Suitability Evaluation of Selected Wetland Soils in Nigeria for Rainfed Rice Cultivation

A.O. Olaleye[1*], A.O. Ogunkunle[2], K.L. Sahrawat[3], O.A. Osiname[3**] & S.A. Ayanlaja[1]

Keywords: Bronzing symptom– Limitations– Rainfed rice– Soils– Suitability– Wetlands

Summary

*Thirty-eight wetland soils in four agro-ecological zones were evaluated for their suitability for rice (*Oryza sativa *L.) cultivation. The results indicated that climatic characteristics are near optimum. Currently, by non-parametric method, most (≥ 97%) of the pedons were found to be marginally suitable (S3). With the parametric method about 3% were highly suitable (S1), 74% marginally suitable (S3) and 23% not suitable (NS). Potentially by non-parametric method, 18% were of high (S1) and moderate (S2) suitabilities respectively, 58% were marginally suitable (S3) and 6% not suitable (NS). With parametric method, 24% were highly suitable (S1), 45 and 31% were of moderate (S2) and marginal (S3) suitabilities. The major limitations to rice cultivation on these soils are low CEC, organic carbon, exchangeable cations and available P, which may predispose rice plants to excessive Fe^{2+} uptake visually expressed as «bronzing» or «yellowing» symptoms. In this and similar environments in the region, good soil management is required before substantial improvement in rice production can be achieved.*

Résumé

Evaluation de l'aptitude de quelques sols inondés à la culture du riz pluvial au Nigeria

*Trente-huit sols inondés ont été choisis dans quatre zones agro-climatiques afin d'analyser leur aptitude à la production du riz (*Oryza sativa *L.). Les résultats obtenus montrent que les conditions écologiques étaient presque optimales. En utilisant la méthode non paramétrique, les résultats montrent qu'en général la plupart des pédons (≥ 97%) était à la limite de l'aptitude à la production du riz (S3) alors qu'avec la méthode paramétrique, 3% des pédons étaient significativement aptes à la production du riz (S1), 70% à la limite de l'aptitude à la production du riz (S3) et 23% non aptes à la production du riz (NA). En utilisant la méthode non paramétrique; 18%, 58% et 6% des pédons étaient respectivement hautement, moyennement et faiblement (NA) aptes à la production du riz. Pour la méthode paramétrique, les pédons étaient respectivement de 24; 45 et 31% hautement (S1), moyennement aptes (S2) et non adéquates (S3) à la production du riz. Les contraintes majeures de la culture du riz dans ces sols sont attribuables à une faible capacité d'échange cationique (CEC), du carbone organique, de l'échange cationique et du phosphore assimilable. Ces propriétés prédisposeraient les plants de riz à la consommation excessive des ions Fe^{2+}, qui s'expriment par des symptômes de «bronzing» ou de «yellowing». Avant d'envisager une culture de riz dans cette zone ou dans des régions environnementales similaires, les meilleures techniques culturales sont requises.*

Introduction

Rice (*Oryza sativa* L.) is a unique crop grown in both upland and lowland ecologies in Nigeria. There are about 200 million ha of inland valleys in sub-Saharan Africa of which less than 10% is cultivated. At a 5% increase a year, rice demand in West Africa is increasing faster than anywhere in the World (28). In Nigeria, the potential for rice cultivation is high, and estimated wetland area grown to rice is 45% of the 880,000 ha under rice cultivation (29).

Climate, topography, hydrology, soil conditions and socio-economic factors determine to a great extent which crops may be grown in any ecological zone. The climatic and soil requirements for lowland rice cul-

1 Ogun State University, PMB 2002, Ogun State, Nigeria.
2 Agronomy Department, University of Ibadan, Nigeria.
3** West Africa Rice Development Association (WARDA), Lowland Breeding Unit, IITA, Ibadan, Nigeria.
3 West Africa Rice Development Association (WARDA), 01 BP 2551, Bouaké, Ivory-Coast.
* Corresponding Address: C/o West Africa Rice Development Association (WARDA), P.M.B. 5320, Ibadan, Nigeria.
Email: adesola_olaleye@hotmail.com
Received on 22.11.99. and accepted for publication on 11.06.01.

tivation have been well documented (4, 7, 21, 24), all of which give optimum requirements for its successful cultivation.

Land evaluation (land capability classification, land suitability evaluation) can tell farmers how suitable their land is in terms of soil limitations, crop yield or profit. The Fertility Capability Classification (FCC) was designed to group soils having similar limitations of fertility (24, 29). It provides a guide for the extrapolation of the fertilizer response experience (8). The FCC focuses attention on surface soil properties most directly related management of field crops and is best used as an interpretative classification in conjunction with a more inclusive natural soil classification. The system consist of three classification levels: type (top soil texture), substratum type (subsoil texture), and certain other soil properties considered as condition modifiers or fertility constraints. Seventy-one wetland soils for rice in West Africa were evaluated using numerical evaluation methods (9) and Fertility Capability Classification (FCC) (14). Results of these studies showed that these soils are infertile. There is paucity of information on wetland evaluation for rainfed rice growing in Nigeria. This information is needed for planning soil fertility research for sustainable exploitation of these fragile wetland soils. Thus, this study seeks to identify soil constraints (or limitations) to rainfed rice production on some wetland soils and suggest plausible management options for their use.

Data sources

Soil and climatic data in four agro-ecological zones were collected (Tables 1 & 2) and summarized (Table 4) (6, 9, 16, 17, 18). These are Humid Forest Zone (HFZ) (13 pedons), Derived/Coastal Savanna Zone (DSZ) (13 pedons), Southern Guinea Savanna Zone (SGSZ) (8 pedons) and Arid-semi/Arid Zone (ARZ) (4 pedons). Land qualities/characteristics in these pedons were summarized (24). The suitability of these soils for rice cultivation was assessed following two methods (parametric and non-parametric).

Evaluation procedure

Conventional (non-parametric) method: Pedons were placed in suitability classes by matching their crop requirements (Table 3) with the land qualities/characteristics (Tables 2 & 4). The suitability class scores for each land qualities/characteristics are shown in figure 5 and the aggregate suitability ratings (i.e., indicated by its most limiting characteristics) are shown in figures 1-4.

Parametric method: Each limiting characteristics was rated as in table 3. The index of productivity (actual and potential) for each pedon was calculated using modified equations (13, 24):

$$IP = A \times \sqrt{(B/100 \times C/100 \times D/100)}$$

Where A= overall lowest characteristic rating of all land quality groups {(chemical fertility (f), B (climate (c)), C (soil physical property (s)) and D (wetness (w)}

Tableau 1
Names of pedons used in each agro-ecological zone

USDA Soil Taxonomy	FAO/ UNESCO
Humid Forest Zone	
1. Typic Tropaquept	Eutric Fluvisol
2. Typic Tropaquept	Dystric Gleysol
3. Typic Tropaquept	Eutric Fluvisol
4. Typic Tropaquept	Eutric Gleysol
5. Aeric Tropaquept	Eutric Gleysol
6. Aeric Tropaquept	Dystric Gleysol
7. Typic Tropaquept	Dystric Gleysol
8. Aeric Tropaquept	Dystric Gleysol
9. Aeric Tropaquept	Eutric Fluvisol
10. Typic Tropaquept	Eutric Gleysol
11. Typic Tropaquept	Dystric Fluvisol
12. Typic Tropaquept	Dystric Fluvisol
13. Aquic Tropudult	Dystric Fluvisol
Derived Savanna Zone	
14. Aeric Tropic Fluvaquent	Eutric Gleysol
15. Typic Fluvaquent	Eutric Gleysol
16. Typic Fluvaquent	Eutric Gleysol
17. Typic Fluvaquent	Eutric Gleysol
18. Aeric Tropic Fluvaquent	Eutric Gleysol
19. Plinthic Tropaquept	Dystric Gleysol
20. Typic Tropaquept	Eutric Gleysol
21. Andaqueptic Fluvaquent	Dystric Gleysol
22. Aquic Kandiustult	Eutric Gleysol
23. Eutric Tropaquet	Eutric Gleysol
24. Aeric Fluvaquent	Eutric Gleysol
25. Aeric Fluvaquent	Eutric Gleysol
Southern Guinea Savanna Zone	
26. Tropic Fluvaquent	Eutric Gleysol
27. Typic Tropaquept	Eutric Gleysol
28. Typic Tropaquept	Eutric Gleysol
29. Typic Tropaquept	Eutric Fluvisol
30. Aquic Quartzipsamment	Dystric Fluvisol
31. Typic Psamment	Dystric Fluvisol
32. Aeric Tropaquept	Dystric Fluvisol
33. Aeric Tropaquept	Dystric Fluvisol
34. Aeric Tropaquept	Eutric Fluvisol
Arid Zone	
35. Andaqueptic Fluvaquent	Eutric Fluvisol
36. Andaqueptic Fluvaquent	Eutric Fluvisol
37. Tropaquent	Eutric Fluvisol
38. Tropaquent	Eutric Fluvisol

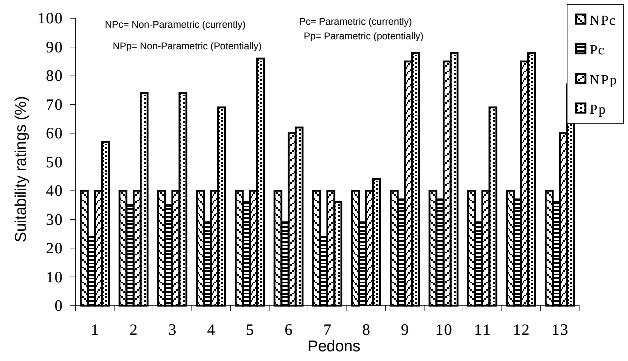

Figure 1: Aggregate suitability ratings of the pedons in Humid Forest Zone

Tableau 2
Land qualities/characteristics of selected wetland soils in Nigeria

Pedons	pH	Ec	Org. C‡	Tot. N¶	Ca	Mg	K	CEC	B.Sat*	P	Fe	Zn	Clay
		ds/mm	%	%	Cmol.kg-1	Cmol.kg-1	Cmol.kg-1	Cmol.kg-1	%	mg.kg-1	mg.kg-1	mg.kg-1	%
Humid Forest Zone (HFZ)													
1. Typic Tropaquept	4.9	0.07	2.0	0.1	0.8	0.3	0.3	2.2	66.7	2.1	22.0	2.9	
2. Typic Tropaquept	5.7	0.09	1.1	0.1	0.4	0.1	0.1	2.9	44.2	0.8	19.5	3.7	
3. Typic Tropaquept	5.5	0.12	1.1	0.1	2.9	0.8	0.1	4.1	74.2	2.4	31.0	5.1	
4. Typic Tropaquept	5.6	0.08	2.2	0.1	1.5	0.2	0.1	2.5	61.5	7.3	14.9	3.2	
5. Aeric Tropaquept	5.5	0.06	2.9	0.1	0.4	0.2	0.1	2.9	54.3	5.6	38.6	2.4	
6. Aeric Tropaquept	4.2	nd†	1.6	nd	0.4	0.6	0.1	11.0	10.4	13.0	51.4	1.2	
7. Typic Tropaquept	5.3	0.08	4.3	0.03	0.7	0.3	0.4	0.7	23.3	2.6	20.1	3.3	
8. Aeric Tropaquept	4.7	nd	0.6	nd	0.4	0.1	0.1	6.8	9.3	12.6	16.8	18.0	
9. Aeric Tropaquept	5.6	0.31	2.4	0.1	11.0	2.7	1.1	21.0	68.4	1.7	19.2	2.1	
10. Typic Tropaquept	5.9	0.41	1.9	0.1	18.0	8.5	0.3	34.7	78.1	2.0	18.0	6.0	
11. Typic Tropaquept	5.8	0.57	2.0	0.1	0.5	0.2	0.2	3.8	30.0	6.4	96.5	5.6	
12. Typic Tropaquept	5.7	0.49	1.9	0.1	2.1	2.1	0.3	26.7	16.7	0.7	25.9	23.0	
13. Aquic Tropudult	5.9	0.36	1.7	0.1	1.4	0.6	0.6	8.5	34.8	6.8	34.9	3.4	
Derived/Coastal Savanna (DSZ)													
14. Aeric Tropic Fluvaquent	7.1	nd	2.3	0.1	5.1	1.6	0.2	7.9	97.7	9.1	164.0	7.7	
15. Typic Fluvaquent	6.5	nd	1.8	0.1	5.1	2.4	0.3	8.6	96.3	31.0	502.0	24.0	
16. Typic Fluvaquent	6.2	nd	1.5	0.1	1.6	1.1	0.4	4.1	82.3	13.0	178.0	8.3	
17. Typic Fluvaquent	6.0	nd	2.4	0.04	1.8	0.8	0.2	4.1	80.7	8.9	219.0	3.6	
18. Aeric Tropic Fluvaquent	6.6	nd	2.1	0.14	4.6	1.5	0.2	7.6	87.5	13.0	216.0	24	
19. Plinthic Tropaquept	4.6	nd†	1.1	nd	0.86	3.0	0.2	7.87	452.0	1.2	30.0	nd	
20. Typic Tropaquept	5.1	nd	1.1	nd	0.86	3.0	0.2	7.87	51.6	1.2	30.0	nd	
21. Andaqueptic Fluvaquent	4.9	0.1	0.8	0.1	4.01	1.7	0.4	25.4	25.7	5.9	1.71	nd	
22. Aquic Kandiustult	5.3	0.1	0.8	0.1	2.32	1.0	0.3	13.8	28.7	2.9	1.11	nd	
23. Eutric Tropaquet	5.0	nd	3.4	nd	24.6	4.6	0.4	30.1	98.3	3.4	30.0	nd	
24. Aeric Fluvaquent	5.7	nd	0.9	5.6	7.4	4.8	0.1	7.9	98.0	4.9	43.3	0.05	
25. Aeric Fluvaquent	6.1	nd	1.8	0.1	4.7	1.5	0.04	10.4	79.0	1.1	63.0	0.05	
26. Tropic Fluvaquent	5.7	nd	2.3	0.2	2.9	1.2	0.02	7.0	82.9	4.2	67.3	0.05	
Southern Guinea Savanna Zone (SGSZ)													
27. Typic Tropaquept	4.3	0.2	0.5	0.1	1.41	0.6	0.2	7.95	74.1	11.4	0.19	nd	
28. Typic Tropaquept	4.9	0.2	0.2	0.02	0.85	0.7	0.05	6.53	70.9	3.4	0.15	nd	
29. Typic Tropaquept	4.5	0.1	0.2	0.03	1.21	0.6	0.04	7.69	69.2	2.5	0.11	nd	
30. Aquic Quartzipsamment	5.3	0.2	0.3	0.03	1.01	0.6	0.13	2.12	83.6	1.9	0.10	nd	
31. Typic Psamment	3.5	nd	1.5	0.08	1.10	0.49	0.06	7.34	39.5	16.3	43.8	0.05	
32. Aeric Tropaquept	3.1	nd	1.6	0.08	2.70	0.79	0.04	11.39	56.1	3.76	41.7	0.05	
33. Aeric Tropaquept	4.0	nd	2.1	0.09	1.80	0.84	0.23	7.96	46.2	15.5	20.4	0.05	
34. Aeric Tropaquept	4.2	nd	0.6	nd	0.95	0.10	0.10	1.90	60.5	10.4	30.0	0.05	
Dry (Sudan) Savanna & Sahel													
35. Andaqueptic Fluvaquent	4.7	0.2	0.7	0.1	7.1	3.1	0.6	39.5	95.9	3.0	2.7	nd	
36. Andaqueptic Fluvaquent	5.7	0.2	0.6	0.1	7.4	3.7	0.3	43.8	95.0	1.3	3.6	nd	
37. Tropaquent	5.5	0.5	0.6	0.04	11.5	7.1	0.7	48.2	97.6	0.9	0.1	nd	
38. Tropaquent	6.2	0.3	0.4	0.1	20.8	7.6	0.4	62.8	98.4	2.7	2.0	nd	

† nd, not determined; ‡ Org. C., organic carbon; ¶ Tot. N, total N; *B. Sat, base saturation

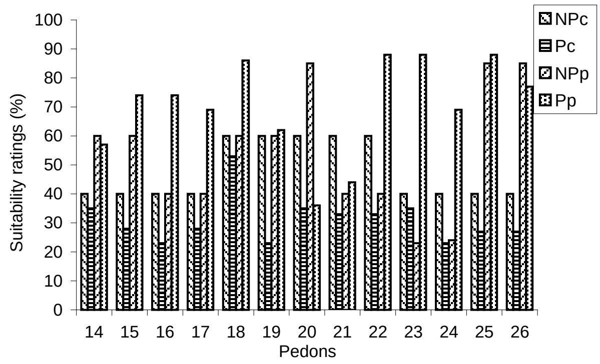

Figure 2: Aggregate suitability ratings of the pedons in Derived savannah

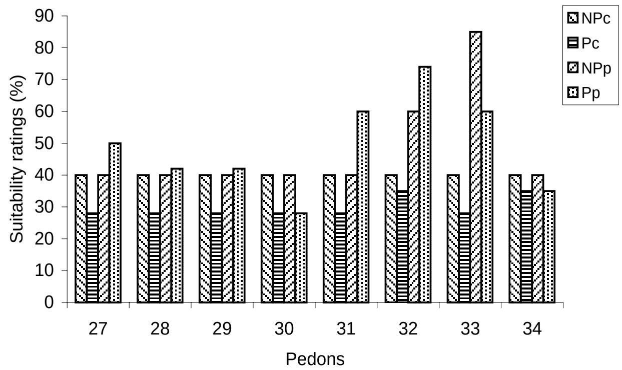

Figure 3: Aggregate suitability ratings of the pedons in Southern Guinea savannah

are the lowest characteristic ratings for their respective land quality groups. The land qualities used in this study for evaluation are: climate, soil physical property, wetness, and chemical fertility. Owing to strong correlation among the members of the same group, (e.g. solar radiation and rainfall ingroup 'c') only one member in each group was used. For example from figure 1, the Index of currrent productivity (IPc) for pedon 1 (Typic Tropaquent) in the (HFZ) was calculated as:

$$IPc= 40 \times \sqrt{(95/100 \times 95/100 \times 40/100)}= 24\% \text{ (N)},$$

while the Index of potential productivity (IPp) for the same pedon was calculated as:

$$IPp= 95\sqrt{(95/100 \times 95/100 \times 40/100)}= 57.1\% \text{ (S2)}.$$

Tableau 3

Factor ratings of land use requirements# for wetland rice

Land qualities	Land Characteristics	Unit	S1	S2	S3	N1	N2
Factors Ratings		%	100-85	84-60	59-40	39-20	19-0
Climate (c)[4]							
	Annual Rainfall	mm	> 1400	1200-1400	950-1100	850-900	< 850
	Solar radiation	$Cal.cm^{-2}.day^{-1}$	> 300	300-200	200-100	< 100	any
Growing Periods[2 3]							
	LPG†	Days	120-180	70-120	< 70	< 70	< 70
Soil Physical Characteristics							
	Soil Depth[14]	cm	> 20	10-20	5-10	< 5	any
	Clay[21]	%	40-25	25-15	15-5	≤ 15; ≥ 5	any
Wetness (W)[4]							
	Drainage	-	1- 3	1-3	3	any	any
	S.W.D	cm	10- 20	20-40	40-60	> 60; < 10	any
	F.D	months	> 4	3-4	2-3	< 2; > 4	any
	G.W.T	cm	0- 15	15-30	30-60	> 60	any
Fertility Status (f)							
	pH[19]	-	5.5-7.5	5.2-5.5	≤ 5.2, ≥ 8.2	≤ 5.2, ≥ 8.2	any
	Total N[20]	%	> 0.2	0.1-0.2	0.05- 0.1	< 0.05	any
	Organic carbon[20]	%	2- 3	1-2	3- 4	> 4; ≤ 1	any
	P (Bray)[18]	$mg.kg^{-1}$	> 20	15-20	10-15	< 10	any
	P (Olsen)[20]	$mg.kg^{-1}$	> 10	7.5-10	5-7.5	< 5	any
	K[20]	$cmol.kg^{-1}$	> 0.2	0.1-0.2	< 0.1	< 0.1	any
	Ca[20]	$cmol.kg^{-1}$	10-15	5-10	1-5	< 1; > 5	any
	Mg[20]	$cmol.kg^{-1}$	2-5	1-2	< 1	< 1; > 5	any
	CEC (soil)[20]	$cmol.kg^{-1}$	> 16	10-16	5-10	< 5	any
Toxicity (t)							
	Active-Fe[22]	%	< 0.75	0.75-1.0	1-1.25	> 1.25	any

Key:
S.W. D= Surface Water Depth
F. D= Flooding Duration
G. W. T= Ground Water Table
1= Imperfect, 2= Moderate; Poor, 3= Good, 4= Very Poor
#= Sources: see references; † LPG= Length of Growing Periods

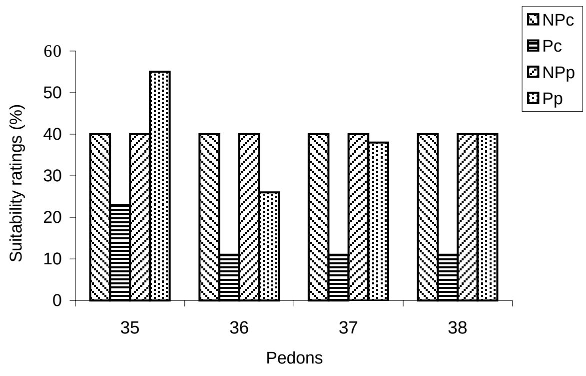

Figure 4: Aggregate suitability ratings of the pedons in Semi Erid Zone

The IPp incorporates CEC and organic carbon in the fertility group, while the IPc incorporates (P, K, Ca, Mg and Zn) along with the requirements for the IPp. Suitability classes S1, S2, S3 and N correspond to IP values of 100-75, 74-50, 49-25, and 24-0 respectively.

Results and discussion

Occurrence of wetlands in Nigeria

Wetlands (hydromorphic soils) are soils with seasonal superficial flooding or those with shallow, seasonally fluctuating groundwater table. Quantitative data on the height, fluctuation, and duration of the groundwater table are scarce for tropical West Africa and in particular, Nigeria (15). Soils with aquic moisture regimes have been identified with the presence of morphological features such as mottles, presence or coated soil materials (quartz grains), and concretions (27). Other features used in addition to these are color of chroma 2 or less or pedons with fluctuating water table or permanently high water table (26). Wetlands in Nigeria are of various types. However, those encountered in this investigation are located in three landform types, namely, inland valley depressions, alluvial plains, and coastal plains.

The former is called “akuro” in the South Western Nigeria, and “fadama” in the Northern Nigeria.

The inland basins are historically the inland depressions that once were occupied by bodies of water but subsequently were filled with fluviatile sediments during the Quaternary, whereas the inland valleys have soil parent materials that are mostly colluvial in origin (15).

Both have stream channels running through them. Geologically, the wetlands in Nigeria derived their origin either from Precambrian basement complex consisting mainly of granites, gneiss, and schists in the South Western Nigeria (9, 23), or from sedimentary rocks and deposits of various ages, Palezoic through Quartenary in the middle belt. Physiographically, these soils occur in coastal plains interior, plateaus or

Tableau 4
Land qualities/ characteristics (ranges) of selected wetland soils in Nigeria

	Parameters	Humid Forest zone	Derived savannah	Southern Guinea savannah	Arid zone
Climate (c)	Annual Rainfall (mm)	2050.00	1255.00	1159.00	700.00
	Solar radiation †	308.00	358.00	380.00	505.40
	Temperature (°C)	20-35	20-35	20-35	20-35
LPG ††	Days	> 270	108-270	75-180	< 75
Wetness (w)	Drainage ‡	IV	IV	IV	IV
Physical properties (s)	% Clay	9.8-56.9	3.9-66.7	22.2-51.0	20-60.8
	Depth (cm)	≥ 50	≥ 50	≥ 50	≥ 50
Chemical properties (c)	pH	4.2-5.9	5.6-7.1	3.1-5.3	4.7-6.2
	Ec (ds/m)	0.06-0.57	0.1	0.10-0.20	0.20-0.50
	Organic C. (%)	0.60-2.90	0.80-3.40	0.20-2.10	0.40-0.70
	Total N (%)	0.03-0.10	0.04-5.60	0.10-0.002	0.10-0.04
	Ca ($cmol.kg^{-1}$)	0.10-8.50	1.60-24.60	2.70-0.85	7.10-20.80
	Mg ($cmol.kg^{-1}$)	0.10-8.50	0.80-4.80	0.84-0.10	3.10-7.60
	K ($cmol.kg^{-1}$)	0.10-0.60	0.02-0.40	0.04-0.23	0.60-0.70
	CEC ($cmol.kg^{-1}$)	0.70-34.70	4.10-30.10	2.12-11.39	39.54-62.8
	B. Saturation (%)	9.30-66.70	25.7-97.7	39.50-83.60	95.0-98.4
	P ($mg.kg^{-1}$)	0.70-13.0	1.10-31.0	1.90-16.30	0.90-3.00
	Fe ($mg.kg^{-1}$)	14.9-96.50	1.11-50.20	0.10-43.80	0.10-3.60
	Zn ($mg.kg^{-1}$)	1.20-23.0	0.05-24.0	0.05	0.05

† $Cal.cm^{-2}.Day^{-1}$
‡ Drainage class, imperfect to poorly drained and impeded at 40 cm depth for between 100- 165 days;
†† LPG, length of rowing periods

highlands. Those occurring in the plateaus and highlands are almost exclusively derived from basement complex, while those occurring in the coastal plains are derived from unconsolidated Quarternary deposits or from sedimentary rocks in the terraces. Climatically, the area of origin of these soils can be divided into four based on the length of the growing periods (LGP) (22). Thus, from all these characteristics, one could observe that the physicochemical properties (Tables 2 & 3) of these soils would differ; hence, their suitabilities for rainfed rice cultivation.

Suitability evaluation of wetlands

The result showed that climate is not a major limitation to rice cultivation as rainfall and solar radiation is near optimum in all agro-ecological zones (Figure 5). The only exception is in the Arid Zone (ARZ) where rainfall may be lower than that required for optimum rice growth. The optimum soil depth proposed for evaluating wetland rice was 50 cm (10) and from figure 5, the soil depth is optimum in all the agro-ecological zones for all pedons. Most of the pedons are poorly drained. However, drainage is in turn dependent on the texture of the sub-surface soils coupled with groundwater table level. Texture and hydrology have been reported as being important land qualities that significantly affect rice growth and yield in West Africa (8,11).

Potential soil fertility

Included here are chemical properties (CEC and organic carbon) that are not easily altered by soil management practices. Most pedons have limitations in these properties (Table 5).

Current soil fertility

Refers to land characterictics that are easily influenced by soil management practices (P, K, Ca, Mg and Zn) along with requirements for the potential fertility. These properties were sub-optimal for all pedons and in some cases, excessive Fe^{2+} levels were observed (Figure 5).

Major limitation to rice cultivation

It could be clearly seen that Nigeria is climatically suitable for rice cultivation. Major limitations to rice cultivation in these pedons are sub-optimal texture (% Clay), low exchangeable cations (K, Ca and Mg), CEC, and organic carbon. Other soil characteristics are sub-optimal contents of total N, available P, and in some pedons high Fe^{2+} levels (especially in pedons 15, 17 and 18). Nartey and Sahrawat (12) reported that ammonia-N significantly correlated with % clay, organic carbon, total N, CEC and pH. Thus, low total N in these pedons may therefore not indicate the status of total N for optimum rice growth. The available P was low for most pedons (Figure 5). Sahrawat *et al*. (20) reported a critical P of between 12.50-15.0 $mg.kg^{-1}$ for some upland rice in West Africa. The low CEC values in some pedons suggest sustained crop production without adequate fertilizer application may not be feasible.

The major soil limitations to rice cultivation each of the agro-ecological zones in Nigeria are as follows: available P (all agro-ecological zones), organic carbon (DSZ, SGSZ and ARZ), Zn (DSZ, SGSZ and HFZ) and Mg (SGSZ and DSZ). Sub-optimal contents of total "N and exchangeable, Ca and CEC were observed" in the southern Guinea savanna Zone (SGSZ). In terms of the length of growing periods (LGP), all the agro-ecological zones were highly suitable (S1) for rice cultivation, while only the Arid Zone is moderately suitable (S2). In their study of irrigated rice soils in the sahelian region, Dondeyne *et al.* (5) observed that the most limiting soil constraints to rice according to the FCC method were limited soil depth, erodibility and high P fixation by soils.

Suitability classes

Individual ratings of the land characteristic (Figure 5) and the aggregate ratings of each of the pedons (Figures 1-4) were made for both the potential and current suitability (considering all characteristics). The suitability classifications of the pedons are shown in table 5 with fertility and soil physical characteristics as the major limitations. Currently, all pedons (37 out of the 38) (97%) were found to be marginally suitable (S3) by non-parametric method, while through the parametric method about 74% (28 of the 38 pedons) were marginally suitable (S3), and about 23% (9 of the 38) of the pedons were not suitable (N).

Potentially by non-parametric method, 18% (9 of the 38) of the pedons were highly suitable (S1) and moderate suitabilities (S2), and 58% (23 of the 38) were marginally suitable (S3).

However, by the parametric method, potentially, 24% (9 of the 38) of pedons were highly suitable (S1), 45% (17 of the 38) of pedons were moderately suitable (S2), and 31% (11 of the 38) of the pedons were marginally suitable (S3).

It would be observed that there are differences in the results of both methods (parametric and non-parametric) of evaluation. The difference in the methods results from the basic differences in the two approaches. Just one characteristic that is least suitable decides the aggregate suitability class by the non-parametric method, but the parametric method considers all characteristics of the land quality groups.

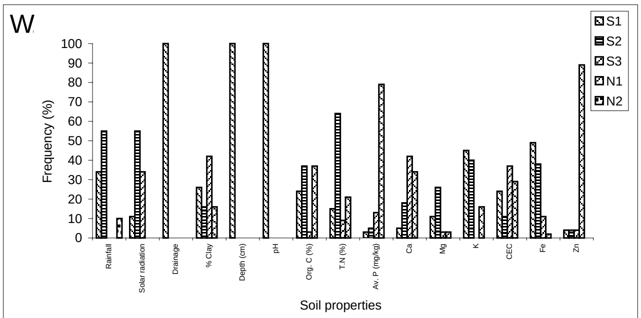

Figure 5: Frequency of suitability class scores of selected wetland soil properties

The efficiency of each method of evaluation depends to a large extent on the relative importance of the most limiting characteristics of the land use in question.

When the most limiting characteristics is climate, soil physical condition or even CEC, the non-parametric method was found to be more accurate. This is because if one of these characteristics is limiting, its effect dominates crop performance rendering others redundant. Where the most limiting characteristic is a chemical property (i.e., those easily altered), the parametric method may be more accurate. Therefore, for the evaluation of these pedons, the parametric method would be suggested.

Conclusion

The land evaluation methods used in this study enabled us to identify soil limitations to rainfed rice cultivation in four agro-ecological zones. The results showed that climatically all the agro-ecological zones considered are suitable for rice cultivation even in terms of the length of growing periods (LGP). The major soil constraints to rice were low CEC, organic carbon, exchangeable cations, and available P and were observed to vary with the agro-ecological zone. Thus, it is suggested that these soils be evaluated with the parametric method. The result of this study provides ready-made information for soil scientists, agronomists, and soil policy planners.

Literature

1. Buol S.W., 1972, Fertility capability soil classification systems. *In*: Soil Department, North Carolina state university. Agronomic-economic research on tropical soils. Annual report for 1971-1972. Raleigh, North Carolina.
2. Buol S.W. & Couto W., 1980, Soil fertility capability assessment for use in the humid tropics. *In*: D.J. Greenland (eds). Characterization of soils in relation to their classification and management for crop production: examples from some areas of the humid tropics. Oxford University Press. Pp 254-261.
3. Clarke G.R., 1951, The evaluation of soils and the definition of quality classes from studies of the physical properties of the soil profile in the field. J. Soil Sci. 2, 50-60.
4. Dent F. J., 1978, The agricultural potential of the Peninsular Thailand. M.S. thesis University of Hull, England.
5. Dondeyene S., Deckers J. & Raes D., 1997, Land evaluation for irrigated rice in the West African Sahel. *In*: Meizan K.M. *et al*. Irrigated rice in the Sahel: Prospects or sustainable development. West Africa Rice Development Association (WARDA), Bouaké, Côte-d'Ivoire. Pp 381-396.
6. Fagbami A. & Ajayi F.O., 1989, Valley bottom soils of the sub-humid tropical southwestern Nigeria on Basement complex rocks: Characteristics and classification. Soil Sci. Plant Nutr. **36**(2), 179-194.
7. Fageria N. K., 1991, Growth and Mineral Nutrition of field crops chapter 6, Rice. Pp 159-204. Narcell Dekker New York.
8. Killian J. & Teissier J, 1972, Méthodes d'investigation pour l'analyse et le classement des bas-fonds dans quelques régions de l'Afrique de l'ouest: Proposition de classification d'aptitudes des terres à la riziculture. FF/IRAT/IITA. Séminaire sur les perspectives pour l'irrigation en Afrique de l'ouest. Mimeogr. 18 p.
9. Kyuma K., Kosaki T. & Juo A.S.R., 1986, Evaluation of the fertility of the soils. Pp 43- 58. *In*: Juo A.S.R. and Lowe J.A. (eds). The wetlands and Rice in sub-Saharan Africa. Intl. Inst. of Trop. Agriculture, Ibadan, Nigeria.
10. Moormann F.R. & Breemen N., 1978, Rice: Soil, Water, Land. International Rice research institute. Manila, Philippines.
11. Moormann F.R. & Dudal R., 1965, Characteristics of soils in which paddy is grown in relation to their capacity classification. Soil Surv. Rep. No 32, Dept. Land Dev., Bangok, Thailand.
12. Nartey L.T. & Sahrawat K.L., 1997, Potentially mineralizable nitrogen in West Africa rice soils. Geoderma **76**(1/2), 145-154.
13. Ogunkunle A.O., 1993, Soil in land suitability evaluation: an example of Oil-palm in Nigeria. Soil Use and Management **9**(1): 35-40.
14. Okusami T.A. & Rust R.H., 1992, Occurrence, characteristics, and classification of some hydromorphic soils from Southwestern Nigeria. *In*: Kimble J.M. (eds). Proc. of the eight International Soil correlation Meeting (VIII ISCOM), 185-197.
15. Okusami T.A., 1985, Properties of some hydromorphic soils in West Africa. Pp 59- 65. The wetlands and Rice in sub-Saharan Africa. Intl. Inst. of Trop. Agriculture, Ibadan, Nigeria.
16. Olaleye A.O., 1998, Characterization, evaluation, nutrient dynamics and rice yields in selected wetland soils in Nigeria. Ph.D. thesis. University of Ibadan, Nigeria. 205 p.
17. Oyediran G.O., 1990, Genesis, classification, and potential productivity of selected wetland soils in the savanna ecosystem of Nigeria. Ph.D. thesis (unpublished). Obafemi Awolowo University, Ife, Nigeria. 335 p.
18. Petters S.W., Usoro E.J., Udo E.J., Obot U.W. & Okpon S.N., 1989, Akwa Ibom State: Physical background, Soils, and Land Use and Ecological Problem. Technical report of the Task Force on Soils and Land Use Survey. Govt. Printer, Uyo. Pp 602.
19. Ponnamperuma F.N., 1994, Evaluation and improvement of lands for wetland rice production. Pp 3-19. *In*: Rice and problem soils in South and southeast Asia (eds). Senadhira. IRRI, Philippines.
20. Sahrawat K.L., Jones M.P. & Diatta S., 1997, Extractable phosphorus and rice yield in an Ultisol of humid forest zone in West Africa. Communications. *In*: Soil- Science and Plant-Analysis. 1997, 28: 9-10, 711-716.
21. Singh B.N., Fagade S., Ukwungu M.N., Williams C.T., Jagtap S.S., Oladimeji O., Efisue A. & Okhidievbie O., 1997, Rice growing environments and biophysical constraints in different agroecological zones in Nigeria. Met. J. **2**(1), 35-44.
22. Singh B.P., 1992, Characteristics of Fe-toxic soils and affected plants and their correction in acid Haplaquents of Meghaya. IRRI News **17**(2), 18.
23. Singh B.P., 1992, Characteristics of Fe-toxic soils and affected plants and their correction in acid Haplaquents of Meghaya. IRRI News **17**(2), 18.
24. Smyth A.J. & Montgomery R.F., 1962, Soils and land use in central south Western Nigeria. Govt. printer, Ibadan, Western Nigeria. 264 p.
25. Sys C., 1985, Evaluation of the physical environment for rice cultivation. *In*: Soil Physics and Rice. IRRI (eds). Pp 31- 43. IRRI, Los Baños, Phillipines.
26. Tanaka A. & Yoshida S., 1970, Nutritional disorders of the rice plant in Asia. *In*: Rice. Res. Inst. Techn. Bull. 10.
27. Veneman P.L.M., Vepraskas M.J. & Bouma J., 1976, The physical significance of soil mottling in a Wisconsin Toposequence. Geoderma, 15, 103-108.
28. Vepraskas M.J. & Bouma J., 1976, Model experiments on mottle deformation simulating field conditions. Geoderma, 15, 217-230.
29. West Africa Rice Development Association (WARDA), 1993, Rice trends in sub-Saharan Africa: A synthesis of statistics on rice production, trade and consumption. West Africa Rice Development Association (WARDA), 1998, Annual Report 1997. Mbe, Côte-d'Ivoire.