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CHARACTERIZATION AND FERTILITY EVALUATION OF SOME WETLAND SOILS IN SOUTHEASTERN NIGERIA

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Abstract

Wetland soils in Southeastern Nigerian were studied with a view to evaluating their agricultural potentials. The profiles were mostly eutric and dystric although humic and gleyic profiles also occurred. The top soils were generally clayey and fine textured and the sand fractions were fine sand dominated. Although low pH values indicated strong acidity, very low electrical conductivity values showed that there was no salinity problem in the soils. Organic matter levels indicated both marginal and high suitability of the soils for crop production while phosphorus indicated moderate and high suitability. A high fertility potential was indicated by the ECEC and base saturation values. The implications of calcium-magnesium ratios and magnesium - potassium ratios to macro - nutrient availability are examined. Traditional small-scale irrigation and water control schemes are advocated as a means of realising the high potential for swamp rice which the wetlands undoubtedly possess.

1. Introduction

Wetlands in Southeastern Nigeria are associated with lowlying areas or basins where seasonal floodwater from rivers and streams are retained. These wetland areas are generally lower than the adjacent floodplains and are separated by old river levees from the other floodplain areas that are covered by normal river flood or tidal upsurge. At the height of the rainy season the wetlands are ecotones since they are transition zones from upland to deep water aquatic systems (Hollis et al 1998). However, some perennial inland streams also drain into these lowlying areas giving them the characteristic of reception inland basins. Thus the wetlands of southeastern Nigeria are permanent landscape features although the breath of the flood gradient expands and contract in consonance with the rainy season flood and dry season drought.

Peasant farmers have followed the flood rhythm for generations, cultivating fallow rice, fluted pumpkin (*Telferia spp*), okra, pepper, maize, mellon, cassava, garden eggs and cocoyams among other staple annual crops. The vegetation which is largely of secondary succession consists of *Raphia*/oil palm forest, swamp bushes and grasslands. However, the agricultural potentials of these wetlands have not been futly utilized due to lack of well articulated agricultural land policy and poor road infrastructure. In this paper, a general assessment of the agricultural potentials of the wetlands is made. The paper aims to define the fertility status of the soils for management purposes.

2. Study Area

The study area is shown in Figure 1. The climate of the area being humid tropical is marked by excess of rainfall over evapotranspiration for more than six months of the year between May and October. The reverse situation occurs for about four months of the years between December, and March. Annual rainfall totals exceed 3000mm while humidity averages about 80% in the rainy season. The mean annual temperature is about 30°C.

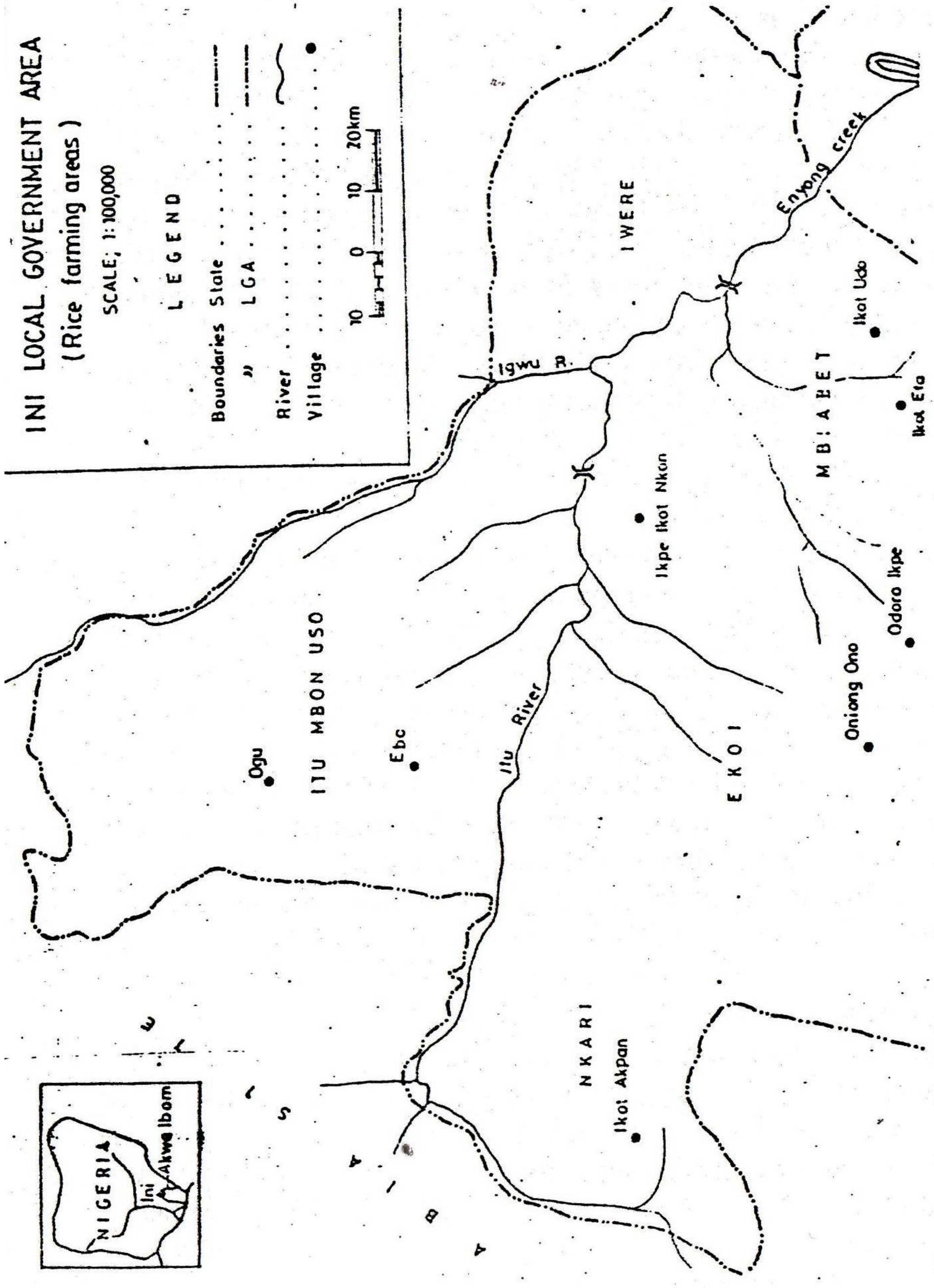

Figure 1: Map of the Itu/Ugwu and Enyong Creek Wetlands in Ini Local Government Area of Akwa Ibom Stat. Nigeria. Location of the Wetlands in Southeastern Nigeria is shown (inset).

The wetland areas occur in Itu/Ugwu and Enyong, associated with the floodplains of the Enyong Creek, a secondary hydrological system in Akwa Ibom State, Nigeria. The Enyong Creek is a tributary of the Cross River which is the major hydrological system in southeastern Nigeria. The Enyong Creek floodplain has been under subsistent cultivation perhaps for centuries, because flooding often result in fertile alluvial deposits over the lowlying areas. The local folks and tenant farmers derive their livelihood from the seasonal flooding phenomenon which enable them to cultivate dry season crops on the wetland soils when adjacent upland farms are often too dry to be cultivated. With a population growth rate of 2.5 - 3.0% in Nigeria, these floodplains could possess high agricultural potentials for their locality, but rarely have their soils and hydrological setting been evaluated for intensive agricultural possibilities. So far, administrative and developmental efforts have been centred on the large floodplain/wetland systems (River Basin Development Authorities) which fail to emphasize local participation in commercial food production. The secondary hydrological systems have largely been ignored (Ukpong and Ibia 1998).

3. Methods of Study

For characterisation and classification purposes "Wetland soil" was regarded as the uppermost 125cm of the wetland surface, although profile investigation could continue to at least 150cm depth. Soil profiles having horizons similar in differentiating characteristics and arrangement and having developed from a particular type of parent material were grouped together and classified according to FAO system (FAO 1974) and USDA Soil Taxonomy (Soil Conservation Service 1975).

Soil investigations were undertaken using a modified grid method of survey, based on aerial photo (Scale 1:5000) interpretation. Transects varying in length between 600 and 2,900m were selectively cut at appropriate sections of the respective swamps. Augering to a depth of 100cm were done along the transects at intervals of 200m apart and at the end of the traverses whenever the last interval was less than 200m. The soil properties identified from the auger samples included colour of the soil matrix, mottles and texture. Environmental data included location, geology/parent material, topographic position, drainage and depth of water table. The location of soil samples was then decided based on the distinguishable soil properties from the auger observations. Each profile was dug to a minimum depth of 150cm except where interrupted by high water table. Soil samples for laboratory analysis were taken from all soil horizons distinguished in the profile pits and where necessary soil samples below the water table were taken with that auger (AKSG 1994). The samples were air dried at room temperature, ground and passed through a 2mm sieve prior to physical and chemical analyses.

Particle size analysis was done by the hydrometer method using calgon as the dispensing agent (Day 1965); pH was determined in water and HCl solution in 1:2 soil to suspension ratio using a pH meter; organic carbon content by the dichromate oxidation method of Walkley - Black (1934); available phosphorus by the Bray P-1 method (Bray and Kurtz 1945) and the concentration of phosphorus in the extract determined by the blue colour method of Murphy and Riley (1962). Exchangeable cations were extracted with neutral ammonium acetate. Calcium and magnesium in the extract were determined by EDTA titration (Jackson 1962) and potassium and sodium by flame photometry. Exchangeable acidity was extracted with N KCl solution while total acidity and extractable aluminium were determined by titration (Juo 1975). The Effective Cation Exchange Capacity (ECEC) was computed as the summation of exchangeable bases and exchangeable acidity. Total nitrogen was obtained by macro-kjelahl digestion and distillation methods (Jackson 1962). Total potassium and phosphorus were extracted by the sulphuric/perchloric acid digestion with the mixture taken up in dilute HCI. Phosphorus in the extract was measured by the blue colorimetric method of Murphy and Riley (1962) and potassium by flame photometry.

4. Results and Discussion

4.1 General

The soil pattern was observed to be primarily the result of the interaction between climate and rainfall, geologic, geomorphic and hydrologic factors over varying periods of time. The geologic imprint is shown in the relative clayey nature of the soils and moderate to high fertility of many of the soils (Tables 1-3). Clearly, the shales, colluvium and alluvium (quartenary deposits) from which the soils were formed have a high base status and weather to a regolith containing little residual quartz sand. While soils of the old levees commonly had sandly layers sandwitched between two clay horizons, soils of the nearly flat floodplain and depressional areas were clayey throughout.

The geomorphological or topographic effects on the distribution of the soils types were also well marked. The flat floodplain were dominated by poorly to very poorly drained, organic-rich sandy clay loam or silty clay loam topsoil over cleyed subsoil. The gently sloping lowlands were poorly to imperfectly drained clays underlain by sandy clays at depth while the moderately sloping middle and upper slopes were dominated by imperfectly to well-drained sandy clay loams over sandy clays or clays. Alluvial stratification seems to be the most common or pronounced soil profile feature of the wetlands (AKSG 1995).

Rainfall seasonality influences soil development. Evidence of varying degrees of wetness or hydromorphic properties due either to periodically high water table and/or slow infiltration of surface water due to the high clay content, was seen in all the floodplain soils. Most of the old levee soils and some of the soils of the lower slopes also reflected these degrees of wetness.

4.2 Soil Classification

The wetland soils were classified according to the FAO system and USDA system (Table 1). In accordance with FAO (1974), three textural classes were recognized namely:

A. **Coarse Textured** - consisting of sands, loamy sands and sandy loams with less than 18% clay and more than 65% sand.

B. **Medium Textured** - consisting of sand loams, loams, sandy clay loams, silt loams, silts, silty clay loams and clay loams with less than 35% clay and less than 65% sand. (Sand fraction could be as high as 82% if the minimum 18% clay is present).

C. **Find Textured** - consisting of clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35% clay.

The textural classes were associated with three drainage classes namely

(i) well drained
(ii) imperfectly drained and
(iii) poorly and very poorly drained.

General Description of Soil Units

1. Utisol/Dystric Acrisol

This classification includes well drained, deep soils with loamy sand to sandy loam topsoil underlain by sandy clay loam subsoil (see Table I). While clay content increased sharply with depth, sand content was over 75% in the top horizons. Surface soil colour varied from dark brown through yellowish brown to brownish grey. The soils were found at middle slopes (4° - 7° gradient) and the soil reaction was strongly acid, with pH ranging from 4.5-5.0

2. Inceptisol/Dystric Cambisol

The classification includes deep, well drained soils on middle slopes of gradient ranging from 2° to 4°. The soils were medium texture on top and underlain by coarse textured subsoil. The sand content (fine sand dominated) was very high (85%) below 50cm. Clay and silt content decreased sharply with depth, the clay changing from 23.4 to 7.4% and silt from 18 to 2% (Table I). Soil colour changed from dark greyish brown to yellowish brown in the surface horizons while the subsoil was mainly brownish yellow. The ECEC was higher on the surface soils than in the subsoils probably due to its sandy nature.

Table 1: Classification, range of particle size, texture and some nutrient properties for selected soil profiles

Depth cm	Particle Size % CS	FS	Silt	Clay	Texture	pH	OC(%)	ECEC (cmol/kg)	BS(%)
1. UTISOL/DYSTRIC ACRISOL*									
0 - 23	66.0-69.8	6.6-14.6	8.0-12.0	11.4-11.6	LS-SL	4.5-4.9	5.2-5.8	5.2-5.8	11-14
23 - 130	45.4-48.0	11.4-17.4	6.0-6.4	30.2-34.2	SCL	4.5-4.6	0.6-5.2	0.6-5.2	5.-11
2. INCEPTISOL/SYSTRIC CAMBISOL*									
0 - 53	31.2-45.9	16.7-35.4	10.0-18.0	19.4-23.4	SL-SCL	4.5-4.6	0.1-0.2	0.1-0.2	50-52
53 - 151	9.8-26.4	60.2-78.8	2.0-4.0	7.4-11.4	S-LS	4.3-4.4	0.1-0.2	0.1-0.2	15-19
3. INCEPTISOL/HUMIC GLEYSOL*									
0 - 56	40.7-67.4	0.5-7.2	5.0-8.0	17.4-52.0	SL-C	4.7-4.9	2.5-2.7	2.5-2.7	90-94
56 - 130	6.0-30.0	0.6-1.8	2.0-12.0	67.4-81.4	C	4.4-4.5	0.0-1.9	0.0-1.9	80-86
4. UTISOL/GLEYIC ACRISOL*									
0 - 46	20.3-24.0	24.1-45.8	13.4-25.4	16.8-30.2	SL-SCL	4.6-4.7	5.0-59	5.0-59	15-38
46 - 153	0.3-11.3	39.2-45.2	14.0-25.5	29.4-34.6	CL-SCL	4.3-4.5	0.0-4.2	0.0-4.2	8-44
5. ENTISOL/EUTRIC FLUVISOL*									
0 - 52	1.4-19.8	0.7-0.8	9.0-19.0	60.8-88.8	C	5.2-5.3	2.2-2.4	2.2-2.4	87-90
52 - 150	19.4-20.1	0.5-7.2	6.0-12.6	66.8-70.0	C	5.2-5.4	0.1-0.7	0.1-0.7	60-66
6. ENTISOL/DYSTRIC FLUVISOL*									
0 - 49	31.7-78.4	8.4-57.1	1.8-5.8	5.4-11.4	S-LS	4.3-4.7	1.6-3.6	1.6-3.6	50-70
49 - 130	56.8-58.7	8.5-14.4	3.0-4.0	26.8-28.8	SCL	3.8-46	0.0-1.9	0.0-1.9	40-52
7. INCEPTISOL/DYSTRIC GLEYSOL*									
0 - 46	30.2-34.1	0.5-1.8	16.6-20.6	44.8-50.8	C	4.8-4.9	0.4-2.0	0.4-2.0	24-69
46 - 142	20.0-27.8	2.8-7.8	10.6-20.0	52.2-58.8	C	4.6-4.7	0.1-0.5	0.1-0.5	19-50

* = Soil Taxonomy/FAO Classification system CS = Coarse sand; FS = Fine sand; LS = Loamy sand; SL = Sandy loam; SCL = Sandy clay loam; CL = Clay loam; C = Clay; OC = Organic carbon; BS = Base saturation

3. *Inceptisol/Humic Gleysol*

These were imperfectly drained and fine textured throughout the profile, except in the organic-rich topmost horizon. The soils occurred in various topographic positions from lower to upper slopes either gently (2° to 4°) or moderately (4° to 7°) sloping. The texture was sandy clay/clay and the sand fraction was coarse sand dominated (Table 1). Soil reaction was very strongly acid with high ECEC and base saturation.

4. *Utisol/Gleyic Acrisol*

This unit consists of imperfectly drained soils with clay loam/ sandy clay loam textures throughout the profile (Table 1). The sand fraction was fine dominated. Organic carbon content showed a sharp decrease with depth and soil reaction was strongly/very strongly acid. Soil colour varied from brownish to yellowish brown/greyish between 50-100cm. ECEC value was moderate but base saturation was low. The soils were commonly grown to cocoa and oil palm since the water table is low most of the year.

5. *Entisol/Eutric Fluvisol*

These soils are poorly to very poorly drained and are medium textured underlain by fine texture at depth (Table I). The surface soils were dark greyish brown/black while the subsoil was commonly light grey - brownish grey/reddish. Organic carbon levels were variable, correlating with vegetation cover. Soil reaction was strongly acid/ very strongly acid while ECEC and base saturation were both high. The soils were commonly grown to swamp rice and fallow secondary swamp forest.

6. *Entisol/Dystric Fluvisol*

The soils are poorly drained, medium textured clay loam to clay subsoil (Table I). Silt content was relatively high compared to other soils and were best represented on level and nearly level surfaces.

Organic carbon content was moderate and soil reaction varied from strongly acid to very strongly acid. ECEC was moderate but with high base saturation. The soils were commonly grown to cocoa, swamp rice and swamp grass fallow.

7. *Inceptisol/Dystric Gleysol*

The poorly drained to very poorly drained soils have coarse textured topsoils underlain by medium textured subsoils. The surface layer was very dark brown/very dark greyish brown underlain by brownish grey/light grey subsoil. Organic carbon content was moderate and soil reaction strongly to very strongly acid. The soils were commonly under bush fallow with mature and immature oil palm trees.

Generally, the wetter soils were gley soils under both the USDA and FAO systems. Classification of individual units showed that most of the units had both eutric and dystric profiles (AKSG 1994).

4.3 Fertility Evaluation

The pertinent soil parameters for the Itu/Igwu and Enyong wetland areas are summarized in Tables 2 and 3 while the rating of some soil characteristics for fertility evaluation are given in Table 4. The pH values of the soils ranged from 4.32 - 5.46, with a mean value of 4.48. These values were generally low. In all cases, the pH (H_20) was higher than pH (KCL), showing that all the soils have a net negative charge on the exchange complex. The low pH values indicate strong acidity. However, the electrical conductivity of the soils was low, ranging from 0.005 - 0.150ds/m, showing that there was no problem of salinity, even to sensitive crops (see Tables 2 and 3).

The soils had organic matter content varying from 0.52 to 6.88%. Several pedons had organic matter content less than 2:0 in the surface horizons while others had higher values.

Table 2: Summary of pertinent soil parameters in the upper 50cm of soils in Itu/Iqwu wetland areas of Enyong Creek, Akwa Ibom State.

Parameter	Range	Mean
pH	4.35-5.38	4.82
Org. Matter %	0.53-5.84	3.03
Avail. P. mg/kg	3.0-47.0	15.9
Exch. K. cmol/kg	0.05-0.34	0.16
ECEC. cmol/kg	6.0-50.20	21.28
Base Satn. %	12-94	53.5
Al. Satn. %	3.8-84.9	23.2
K. Satn %	0.2-4.6	0.95
Clay content %	5.4-88.6	30.5
$EC_{25}0$ ds/m	0.005-0.130	0.044

Table 3: Summary of pertinent soil parameters in the upper 50cm of soils in Enyong wetland areas of Enyong Creek, Akwa Ibom State.

Parameter	Range	Mean
pH	4.32-5.46	4.86
Org. Matter %	0.82-6.88	1.65
Avail. P. mg/kg	2.3-93.0	19.1
Exch. K. cmol/kg	0.6-0.67	0.12
ECEC. cmol/kg	5.48-29.74	14.74
Base Satn. %	21-90	68.9
Al. Satn. %	8.0-79.4	27.0
K. Satn %	8.0-79.4	2.1
Clay content %	0.2-9.5	38.9
$EC_{25}0$ ds/m	0.010-0.150	0.066

According to the FAO (1976) rating (see Table 4), the lower organic matter group is marginally suitable for crop production while the higher levels indicate suitability of the soils for crop production.

Available phosphorus values ranged from 2.3 - 93.0mg/kg, with a man of 17.8mg/kg. However nine pedons had values below 10mg/kg and therefore were deficient in available phosphorus. Four pedons had values above 50mg/kg and are rated as being highly suitable while

six pedons with values between 10 and 40mg/kg are rated moderately suitable with respect to phosphorus availability (see table 4).

Effective Cation Exchange Capacity (ECEC) was also high in most of the soils with values ranging from 5.48 to 50.20 cmol/kg and a mean of 18.35 cmpl/kg. Eight pedons had ECEC values between 15 and 20cmol/kg and are therefore described as being marginally suitable. Base saturation was generally high, ranging from 12 to 94% with a mean of 63.4%. Although three pedons had values below 50% base saturation, the soils were largely utric which indicate potential high fertility.

Most of the soils were high in exchangeable aluminium. But since saturation of the exchange complex was generally below 60%. aluminium toxicity may not be a serious problem. All the soils in the area were however described as acidic since the % aluminium saturation ranged between 10-60% in most pedons (AKSG 1995).

Table 4: Rating of some soil characteristics for fertility evaluation (FAO, 1976)

Characteristics	S_1	S_2	S_2
Texture	L,SCL	LC,C	LS,SC,C
CEC (cmol/kg)	720	15-20	10-15
Org. Matter (%)	2-3	1-2	1
Bray P-1 (mg/kg)	40	10-40	10
Exch. K (cmol/kg	0.40	0.20-0.40	0.10-0.20
pH	5.5-7.5	4.5-5.5	4.0-4.5

S_1 = Highly suitable
S_2 = Moderately suitable
S_3 = Marginally suitable
L = Loam
SC = Sandy clay
SCL = Sandy clay loam
LS = Loamy sand
LC = Loamy clay
C = Clay

Exchangeable potassium was generally low, with values raining from 0.05 to 067 cmol/kg of soil and a mean of 0.14cmol/kg (Table 2 and 3). Six pedons had values above 0.20cmol/kg which is taken as the critical level for most crops (FPDD 1989). Exchangeable potassium percentage (EPP) ranged from 0.2 to 9.5 with a mean of 1.8%. Four pedons had values above 2% which is regarded as the minimum levels to avoid potassium deficiency in humid tropical soils.

Calcium - magnesium ratios ranged from 0.17:1 to 6.5:1. Since the approximate range for most crops is 3:1 to 4:1, only two pedons were observed to have the desired ratio. The relatively low ratios indicate high values of exchangeable magnesium. Calcium availability may be reduced in soils with very low ratios, while at the high values about 5.1, magnesium may become less available to plants.

Magnesium - potassium ratios ranged from 4:1 to 90:1. The high ratios indicate excess availability of magnesium in some pedons relative to that of potassium. With ratio values less than 2:1, magnesium may be inhibited (Landon 1981). The exchangeable sodium percentage (ESP) was low in all the soils, the values being much below 15%, above which the soil becomes sodic.

5. Conclusion

Sanchez and Buol (1985) had proposed a fertility capability classification for wetland soils. Based on the classification, wetland soils in southeastern Nigeria, being clayey and heavy textured have high suitability for paddy rice. This suitability for irrigated agriculture is however affected by the duration - periodicity and depth of flooding and their occurrence in relation to stage of crop growth. Most suited to wetland rice are the soils of the minor valleys and back swamps where the water table is always in the root zone and the soils of the terrace and floodplain depressions where runoff is ponded.

The wetland soils are acid soils. The very low pH values are bound to create in the long term acidity problems e.g. aluminium, iron and manganese toxicity and reduction in available phosphorus.

Mitigating measures like liming are expected to form part of the soil management practices in the area. Although acidic conditions are pronounced, none of the soils is saline as indicated by the very low electrical conductivity values of the soil-water extracts.

As the ECEC is high, the soils have inherent fertility. Macro-nutrient problems e.g low potassium availability can however be managed with adequate fertilizer application and organic matter utilization. Likewise, low phosphorus availability in the soils calls for adequate fertilization schemes and regular soils testing, particularly for phosphorus management. A high dressing of nitrogen would be required in the soils. However, nitrogen sources such as sulphate of ammonia and urea which impart acid residue to the soil should be accompanied by liming. Generally, the soils so managed have a high potential for swamp rice development.

Between July and October, the swamps are usually flooded. As the water table rises to the soil surface the creeks over flow their banks, to flood the tributary streams such that ponding and blocking of the channels by sediments and wrack result in impeded soil drainage. Some control of the major streams are required to facilitate drainage and water management on valleys. Traditional small scale irrigation systems are advocated rather than large scale schemes. The large scale schemes have been known to adversely affect the magnitude of the wet-season floods and could cause a shift from those crops that are naturally adapted to the area, to lower value crops or species (Hollis et al 1988).

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7. References

A.K.S.G. 1994. Enyong Creek Swamp Rice Study, Stage I Report. Akwa Ibom State Government, Nigeria.

A.K.S.G. 1995. Northern Akwa Ibom Swamp Resources Dev. Study. Akwa Ibom State Government, Nigeria.

Bray, R. H. and Kurtz, L. T. 1945 Determination of total, organic and available form of P in soil. *Soil Science* 59:39-45.

Day, P. R. 1965 Particle fractionation and particle size analysis. In C. A. Black (ed). Methods of soils Analysis. *Agron. part 2* pp. 545-677 SSSA, Madison, Wisc.

F.A.O 1976 A framework for land evaluation. *FAO Soils Bull.* 32, FAO/UNESCO. France.

FPDD 1989 Fertilizer use and Management practices for crops in Nigeria. *Federal Ministry of Agriculture and Rural Development*, Lagos.

Hollis, G. E., Holland, M. M., Maltby, M. and Larson, J. S. (1988) Wise use of wetlands. *Nature and Resources* 26:2-13.

Jackson, M. L. 1962 *Soil Chemical Analysis* Prentice-Hall Inc. Englewood Cliffs, N. J.

Landon J. R. (ed) 1981 Booker Tropical soil Manual. A handbook for soil survey and agricultural and evaluation in the tropics and subtropics.

Murphy J. R. and Riley, J. P. 1962 A modified single solution method for determination of phosphate in natural waters. *Annals of Chemistry Acta* 27:31-36.

Sanchez, P. A. and Buol, S. 1985 Agronomic taxonomy for wetland soils. In: IRRI wetland soils characterization, classification and utilization. *Proceedings of the Los Banos Workshop,* Philippines IRRI, pp. 207-227.

Soil Conservation serve, USDA 1975 Soil taxonomy, a basic system of soil classification of making and interpreting soil surveys. *USDA Agriculture Handbook,* Washington D.C.

Ukpong, I. E. and Ibia, T. O. 1998 Characterization of the Enyong Creek wetland soils for agricultural landuse potentials and management. In: Ukpong, I. E. (ed). *Geography and the Nigerian Environment.* The Nigeria Geographical Association. Uyo (in print).

Walkley, A. and Black, C. A. 1934 An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic and titration method. *Soil Science* 37:29-38.