Suitability Evaluation of Wetland Soils for Rice production in Ndoni, Rivers State, Southern Nigeria

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Abstract
Land suitability assessment of soils in Okiyeobi community in Ndoni, Rivers State to evaluate its rice production potentials on sustainable basis using the inherent physicochemical properties of the soils was carried out. Two important mapping units were identified on the field through a reconnaissance survey based on land physiography and vegetation. All soils identified were poorly drained. One profile pit was dug in each mapping unit designated as pedon1 and 2. The soils were predominantly medium textured with sub-angular, angular to blocky structure. Soil colour varied across the various soil horizons from greyish brown, dark greyish brown (10YR 5/2) to dark yellowish brown (10YR4/6). The soil textural class ranged from sandy loam (SL) to Sandy clay loam (SCL). Sand fractions dominated both pedon I and 2 with mean fraction of 542 and 445g/kg^{-1} respectively. Followed by silt in pedon 1 (251g/kg^{-1}), but silt fractions were low (233g/kg^{-1}) in pedon 2, while mean clay fraction was (207g/kg^{-1}) in pedon 1, but higher in pedon 2 (322g/kg^{-1}). Mean bulk density ranged from 1.50g/cm^3 in pedon 2 to 1.74g/cm^3 in pedon 1. Soil moisture content in pedon 1 was low (49.15%) compared to that of pedon 2 (58.73%). Mean soil reactions in both pedons indicated that the soils pH were relatively low (pH4.80, highly acidic). Organic carbon and available phosphorus were also low in both pedons (0.71 and 0.83 g/kg^{-1}) (0.74 and 1.17 mg/kg^{-1}). Exchangeable bases (calcium, magnesium, sodium and potassium) were relatively low in both pedons. The results placed the land under moderately suitable class (S2) as the lands did not meet the required criteria for rice production. Therefore, for the soils to be suitable for rice production, some soils amendment materials such as crop residue and farmyard manure should be incorporated into the soil to enhance soils nutrient availability. Thus application of fertilizer should be encourage to improve the soils for sustainable crop production.

Keywords: *Suitability, Evaluation, Wetland, Rice, Soils and Ndoni*

Introduction

Soils are important natural resource for crop production and sustainable soil management is the key to sustainable agricultural production (Ogunkule 2004). Soil resources played important role in agricultural production. Therefore, there is urgent needs to match soil type and land use for sustainable food production for the teaming population of a country like Nigeria (Onweremadu and Peter 2016). Soil is a natural body upon which crop grow and obtained their nutrients. Available information (Ayolagha and Onuegbu 2006) shows that, in Rivers state, there is upland and wetland soils based on the geological deposits in the state. Wetland resources constitute an important agricultural ecology in the world and are major contributors of economic growth of the society (Onweremadu and Peter 2016). 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 2007*). Wetlands also refer to areas of land with low water table very close to soil surface. Wetland provides food and economy trees for various purposes and reeds to make shelter materials (Onweremadu and Peter 2016). Rice (*Oryzasativa*) is primarily a tropical and subtropical crop. It is grown in wide variety of climate, soil-hydrological regimes and it is a heat and water-loving plant that requires high temperature and adequate water supply (Matsuo, 1955). Rice is a cereal crop belonging to the Gramineae family; a large monocotyledonous family of about 600 genera and around 10,000 species (Ayolagha et al 2012). It is valued as the most important staple food for over half of the world population and ranks third after wheat and maize in production on world basis. Land evaluation which includes land capability classification, can tell farmers how suitable their land is in terms of soil limitations, crop yield or profit. Increase in urbanization has led to more agricultural land being converted to housing for the ever increasing human population. The problem of food supply in the country is increasing on a daily basis; especially, rice which is being consumed by majority of rural and urban dwellers. Fallow period which helps to restore soil fertility are shortened or limited land use intensification impact negatively on soil quality, hence the need for suitability assessment of the limited land resources. Ever increasing demand for food has intensified quest for more production per unit area, as intensification of land use leads to soil degradation and decreasing crop yield. Rice is a crop in Nigeria, but local production of rice is limited and its internal demand is increasing on a daily basis. However, some work have been done in the Southern part of Nigeria on wetland soils for rice production, hence there is a need to evaluate the wetland soils of Ndoni for rice production which is the main objective of this study, to evaluate the suitability of wetland soils for rice production in Ndoni, Rivers State.

Materials and Methods

Study Area

This study was carried out in Okiyeobi community, Ndoni, in Ogba/Egbema/Ndoni Local Government Area, Rivers State. It lies between latitude 0.5 47787'N and longitude 006.62789'E with an elevation of 24m above the sea level. The region experienced two major seasons wet and dry season (Balogun, 2001). It has a mean annual rainfall of 2500 – 3000mm in a bimodal form and a mean temperature of 27^0c and 29^0c.The study area is within the humid tropical climate and has a high relative humidity depending on the season of the year. It is influenced by temperature, rainfall, humidity as well as wind and because of these factors, the daily weather varies according to their changes. The soils of the study area are derived from the coastal plain and deltaic marine deposits. Ndoni is located in the tropical rainforest zone and therefore has the rainforest pattern of vegetation.

Land use

The land use type within the studied area varies among oil palm (*Elaiseguineensis*) and plantain (*Musa spp*) cultivation. Oil palm is dominated in the area and palm oil production is one the lucrative business in the community.

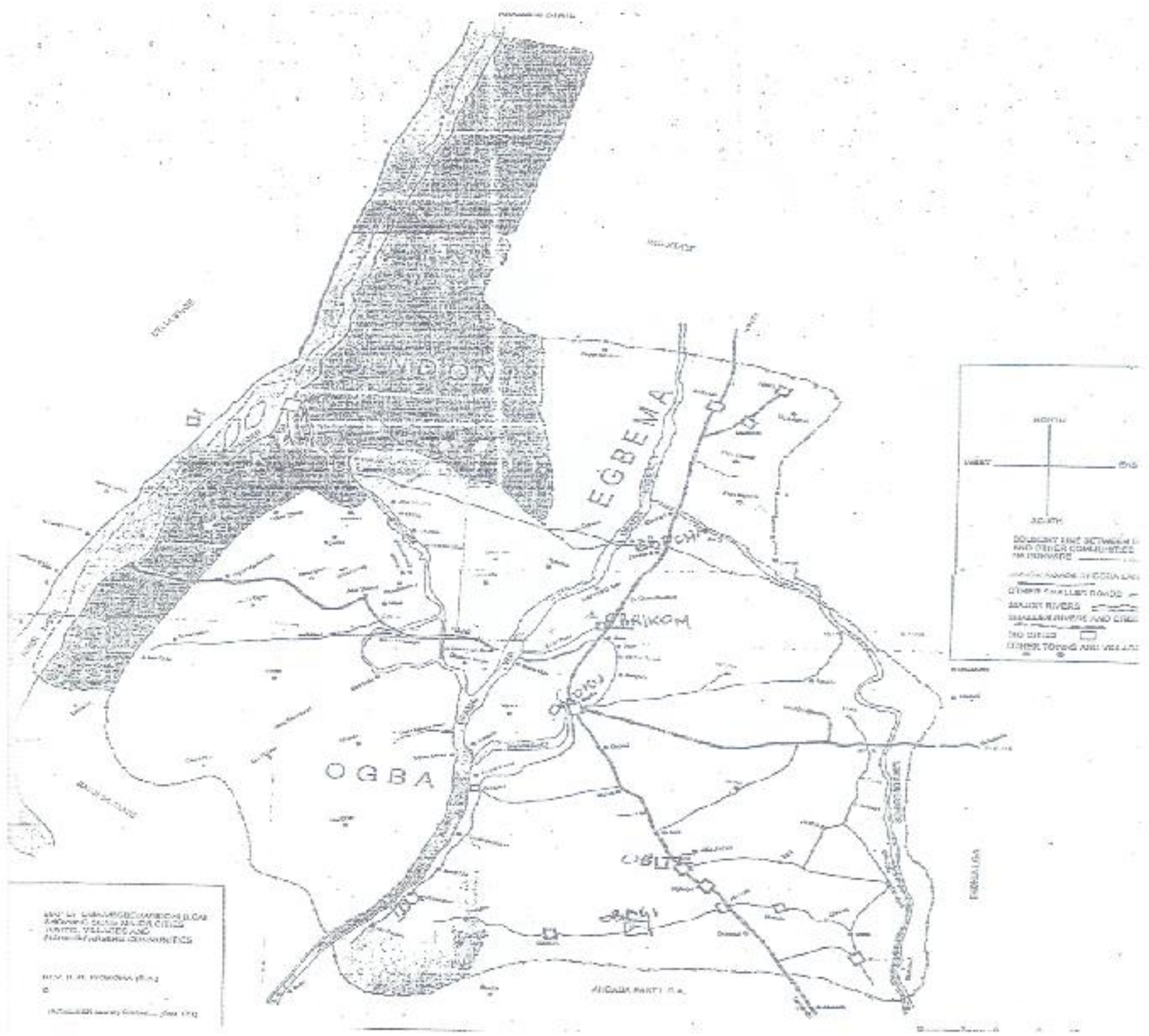

Fig 1: Map of the Study Area

Pre-field

A reconnaissance survey was be made for the purpose of identifying wetland site within the study area using relevant topographic and geological map of the area. During the pre-field visit, hand held GPS was used to determine the coordinates of modal profile points in the two mapping units identified.

Field Studies

The field work was carried out in July, 2018. A free soil survey technique was used for the study. Two wetland sites were identified. Two modal soil profile pits of 2 X 2 X 2m were sunk and described according to FAO (1999) procedure. A handheld GPS was used to determine the geographical positioning and coordinates of the profile pits at their various mapping units. Soil samples were collected from different horizons from bottom to top to avoid contamination. Soil morphological characteristics was determined and recorded; while soil colour was determined using munsell colour chart. The collected soil samples were bagged in polythene bags and well labelled. Core samples for bulk density determination were taking using a core sampler. All soil samples collected were air-dried, crushed and sieved using 2mm sieve for routine analysis.

Morphological Properties of Pedons

Soil colours of the pedons were identified using Musell colour chart. Other morphological properties examined were the depth, texture, structure and consistency of each horizon. The morphological properties of each pedon were described according to Soil Survey Staff (1951), while the horizons were identified and designated according to the revision in Soil Taxonomy (Soil Survey Staff, 1999). Morphological properties of the pedons of the study area are presented below:

Laboratory Soil Analysis

The soil samples were air dried and passed through a 2mm sieve. The prepared soils samples were used for the following physical and chemical analysis.

Particle Size

Particle size was determined using the bouyoucos hydrometer method (Gee, 2002). This analysis depends on Stoke's law of settling velocity proposed by Stoke. Textural classes were determined using the soil textural triangle.

Bulk Density

This was done by the procedure described by Blake and Hartge (1986). Undisturbed soil samples were collected using a cylindrical core. The bulk density was derived from the following:

$$\ell b \quad \frac{Ms}{Vb} \quad (gcm^{-3})$$

$$Where: \ell b = bulk \;\; density$$

$$Ms = Mass \;\; of \;\; oven\; dry\; soil \;\; (g)$$

$$Vb \quad = \quad bulk \;\; volume \;\; of \;\; soil \quad (Cm^3)$$

Soil pH

This was determined by using the hydrometer method. 10g of soil was weighed into a pH cup and 25ml distilled water was added. It was stirred with glass rod stirrer and allowed for 30 minutes to settle. The pH meter electrode was allowed to stabilize using a buffer solution (pH 4.0 or 7.0). Then the electrode was rinsed with the soil solution and readings were taken.

Organic Carbon

This was determined by Walkley and Black (1934) wet oxidation method and computation was done by applying the formula and organic matter was obtained by multiplying the organic carbon value by 1.724 (Van Bemmelen correlation factor).

% OC =

Total Nitrogen

This was determined by the macro-kjedahl digestion distillation method (Bremner and Mulvaney, 1982). 1g of soil was disintegrated with concentrated H_2SO_4. The digest was then distilled with acid. The percentage nitrogen was calculated using the formula as expressed:

$$\% \quad TN = \frac{N(T-B)\,X\,14\,X\,100g}{1000\ X\ N}$$

Where: N = Normality of acid used (H_2SO_4)
T = Burette reading for samples
B = Burette reading for blank
W = Weight of soil used

Effective Caution Exchange Capacity (ECEC)
This was determined using summation method following the extraction of exchangeable acidity in 1N KCl.

Available phosphorus
Extractable phosphorous was determined using Bray and Kurtz No.1 (1945) method. This was done by agitating the soil with a solution containing 0.03M NH_4F and 0.25MHCl. Phosphorous standards were prepared, absorbance of the samples containing the soil extracts were also measured using visible spectrophotometer and concentration of P was determined from a standard curve graph.
This can be calculated as:

$$\text{Available P in soil} \quad \frac{50}{10y}\ X\ \frac{20}{2.85}\ (ppm)$$

Where: Y = Graph reading of samples
2.85g = Weight of soil used
20 = Amount of extracting solution

Exchangeable bases
Exchangeable bases: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} were extracted by 1N NH_4OAc buffered at pH 7. Ca and Mg were determined using Ethylene diamine tetra acetic acid (EDTA) titration method, while the concentration of Na and K were measured with the flame photometer method.

Exchangeable Acidity
This was determined using the titration method. 5g of soil was weighed into a 50ml shake bottle and 100ml of 1N, KCl was added and shaken for 1 hour mechanically. The constituent was filtered using whatman No. 42 filter paper into 250ml Erlenmeyer flask. 25ml of the aliquot was pipetted into another Erlenmeyer flask (250ml) and 10 drops of phenolphthalein indicator was also added. The solution was titrated with 0.01N, NaOH to a permanent pink end point with alternate stirring and standing the readings obtained was noted for exchangeable Al^{3+}. To the same flask, 1 drop of 0.05N, HCl was added to bring the solution back to the colorless condition and 10ml of NaF solution was added, color changes back to pink while stirring the solution continuously, titrate with 0.05N HCl until the color disappears completely and does not return within 2 minutes this last titration was for exchangeable H+ present of which the formula below can be used for the calculation of exchangeable acidity.

$$\text{Total E.A (H+AL) in 100ml or 5g soil} = N_1V_1\ X\ \frac{100}{50} Meq$$

$$\text{Total E.A in 100g soil} \ = N_1 V_1\ X\ \frac{100}{50}\ X\ \frac{100}{50} Meq = 40 N_1 V_1$$

Exchangeable AL in 50ml extract = $N_2\ V_2$Meq

Exchangeable Al in 100ml extract $\frac{100}{50} N_2 V_2 \, Meq$

Exchangeable Al in 5g soil = $\frac{100}{50} N_2 V_2 \, Meq$

Exchangeable Al in 100g soil = $\frac{100}{50} X \frac{100}{5} \; N_2 V_2 = 40 \; N_2 V_2 \, Meq$

Where: exact strength of NaOH and HCl = N_1 and N_2 respectively burette reading of NaOH = V_1 and N_2 respectively burette reading of NaOH - V_1 ml, and that of HCl is V_2ml, total E.A. (H+Al) in 50ml extract = N_1 V_1

Results and Discussions

Morphological Properties of soils in the Study Area.

The morphological properties of soils in the study area as shown in Table 1 indicated that the colour, (hue, chroma and value moist using Munsell colour chart) ranged from greyish brown 10YR 5/2 to dark yellowish brown 10 YR 4/6 (0 – 200cm) in pedon 1 and varied from dark greyish brown 10 YR 4/2 to dark yellowish brown 10 YR 4/6 (0 – 70cm) in pedon 2. The grey colour observed at surface level in pedon 1 is an indication that the soil had low organic matter. This opposed the findings of Brady and Weil (2002) who stated that soil colour at surface horizons are brownish to dark due to the presence of organic matter. Besides the soils were poorly drained, hence the grey colouration. Soils in pedon 1 were deep (0 – 200cm) compared to pedon 2 (0 – 70cm) with abundant roots at surface horizon in both pedons. Textural class in pedon 1 ranged from sandy loam (surface horizons) to sandy clay loam at subsurface horizons, while in pedon 2, textural classes were all sandy clay loam at both surface and subsurface horizons. Soil structures ranged from sub angular blocky (SAB) to blocky (B) in pedon 1 and varied from angular blocky (AB) to blocky (B) in pedon 2. There were more floral and faunal activities at surface horizons in both pedon 1 and 2. AB Horizon had fewer roots, having a depth of 10-50cm. Bt_1horizon also had fewer roots with a slightly sticky and non-friable consistency when moist and dried respectively

Table1: Morphological Properties of Soils in the study Area

Location	Horizon	Depth (cm)	Colour Description	Texture	Structure	Consistency	Features
Pedon 1							
	AP	0-10	10YR 5/2 greyish brown	SL	SAB	Wet, Nil Moist, P Dry, F	AR
	AB	10-50	10YR 5/4 yellowish brown	SCL	AB	Wet, Nil Moist, P Dry, F	FR
	Bt_1	50-110	10YR 4/6 dark yellowish brown	SCL	B	Wet, Nil Moist, P Dry, NF	FR
	BK	110-200	10YR 4/6 dark yellowish brown	SL	B	Wet, Nil Moist, SS Dry,NF	NR
Pedon 2							
	AB	0-12	10YR 4/2 dark greyish brown	SCL	AB	Wet, Nil Moist, P Dry, NF	AR
	Bt_1	12-37	10YR 4/6 dark yellowish brown	SCL	B	Wet, Nil Moist, P Dry, NF	FR
	Bt_2	37-70	10YR 4/6 dark yellowish brown	SCL	B	Wet, Nil Moist, SS Dry, NF	NR

SCL = Sandy Clay Loam, SL = Sandy Loam, SAB = Sub Angular Blocky, AB = Angular Blocky, B = Block, P = Plastic, NF = Not Friable, AR = Abundant Roots, FR = Few Roots, NR = No Root

Physical Properties of Soils in the Study Area

Table 2 revealed the physical properties of soils in the study area. Sand fractions varied across the different soil horizons in both pedons from 492-612g/kg^{1} with an average mean of 542g/kg^{1} in pedon1, while in pedon 2, sand fractions ranged from 432-452g/kg^{1} with an average mean of 445g/kg^{1}. The silt content varied also in both pedons at different soil horizons and ranged from 226-266g/kg^{1} with an average mean of 251g/kg^{1} in pedon1, while in pedon2 it varied across the different soil horizons from 206-266g/kg^{1} with an average mean of 233g/kg^{1}.The clay content also varied in the different soil horizons from 162-262g/kg^{1} with an average mean of 207g/kg^{1} in pedon1, while in pedon2, it varied across the different soil horizons from 282-342g/kg^{1} with an average mean of 322g/kg^{1}. However, sand values were high in both pedons, followed by clay and silt. There was an increase in clay content down the profile from 282g/kg^{-}

[1] in the surface horizon to 342 g/$^{kg-1}$ in the subsurface horizons in peodn 2. The increase in clay content down the profile in pedon 2 might be as a result of eluviation/illuviation processes that have taking place in the soils. This is in line with the report of Singh (1999) and Adamu (2012). Again, the results of the particle size distribution shows that the sand fractions dominated in all the horizons followed by clay and silt in pedon 2. This in line with the findings of Akamigbo and Asadu (1983) who reported that, this trend is applicable to soils in southern Nigeria. However, in pedon 1, the trend were not the same, sand fractions was higher follow by silt and clay in that order. Bulk density varied among the different horizons. In pedon 1, bulk density ranged from 1.67-1.80g/cm^3 with an average mean of 1.74g/cm^3, while in pedon 2 it ranged from 1.34-1.67g/cm^3 with an average mean of 1.50g/cm^3. Bulk density in pedon 1 was higher than in pedon 2. The moisture content decreased down the horizons in pedon 1 from 60.8-40.8% with an average mean of 49.15% and varied across the horizons in pedon 2 from 54.0-62.1% with an average mean of 58.73. Moisture content in pedon 2 was higher than that in pedon 1.

Table 2: Physical Properties of Soils in the Study Area

Location	Horizon	Sand →	Silt gkg^{-1}	← Clay	Bulk Density (g/cm^3)	Moisture Content (%)	Textural Class
Pedon 1							
	AP	572	266	162	1.67	60.8	SL
	AB	492	246	262	1.74	49.5	SCL
	Bt_1	492	266	242	1.74	45.5	SCL
	BK	612	226	162	1.80	40.8	SL
Mean		**542**	**251**	**207**	**1.74**	**49.15**	
Pedon 2							
	AB	452	266	282	1.48	62.1	SCL
	Bt_1	452	206	342	1.34	60.1	SCL
	Bt_2	432	226	342	1.67	54.0	SCL
Mean		**445**	**233**	**322**	**1.50**	**58.73**	

SL = Sandy Loam, SCL = Sandy Clay Loam

Chemical properties of Soil in the Study Area

Chemical properties of the various soil horizons in pedon 1 and 2 are shown in Table 3. Soil reactions (pH) of the different soil horizons varied. In pedon 1, it ranged from 4.48 - 5.07 with an average mean of 4.80., while the soils pH of the different horizons in pedon 2 varied from 4.64 - 4.99 with an average mean of 4.80. This showed that soils in both pedon1 and 2 are strongly acidic according to FAO (2004). Organic carbon content of the soils in pedon1 varied across the different soil horizons, it ranged from 0.16 -2.07g/kg^{1}with an average mean of 0.71g/kg^1, while in pedon 2, organic carbon content varied across the different soil horizons, it ranged from 0.13-0.20g/kg^1 with an average mean of 0.83g/kg^1. Organic carbon was very low in both pedons according to Metson (1961). Concentration of available phosphorous varied across the different soil horizons and ranged from 0.07-1.40Mg/kg with an average mean of 0.74Mg/kg in pedon1, while it varied across the different horizon from 0.07-1.40Mg/kg in pedon2 with an average mean of 1.17Mg/kg. Available phosphorous in both pedons were relatively low according to Enwezor *et al.*, (1989). Exchangeable acidity in pedon 1 varied across the different soil horizons from 1.04-3.54Cmol/kg with an average mean of

2.04Cmol/kg, and ranged across the different soil horizons in pedon 2 from 2.81-5.36Cmol/kg with an average mean of 3.80Cmol/kg. Exchangeable acidity ranged from very strongly acid to strongly acid in pedon 1 and 2 respectively. Calcium content in pedon 1 varied across the different soil horizons from 1.20-6.00Cmol/kg with an average mean of 3.15Cmol/kg, and also varied across the soil horizons in pedon 2 from 6.00-7.60Cmol/kg with an average mean of 6.8Cmol/kg. Calcium concentration ranged from low to moderate in pedon 1 and 2 respectively. Magnesium concentration varied across the soils in pedon 1 from 2.20-5.20Cmol/kg with an average mean of 3.30Cmol/kg, and also varied across the different soil horizons in pedon 2 from 6.00-7.80Cmol/kg with an average mean of 3.80Cmol/kg. The concentration of magnesium was high in both pedons. Potassium concentration in pedon1 varied across the different horizons from 0.15-1.00Cmol/kg with an average mean of 0.44Cmol/kg, while it varied across the soil horizons from 0.20-0.35Cmol/kg with an average mean of 0.27Cmol/kg in pedon2. The concentration of K was very low in both pedons. Sodium concentration in pedon1 varied across the different soil horizons from 0.16-0.17Cmol/kg with an average mean of 0.17Cmol/kg, while it varies across the different soil horizons in pedon2 from 0.13-0.27Cmol/kg with an average mean of 0.19Cmol/kg. It showed that the concentration of sodium was low in both pedons. Base saturation in pedon 1 varied among the different soil horizons and ranged from 66.22-86.95% with an average mean of 77.69%, while in pedon 2 it varied among the different soil horizons and ranged from 66.65-83.35% with an average mean of 73.61%. Base saturation in pedon 1 was higher than that inpedon2.ECEC in pedon1 varied across the different soil horizons from 7.83-11.20Cmol/kg with an average mean of 9.09Cmol/kg, while in pedon 2 it varied across the soil horizons from 12.72-16.88Cmol/kg with an average mean of 14.65Cmol/kg.CEC inpedon1 varied across the different soil horizons from 5.83-9.36Cmol/kg with an average mean of 28.23Cmol/kg, while in pedon 2 it varied across the soil horizons from 8.99-14.07Cmol/kg with an average mean of 32.58Cmol/kg

Table 3: Chemical properties of Soil in the Study Area

	Horizon	pH (H_2O)	OC (g/kg^1)	AvP Mg/kg	Ca^+ →	Mg^+ →	K^+ Cmol/kg	Na^+ ←	TEA ←	BS (%)	ECEC (Cmol/kg)
Pedon 1											
	AP	5.07	2.07	0.07	6.00	2.20	1.00	0.16	1.84	83.57	11.20
	AB	4.48	0.39	0.07	1.20	5.20	0.36	0.17	1.04	86.95	7.97
	Bt_1	4.68	0.16	1.40	2.20	3.20	0.26	0.17	3.54	62.22	9.37
	BK	4.91	0.23	1.40	3.20	2.60	0.15	0.16	1.72	78.03	7.83
Mean		**4.80**	**0.71**	**0.74**	**3.15**	**3.30**	**0.44**	**0.17**	**2.04**	**77.69**	**9.09**
Pedon 2											
	AB	4.74	1.17	0.07	7.60	2.00	0.35	0.17	3.20	74.84	12.72
	Bt_1	4.99	1.13	1.40	6.80	6.80	0.20	0.27	2.81	83.35	16.88
	Bt_2	4.64	0.20	1.40	6.00	2.60	0.26	0.13	5.36	62.65	14.35
Mean		**4.80**	**0.83**	**1.17**	**6.8**	**3.8**	**0.27**	**0.19**	**3.80**	**73.61**	**14.65**

OC = Organic Carbon, AvP = Available Phosphorous, TEA = Total Exchangeable Acidity, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, BS = Base Saturation, ECEC = Effective Cation Exchange Capacity

Suitability Classification for Rice Production in the Study Area

The suitability classification for rice production in the study area was done using the interpretation guide for evaluating analytical data (SPFS, FMARD) FAO (2004).

Table 4: Interpretation Guide for Evaluating Analytical Data

a) Cation Exchange Capacity (CEC)

Cmol/kg

Range (%)	Class
<6	Very low
6-12	Low
12-25	Moderate
25-40	High
>40	Very high

b) Percentage Base Saturation (%)

Range (%)	Class
0-20	Very low
20-40	Low
40-60	Moderate
60-80	High
>80	Very high

c) Organic Matter Rating and Interpretation Rating by Metson (1961)

Range (%)	Class
<2	Very low
2-4	Low
4-10	Moderate
10-20	High
>20	Very high

Land Suitability Evaluation

Using the matching of land quality rating or characteristics, as shown by soil characteristics from the study area with requirements to produce the various suitability class for rice production in the study are as shown in Table 5. However soils in the study area did not vary significantly to enhance the soil-sit suitability evaluation for rice production. From the results, major obstacle for rice production in the study area were the soil fertility status with respect to rice production in the study area. From the result, it shows that the studied area was moderately suitable (S2) for rice production based on the soil defects of low nutrient status.

Table 5: Suitability Class Scores and Aggregate Suitability Classification for Rice Production

Location	MAR (mm)	MAT (^{0}C)	Texture	CEC Cmol/kg	BS (%)	OM g/kg	ASC	SuC
Pedon 1	S1	S1	S1	S2	S1	S2	S2	S2f
Pedon 2	S1	S1	S1	S2	S1	S2	S2	S2f

MAR = Mean Annual Rainfall, MAT = Mean Annual Temperature, CEC = Cation Exchange Capacity, BS = Base Saturation, OM = Organic Matter, ASC = Aggregate Suitability Class, SuC = Suitability Subclass with (f) Soil Fertility Limitation, S1 = Highly Suitable, S2 = Moderately Suitable

Conclusion and Recommendations

Soil properties within the study are did not vary much to enhance their Soil-site suitability evaluation for rice production in the study area. This is because of some soil fertility criteria in the study area. The study shows that the study area were moderately suitable for rice production. The only major constrains were that of low fertility status of soils in the study area. This low fertility status is not a permanent one, but could be corrected using a well plan soil fertility management to boost the nutrient capacity of the soils. This could also be achieve through the use of organic manure to boost the low soil nutrients of soils of the study area.

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