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Research Article

Land Evaluation of the Wetland Soils of Ogba Egbema Ndoni LGA for Some Selected Crops

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Abstract

The present study was carried out to evaluate the potential of the wetland soils in Ogba-Egbema-Ndoni LGA Rivers State in Nigeria for three selected crops (Cassava, Oil Palm and Maize). Three modal profile pits were dug and described based on FAO guidelines for soil profile description. The soils texture of the study was mostly loamy sand and sandy loam. Soil reaction (pH) tended to be very strongly acidic to moderately acidic with a range of 4.5 to 5.2. Three standard Land Evaluation methods were used; Land suitability, Land capability and fertility capability classification (FCC) to evaluate the selected crops. The results revealed that the land capability classification of the soils were moderately capable with limitations of fertility for profile B2PR and B3OKS with profile BIOSI having limitation of wetness. For suitability classification all soils were marginally suitable for cassava, for maize profile BIOSI and B3OKS were marginally suitable, while B2PR was moderately suitable and for oil palm profile B2PR and B3OKS were moderately suitable and BIOSI was marginally suitable. For fertility capability classification, the soils were classified as SSKeg, SLkeg and SSkeg.

Keywords: Wetland, Land capability classification, Land suitability Evaluation and Fertility capability classification, Cassava, Oil palm, Maize

INTRODUCTION

Soil is a vital natural resource necessary for crop production, and sustainable soil management is the key to sustainable agricultural production. Soil resources played important role in agricultural production. Therefore, there are urgent needs to match soil type and land use for sustainable food production for the teaming population of a country like Nigeria. Wetlands are frequently transitional landscapes between terrestrial and aquatic systems and therefore possess characteristics of both. Wetlands are among the most productive and economically valuable ecosystems in the world. They provide critical ecosystem goods and services, including carbon storage, biodiversity, conservation, fish production, fuel production, water purification, flood and shoreline surge protection and erosion control, and recreation Moreno-Mateos D *et al.,* (2012). Wetland resources constitute an important agricultural ecology in the world and are major contributors of economic growth of the society. Wetlands are distinguished by the presence of water, either at the surface or within the root zone, seasonally or permanently and often have unique soil conditions that differ from adjacent uplands, and they support vegetation adapted to the wet condition (hydrophytes) Mitsch and Gosselink (2000). It is therefore necessary that policy makers carefully determine appropriate strategies for the sustainable use and management of wetlands for agriculture or other purposes. Development of such policies and strategies can only be possible where information, on the characteristics and functioning of wetlands is carefully collected, assembled and interpreted. The process of assessing these wetlands to meet the user's need is called land evaluation and this serves as the basis for proper land use planning Fasina and Adeyanju (2007). The objective of the study was to generate information about wetlands soils in Ogba/Egbema/Ndoni Local Government Area in Nigeria, to contribute to the database required for the precise characterization,

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classification, evaluation and understanding of wetland resources in Nigeria.

MATERIALS AND METHODS

The study area is located in Ogba/Egbema/Ndoni L.G.A of Rivers State **(Figure 1)**. The location selected was Egbeda, Osiakpo and Okansu lie on latitude 5.33°N and longitude 6.69°E.The soil is predominantly Sandy loam and Loamy sand. The area has a humid tropical climate annual rainfall distribution which ranges from 2800mm to 3500mm per annum, with an annual Temperature range of 26°C – 31°C throughout the year with a high relative humidity. The area covers over 1,500ha of farm land. Soils of Ogba/ Egbema/ Ndoni are derived from coastal plain sands. The area has a swamp mixture and rainforest with different types of trees with coconut (*Cocoa nucifera* dominating plant species including palm trees, cocoyams, vegetables), and agroforestry (Oil palms, *Heveabrasiliensis, Irvingia sp., Cola sp., Musa sp*.).

Three modal profile pits were dug and described according to international standard of profile description. Soil samples were collected at different genetic horizons and sent to the laboratory for analysis. The samples were collected from the deepest horizon upward to avoid contamination. The samples were placed in appropriate labeled polythene bags

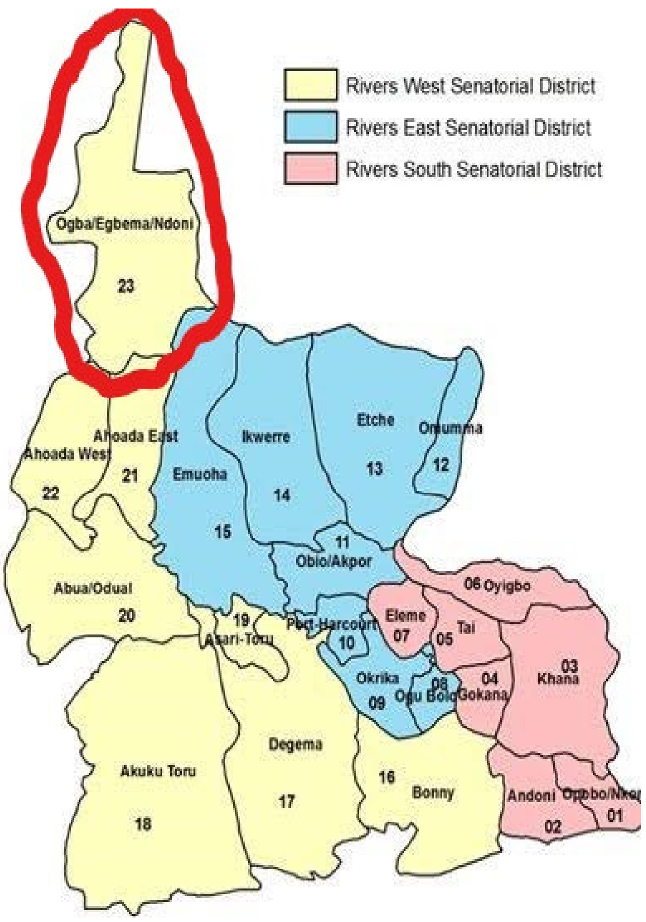

Figure 1. Geographical map of the study area.

and transported to the laboratory. All the soil samples were air-dried under shade for 1 week, crushed with pistle and mortal and passed through a 2mm sieve prior to routine laboratory analysis. Morphological Properties of the soil colours of the pedons were identified using Munsell colour chart. Other morphological properties examined were the depth, texture, structure, consistency and horizon boundary of each horizon. The morphological properties of each pedon was described according to Soil Survey Staff (2010), while the horizons were identified and designated according to the keys to soil taxonomy and World reference base system 2014.

Laboratory analysis

The particle size fractions were determined by the modified Bouyoucos hydrometer method (Anderson and Ingram, 1993). The soil hydraulic conductivity were determined by core sampling method, this was determined using undisturbed soil cores samples using a constant head permeameter method Klute (1986) and calculated using the transposed Darcy's equation for the vertical flow of liquids. The soil pH was determined using glass electrode pH meter both in distilled water and in 0.1N KCl suspension using soil-liquid ratio of 1:2.5. Soil organic carbon was determined by the Walkley and Black wet digestion method as contained. Total nitrogen was determined by the modified macro-kjeldahl digestion and distillation method as described. Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945); while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral NH_4OAC. Calcium, Potassium and Sodium were measured through flame photometer, while Magnessium was determined by Atomic Absorption spectrophotometer Rhoades (1982). Exchangeable acidity was determined by 1N KCl extraction and titrated with 0.05N NaOH solution Black (1975). Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micro- nutrients (Fe, Mn, Cu and Zn) were determined in 1N HCl and evaluated using the AAS. Base saturation was computed as the summation of the basic cations.

Land evaluation

The potentials of these soils for cassava, maize and oil palm were assessed using the following land evaluation methods:

1. Land Capability Classification (LCC) as modified by USDA Klingebiel and Montgomery (1961)
2. Land Suitability Evaluation (LSE)
3. Fertility Capability Classification (FCC) Sanchez PA, *et al*., (2003).

RESULTS AND DISCUSSION

Morphological and physical characteristics

Data on morphological properties of the study soils are presented in **(Table 1)**. Groundwater was encountered in all the profiles. The soils of the study area are varied from poorly to moderately drained which is a characteristic of wetland soils, Differences were observed in texture, structure, consistence. All the soils are mottled or gleyed and have a hue of 10YR. The major morphological features such as grey mottles observed in these pedons is an indication of soil wetness brought about by oxidation-reduction cycles due to ground water fluctuation. Ahn (1970), Smyth and Montgomery (1962) reported inter-relationship between these features. The iron present in these soils impact grayish colour on the soil matrix. The physical properties are presented in **(Table 1)**. The particle size distribution pattern showed that the sand content is very high in all the profiles and ranges from (73.8% to 87.8%), Silt (2% to 14%) and clay (6.2% to 16.2%). This sandy nature can be attributed to the parent materials of the area, coastal plain sands Akamigbo (2000). Reported highest acidity in sand- sized fractions of tropical soils. Akamigbo (1984) reported low silt content in soils of south eastern Nigeria. This indicates the degree of leaching it has undergone and the type of parent material. The data for bulk density are given in **(Table 1)**. The results show that B3OKS had the highest mean bulk density of (1.59g/cm3) and the lowest mean bulk density at B1OSI (1.40g/cm3). Vertically down the profile, bulk density decreased with depth in B1OSI. The value of bulk density is often dependent on soil texture, organic matter, root penetration and soil structure. According to, increase in bulk density maybe due to lower organic matter content. The data for saturated hydraulic conductivity presented in **(Table 1)** shows a very wide range mean value (32.22-42.65cm/hr). The K_{sat} permeability rate was rapid using

Table 1. Morphologiical features & physical properties of the soils of the study area.

Horizon	Depth (cm)	Colour (moist)	Mottling	Gleying	Texture	Structure	Consistence	Roots	Hb	Clay %	Silt %	Sand %	BD g/cm3	Ksat (cm/hr)
B1OSI														
1	0-16	Black (10YR2/1)	Absent	Absent	LS	G	Fri	Mmi,ma &me r	Cs	8.2	6	85.8	1.6	41.34
2	16-54	Brown (10YR 4/3)	Present	Absent	SL	G	Fri	Mmi,ma &me r	Gw	10.2	14	75.8	1.56	28.56
3	54-74	Light yellowish brown(10YR 6/4)	Present	Present	SL	Sab	Fri	Fwr	Gw	14.2	6	79.2	1.31	51.54
4	74-164	Very pale Brown (10YR 8/4)	Present	Present	SL	Ab	Fi	Fwr	Gw	14.2	12	73.8	1.11	7.43
Mean													**1.4**	**32.22**
B2PR 2														
1	0-15	Dark greyish brown (10YR 4/2)	Absent	Absent	LS	G	Fri	M mi,ma r	Cw	12.2	4	83.8	1.51	83.33
2	15-28	Brown (10YR 4/3)	Absent	Absent	LS	G	Fri	Mma,mi me r	Gw	10.2	4	85.8	1.24	71.39
3	28-50	Dark yellowish brown (10YR 4/4)	Absent	Absent	LS	Ab	Fi	Fw mi,ma,me r	Gw	12.2	4	83.8	1.73	30.6
4	50-70	White (10YR 8/1)	Present	Absent	SL	Asb	Fi	Fwr	Cw	16.2	8	75.8	1.61	9.17
5	70-136	Very pale brown(10YR 8/4)	Present	Present	LS	Sab	Fi	Fwr	-	14.2	2	83.8	1.67	9.66
Mean													**1.55**	**40.83**
B3OKS														
1	0-20	Very dark gray (10YR 3/1)	Absent	Absent	LS	g	Fri	Mmi ma r & fw me	Cw	10.2	4	85.8	1.67	78.76
2	20-45	Brown (10YR 5/3)	Absent	Absent	S	G	Fri	fwr,Mme	Gs	6.2	6	87.8	1.39	69
3	45-60	Light gray (10YR 7/1)	Present	Present	LS	Ab	Fri	fwr,fwme	Cw	14.2	6	79.8	1.67	16.38
4	60-176	White(7.5YR 8/1)	Present	Present	SL	Ab	Fi	fwr,fw me		12.8	13.4	73.8	1.62	6.47
Mean													**1.59**	**42.65**

Key: LS=Loamy sand, SL=Sandy loam, S=Sand, g=granular, ab=Angular blocky, sab= Sub-angular blocky, Fri=friable, Fi=firm, fwr=few roots, fw me=few mesophytic roots, Mme=many mesophytic roots, fw mi,ma&me r=few micro, macro and mesophytic roots, M ma,mi &me r= Many macro,micro,mesophytic roots. Hb=horizon boundary, Cs=clear smooth, cw=clear wavy, gs=gradual smooth, gw= gradual wavy, Ksat=saturated hydraulic conductive.

Darcy's rating. The saturated hydraulic conductivity was very rapid at 0-15cm soil at B2PR and 0-20cm soil at B3OKS. This can be as a result of high sand and high proportion of macro pores which have implications for infiltration of water into the soil and availability of water to plant roots and leaching losses Kamalu, *et al*., (2017).

Chemical properties of the study area

Soil reaction: The chemical properties of the study soils are presented in **(Table 2)**. The soils very strongly acidic to moderately acidic. The pH (kcl) ranged from 4.5-5.2. The kcl brought more of the acidity to the soil solution, leading to the exchange complex being dominated by Al^{3+} and H^{+} ions. The pH values of the study soils agree with the assertion of that such reaction is characteristic of soils in Nigeria's South-eastern region and is the result of acidic nature of parent rocks, coupled with the influence of leached profiles under higher annual rainfall conditions.

Total organic carbon: The total organic carbon content soil in the soil profile B1OSI ranges from 5.88-8.68% with a mean value of 7.02%, B2PR soil range from 6.3%-7.74% with a mean value of 7.07% and B3OKS soil with a mean value of 7.12%. The organic matter content varied across the different soil horizons, of the soil ranged from low–high, (10.11-15.14%) for all the profiles and Organic carbon was low to medium in the pedions.

Total nitrogen: Total nitrogen was low. The mean values for the three profiles were 0.20%, 0.068% and 0.078% respectively. This compares well with the report of that N is normally deficient in most wetland soils for growing. The low levels may be associated with leaching coupled with intermittent flooding and drying which is known to favour N loss through nitrification-denitrification process.

Available phosphorus: Concentration of available phosphorous varied across the different soil horizons and ranged from 1.499mg/kg, 3.07mg/kg and 3.43mg/kg B1OSI, B2PR and B3OKS respectively, Available phosphorous in the pedons were relatively low. The low content of available phosphorus in these soils could be attributed to the pH level of the soils, similar observation has been made by in similar soils. The low available phosphorus in the area could be due to the nature of parent material in the area and to a limited extent, erosion, leaching and low organic matter content in the area. Reported that available Phosphorous is generally low for all the wetland soils, with average values less than 15mg/kg.

Potassium: Potassium deficiency occurred in all the profiles because all the soils in the study area are very high in sand content , the sandy texture of the soils in the soil must have encouraged the leaching of the available soil nutrients as K^{+} which are highly soluble. And potassium plays a lot of roles in plants such as protein synthesis, opening and closing of stomata, activation of some enzymes, phloem solute transport, and maintenance of cation: anion balance in the cystol and vacuole, a deficiency in K will impair a plants ability to maintain the processes.

Exchangeable cations: Calcium and Magnesium are the predominant exchangeable bases. The cation distribution is in the order: Mg >Ca>Na >K in all the soils, **(Table 2)**. The exchangeable bases are low. This may be due to the nature of the parent material in the location, intense leaching, weathering etc and hence, low inherent fertility status with regards to the major and micro nutrients. This agreed with the findings. In ferrolysis, excessive Fe^{3+} in the soil solution

Table 2. Chemical properties result of the studied area.

Sample Id	Profile 1 Depth (cm)	pH In kcl	P Mg/kg	TN %	TOC %	OM %	Ca Cmol/kg	Mg Cmol /kg	Na Cmol/Kg	K Cmol/kg	Ex Aci (H&A)	CEC Meq/100g	BS %	Mn Mg/kg	Zn Mg/kg	Cu Mg/kg	Fe Mg/kg
B1OSI	0-16	5.2	1.12	0.1288	6.72	11.56	0.56	0.16	0.18	0.07	1.6	2.57	37.74	74.589	209.272	52.374	1,686.142
B1OSI	16-54	4.8	0.036	0.56	6.78	11.66	0.02	0.37	0.08	0.03	1.4	1.9	26.32	296.712	94.692	69.834	1,598.848
B1OSI	54-74	5.2	2.56	0.0672	8.68	14.93	0.18	0.19	0.20	0.14	1	1.71	41.52	310.569	78.374	74.484	1,552.706
B1OSI	74-164	5.0	2.28	0.0504	5.88	10.11	Nil	0.22	0.10	0.04	1.6	1.96	18.37	352.323	56.952	86.052	1,641.182
Mean		**5.1**	**1.499**	**0.20**	**7.02**	**12.07**	**0.19**	**0.24**	**0.14**	**0.07**	**1.4**	**2.04**	**31.04**	**258.55**	**109.82**	**70.69**	**1,619.72**
B2PR	0-15	4.6	1.91	0.084	6.3	10.84	0.48	0.28	0.08	0.06	1.4	2.3	39.13	352.468	55.876	56.932	1,692.588
B2PR	15-28	4.7	3 .25	0.0952	6.6	11.35	0.10	0.76	0.15	0.07	1	2.08	51.92	489.692	264.162	96.578	1,996.744
B2PR	28-50	4.7	3.51	0.0616	7.02	12.07	0.0038	0.38	0.19	0.06	9	9.63	6.58	510.408	42.948	70.444	1,658.044
B2PR	50-70	4.9	3.58	0.0392	7.74	13.31	0.16	0.18	0.16	0.06	1.8	2.36	23.73	434.268	229.883	26.048	1,697.892
B2PR	70-136	5.0	3.11	0.0616	7.68	13.21	0.08	0.19	0.11	0.05	1.6	2.03	21.48	912.296	82.204	151.484	1,737.144
Mean		**4.8**	**3.07**	**0.068**	**7.07**	**12.16**	**0.16**	**0.36**	**0.14**	**0.06**	**3.0**	**3.68**	**28.57**	**539.83**	**135.01**	**80.30**	**1,756.48**
B3OKS	0-20	4.5	5.21	0.1288	6.06	10.42	0.0015	0.05	0.12	0.07	3	3.24	7.45	229.846	62.372	156.932	1,696.587
B3OKS	20-45	5.0	3.25	0.0672	6.72	11.56	Nil	0.25	0.19	0.07	1.2	1.71	29.82	198.616	50.164	176.880	1,659.921
B3OKS	45-60	4.8	2.89	0.056	6.9	11.89	0.004	0.79	0.15	0.05	1.4	2.39	41.59	219.552	78.528	60.308	1,715.143
B3OKS	60-176	5.1	2.35	0.0616	8.8	15.14	0.36	0.78	0.55	0.15	0.8	2.64	69.70	705.372	239.232	46.396	1,737.072
Mean		**4.9**	**3.43**	**0.078**	**7.12**	**12.25**	**0.09**	**0.47**	**0.25**	**0.09**	**1.6**	**2.50**	**37.14**	**338.35**	**107.574**	**110.13**	**1702.18**

Keys: KCl= potassium chloride, H_2O= Water, pH= soil reaction, TOC= total organic carbon, OM= organic matter, Ca= calcium,Mg= magnesium,Na= sodium, K= potassium, Ex Aci= exchangeable acidity (H&AL), Zn= zinc, Mn= manganese, Cu= copper, Fe= iron, TN= total nitrogen, P= available phosphorus and CEC= cation exchangeable capacity.

displaces exchangeable cations from the exchange complex into the soil solution and these are eventually replaced mainly by Al from clay lattices after oxidation.

Cation exchange capacity: Cation Exchange Capacity (CEC) was low for all the pedons ranging from 2.04 to 3.68cmol/kg. These are in line with the values reported for most Nigerian soils.

With percentage base saturation varied from 28.57 to 37.14% in all the profiles of the studied soils. The CEC of soils influence soil structure stability, nutrient availability, soil pH and other ameliorants. Soils with low CEC are more likely to develop deficiencies in K, Mg and other cations.

Micronutrients: The soil possesses appreciable amount of Mn^{2+}, Zn^{2+}, Cu^{2+} and Fe^{3+}, with Fe^{3+} as the highest value in the soil. The release of large amount of Fe^{3+} and Mn^{2+} into the soil solution during soil submergence is also known to displace the exchangeable cations from the soil exchange complex. The soils are poorly drained, which is a characteristic of wetland soils

LAND EVALUATION

Land capability classification

It was observed that the soil profile B1OSI, B2PR, and B3OKS are moderately capable with limitations such as low fertility. The low soil fertility and possibility of periodic high-water **(Table 3)** (wetness).

Land suitability evaluation (LSE)

It was observed that B1OSI, B2PR and B3OKS are marginally suitable for cassava production with limitation such as soil physical constraints, as well as low fertility and drainage/high level of wetness, low fertility in B1OSI. This was similar to the result obtained in a study on alfisols and ultisols in Ogun State which showed that all the pedons were marginally suitable (S3), the major limitations are soil texture and structure, which directly affect water-holding capacity, permeability of the soil and other physical properties **(Table 4)**. Other limiting factors were drainage and soil fertility, measured by CEC, organic matter and total nitrogen content. However, good soil management practices that encourage the use of organic manure, cultivation of cover crops, zero tillage as well as correct usage of the land for the use it is meant for are required for sustainable production. Soil profile B2PR is moderately suitable with limitations of low fertility while B1OSI and B3OKS are marginally suitable with limitations such as low fertility and drainage/high level of wetness for oil palm.

Fertility capability classification

Based on fertility capability classification, of the different condition modifiers used in the evaluation **(Table 5)**, potassium deficiency (k- <0.20cmol/100g) and low cation exchange capacity (e- <15cmol/kg) occurred in the soils studied. The soil profiles were thus classified as Skleg, SLkeg and SSkeg for the soil profiles (B1OSI, B2PR and B3OKS

Table 3. Land capability classification of the soils of the study area.

	B1OSI	B2PR	B3OKS
Slope%	0–4	0-4	0-4
Drainage	Poorly drained	Moderately drained	Moderately drained
Effective soil depth	164cm	136cm	176cm
Soil texture class 0 – 30cm	S L– S	LS – LS	LS – LS
Fertility			
pH (KCL)	4.5 – 5.2	4.6 – 5.0	4.5 – 5.1
Total N	0.0504– 0.56	0.0392-0.0952	0.056– 0.1288
Total organic carbon (TOC)	5.88 – 8.68	6.3 – 7.74	4.5– 8.8
Available P	0.036 – 2.56	0.111 – 3.58	2.35– 5.21
Exc K	0.04 – 0.14	0.05– 0.09	0.04 – 0.15
Exc Ac	1– 1.6	1- 9	0.8 – 3
CEC	1.71 – 3.25	2– 9.63	1.71 – 3.24
B.s	18.37 – 50.77	6.58 – 51.92	7.45 – 69.70
Mn	69.852 – 463.564	352.468 – 912.296	198.616– 705.372
Cu	45.508 – 86.052	26.048-151.484	46.396 – 176.880
Iron	1552.706 – 1686.142	1586.746-1996.744	1659.921 – 1737.072
Zinc	56.952-228.008	42.948 – 315.208	50.164– 239.232
Capability class **Capability unit**	Moderately capable IIfw	Moderately capable IIf	Moderately capable IIf

Key
II - Capability class II (Moderately capable)
F - Fertility deficiency
w - Wetness/drainage

Table 4. Land Suitability Evaluation of the soils for some selected crop.

Crop/Sample Id	B1OSI	B2PR	B3OKS
Cassava	S3wf	S3f	S3f
Maize	S3wf	S2f	S3f
Oil Palm	S3wf	S2f	S2f

S1 – Highly suitable S2 – Moderately suitable S3 – Marginally suitable N2- Permanently not suitable
Limitations: s - Soil physical constraints (e.g. ironstone pan, high infiltration rate, etc); E - Susceptibility to erosion; c – Climate; f - Low fertility; w - Drainage/high level of wetness.

Table 5. Fertility capability classification (fcc) of the soils of the study area.

Description	B1OSI	B2PR	B3OKS
Texture			
Type 0-20cm	S	S	S
Substrata type 0-50cm	S	L	S
k exchangeable K is < 0.20 cmol/kg	K	K	K
e soils with low CEC in the plow layer	E	E	E
FCC	SSkeg	SLkeg	SSkeg

S-Sandy top soil; loamy sands and sand Sub-strata type; L-Loamy subsoil; S- Sandy subsoil Condition Modifiers
k- Soils having very low amounts of potassium (exchangeable K less than 0.2cmol/100g soil); e- Soils with low CEC in the plow layer; g- prolonged waterlogging(soil saturated with wetness for over long period)

respectively). Potassium deficiency occurred in all soils because majority of the soils are very high in sand content, the sandy texture of the soils as well as high concentration of the gravels in the soil must have encouraged the leaching of the available soil nutrients as K^+ which are highly soluble.

CONCLUSION AND RECOMMENDATION

The study soils are moderately to poorly drained soil and predominant on sandy loam and loamy sand. The soil reaction varied from very strongly acid to strongly acid, low in total nitrogen, available phosphorous and moderate in organic carbon, organic matter but high in iron, manganese, copper and zinc. It was observed that for land capability classification the soils were moderately capable with capability unit IIfw and IIf with limitations of fertility and wetness. For suitability classification the soils were moderately (S2) and marginally (S3) suitable for cassava, maize and oil palm and for fertility capability classification, the soils were classified as SSKeg, SLkeg and SSkeg showing low condition modifiers. The Identified major limitation on these soils for wetland cassava,maize and oil palm production is mostly fertility problem, the soil fertility problem can be amended using appropriate fertilizers to move these soils to moderately suitable (S2) for the crop production. The K, pH and CEC are the most relevant soil properties needed to contribute to the yield of these crop production in the study area and can be useful in soil fertility evaluation studies when determining optimum levels of nutrients for wetland production thereby concentrating more on the most relevant soil properties required in order to save cost on fertilizer use.

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