0-15	25.0	358.0	617.0	Sandy loam
		15-30	82.0	429.0	489.0	Loam
9	**Isiokpo**	0-15	24.0	357.0	619.0	Sandy loam
		15-30	47.0	480.0	473.0	Loam
10	**Bori**	0-15	41.0	68.0	891.0	Sand
		15-30	120.0	315.0	565. 0	Sandy loam

with a mean value of 28.68 for surface soils and 4.20 to 72.30 with a mean value of 37.20 for sub surface soils. Clay content ranged from 2.50 to 23.10 with a mean value of 63.80 for surface soils and 4.70 to 16.30 with a mean value of 52.69 for sub surface soils.

3.2 Nutrient Parameters of the Soils

The results of some nutrient parameters studied are as shown in Table (2 and 3).

3.3 Soil Reaction (pH)

The soil reaction (pH) ranged from 3.3 to 4.9 with a mean value of 4.18 for surface soils and 3.0 to 4.2 with a mean value of 3.74 for sub surface soils. The highest value was recorded at Isiokpo 4.9 with the least value recorded at Kono 3.0. The pH values of the hydromorphic soils are generally acidic while a large portion of the soils may be described as being highly acidic. The parent material forming the soils and marked leaching of the exchangeable bases as a result of high rainfall, contributed to the high acidity of the soils [16]. The exchangeable cations in the soils were predominantly Ca and Mg. The indirect negative fertility effect of leaching Ca and Mg is the rise in the level of exchangeable Aluminium and Hydrogen which is reflected in the low pH of the soils. As soils become more acidic, cations are replaced by H^+, Al^{3+} and Mn^{2+}.

3.4 Organic Matter (g/kg)

The Organic matter (g/kg) ranged from 16.00 g/kg to 33.50 g/kg with a mean value of 24.41g/kg for surface soils and 20.40 g/kg to 41.40 g/kg with a mean value of 30.10 g/kg for sub surface soils. The highest value was recorded at Okrika 41.40 g/kg with the least value recorded at Bori 16.00 g/kg. The lower mean value of organic matter at the surface soils (Table 4) could be due to the regular flooding of the surface soil by means of current carrying organic materials into the source of water and this probably resulted in lower organic matter in the surface soils. The high organic matter in the subsurface soils is as a result of low mineralization due to reduced microbial activities resulting from poor soil aeration and drainage [17]. There is a high variation in the degree of decomposition of the soil organic matter. This is a reflection of the organic carbon content in the soils (Onweremedu, 2008). In comparison with the critical limit of 20g/kg, organic matter established for soils [18], the studied hydromorphic soils are high in organic matter.

3.5 Total Nitrogen (mg/kg)

The Total Nitrogen (mg/kg) ranged from 0.50 mg/kg to 3.80 mg/kg with a mean value of 1.67 mg/kg for surface soils and 0.40 mg/kg to 7.50 mg/kg with a mean value of 2.16mg/kg for sub surface soils. The highest value was recorded at Okrika 7.50 mg/kg with the least value recorded at Kono and Oyigbo 0.50 mg/kg. The total Nitrogen was low in some of the soils, which could be attributed to ineffective microbial decomposition of organic matter in the waterlogged soils. The soil is usually flooded for a period of 6-8 months in a year with a few months of dryness [6]. The values for Nitrogen in some of the soils were below1.5 g/kg, that is, the critical value where response is unlikely and fertilizer may not be necessary [18]. The amount of total Nitrogen on the soils reflects the organic carbon content of the soils.

3.6 Available Phosphorus (mg/kg)

The Available phosphorus (mg/kg) ranged from 1.80 mg/kg to 13.50 mg/kg with a mean value of 8.44 mg/kg for surface soils and 4.10 mg/kg to 14.70 mg/kg with a mean value of 10.18 mg/kg for sub surface soils. The highest value was recorded at Omuma14.70 mg/kg with the least value recorded at Degema 1.80 mg/kg. Most of the hydromorphic soils in the areas investigated had available phosphorus greater than 10mg/kg. With respect to values recorded for Nitrogen and Phosphorus, we consider these soils moderately suitable for crop production in line with FAO [19] recommendation. Soils with phosphorus values below 10mg/kg are generally considered marginally suitable. Nitrogen and Phosphorus are organic matter dependent, as organic matter mineralizes; these elements are released into the soils [3].

3.7 Sodium (Na) Cmol/kg

The sodium (Na) ranged from 0.02 Cmol/kg to 0.40 Cmol/kg with a mean value of 0.12 Cmol/kg for surface soils and 0.03 Cmol/kg to 0.35 Cmol/kg with a mean value of 0.11 Cmol/kg for sub surface soils. The highest value was recorded at Okrika 0.40 Cmol/kg with the least value recorded at Omuma 0.02 Cmol/kg. Exchangeable sodium percentage indicates if soils have sodic properties. The critical level of sodium in soils is 6 Cmol/kg. Results from studied hydromorphic soils shows values far less than 6 Cmol/kg which indicates low sodicity in the soils. Sodic soils are often with poor structural characteristics.

3.8 Potassium (K) Cmol/kg

The potassium (K) ranged from 0.11 Cmol/kg to 1.57 Cmol/kg with a mean value of 0.33 Cmol/kg for surface soils and 0.14 Cmol/kg to 2.27 Cmol/kg with a mean value of 0.57 Cmol/kg for sub surface soils. The highest value was recorded at Bori 2.27 Cmol/kg with the least value recorded at Omuma 0.11 Cmol/kg. Potassium is a key element in the fertilization of both the tree and agricultural crops. It is one of the cations lost in large quantities through leaching. The potassium status in all the study sites appeared to be adequate for plant growth. In most of the soils, the values were greater than 0.2 Cmol/kg [17].

3.9 Calcium (Ca) Cmol/kg

The Calcium (Ca) ranged from 0.21 Cmol/kg to 2.50 Cmol/kg with a mean value of 1.02 Cmol/kg for surface soils and 0.27 Cmol/kg to 5.80 Cmol/kg with a mean value of 2.61 Cmol/kg for sub surface soils. The highest value was recorded at Okrika 5.80 Cmol/kg with the least value recorded at Kono 0.21 Cmol/kg. The content of exchangeable calcium in most soil is low. This is because most of the values obtained were below 4Cmol/kg which is regarded as the lower limit for fertile soils [17].

3.10 Magnesium (Mg) Cmol/kg

The magnesium (Mg) ranged from 0.29 Cmol/kg to 0.80 Cmol/kg with a mean value of 0.55 Cmol/kg for surface soils and 0.53 Cmol/kg to 0.84 Cmol/kg with a mean value of 0.69 Cmol/kg for sub surface soils. The highest value was recorded at Onne 0.84 Cmol/kg with the least value recorded at Kono 0.29 Cmol/kg. Majority of the soils have values for exchangeable magnesium above 0.15Cmol/kg regarded as the critical level [13].

3.11 Total Exchangeable Base TEB (Cmol/kg)

The Total exchangeable base (TEB) ranged from 0.84 Cmol/kg to 3.37 Cmol/kg with a mean value of 2.12 Cmol/kg for surface soils and 1.27 Cmol/kg to 6.95 Cmol/kg with a mean value of 3.70 Cmol/kg for sub surface soils. The highest value was recorded at Okrika 6.95 Cmol/kg with the least value recorded at Kono 0.84 Cmol/kg.

3.12 Exchange acidity EA (Cmol/kg)

The exchange acidity (EA) ranged from 0.70 Cmol/kg to 1.56 Cmol/kg with a mean value of 1.08 Cmol/kg for surface soils and 0.50 Cmol/kg to 1.86 Cmol/kg with a mean value of 1.29 Cmol/kg for sub surface soils. The highest value was recorded at Degema 1.86 Cmol/kg with the least value recorded at Etche 0.50 Cmol/kg.

3.13 Effective Cation Exchange Capacity ECEC (Cmol/kg)

The Effective cation exchange capacity ECEC (Cmol/kg) ranged from 1.96 Cmol/kg to 4.33Cmol/kg with a mean value of 3.27 Cmol/kg for surface soils and 2.52 Cmol/kg to 8.49 Cmol/kg with a mean value of 5.26 Cmol/kg for sub surface soils. The highest value was recorded at Okrika 8.49 Cmol/kg with the least value recorded at Kono 1.96 Cmol/kg.

3.14 Base Saturation (%)

The base saturation (%) ranged from 42.86 % to 77.83 % with a mean value of 63.54 % for surface soils and 50.40 % to 90.89 % with a mean value of 3.74 % for sub surface soils. The highest value was recorded at Etche 90.89 % with the least value recorded at Kono 42.86 %. The percentage base saturation values were moderate to high, with all the values above 35%, which is regarded as the critical level for the growth, development and yield of most crops (Ibanga and Udo, 1996).

3.15 Electrical Conductivity EC (ds/m)

The Electrical conductivity EC (ds/m) ranged from 0.11 ds/m to 1.70 ds/m with a mean value of 0.70 ds/m for surface soils and 0.30 ds/m to 1.90 ds/m with a mean value of 1.02 ds/m for sub surface soils. The highest value was recorded at Kono 1.90 ds/m with the least value recorded at Omagwa 0.11 ds/m. The electrical conductivity was less than 4dm/s. This is an indication that the soils are not saline. Salinity may have adverse effect on non-tolerant plants by direct toxicity of plants and ionic imbalance, so that unadapted plants may not be able to survive. According to Slavich and Patterson [20], values within the range of 0-2dm/s indicates low salinity, 2-4dm/s shows the level at which sensitive plants can be affected, 4- 16dm/s represent level of moderate to high salinity.

3.16 Iron (Fe) mg/kg

The Iron (Fe) ranged from 6.94 mg/kg to 32.20 mg/kg with a mean value of 15.75 mg/kg for surface soils and 9.76 mg/kg to 32.00 mg/kg with a mean value of 16.10 mg/kg for sub surface soils. The highest value was recorded at Onne 32.20 mg/kg with the least value recorded at Bori 6.94 mg/kg. The high concentrations of Fe may be attributed to the high acidity of the soils, due to its organic matter content. Organic matter hastens its reduction and favours early buildup of Fe in flooded soils. Electrochemical and biochemical changes are caused by solubility and availability of these micronutrients in the soil [21,22,23].

Table 2. Nutrient parameters of some hydromorphic soils of Rivers State

S/n	Location	Depth (cm)	Soil pH	Org.m (g/kg)	Total N(g/kg)	Avail P(mg/kg)	na ←	K (cmol/kg)	Ca	Mg →
1	**Onne**	0-15	3.5	23.50	1.40	4.30	0.10	0.14	1.22	0.47
		15-30	3.2	35.90	2.80	6.70	0.08	0.26	3.60	0.84
2	**Degema**	0-15	4.2	25.10	3.80	1.80	0.09	0.45	0.57	0.80
		15-30	3.8	36.20	4.20	4.10	0.06	1.72	0.75	0.68
3	**Kono**	0-15	3.3	30.70	0.50	9.70	0.14	0.20	0.21	0.29
		15-30	3.0	38.60	0.60	10.20	0.12	0.16	0.27	0.72
4	**Okrika**	0-15	3.9	33.50	5.20	10.60	0.40	0.18	1.67	0.56
		15-30	3.4	41.40	7.50	7.50	0.35	0.27	5.80	0.53
5	**Oyigbo**	0-15	4.2	29.40	0,50	13.50	0.04	0.13	1.32	0.76
		15-30	3.9	28.10	0.40	11.50	0.08	0.15	4.20	0.80
6	**Omuma**	0-15	4.3	23.20	1.60	12.50	0.02	0.11	1.26	0.64
		15-30	4.0	26.40	1.10	14.70	0.07	0.19	1.34	0.68
7	**Etche**	0-15	4.8	22.00	1.20	12.70	0.11	0.18	1.23	0.53
		15-30	4.2	24.10	1.40	14.50	0.09	0.14	4.10	0.66
8	**Omagwa**	0-15	4.7	19.40	0.60	7.50	0.22	0.18	2.50	0.47
		15-30	4.1	25.80	1.00	10.10	0.14	0.25	5.10	0.68
9	**Isiokpo**	0-15	4.9	21.30	0.90	7.30	0.05	0.17	0.62	0.44
		15-30	4.2	24.10	1.30	11.90	0,03	0.25	0.48	0.72
10	**Bori**	0-15	4.0	16.00	1.00	4.50	0.04	1.57	0.59	0.56
		15-30	3.6	20.40	1.30	10.30	0.08	2.27	0.42	0.59

Table 3. Other nutrient parameters of the hydromorphic soils of Rivers State

S/N	Location	Depth (cm)	TEB (Cmol/kg)	E A (Cmol/kg)	ECEC (Cmol/kg)	% B.S	EC (ds/m)	Fe (mg/kg)	Mn (mg/kg)
1	**Onne**	0-15	1.93	1.23	3.16	61.08	0.51	32.20	36.50
		15-30	4.78	1.35	6.13	77.98	0.30	32.00	31.00
2	**Degema**	0-15	1.91	1.30	3.21	54.50	1.10	24.00	17.10
		15-30	3.21	1.86	5.07	63.31	1.60	23.10	27.80
3	**Kono**	0-15	0.84	1.12	1.96	42.86	1.70	13.72	15.00
		15-30	1.27	1.25	2.52	50.40	1.90	13.06	21.00
4	**Okrika**	0-15	2.81	1.43	4.24	66.28	1.20	14.90	6.50
		15-30	6.95	1.54	8.49	81.86	1.80	14.60	6.20
5	**Oyigbo**	0-15	2.25	1.04	3.29	68.39	0.73	15.15	4.50
		15-30	5.23	1.30	6.53	80.09	0.48	15.03	5.50
6	**Omuma**	0-15	2.03	1.04	3.07	66.12	0.70	12.50	4.00
		15-30	2.28	1.30	3.58	63.69	0.40	12.10	4.10
7	**Etche**	0-15	2.05	0.70	2.75	74.55	0.45	17.50	2.00
		15-30	4.99	0.50	5.49	90.89	0.90	21.00	2.10
8	**Omagwa**	0-15	3.37	0.96	4.33	77.83	0.11	11.55	9.70
		15-30	6.17	1.05	7.22	85.46	0.60	11.63	7.00
9	**Isiokpo**	0-15	1.29	1.06	2.35	54.89	0.30	9.00	1.00
		15-30	1.48	1.09	2.57	57.59	0.90	9.76	1.10
10	**Bori**	0-15	2.76	1.56	4.32	63.89	0.20	6.94	34.00
		15-30	3.36	1.65	5.01	67.07	0.80	9.76	33.00

Table 4. Summary of nutrient parameters of some hydromorphic soils in Rivers State

S/N	Soil parameters	Surface (0-15cm)			Subsurface (15-30cm)		
		MEAN	S.D	%CV	MEAN	S.D	%CV
1	**Soil reaction (pH)**	4.18	0.53	12.69	3.74	0.42	11.36
2	**Organic matter (g/kg)**	24.41	5.39	22.07	30.10	7.25	24.09
3	**Total Nitrogen (mg/kg)**	1.67	1.57	94.09	2.16	2.19	1.01
4	**Available P (mg/kg)**	8.44	4.02	47.63	10.18	3.22	31.64
5	**Na (Cmol/kg)**	0.12	0.36	296.60	0.11	0.09	8.96
6	**K (Cmol/kg)**	0.33	0.45	134.60	0.57	0.77	135.28
7	**Ca (Cmol/kg)**	1.02	0.64	63.21	2.61	2.16	82.97
8	**Mg (Cmol/kg)**	0.55	0.15	27.50	0.69	0.09	13.07
9	**TEB(Cmol/kg)**	2.12	0.74	34.69	3.70	1.95	52.56
10	**Exchange Acidity (Cmol/kg)**	1.08	0.26	23.67	1.29	0.37	28.84
11	**ECEC (Cmol/kg)**	3.27	0.82	25.23	5.26	1.95	37.14
12	**% B.S**	63.54	9.44	15.66	71.92	12.57	18.42
13	**Electrical Conductivity(ds/m)**	0.70	0.50	71.70	1.02	0.58	57.36
14	**Fe (mg/kg)**	15.75	7.44	47.25	16.10	7.14	44.34
15	**Mn (mg/kg)**	13.03	12.85	96.61	13.88	12.81	92.31

Table 5. Variability grouping of soil properties among the different soil depths

S/N	GROUP	CV (%)	Soil properties	
			Depth (0-15 cm)	Depth (15-30 cm)
1	Least variable	0-15	pH	pH, N, Na, Mg.
2	Moderately variable	15-35	Organic matter, Mg, TEB, EA, ECEC, BS.	Organic matter, P, EA, BS
3	Extremely variable	>35	N, P, Na, Ca, EC, Fe, Mn	Ca, K, TEB, ECEC, EC, Fe, Mn

Where TEB- Total Exchangeable Bases, EA- Exchange Acidity, BS- Base Saturation, ECEC- Effective Cation Exchange Capacity, EC- Electrical Conductivity.

3.17 Manganese (Mn) mg/kg

The Manganese (Mn) ranged from 1.00 mg/kg to 36.50 mg/kg with a mean value of 13.03 mg/kg for surface soils and 1.10 mg/kg to 33.00 mg/kg with a mean value of 13.88 mg/kg for sub surface soils. The highest value was recorded at Onne 36.50 mg/kg with the least value recorded at Isiokpo 1.00 mg/kg. The levels of available Mn in these soils appeared to be adequate and even too high in some soils. The concentration of soluble Mn^{2+} in the soil solution is dependent on both pH and redox potential. Agbemien (1982) reported that at pH below 5, the solubility is controlled by pH alone.

In terms of the coefficient of variation (%), soil depth influence some of the chemical properties examined in Table (5). When the soil properties were grouped on the basis of CV (%) as suggested by Wilding and Dress [15], the groupings were different among the depths for TEB, ECEC, N, Mg and Na (Table 5). These findings seems to suggest that the differences observed among the soil depths in the coefficient of variation of pH, organic matter, base saturation, Ca, Exchange acidity, Electrical conductivity, Fe and Mn (Table 4), may not be actually significant. However, this may not necessarily be so because a small coefficient of variation value in one property, e.g. pH, may have a serious impact on crop production than some properties with large coefficient of variation value. Ogunkunle and Erinle (1994) made similar observation and reported that a small coefficient value in one property, example, texture, may have pronounced effect on crop production than a large coefficient value to another property, example Exchangeable cation.

4. CONCLUSION AND RECOMMENDATION

Soil management can be defined as preparation and treatment of soils for the production of all types of agricultural economic plants. A good system must ensure that the nutrient status of the soils is maintained, that all factors directly harmful to plant growth, such as high acidity or alkalinity, poor drainage are absent. Management of hydromorphic soils is aimed at amendments of extreme acidic nature soils, poor drainage and accessibility currently inherent in the environment. Management of hydromorphic soils for sustainable crop production can be achieved through the following ways; the use of soil conditioners. Soil conditioners such as lime or calcite ($CaCO_3$) have been successfully used to improve the structure of acidic soils. Liming of soil increases the soil pH to near neutral and makes P, exchangeable Ca and Mg more available in the soil.

The second management criterion is the use of drainage systems. The objective of soil drainage is to control excess water from accumulating at the soil surface leading to conditions such as ponding, runoff or loss of nutrients through erosion or accumulation at the soil surface which may result in waterlogging and salinization, so as to make the soil more stable for optimum plant growth. Apart from leaching excess salts from the soil, drainage ventilates the soil, moderates soil temperature and makes soil moisture available to the rooting zone. Drainage also elongates crop growing season and makes early planning and planting easy. The third factor to consider is the agronomic practices such as ploughing and harrowing, use of minimum tillage tools and implements to ensure good tilt, leveling of the land and making high mounds, ridges or beds enables us to put hydromorphic soils into good use. The objective here is to lower the water table whereas the top soil is maintained at field capacity moisture levels. Other agronomic practices include application of fertilizer to boost soil fertility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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