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CLASSIFICATION AND SUITABILITY EVALUATION OF THE SOILS OF A TOPOSEQUENCE AT ODEDA, OGUN STATE FOR THE PRODUCTION OF RICE (*Oryza sativa*)

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ABSTRACT

A detailed survey of the soils of a toposequence at Odeda, Ogun State was conducted to characterize, classify and assess the suitability of the soils for sustainable production of rice. The rigid grid method of survey was adopted for soil mapping while the linear parametric and square root models were used for assessing the suitability of the land for rice production. The result of the study showed that the soils of the three pedons were loamy sand to sandy clay loam texture, fine to coarse sub-angular blocky structure and loose to hard consistency. All the pedons had redoximorphic properties with varying quantities of iron-manganese concretion in the sub soils. Soil reaction ranged from strongly acid to neutral (pH of 5.3 – 6.8) with low organic carbon (<1.6%) and available nitrogen. Apart from potassium contents which were considered adequate for rice production, other exchangeable cations, available phosphorus and micro-nutrients were very low. Pedon 1 (upper slope) was classified as Typic Hapludalf (Lixisol; Cutanic, Hypereutric), pedon 2 (middle slope) as Plinthic Kandiudalf (Lixisol; Plinthic Hypereutric) and pedon 3 (lower slope) as Aeric Endoaquept (Cambisol; Endogleyic, Hypereutric). All the pedons had index of current productivity (IPc) ranging between 1.13 and 5.32 and were currently not suitable (N2) for both upland and lowland rice production as assessed by the linear and square root models. Potentially, using the linear model, the index of potential productivity (IPp) ranged between 37.8 and 76.50 for upland rice production and between 44.10 and 54.00 for low land production. Thus, pedon 1 is highly suitable for upland rice but moderately suitable for low land rice production. Pedon 2 is moderately suitable (S2) for the production of upland rice but marginally suitable (S3) for lowland rice production. Pedon 3 is potentially marginally suitable (S3) for both upland and lowland rice by the linear model. The square root model gave higher values of IPp ranging between 47.62 and 80.60 with a trend similar to the results of the linear model for upland rice production.

INTRODUCTION

Nigeria is the largest producer of rice in the West Africa sub-region. Today, rice is no longer a luxury food to millions of Nigerians but has become the cereal that constitutes a major source of calories for the rural and urban poor with demand growing at an annual rate of 5%.

Domestic Production of rice in Nigeria has never been able to meet the demand and this has led to considerable importation. According to Akande (2008), balance of payment position between 1991 and 1999 shows that Nigeria had spent $ 4 billion on rice importation alone, an average annual import value of $1021 million. This shortfall is as a result of low yielding varieties, use of poor (low fertility) soils used for rice production among others (Adeoye, 2002). This situation obviously calls for urgent steps toward increasing domestic production of rice. One of the serious problems affecting agricultural productivity in the developing countries like Nigeria is the ineffective and unplanned use of agricultural land (Fasina *et al*., 2007). It is necessary that every hectare of land be used according to its potential capacity. The primary and most effective land conservation method is appropriate allocation of lands to use for which they are most suitable (Fasina *et al*., 2007).

In principle, the main objective of land evaluation is the studying of land characteristics and economic conditions for achievement of optimum use of land resources without land degradation (FAO, 1976). Crop – land suitability analysis is a pre-requisite to achieving optimum utilization of the available land resources for sustainable agricultural production (FAO, 1993).

The determination of the suitability of a piece of land for a specified use, involves the matching of land qualities/land characteristic with the requirements of envisaged land use (Beek, 1978, Braimoh, 2000). The usefulness of an evaluation depends on the correlations between the attributes of the land and the requirements for the envisaged use. Many studies related to various aspects of land suitability for crop cultivation have been conducted on the basis of FAO framework in different areas (Alcatara *et al.,* 1977; Donnollan *et al.,* 1990; Friede and Stahr, 1999; Hassan *et al.,* 2002; Mujica *et al.,* 1995; Young and Goldsmith, 1997). Osie (1993), used FAO guideline for evaluation of land suitability for dry land farming in South –West of Nigeria. Several other researches (Ogunkunle, 1993; Fashina *et al.,* 2007) conducted in Nigeria were also based on FAO framework. In other parts of the world, there are also several records of the use of FAO framework for land evaluation (Menjiver *et al.,* 2003; Van Lanen *et al.,* 1992).

The matching procedures in land evaluation could be by use of limiting conditions, arithmetic procedures, or modeling. It is apparent that some of these methodologies are subjected to human bias. It is pertinent to emphasize that while the need to make value judgments is inevitable in any land evaluation exercise (Davidson *et al.,* 1994), there is nevertheless, the need to explore strategies that are intuitively superior, and takes into cognizance the relative importance of differentiating characteristic to crop performance. Although, the multiplicative parametric approach has been seriously criticized (Braimoh, 2000; Burrough *et al.,* 1992, Davidson *et al.,* 1994; Tang and Van Ranst, 1992) as failing in considering the relative importance of stable soil properties capable of dominating crop performance in the determination of suitability classes, the proposed Fuzzy set techniques also has some limitations that make its use practically difficult. The fuzzy set would obviously be more appealing if threshold 'fussy suitability indices' could be developed similar to land productivity indices corresponding to different suitability classes and applicable to various uses. Furthermore, mapping variability in soil properties entailed the use of several sampling points. According to Burrough *et al.* (1997), a minimum of 50 samples was required to construct an acceptable variogram required for the construction of Fuzzy membership value. Very often however, individual delineations of soil classes are so small that they contain at most only one or two observations, insufficient for variogram modeling (Voltz and Webster, 1990). However, some studies (Van Kuilenberg *et al.,* 1982; Bregt *et al.,* 1987;

Leenhardt *et al.*, 1994) have shown that conventional classification and mapping can sometimes provide predictions that are as good as those obtained by kriging using the Fuzzy technique. The use of the double crispy (Boolean) will still continue in situations where the limitations of the Fuzzy technique make it less appropriate.

MATERIALS AND METHODS

Field survey was conducted in a selected toposequence measuring 600 m by 1000 m (600,000 m^2) using the rigid grid systematic survey method with traverses cut at intervals of 50 m in both the vertical and horizontal directions and at right angles (90°) to each other. Chisel-hole samples were collected at the intersections of the traverses. Two hundred and seventy three (273) chisel-holes were dug and eight samples were collected per chisel-hole at intervals of 15cm from the soil surface to a depth of 120cm (0 -15cm, 15cm - 30cm… 105cm – 120cm).

All the samples collected from the chisel-holes were described morphologically on the field in terms of soil colour, presence or absence of mottles, mottle colour, soil texture by 'feel', soil structure and consistency, stoniness, roots content, presence or absence of concretions, field pH etc. Soils from the chisel-hole points were grouped into mapping units based on the similarities of the above mentioned morphological properties both in the vertical and horizontal dimensions. Three mapping units were thus, delineated from the selected area.

Soil profile pits were dug at points typical of each mapping unit and soils of the pedogenic horizons of each profile were studied morphologically on the field. The soils collected from the horizons were air-dried and passed through a 2mm sieve. Particle size distribution was determined by the hydrometer method (Buoyoucos, 1962) after the removal of organic matter with hydrogen peroxide and dispersion with sodium hexametaphosphate (IITA, 1979). The pH was determined with glass electrode pH meter in soil: water and soil: KCl media, each at ratio 1:1. Exchangeable cations (calcium, magnesium, potassium and sodium) were extracted with neutral normal sodium acetate (NH_4OAc at pH 7.0). Calcium and magnesium in the ammonium acetate extract were determined by atomic absorption spectrophotometry, while potassium and sodium were determined by flame photometry. Cation exchange capacity (CEC) was determined according to the procedure of Hossner, (1970). Organic matter was determined by the method of Shamshuddin *et al*. (1995). The data generated from the above analyses were combined with the morphological data for the soil classification.

Land Evaluation procedures

Although, there are several models of the parametric linear model of land evaluation method, the model of Stories (1933) and the square root models (Ogunkunle, 1993; Uddoh and Eyo, 2006; Uddoh, 2008) were used for the quantitative land evaluation. Each pedon was assigned to a suitability class by matching its characteristics and qualities (Tables 1 and 2) with the land requirements for rice production (Table 1) following the rating of the characteristics (Table 2). According to Liebig's Law of minimum, the most limiting characteristic in a group determines performance of the group and this applies to the performance or suitability of a soil type.

The group of land qualities considered for evaluation were climate (c), topography (t), drainage characteristics (w), soil physical characteristics (s) and soil chemical fertility (f). The soil fertility (f) was assessed using the soil reaction, level of macro and micro nutrients. In computing the potential suitability for rice production, the fertility factors that can be amended by fertilizer additions and management practices were excluded. These factors include the level of available micro-nutrients (Fe, Zn and Mn), the levels of N, P, K and the organic matter content of the soil. However, the soil CEC, percent base

saturation and pH were considered.

The current suitability were computed linearly using index of current (actual) productivity (IPC) of Storie (1933);

$IP_C = A \times B/100 \times S/100 \times C/100 \times \ldots.. F/100$ ----- (i)

Where, IP_C is index of current (actual) productivity, A the overall least rating characteristic and B, C..... are the least rating characteristic for each land quality group.

The potential suitability (IP_P) was similarly computed using the potential index of productivity:

The IPc and IPp were similarly computed using the square root model as stated below:

IPc = A (SQRT (B/100 × S/100 × C/100 ×….. F/100)) ----- (ii)

Where, SQRT is square root, A the overall least characteristic rating and B, C..... are the least rating characteristic for each land quality group

RESULTS AND DISCUSSION

Table 3 presents the physical and morphological properties of the soils of the toposequences. All the mapping units are very deep (>120 cm) and are all considered suitable for the production of rice. However, mapping unit 2 has plinthic horizons with increasing plinthite content from the third horizon (83 cm) through to the last horizon.

This probably accounted for the observed redoximorphic condition of this mapping unit as indicated by the presence of few to many, medium to coarse and distinct to prominent mottles occurring from the second horizon (30 cm) through to the last horizon.

However, the soil may not have been under permanently water saturation for a period longer than some few weeks as indicated by the soil colour which ranged from yellowish red to red (5YR – 10R). This condition is not considered as a limitation for rice production.

The texture of the soils ranged from sandy loam to sandy clay. According to Sys (1991, 1993), upland rice requires a loamy soil for optimum yield while a texture of loamy clay to sandy loamy clay was considered as most adequate for the production of low land rice. Thus the soils of the toposequence present a very slight limitation to rice yield (Table 3) and were rated 90%. The structure of the soils ranged between fine sub-angular blocky to coarse sub angular blocky. Crumbs are generally regarded as most appropriate for upland rice (Sys, 1993), while sub-angular blocky structure is required for lowland rice production (Table 4). The structure of mapping units 1 and 2 were considered to have very slight limitation (Table 3) for upland rice production but suitable for the production of lowland rice.

Pedon 3 however, was considered structurally suitable for the production of both upland and lowland rice.

Table 1: Land Requirement for Suitability classes for upland and lowland rice cultivation

Land Qualities	$S1_1$	$S1_2$	S2	S3	N1	N2
Climate (c)						
Annual Rainfall (mm)	>1000	900-1000	800-900	600-800	600-500	<500
Mean annual temperature (°C	>25	22 – 25	20 – 22	18 – 20	16 – 18	<16
Relative humidity (%)	>75	70 – 75	65 – 70	60 – 65	<60	
Topography (t): Slope (%)	<2	3-4	5 – 6	7 - 8	9 – 10	>10
Drainage (s):						
Wetness	WD (ID)†	MWD (ID) †	MD	ID (WD) †	PD (WD) †	PD (WD) †
Flooding	Fo	Fo	F1	F1	F2	F3
Soil physical properties (s)						
Texture	L (LC)†	Lfs (SLC) †	LS (SL) †	S	S	S
Structure	Cr (SAB) †	C (SAB) †	SAB (Cr) †	SAB (Cr) †	Col (Cr) †	Col (Cr) †
Coarse fragments (%) (0-45cm)	<3	3 – 5	5 – 10	10 – 15	>15	
Soil depth (cm)	>75	65 -70	50 – 65	35 – 50	30 – 35	<30
Fertility (f)						
pH	5.5 – 6.5	5.0 - 5.5	4.5 – 5.0	4.0 -4.5	<4.0	
Cation Exchange Capacity (cmol Kg^{-1})	>16.0	12.0 -16.0	8.0 -12.0	5.0 – 8.0	<5.0	
Base saturation (%)	>80	70 – 80	50 -70	40 – 50	25 -35	<25
Organic carbon (%) (0-30 cm)	>2.0	2.0 – 1.5	1.2 – 1.5	1.0 – 1.2	1.0	<1.0
Macro- nutrients						
Nitrogen (%)	>2.0	1.5 – 2.0	1.0 – 1.5	0.5 – 1.0	<0.5	
Phosphorus (mg kg^{-1})	>20	15 – 20	8 – 15	5 – 8	3 – 5	<3
Potassium (cmol/kg)	>0.5	0.3 -0.5	0.2 – 0.3	0.1- 0.2	<0.1	
Micro-nutrient (0.5 N Hcl)						
Iron (Fe) (mg kg^{-1})	>4.5	3.5 – 4.5	2.5 – 3.5	1.5 – 2.5	1.0 – 1.5	<1.0
Zinc (Zn) (mg kg^{-1})	2.0-2.5	1.5 – 2.0	1.0 – 1.5	0.8 – 1.0	0.6 -0.8	<0.6
Manganese (Mn) (mg kg^{-1})	1.5 – 1.7	1.0 – 1.5	0.8 – 1.0	0.6 – 0.8	0.5 – 0.6	<0.5

***Source**: Sys et al., (1991, 1993); De Datta (1989)*

† = ratings for lowland rice production; SAB =Sub Angular Blocky; Col = Columnar; Cr = crumb; WD = Well Drained; MWD = Moderately Well Drained; ID= Imperfectly Drained; PD = Poorly Drained; L= Loamy; SL= Sandy Loam; LS= Loamy Sand; Lfs = Loamy fine sand; SCL= Sandy Clay Loam; Fo =Rarely flooded; F1= Flooding expected; F2= Irregularly Flooded; F3 = regularly Flooded

Table 2: Rating of limiting characteristics

Symbol	Definition	Land Index
S1	None	95.0 – 100
$S1_2$	Very slight	70.0 – 94.0
S2	Slight	55.0 – 69.0
S3	Moderate	40.0 – 54.0
N1	Severe	20.0 - 39.0
N2	Very severe	0.00 – 19.0

The soil chemical properties which could affect their suitability for rice production are acidity, salinity and fertility. The reactions of the soils ranged from strongly acid to neutral (pH 5.5 – 6.8). Although this pH level may not pose serious problem for P uptake, pH above 6.0 may limit the availability of micronutrient such as Fe, Zn, Mn and Cu which form metallic cations that precipitate into low solubility compounds at high pH levels. Total exchangeable acidity ($H^+ + Al^{3+}$) ranged between 0.16 cmol kg^{-1} and 0.44 cmol kg^{-1} indicating that the level of exchangeable aluminium is still below toxic range.

The CEC of the soils were moderate low (<16 cmol kg^{-1}) and ranged between 6.84 cmol kg^{-1} and 15.57 cmol kg^{-1}. The average values of the CEC both at the surface and subsurface horizons decreased down the toposequence with the upper slope having the highest average values. Although the CEC values fall within the moderate level (FPDD 1989), with the high rainfall intensity within the area, fertilizer application must be in several splits to avoid leaching. Split application of fertilizer has implication for increased production costs. The moderate CEC values of these soils present a very slight limitation (Table 1) to rice production.

These soils have medium to high levels of exchangeable K, low to medium values of exchangeable Ca, Mg and Na and low levels of N and Bray-1 P. The levels of micronutrients (Zn, Mn and Fe) were also very low. With exception to K, both the major nutrient elements as well as the micronutrients contents of the soils were lower than the critical requirements for rice production (De Datta, 1989). The greatest limitation to rice production is related to the fertility status of the soils. This result agreed partly with an earlier survey carried out in Ogun State rice producing areas (Moloko, Asipa, Ilaro, Iperu, Wasimi and Ayiuere) by Adesanwo (2002). The result of the survey revealed that the levels of organic matter, nitrogen, exchangeable cations and Mn were below the critical requirements for rice production while the concentration of iron (Fe) showed an evidence of Fe toxicity. High iron build-up is a problem in the country (Adeoye, 2002).

The climate of the studied area is quite favourable for the production of rice. The mean annual temperature (24°C – 32°C), average sunshine hours (>5 Hr), total annual rainfall and distribution pattern (> 1100 mm) and relative humidity during the cropping season (> 75%) are all adequate by the standard of Sys (1993).

Table 3: Physical and Morphological characteristics of the soils of a toposequence at Odeda, Ogun State.

Position/ Designation	Horizon Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Gravel (%)	Soil Texture†	Soil Structure‡	Consistence+	Soil colour (moist)	Mottles++	Concretion+++
UP- A	0 -13	67.3	12.8	19.9	0.78	SL	2msbk	fr	Very dark brown (10YR 2/2)	Absent	Absent
Bt1	13 – 32	63.3	2.8	33.9	0.75	SCL	2msbk	fr	Dark reddish brown (5YR ¾)	Absent	Absent
B2	32 – 77	55.3	4.8	39.9	0.65	SC	2csbk	frm	Yellowish red (5YR 5/8)	f1ft; 5YR 6/8	Absent
C	77 – 146	65.3	6.8	27.9	1.23	SCL	3csbk	frm	Yellowish red (5YR 5/8)	m3p; 5 YR 5/8	Fe- Mn, f, r
MD- A	0 – 30	63.3	18.8	17.9	0.33	SL	1fsbk	fr	Dark reddish brown (5YR 3/3)	Absent	Absent
Bt1	30 – 83	59.3	2.8	37.9	0.85	SCL	2csbk	frm	Yellowish red (5YR 5/8)	f2d ; 2.5YR 4/6	Fe- Mn, f, r
B2	83 – 115	55.3	2.8	41.9	23.39	SC	2csbk	frm	Red (2.5YR 7/4)	m3p; 2.5YR 4/6	Fe- Mn, c, r
C	115 – 144	67.3	10.8	21.9	34.32	SCL	3csbk	frm	Red (10R 4/8)	m3p; 2.5YR 6/2	Fe - Mn, m, r
LS- A	0 – 25	66.5	9.3	24.2	0.25	SCL	1fsbk	fr	Black (10YR 2/1)	Absent	Absent
B	25 – 35	62.5	9.3	28.2	1.87	SCL	2fsbk	fr	Light olive brown (2.5Y 5/4)	f2d ; 10YR 3/2	Fe – Mn, f, r
C	35 – 120	64.5	7.4	28.2	5.65	SCL	2msbk	fr	Light olive brown (2.5Y 5/4)	m3p; 10YR 3/2	Fe – Mn, f, r

† SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam
‡ sbk = sub angular blocky; f= fine; m =medium; c= coarse; 1= weak; 2 = moderate; 3 = strong
\+ fr = friable; frm = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft
++ 1= few; 2= common; 3 = many; f = fine; md = medium; c= coarse; ft = faint; d =distinct; p =prominent
+++ Fe = Iron; Mn = manganese; f = few, c = common; r = rounded
UP = Upper slope; MD = Middle slope; LS = Lower Slope

Table 4: Chemical characteristics of the soils of a toposequence at Odeda, Ogun State.

Position/ Designation	Horizon Depth (cm)	pH (H_2O)	OC (%)	Total N (%)	Avail P mg kg^{-1}	K^+	Ca^{2+}	Mg^{2+}	Na^+	TEA	CEC	CEC clay	PBS (%)	Fe	Zn	Mn
						← cmol kg-1 →								← mg kg^{-1} →		
UP- A	0 -13	6.8	1.27	0.04	0.47	11.25	2.15	1.39	0.59	0.20	15.57	55.90	98.72	0.14	0.12	0.07
Bt1	13 – 32	6.1	1.10	0.05	0.46	5.63	1.82	1.44	0.48	0.20	9.57	16.87	97.91	0.11	0.12	0.06
B2	32 – 77	6.4	.80	0.06	0.43	7.16	1.84	1.40	0.33	0.24	10.97	20.47	97.81	0.12	0.13	0.06
C	77 – 146	6.8	0.47	0.02	0.71	7.16	1.62	1.38	0.35	0.24	10.75	32.63	97.76	0.12	0.13	0.06
MD- A	0 – 30	6.5	1.14	0.05	0.40	3.58	2.02	1.34	0.46	0.24	7.64	20.39	96.86	0.13	0.13	0.07
Bt1	30 – 83	5.4	0.89	0.03	0.54	2.56	1.76	1.28	0.43	0.28	6.31	8.43	95.56	0.13	0.13	0.06
B2	83 – 115	6.6	0.42	0.04	1.86	6.65	2.11	1.32	0.52	0.16	10.76	22.17	98.51	0.12	0.12	0.07
C	115 – 144	6.2	0.34	0.02	0.43	4.60	1.78	1.41	0.44	0.20	8.43	33.06	97.63	0.13	0.11	0.08
LS- A	0 – 25	5.4	1.52	0.03	0.46	3.07	1.89	1.24	0.48	0.16	6.84	6.28	97.66	0.12	0.12	0.05
B	25 – 35	5.3	1.35	0.02	0.46	2.05	2.06	1.26	0.37	0.44	6.18	5.16	92.88	0.12	0.11	0.06
C	35 – 120	5.6	0.30	0.03	0.43	2.56	1.76	1.29	0.30	0.36	6.27	18.51	94.26	0.13	0.10	0.07

The topography of the toposequence is also considered adequate (slope 3% – 5%). The upper and middle slopes are well drained except during the peak of rains when the middle slope becomes partially saturated after heavy down pours. The lower slope (LS) however, is poorly drained (permanent saturation) for a period exceeding four months (July – October). The lower slope is considered most suitable for lowland rice production.

Classification

Pedon 1 (Upper) has an argillic horizon; CEC of clay > 16 cmol kg^{-1} clay; base saturation > 50% by NH_4OAc at pH 7.0 and udic moisture regime. Pedon 2 (Middle) has a Kandic horizon with CEC of clay < 16 cmol kg^{-1} clay, a base saturation that was greater than 50% by NH_4OAc at pH 7.0, a udic moisture regime and Plinthic subsurface horizon. Pedon 3 (Lower slope) has no argillic, kandic or any distinct diagnostic horizon but has evidence of little colour variation between the surface and subsurface horizons; no change in texture with increase in soil depth; aquic moisture regime with increasing size, abundance and distinctiveness of mottling down the profile and development of iron-manganese concretions.

Based on the above properties, the pedon 1 was classified as Typic Hapludalf (Lixisol; Cutanic, Hypereutric), pedon 2 (middle slope) as Plinthic Kandiudalf (Lixisol; Plinthic Hypereutric) and pedon 3 (lower slope) as Aeric Endoaquept (Cambisol; Endogleyic, Hypereutric).

Evaluation for rice production

Suitability ratings of the land characteristics (Table 5) were obtained by comparing their values (Tables 3 and 4) with the land requirement for upland and low-land rice (Table 1) using the ratings for the limited characteristics in Table 2. Aggregate suitability ratings (potential and actual) were computed using the linear and square root parametric models.

Apart from potassium contents that range from 2.6 – 11.25 cmol kg^{-1}, other exchangeable cations, available phosphorus and micro-nutrients were very low. All the pedons had index of current productivity (IPc) of less than 12.5 and were classified as permanently not suitable (N2) for both upland and lowland rice production as assessed by the linear and square root models (Tables 5 and 6). The limiting factors were mainly low levels of available macronutrients, micronutrients, organic matter content and low cation exchange capacity. The evaluation of the potential suitability of the soils (without considering the levels of organic carbon, macro- and micronutrients which is regarded as temporary limitation) using the linear model indicated that pedon 1 which has an index of potential productivity (IPp) greater than 75.00 is highly suitable (S1) for upland rice and moderately (IPp > 50.00) suitable (S2) for lowland rice production.

In the same vein Pedon 2 was rated as potentially moderately (IPp > 50) suitable (S2) for upland rice but marginally suitable for lowland rice. Pedon 3 was marginally suitable (S3) for upland rice (IPp < 50.00) and moderately suitable (S2) for lowland rice production.

Table 5.: Suitability ratings of land characteristics for upland and lowland rice production.

Land Qualities	Upland Rice			Lowland Rice		
	P1	**P2**	**P3**	**P1**	**P2**	**P2**
Climate (c)						
Annual Rainfall (mm)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Mean annual temperature (°C	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Relative humidity	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Topography (t): Slope (%)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Drainage (w):	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Wetness	100 (S_1)	100 (S_1)	70 ($S1_2$)	70 ($S1_2$)	70 ($S1_2$)	100 (S_1)
Flooding	100 (S_1)	100 (S_1)	80 ($S1_2$)	100 (S_1)	100 (S_1)	80 ($S1_2$)
Soil physical properties (s)						
Texture	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)
Structure	90 ($S1_2$)	90 ($S1_2$)	100 (S_1)	100 ($S1_2$)	100 ($S1_2$)	100 (S_1)
Coarse fragments (%) (0-60 cm)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Soil depth	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Fertility (f)						
pH	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)
Cation Exchange Capacity (cmol Kg^{-1})	85 ($S1_2$)	70 ($S1_2$)	60 ()	85 ($S1_2$)	70 ($S1_2$)	60 ()
Base saturation (%)	90 ($S1_2$)	100 (S_1)	90($S1_2$)	90 ($S1_2$)	100 (S_1)	90 ($S1_2$)
Organic carbon (%) (0-60 cm)	70 ($S1_2$)	65 (S_2)	80 ($S1_2$)	70 ($S1_2$)	65 (S_2)	80 ($S1_2$)
Macro- nutrients						
Nitrogen	30 (N_1)	30 (N_1)	30 (N_1)	30 (N_1)	30 (N_1)	30 (N_1)
Phosphorus (mg kg^{-1})	20 (N_1)	20 (N_1)	20 (N_1)	20 (N_1)	20 (N_1)	20 (N_1)
Potassium (cmol/kg)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)	100 (S_1)
Micro-nutrient (0.5 N Hcl)						
Iron (Fe)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)
Zinc (Zn)	15 (N_2)	15 (N_2)	25 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)
Manganese (Mn)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)	15 (N_2)
Actual Suitability†	1.89 (N2)	1.76(N2)	1.13(N2)	1.32(N2)	1.23(N2)	1.62(N2)
Potential Suitability†	76.50 (S1)	63.00(S2)	37.8(S3)	53.55(S2)	44.10 (S3)	54.00(s2)
Actual Suitability*	5.32(N2)	5.13(N2)	4.12(N2)	4.45(N2)	4.29(N2)	4.92(N2)
Potential Suitability*	80.60(S1)	61.66(S2)	47.62(S3)	67.44(S2)	55.56(S2)	50.92(S2)

† Suitability by linear model; * Suitability by square root model

Table 6: Qualitative land suitability classes for the different land indices

Symbol	Definition	Land Index
S1	Highly suitable	75.0 – 100
S2	Moderately suitable	50.0 – 75.0
S3	Marginally suitable	25.0 – 50.0
N1	Presently not suitable	12.5 – 25.0
N2	Permanently not suitable	0.00 - 12.50

Evaluation of the potential suitability using the square root model indicated pedon 1 as highly suitable (S1), Pedon 2 as moderately suitable (S2) and pedon 3 as marginally suitable (S3) for upland rice. All the three pedons are potentially moderately suitable (S2) for lowland rice production by the square root model.

The implications of the deficient nutrient status in most of the soils on which rice production is carried out in Odeda, Ogun State and Nigeria at large cannot be ignored. There is an urgent need for fertility strategies beyond mineral fertilizer application. The fertility management techniques must be compatible with the diverse farming systems and could include crop rotation, rapid grain legume fallowing (*Mucuna*), plant residue recycling and organic agriculture, among others.

Rice is highly sensitive to zinc (Zn), iron (Fe) and manganese (Mn) deficiency, and Zn is the most important micronutrient limiting rice growth and yield (Neue *et al*., 1998; Dong *et al*., 2006). Generally, Zn, Fe and Mn deficiency is common on neutral and calcareous soil, intensively cropped soils, paddy soils and poorly drained soils. Fertilizer recommendations for rice production in many parts of Africa often neglect the importance of micro-nutrients in achieving good yield. Thus, Africa Rice Center, Cotonou, Benin (WARDA, 2006) accepted the possibility of iron and zinc deficiencies occurring between 1-2 and 3-4 weeks after seedling emergence respectively. This research institute recommended the application of foliar spray of ferrous sulphate or zinc sulphate only as corrective measure. However, the current study has underscored the necessity of assessing the micro-nutrient status of the major rice growing soils of Nigeria if the country will realize increase per hectare output of rice needed to achieve self-sufficiency in rice production. Although there was apparent deficiency of nitrogen and phosphorus in these soils, the present system of fertilizer recommendation (FDPP, 1989) would have corrected these deficiencies without increase in rice yield due to the neglected micro-nutrient deficiencies. To avoid over application of these micro-nutrients, a situation that will lead to toxicity, the use of organic and green manures have been suggested in India (Nayyar and Chhibba, 2000). It is our opinion however, that a suitable combination of organic and inorganic fertilizer at appropriate rates after careful laboratory and field studies will be of tremendous importance in solving the problems of low fertility in the major rice growing soils of Nigeria.

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