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Soil Clay Content and Fertility as Major Limiting Factors to Optimum Wetland Rice (*ORIZA SATIVA*) Production in Ini Local Government, Akwa Ibom State, Nigeria

Udoh, B. T. And Akpan, U. S.
Department of Soil Science and Land Resources Management
University of Uyo Akwa Ibom State, Nigeria
Corresponding author: Akpan, U. S. udemakpan@uniuyo.edu.org
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Abstract
A study involving field survey, laboratory characterization and fertility capability classification (FCC) of soils in the rice ecosystem in Ini Local Government of Akwa Ibom state was carried out.The aim was to identify the major soil constraints limiting optimum and sustainable wetland rice (Oriza sativa) production in the study area. Three communities: Ekoi Mbat, Ibam Ukot and Ibiono Ewuro, with long history of wetland rice cultivation, were selected for the study. In each community, three profile pits were sited at representative locations within the rice field covering about 100 hectares. Each pit was studied and described in accordance with the FAO guidelines for soil profile description. Soil samples were collected from each genetic horizon for laboratory analysis. The result showed that all profiles were dominated by sandy textures and the average clay content of each profile was less than 50-25% which is the requirements for optimum rice performance. Mean soil pH was very strongly aid (pH 5.0), extremely acid (pH 4.5 and 4.3) for Ibiono Ewuro, Iban Ukot and Ekoi Mbat, respectively. Fertility capability classification (FCC) placed the nine pedons in eight different FCC units as follows: Saegh, Sgh, Laegh (Ekoi Mbat) Legh, LSegh, LSeghk (Ibiono Ewuro) and Sgh, Lagh, SLaegh (Ibam Ukot). The result showed that irrespective of location, three of the nine pedons (33.33%) had sandy top and sub-soils(S); also 33:33% had loamy top and sub soils (L); two pedons (22.22%) had loamy top - and sandy sub soils (LS); while one pedon (11.11%) had sandy top and loamy sub - soil(SL). The FCC also revealed the following constraints to rice cultivation in the study are acidic reaction (h), low K reserves (K) low CEC(e) and aluminum toxicity (a). While acidic reaction (h) affected all the nine pedons, other constraints affected some locations more than others. On the other hand, the results also revealed that soils in the study area were salt - free (with mean value for EC<0.07dSm^{-1}) and exchange Fe was below the toxic level of 50mgkg^{-1}

Keywords: *Wetland soils, rice cultivation, major soil constraints, optimum production, Ini Local Government Area*

INTRODUCTION

The Enyong Creeke floodplain (rice ecosystem) which occupies parts of Ini Local Government Area, Akwa Ibom State, covers about 85 sq km in area (Tahal, 1982). The soils of this floodplain are formed from alluvial deposits, and from previous studies (Tahal, 1982, Petters *et al.*, 1989; Akpan, 2005 and Udoh, *et al.*, 2011), the area has been recognized as having potentials for rice production.

Rice (*Oriza sativa*) being the second largest consumed cereal (after wheat) shapes the lives of millions of people. Over half of the world's population depends on rice for 80 percent of its food calorie requirements. According to the Food and Agriculture Organization (FAO), the global rice requirements in 2025 will be in the order of 800 million tones. The present production is little less than 600 million tones and additional 200 million tones will have to be produced by increasing productivity per hectare to meet the future requirements (Swaminathan, 2006). Also, additional hectares of land must also be brought under rice cultivation if the demand for this crop by the ever increasing population is to be met.

The task before the Federal and State Governments in Nigeria is to produce sufficient food including rice, to meet domestic demand and for export. However, in many developing countries like Nigeria, agricultural productivity is adversely affected by ineffective and unplanned use of agricultural land. It has been established that the characterization of the natural resources especially the soil will provide basic tools for better crop management practices (Kar and Singh, 2002). Specifically this will help in the development of potential areas for rice production in Akwa Ibom State. By matching the land qualities/characteristics of the study area with the established requirements for rice cultivation, each farmer would be aware of the suitability or potential and limitations of his land for rice cultivation. This is called land evaluation (FAO, 1976, Sys, 1985; Braimob, 2000, Udoh *et al.*, 2011).

Among the major problems confronting farmers in Akwa ibom is poor soil fertility replenishment strategy that could allow for sustainable Agricultural productivity (Mutsaers, 1990). Also Kusami *et al.* (1987) and Fasing *et al.* (2005), observed that a major factor limiting the growth and development of agriculture is the lack of detailed information and adequate knowledge of the soil and land characteristics.

Soil characterization in terms of its physical, chemical and biological properties in relation to its fertility is important for optimum utilization of available soil resources for agriculture. Delgade and Gomez, (2016). Raju *et al.* (2005), emphasized that the inherent ability of soils to supply nutrients for crop growth and the maintenance of soil physical conditions to optimize crop yields are the most important components of soil fertility that virtually determine the productivity of the soil resources of the Ini Local Government rice ecosystem is indispensable for planning it's agricultural, and specifically, rice production development (Sangita, 2015)

The fertility capability classification (FCC) system is a technical system for grouping soils according to the kinds of problems they present for agronomics management of their physical and chemical Properties. It emphasizes quarantifiable topsoil parameters as well assubsoil properties directly relevant to plant growth (Sanchez *et al.*, 2003 Udoh *et al.*, 2013; Udoh and Ibia, 2022) Therefore, the aim of this proposed study is to characterize and classify the soils of Enyong Creek floodplain and assess the constraints and potentials of these soils for rice cultivation in Akwa Ibom State. This is with a view to determining appropriate land/soil management and production practices for optimum and sustainable land productivity for this rice ecosystem.

Therefore, the aim of this study was to characterize the soils of wetland rice ecosystem in Ini L.G. A. of Akwa Ibom State as well as use the FCC system to determine the constraints/potentials of these soils for rice cultivation. This is with a view to helping the farmers develop appropriate soil/land management option for optimum and sustainable Rice production in the study area.

MATERIALS AND METHODS

Study Area

The study was conducted in Ini Local Government Area of Akwa Ibom State south-south region of Nigeria. It is located in Northeastern part of the State and lies between latitudes: 5°14′ 0″ and 5^0 23'33″ N and longitudes 7°53′0″ and 7^0 8′ 33″ E. The landscape of Ini Local Government Area comprises level to gently undulating plains, intensely dissected broken valley and ridges terrain and hills and ravines as well as the lowlands and floodplains of the Enyong Creek and Cross River valley (Petters *et al*., 1989). The floodplains are used for the cultivation of rice, cassava, cocoyam as well as vegetables. The study area is underlain by sandstone of the Bende-Ameke formation and alluvial deposits (Petters *et al*., 1989). The annual rainfall ranges from more than 2500 mm to about 3000 mm, with 1 – 3 dry months in the year. Mean annual temperature varies between 26 and 28^0 C, while relative humidity varies between 75 – 80 % (Petters *et al.*, 1989).

Field work

Three sites known for wetland rice cultivation over the years were selected for the study. The sites were Ibiono Ewuro, Ekoi Mbat and Ibam Ukot. In each site, three profile pits were dug in three representative locations. Each profile pit was described in accordance with FAO, 2016 guidelines for profile description. Soil samples were collected based on genetic horizon for laboratory analysis.

Laboratory Analysis

The following analyses were carried out using appropriate standard procedures: Particle size analysis was carried out using the Bouyoucos hydrometer method as described by Udo *et al;* (2009). Soil pH was determined in water using a 1:2.5 soil to water suspension and the soil pH was read using a glass electrode. Electrical Conductivity was determined using the conductivity bridge (Udo *et al;* (2009). Organic carbon was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). Available phosphorus was determined using the Bray P.1 extractant. The phosphorus in extract was measured by the blue method as described by Udo *et al;* (2009). Total nitrogen was determined by Kjeldahl digestion and distillation method as described by Udo *et al*. (2009). Exchangeable bases (Ca, Mg, Na, K) were extracted using normal ammonium acetate (Thomas, 1996). The exchangeable K and Na were determined by flame photometer while Ca and Mg were determined using atomic absorption spectrometer. Exchange acidity was determined using one normal potassium chloride (1NKCl) and by titration method as described by Udo *et al*; (2009). Effective cation exchange capacity (ECEC) was determined by summing up exchangeable cations and exchangeable acidity. Base saturation was calculated by dividing the total exchangeable bases by the effective cation exchange capacity and multiplied by 100.

$$\% \text{ BS} = \frac{Total\ Exchangeable\ Base \times 100}{ECEC}$$ *(Udo et al., 2009).*

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) using randomized completely block design and means were separated using Duncan multiple range test (DMRT) at 5% level of significance.

Potentials and constraints of soils of the study area (Fertility capability classification)

The potentials and constraints of soils of the study area for wetland rice cultivation were evaluated using fertility capability classification (FCC) system. The FCC system adopted was that of Sanchez et al. (1982) version. The system consist of three categorical levels namely: 'type' (texture of the plough layer or top 20 cm), 'substrata type' (texture of the subsoils) and 'condition modifiers'(soil properties or conditions which act as constraints to crop performance). Class designations from the three categorical levels are combined to form a FCC unit. In this study data obtained from field morphological study and laboratory analyses were used for the FCC. The FCC units of the nine pedons representing the study area are shown in Table 3.

RESULTS AND DISCUSSION

Physical characteristics of soils in the study area

The mean soil texture was sandy loam in Ibiono Ewuro and Ibam Ukot and loamy sand in Ekoi Mbat (Table 1). In Ibiono Ewuro, the sand fraction varied from 60.56 to 92.52 % with a mean of 77.49 % within the profile. The silt fraction varied from 3.36 to 24.48 % with a mean of 7.42 % while the clay reaction varied from 2.09 to 28.04 % with a mean of 15.09 % within the profile. The mean soil texture was sandy loam within the profile. Similarly in Ibam Ukot, the sand fraction varied from 66.28 to 91.68 % with a mean of 78.44 %, the silt fraction varied from 2.24 to 8.28 % with a mean of 4.08 % while the clay reaction varied from 5.76 to 29.56 % with a mean of 17.48 % within the profile. The mean soil texture was sandy loam. Furthermore, in Ekoi Mbat wetland soils, the sand fraction varied from 69.80 to 94.36 % with a mean of 84.61 %, the silt fraction varied from 0.44 to 6.48 % with a mean of 4.10 % while the clay reaction varied from 4.20 to 23.88 % with a mean of 11.30 % within the profile. The mean soil texture was loamy sand within the profile. The coarse soil texture of the study area could be attributed to ferrolysis. Quintero *et al*., (2007) reported that constant wet-dry season destroy the clay and releases silicic acid resulting in abundance of quartz in the clay fraction and the formation of sandy horizon.

Mean bulk density was ideal for crop growth in the study area. There was no significant different ($p < 0.05$) in mean bulk density among the soils under study. In Ibiono Ewuro flooded soils, bulk density varied from 1.0 to 2.3g/cm^3 with a mean of 1.5 g/cm^3 within the profile (Table 1). In Ibam Ukot, bulk density varied from 1.0 to 1.8 g/cm^3 with a mean of 1.3 g/cm^3 within the profile while in Ekoi Mbat, bulk density varied from 0.0 to 1.9 g/cm^3 with a mean of 1.4 g/cm^3 within the profile. The ideal bulk density could be attributed to excellent aggregation of the soil particles by iron oxides (Asio, 1996).

The rate of water flow after soil saturation (saturated hydraulic conductivity) was very slow in Ibiono Ewuro and Ibam Ukot and moderate in Ekoi Mbat. In Ibiono Ewuro wetland soils, saturated hydraulic conductivity varied from 0.0 to 2.5 cm/hr with a mean of 0.7 cm/hr. In Ibam Ukot, saturated hydraulic conductivity varied from 0.0 to 3.9 cm/hr with a mean of 0.7 cm/hr within the profile while in Ekoi Mbat soils, saturated hydraulic conductivity varied from 0.0 to 33.7 cm/hr with a mean of 3.1 cm/hr within the profile. .

Mean total porosity was within the level that does not restrict root growth in the study area and significantly higher ($p < 0.05$) in Ibam Ukot than Ibiono Ewuro and Ekoi Mbat wetland soils (Table 1). In Ibiono Ewuro soils, total porosity varied from 14.0 to 61.9 % with a mean of 44.0 %; in Ibam Ukot soils, total porosity varied from 49.9 to 61.9 % with a mean of 53.2 % while in Ekoi Mbat soils, total porosity varied from 0.00 to 52.5 % with a mean of 40.7 % within the profile. The high porosity in Ibam Ukot compared to others could be attributed to aggregation of the soil particles. Asio, (1996) reported excellent aggregation of the soil particles by iron oxide.

Table 1: Minimum, maximum and mean of physical properties of soils of the study area

Soil property		**Ibiono Ekwuro**	**Ibam Ukot**	**Ekoi Mbat**
Bulk density (g/cm^3)	Mini	1.01	1.01	0.00
	Max	2.28	1.77	1.85
	Mean	**1.48a**	**1.30a**	**1.39a**
Saturated hydraulic conductivity (cm/hr.)	Mini	0.00	0.00	0.00
	Max	2.48	3.89	33.65
	Mean	**0.70a**	**0.73a**	**3.11a**
Total Porosity (%)	Mini	13.96	49.86	0.00
	Max	61.89	61.89	52.45
	Mean	**43.99a**	**53.19b**	**40.67a**
Sand (%)	Mini	60.56	66.28	69.80
	Max	92.52	91.68	94.36
	Mean	**77.49a**	**78.44ab**	**84.61b**
Silt (%)	Mini	3.36	2.24	0.44
	Max	24.48	8.28	6.48
	Mean	**7.42b**	**4.08a**	**4.10a**
Clay (%)	Mini	2.08	5.76	4.20
	Max	28.04	29.56	23.88
	Mean	**15.09ab**	**17.48b**	**11.30a**

Texture	**Loamy sand**	**Sandy loam**	**Loamy sand**

Chemical characteristics of soils in the study area

Mean soil pH was very strongly acid in Ibiono Ewuro and extremely acid in Ibam Ukot and Ekoi Mbat wetland soils. Mean soil pH was significantly higher ($p < 0.05$) in Ibiono Ewuro than Ibam Ukot and Ekoi Mbat wetland soils. In Ibiono Ewuro soils, soil pH varied from 4.5 to 5.5 with a mean of 5.0 ;in Ibam Ukot, soil pH varied from 4.1 to 4.9 with a mean of 4.5 while in Ekoi Mbat, soil pH varied from 4.1 to 5.3 with a mean of 4.3 within the profile. The variation in soil pH among the studied soils could be attributed to variation in the rate of release of Fe^{2+} among the soils and the degree of replacement of +2 and +1 base cations by Fe^{2+} in the exchange sites. The rate of replacement of +2 and +1 base cations by Fe^{2+} in the exchange sites may have been more in Ibiono Ewuro wetland soils than Ibam Ukot and Ekoi Mbat soils. Fageria, (2009) reported that the majority of oxidation-reduction reaction in flooded soils resulted in the release of base cations into the soil solution.

There was no significant difference ($p < 0.05$) in mean electrical conductivity among the soils under study. The study area was salt free as indicated by the mean values of electrical conductivity (Table2). In Ibiono Ewuro soils, electrical conductivity varied from 0.02 to 0.07 dSm^{-1} with a mean of 0.05 dSm^{-1} , in Ibam Ukot soils, electrical conductivity varied from 0.02 to 0.12 dSm^{-1} with a mean of 0.07 dSm^{-1} while. in Ekoi Mbat, electrical conductivity varied from 0.02 to 0.18 dSm^{-1} with a mean of 0.06 dSm^{-1} within the profile.

Table 2: Minimum, maximum and mean of chemical properties of soils of the study area

Soil property		Ibiono Ekwuro	Ibam Ukot	Ekoi Mbat
pH (water)	Mini	4.48	4.14	4.05
	Max	5.46	4.93	5.25
	Mean	5.0b	4.5a	4.3a
Electrical conductivity (dSm^{-1})	Mini	0.02	0.02	0.02
	Max	0.07	0.12	0.18
	Mean	0.05a	0.07a	0.06a
Organic carbon (%)	Mini	0.50	0.30	0.70
	Max	1.70	2.35	3.07
	Mean	1.1ab	1.0a	1.6b
Organic matter (%)	Mini	0.86	0.52	1.21
	Max	2.94	4.06	5.81
	Mean	1.96a	1.91a	2.78a
Total N (%)	Mini	0.02	0.01	0.03
	Max	0.07	0.10	0.13
	Mean	0.05a	0.05a	0.07a
Available P (mg/kg)	Mini	2.50	5.42	6.88

	Max	13.13	21.04	22.29
	Mean	7.8a	11.7b	12.7b
Exch. Ca (cmol/kg)	Mini	1.44	1.68	0.96
	Max	5.04	8.40	8.16
	Mean	3.5a	4.7a	4.5a
Exch. Mg (cmol/kg)	Mini	1.02	1.02	0.48
	Max	3.86	5.22	5.12
	Mean	2.4a	3.1a	2.9a
Exch. Na (cmol/kg)	Mini	0.10	0.23	0.15
	Max	0.96	0.78	0.65
	Mean	0.5a	0.5a	0.4a
Exch. K (cmol/kg)	Mini	0.09	0.39	0.42
	Max	0.53	0.56	0.96
	Mean	0.33a	0.50b	0.50b
Exch. Acidity (cmol/kg)	Mini	0.48	0.64	0.80
	Max	2.56	2.40	2.86
	Mean	1.17a	1.46a	2.01b
Al (%)	Mini	0.16	0.16	0.32
	Max	0.64	0.80	0.96
	Mean	0.31a	0.37a	0.61b
Total Exch. Bases (cmol/kg)	Mini	2.69	3.69	2.21
	Max	9.88	14.42	14.40
	Mean	6.73a	8.73a	8.23a
ECEC (cmol/kg)	Mini	3.81	6.09	3.33
	Max	10.36	15.54	17.28
	Mean	7.9a	10.2a	10.3a
Base saturation (%)	Mini	70.60	60.59	57.37
	Max	95.37	92.79	94.65
	Mean	84.3a	84.5a	77.6 a
Fe (mg/kg)	Mini	4.00	10.25	9.56
	Max	31.85	34.65	29.98
	Mean	20.61a	16.95b	12.91c

Mean organic carbon was significantly higher ($p < 0.05$) in Ekoi Mbat than Ibiono Ewuro and Ibam Ukot wetland soils (Table 2). Mean soil organic carbon was high in Ekoi Mbat and moderate in Ibiono Ewuro and Ibam Ukot soils. In Ibiono Ewuro, organic carbon varied from 0.5 to 1.7 % with a mean of 1.1 % ; in Ibam Ukot , organic carbon varied from 0.3 to 2.4 % with a mean of 1.0 % while in Ekoi Mbat soils, organic carbon varied from 0.7 to 3.1 with a mean of 1.6 % within the profile. The low level of organic carbon in Ibiono Ewuro and Ibam Ukot soils compared to Ekoi Mbat could be attributed to microbial community structure shifts to microbes capable of anaerobic respiration upon flooding. Unger *et al*., (2009) reported that microorganisms utilize alternative electron acceptors such as NO_3^-, Mn^{4+}, Fe^{3+} and SO_4^{2-} to maintain their metabolism and decomposed organic matter.

Total N was low in the study area. There was no significant different ($p < 0.05$) in mean total N among the soils under study. In Ibiono Ewuro, total N varied from 0.02 to 0.07 % with a mean of 0.05 % ; ;in Ibam Ukot, total N varied from 0.01 to 0.10 % with a mean of 0.05 % while in Ekoi Mbat , total N varied from 0.03 to 0.13 with a mean of 0.07 % within the profile. The low total N in the study area could be attributed to de-nitrification, which is the reduction of nitrate to N gas or nitrous oxide or both by micro-organisms upon flooding. Fageria *et al* (2007) reported that the utilization of added N is generally poor in flooded soil because of de-nitrification.

Available P was low in Ibiono Ewuro and moderate in Ekoi Mbat and Ibam Ukot wetland soils (Table 2). Mean available P of Ekoi Mbat and Ibam Ukot was significantly higher ($p < 0.05$) than that of Ibiono Ewuro soils. The values varied from 2.5 to 13.1 mg/kg with a mean of 7.8 mg/kg in Ibiono Ewuro; in Ibam Ukot, available P varied from 5.4 to 21.0 mg/kg with a mean of 11.7 mg/kg and in Ekoi Mbat, available P varied from 6.9 to 22.3 mg/kg with a mean of 12.7 mg/kg within the profile. The higher available P in Ekoi Mbat and Ibam Ukot than Ibiono Ewuro wetland soils could be attributed to high rate of reduction of ferric iron (Fe^{3+}) phosphate to the more soluble ferrous (Fe^{2+}) form and the hydrolysis of phosphate compounds (Fageria *et al*., 2007).

There was no significant different ($p < 0.05$) in mean exchangeable Ca, Mg and Na among the wetland soils under study. Mean exchangeable K of Ekoi Mbat was significantly higher ($p < 0.05$) than that of Ibiono Ewuro but not different from that of Ibam Ukot. Exchangeable Ca varied from 1.4 to 5.0 cmol/kg with a mean of 3.5 cmol/kg in Ibiono Ewuro; in Ibam Ukot, exchangeable Ca varied from 1.7 to 8.4 cmol/kg with a mean of 4.7 cmol/kg while in Ekoi Mbat, exchangeable Ca varied from 1.0 to 8.2 cmol/kg with a mean of 4.5 cmol/kg within the profile. Mean exchangeable Ca was low in the studied soils. Exchangeable Mg varied from 1.0 to 3.9 cmol/kg with a mean of 2.4 cmol/kg in Ibiono Ewuro; in Ibam Ukot, exchangeable Mg varied from 1.0 to 5.2 cmol/kg with a mean of 3.0 cmol/kg while in Ekoi Mbat, exchangeable Mg varied from 0.5 to 5.1 cmol/kg with a mean of 2.9 cmol/kg within the profile. Mean exchangeable Mg was moderate in the studied soils. Exchangeable K varied from 0.09 to 0.5 cmol/kg with a mean of 0.3 cmol/kg in Ibiono Ewuro; in Ibam Ukot, exchangeable K varied from 0.4 to 0.6 cmol/kg with a mean of 0.5 cmol/kg while in Ekoi Mbat, exchangeable K varied from 0.4 to 1.0 cmol/kg with a mean of 0.5 cmol/kg within the profile. Mean exchangeable K was moderate in the studied soils. The relatively higher exchangeable K of Ekoi Mbat wetland soil compared to that of Ibiono Ewuro and Ibam Ukot soils could be attributed to high rate of reduction of Fe and Mn oxides into soil solution and their displacement of K from exchange sites into soil solution with low level of leaching out of soil system. Fageria *et al* (2007), reported that the reduction of Fe and Mn oxides into soil solution and their displacement of K from exchange sites into soil solution resulted in greater availability of K to rice in flooded soil.

Mean Al saturation of exchange sites of Ekoi Mbat soils was significantly higher ($p < 0.05$) than that of Ibiono Ewuro and Ibam Ukot wetland soils. The values from 0.2 to 0.6 % with a mean of 0.3 % in Ibiono Ewuro; in Ibam Ukot, Al saturation of exchange sites varied from 0.2 to 0.8 % with a mean of 0.4 % whereas in Ekoi Mbat wetland soils, Al saturation of exchange sites varied from 0.3 to 1.0 % with a mean of 0.6 % within the profile. The high Al saturation of the exchange complex of Ekoi Mbat soils compared to that of Ibiono Ewuro and Ibam Ukot soils (low) could be attributed to the content of active Fe (Fe^{2+}) of the soil. Fageria *et al* (2007) reported that replacement of Al^{3+} by Fe^{2+} from the exchange sites account for high Al saturation.

ECEC was low in the study area. There was no significant different ($p < 0.05$) in mean ECEC among the wetland soils under study. The values varied from 3.8 to 10.4 cmol/kg with a mean of 7.9 cmol/kg in Ibiono Ewuro; in Ibam Ukot, ECEC varied from 6.1 to 15.5 cmol/kg with a mean of 10.2 cmol/kg while in Ekoi Mbat soils, ECEC varied from 3.3 to 17.3 cmol/kg with a mean of 10.3 cmol/kg within the profile. The low ECEC of the study area could be attributed to the destruction of the clay minerals through the attack of octahedral sheet by H^+ resulting in low CEC (Fageria *et al*., 2007).

Mean exchangeable Fe of Ibiono Ewuro soils was significantly higher ($p < 0.05$) than that of Ekoi Mbat and Ibam Ukot soils. The values vary from 4.0 to 31.9 mg/kg with a mean of 20.6 mg/kg in Ibiono Ewuro; in Ibam Ukot , exchangeable Fe varied from 10.3 to 34.7 mg/kg with a mean of 17.0 mg/kg while in Ekoi Mbat soils, exchangeable Fe varied from 9.6 to 30.0 mg/kg with a mean of 12.9 mg/kg within the profile. The high exchangeable Fe of Ibiono Ewuro wetland soils than Ekoi Mbat and Ibam Ukot wetland soils could be attributed to high rate of reduction of ferric (Fe^{3+}) to the more soluble ferrous (Fe^{2+}) form (Fageria *et al*., 2007). Fe was below 50 mg/kg, although relatively high in the study area.

Fertility capability classification (FCC) showing the soil constraints and limiting factors to wetland rice production in the study area

The result of the fertility capability classification of the nine pedons is shown in Table 3. Data obtained from field morphological study and laboratory analyses of soil samples from the nine pedons were used for the fertility capability classification. The conversion data used in evaluating the soils are as outlined by Sanchez *et al.* (1982). The result showed that the nine pedons identified in the study area are classified into eights FCC units as shown the Table 3. Two of the nine pedons- pedon 2 (Ekoi Mbat) and Pedon 1 (Ibam Ukot) belong to the same FCC unit (Sgh). Also, irrespective of location, three of the nine peons (33.33%) had sandy top- and sub-soil (S); also 33.33% had loamy top-and sub-soils (L); furthermore two pedons (22.22%) had loamy top and sandy sub-soils (LS); while one pedon (11.11%) had sandy top and loamy sub-soils (SL). The FCC result also revealed four major condition modifiers – soil characteristics which are constraints to wetland rice cultivation in the study area. These are (i) soil acidic reaction (h) – which affects all (100%) of the pedons, (ii) low ECEC (e) –which affects six (66.67%) of the pedons (iii) aluminum toxicity(a) – which affects four(44.44%)of pedons and low reserves (k) – which affects one (11.11%) of the pedons (Table 3).

Location	pedon	FCC Unit	Brief Interpretation
Ekoi Mbat	1	Saegh	Soil profiles characterized by sandy topsoil and sandy subsoil(S) Major constraints to rice cultivation are: aluminum toxicity (a); low effective cation exchange Capaccity (ECEC) (e) and acidic reaction (h)
	2	Sgh	Soils also have sandy top- and sub-soil (S), with acidic reaction(h)
	3	Laegh	Soils also have loamy top and sub-soils. Also, major constraints to rice production are aluminum toxicity (a), low ECEC (e) and acidic reaction (h)
Ibiono Ewuro	1	Legh	Soil profiles are characterized by loamy top-and sub-soil (L). Also have low ECEC (e) and acidic reaction as constraints
	2	Lsegh	Soil profiles characterized by loamy top-and sandy sub-soil. Major constraints are low ECEC (e) and acidic reaction (h)
	3	LSeghk	Soil profiles characterized by loamy top-and sandy sub – soils. Major constraints to rice cultivation are low ECEC(e), acidic reaction(h) and low potassium(K) reserves (K)
Ibam Ukot	1	Sgh	Soils with sandy top- and sub-soils and characterized by acidic reaction as a major constraint (this pedon is similar to pedon 2 of Ekoi Mbat)
	2	Lagh	Soil profiles characterized by loamy top- and sub-soils. Major constraints to rice production are aluminum toxicity (a) and acidic reaction (h)
	3	SLaegh	Soil profiles characterized by sandy top- and loamy sub-soils. The constraints to wetland rice production are aluminum toxicity (a), low ECEC (e) and acidic reaction (h)

Table 3: Fertility Capability (FCC) Units in the study area: Brief Interpretation

Conclusion

The study revealed that all profiles were dominated by sandy textures and the average clay content of each profile was less than 50-25% which is the requirements for optimum rice performance. Mean soil pH was very strongly acid (pH 5.0), extremely acid (pH 4.5 and 4.3) for Ibiono Ewuro, Ibam Ukot and Ekoi Mbat, respectively. Fertility capability classification (FCC) placed the nine pedons in eight different FCC units as follows: Saegh, Sgh, Laegh (Ekoi Mbat) Legh, LSegh, LSeghk (Ibiono Ewuro) and Sgh, Lagh, SLaegh (Ibam Ukot). The result showed that irrespective of location, three of the nine pedons (33.33%) had sandy top and sub-soils(S); also 33:33% had loamy top and sub soils (L); two pedons (22.22%) had loamy top - and sandy sub soils (LS); while one pedon (11.11%) had sandy top and loamy sub - soil(SL). The FCC also revealed the following constraints to rice cultivation in the study area: acidic reaction (h), low K reserves (K), low CEC(e) and aluminum toxicity (a). While acidic reaction (h) affected all the nine pedons, other constraints affected some locations more than others. On the other hand, the results also revealed that soils in the study area were salt - free (with mean value for EC<0.07dSm^{-1}) and exchange Fe was below the toxic level of 50mgkg^{-1}.

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