

Suitability Evaluation of Selected Soils for Rice Cultivation in Riggi, Lau Local Government Area, Taraba State, Nigeria

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ABSTRACT

This study evaluated the suitability of selected soils for rice cultivation in Riggi, Lau Local Government Area, Taraba State, Nigeria. Two representative pedons were examined for their morphological, physical, and chemical properties to determine their potential for sustainable rice production. Results revealed significant variability between the pedons. Pedon 3 exhibited a near-neutral slightly acidic pH (6.00-6.20), moderate organic carbon, and very high cation exchange capacity (95.49-99.10 cmol/kg), but was severely constrained by critically low available phosphorus (1.18-3.41 mg/kg), dominance of exchangeable acidity (over 95% of ECEC), and high bulk density (1.87-1.97 g/cm³). Pedon 6 slightly showed alkaline pH (7.23-7.38), very low organic matter and total nitrogen, low available phosphorus (1.54-7.37 mg/kg), and severe compaction (bulk density up to 2.10 g/cm³). Electrical conductivity values were low across both pedons, indicating no salinity constraints. Based on the FAO framework, both pedons were classified as marginally suitable (S3) for rice cultivation due to multiple physical and chemical limitations. The study concludes that while the soils have potential for rice production, they require site-specific management interventions including phosphorus fertilization, organic matter incorporation, liming for Pedon 3, and amelioration of alkalinity for Pedon 6 to achieve sustainable productivity of the crop.

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INTRODUCTION

Rice (*Oryza sativa* and *Oryza glaberrima*) is an important staple crop in Nigeria and contributes substantially to food security and agricultural development (FAO, 2020). Increasing population, urbanization, and changing dietary preferences have intensified demand for rice, resulting in expansion of production into diverse agro-ecological environments. However, rice productivity depends strongly on soil properties, particularly texture, drainage, organic matter, nutrient availability, and soil reaction (Esu, 2010). Taraba State has considerable agricultural potential, including areas suitable for rice cultivation. Riggi, in Lau Local Government Area, is an important rice-producing area where soil and water conditions are closely linked to crop performance. However, constraints such as nutrient depletion, soil degradation, and inappropriate soil and water management may limit sustainable production (Obalum et al., 2017). Characterizing the physical and chemical properties of these soils is therefore essential for identifying production constraints and developing appropriate management strategies. Soil suitability evaluation provides a systematic basis for assessing the capacity of land to support specific crops by comparing measured soil characteristics with established crop requirements (Sys et al., 1991). Such evaluation helps identify limiting factors and provides a basis for sustainable land-use planning and management. This study therefore assessed selected physical and chemical properties of soils in Riggi, Lau LGA, and evaluated their suitability for rice production. The findings are expected to provide baseline information for improved soil management and sustainable rice production in the study area.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Riggi in Lau Local Government Area (LGA), Taraba State, northeastern Nigeria, within the Sudan Savanna agroecological zone. The area lies approximately between 9.0274–9.3530°N and 11.6790–11.9820°E. It experiences a unimodal rainfall regime, generally from April to October, followed by a dry season from November to March. Annual rainfall is approximately 900–1,400 mm, with mean annual temperatures of about 26–38°C. Major land-use activities include rice and other crop production, livestock rearing, fishing, and local trading. The landscape is predominantly floodplain, with alluvial deposits derived from sedimentary materials associated with the Benue Basin. Seasonal flooding produces alternating wet and dry soil conditions that influence soil development, drainage, and nutrient dynamics. Vegetation is characteristic of the Sudan Savanna, comprising grasses, shrubs, and scattered trees, with wetland areas supporting species such as *Typha* and *Echinochloa* spp.

Reconnaissance Survey and Field Sampling

A reconnaissance survey was conducted to identify representative sampling locations and obtain preliminary information on the landscape and soil conditions. Geological and ancillary information was obtained from relevant government sources. Field equipment included a handheld GPS (Garmin 76Cx), soil auger, core sampler, shovel, trowel, measuring tape, Munsell soil colour chart, sample bags, profile description sheets, and other standard soil-survey equipment.

Representative soil profile pits were excavated and described according to standard procedures (Soil Survey Staff, 2016). Morphological characteristics, including horizon depth, colour, texture, structure, consistency, mottling, and boundary characteristics, were recorded. Soil samples were collected separately from each identified horizon, labelled, geo-referenced, and transported to the laboratory. Undisturbed core samples were collected for bulk density and moisture-content determination.

Soil Sample Preparation

Soil samples were air-dried, gently disaggregated, and passed through a 2-mm sieve. Subsamples were further ground and passed through a finer sieve where required for chemical analyses. The prepared samples were stored in clean, labelled containers prior to laboratory analysis (Bremner, 1996).

Determination of Soil Physical Properties

Particle-Size Distribution

Particle-size distribution was determined by the hydrometer method following standard procedures (Gee & Or, 2002; Van Reeuwijk, 2002). The proportions of sand, silt, and clay were calculated from hydrometer readings after appropriate dispersion and sedimentation.

(%Clay = {corrected hydrometer reading at the specified settling time} / {weight of soil sample} × 100)

(%Silt = 100 - (%Sand + %Clay))

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Soil textural classes were determined using the appropriate soil textural triangle.

Bulk Density, Particle Density and Total Porosity

Bulk density was determined using the core method as the ratio of oven-dry soil mass to the volume of the soil core (Blake & Hartge, 1986 and Gee and Or, 2002):

$$\text{Bulk density} = \frac{\text{Mass of dry soil}}{\text{Total soil volume}} \quad (1)$$

$$\text{Particle density} = \frac{\text{Mass of particles}}{\text{Volume of solid phase}} \quad (2)$$

Porosity was calculated as:

$$\text{Porosity } (\phi) = 1 - (\rho_b / \rho_p)$$

Where ρ_b = bulk density, ρ_p = particle density (2.65 g/cm³)

Gravimetric Moisture Content

Gravimetric moisture content was determined by oven-drying core samples to constant mass (Obi, 1990):

W1 = weight of can with lid

W2 = weight of soil + weight of can with lid, W3 = weight of oven-dry soil

$$\%MC \text{ (wet — soil basis)} = \frac{W2 - W3}{W2 - W1} \times 100 \quad (3)$$

Determination of Soil Chemical Properties

Soil pH and electrical conductivity (EC) were determined using standard procedures with appropriate pH and conductivity meters (Brady & Weil, 2008; Sparks et al., 1996). Organic carbon was determined by the appropriate oxidation procedure, while organic matter was estimated from organic carbon using the conventional conversion factor:

$$OM(\%) = OC \times \frac{100 \times 1.724}{0.58} \quad (4)$$

$$OC = \frac{\text{Mass of CO}_2 \text{ produced}}{\text{Mass of dry soil}} \times 100\% \quad (5)$$

Total nitrogen was determined using the Kjeldahl method (Bremner, 1996). Available phosphorus was determined by the appropriate extraction and spectrophotometric procedure (Olsen et al., 1954). $TN \text{ (mg/kg)} = \frac{V \times N \times 14}{1000}$

Exchangeable acidity was determined following standard extraction and titration procedures. Exchangeable Ca, Mg, K, and Na were determined using ammonium acetate extraction (Thomas, 1982). Cation exchange capacity (CEC) was calculated from the measured exchangeable cations.

$$\% \text{ Base saturation} = \left(\frac{\text{Sum of exchangeable bases}}{\text{CEC}} \right) \times 100 \text{ (Rhoades, 1982)}$$

Sodium Adsorption Ratio (SAR)

SAR was calculated using:

$$SAR = \frac{Na^+}{\sqrt{[(Ca^{2+} + Mg^{2+})/2]}} \text{ (Richards, 1954)}$$

Exchangeable Sodium Percentage (ESP)

$$ESP = \left(\frac{\text{Exchangeable Na}}{\text{CEC}} \right) \times 100$$

Land Suitability Evaluation

Land suitability for rice production was evaluated using the FAO land-evaluation framework (FAO, 1976; Sys, 1985). The measured soil characteristics were matched with the requirements of rice and assessed according to the severity of identified limitations. The soils were subsequently assigned to the suitability classes S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable). The dominant limitations and corresponding management requirements were identified for each pedon.

RESULTS AND DISCUSSION

Morphological Characteristics of the Soils

Two representative soil pedons were described using standard soil morphological procedures, considering depth, moist colour, mottling, texture, structure, consistency, and horizon boundaries (Table 1). Both pedons were deep and poorly drained, with distinct horizon differentiation and morphological features indicative of periodic saturation.

Pedon 1 exhibited a dark brown, mottled surface horizon with sandy loam texture, moderate medium subangular blocky structure, and firm consistency. Subsurface horizons ranged from reddish-brown to yellowish-brown, with textures varying from sandy clay loam to clay loam and moderate subangular blocky structure. The occurrence of mottling and firm to very firm consistency indicates fluctuating water conditions and restricted drainage.

Pedon 2 was also deep and poorly drained, occurring in a lower landscape position subject to seasonal flooding. The profile had an effective depth of approximately 150 cm, with sandy clay loam surface material and sandy clay in the subsurface. Moderate granular and subangular blocky structures were observed throughout the profile, indicating relatively well-developed aggregation.

The morphological characteristics of both pedons reflect strong hydrological influence typical of floodplain environments. Mottling, dark surface horizons, and variation in subsurface colour indicate periodic saturation and redoximorphic processes. Textural variation from sandy loam to clay loam is consistent with alluvial deposition and influences water retention and drainage. Despite the poor drainage and seasonal flooding, the soils possess favourable characteristics for wetland rice production, particularly under appropriate water and soil management practices. Detailed pedon descriptions are presented in Appendix A.

Table 1: Morphological Properties of the Soil Study Area

Horizon	Depth (cm)	Color (moist)	Mottle	Texture	Structure	Consistence	Boundary
PEDON 3: (9°05'46.26"N, 11°16'27.85"E)							
Ap	0-36	Gray brown	Nil	Sandy loam	3PR	Firm	Distinct
B	36-75	Light grey brown	<2	Sandy Clay loam	3ABK	V. firm	Distinct
C	75-120	Yellowish brown	Nil	Sandy clay	4ABK	V. firm	Distinct
PEDON 6: (9°05'46.26"N, 11°16'27.85"E)							
Ap	0-15	Dark gray brown	Nil	Loam	3MG	Firm	Distinct
E	15-35	Grey brown	Nil	Loam	1CG	V. friable	Faint
B	35-65	Light grey brown	<2	Sandy clay	3SBK	V. firm	Distinct
C	65-145	Yellowish gray	<2	Sandy clay	4PR	V. firm	Distinct
R	145-150	Light yellowish gray	<2	Sandy clay	3SBK	V. firm	Distinct

Key: Structure: 1=structureless, 2=weak, 3=moderate, 4=strong, F=fine, M=medium, Coarse G=granular, CR=crumb, SBK=subangular blocky, ABK=angular blocky, PR=prismatic, PL=platy

Physical Properties of the Soils

The physical properties of the soils are presented in Table 2. Considerable variation occurred among horizons, reflecting differences in sediment deposition, parent material, and pedogenic processes. The observed properties also indicate the influence of hydrological conditions on soil development within the floodplain environment.

Particle Size Distribution

The soils were dominated by loam, sandy loam, sandy clay loam, and sandy clay textures. Sand constituted 41–60% of the soil, while silt and clay ranged from 18–46% and 10–38%, respectively. Surface horizons were generally coarser, whereas clay content tended to increase with depth. The accumulation of clay in subsurface horizons suggests downward movement of fine particles and associated eluviation–illuviation processes (Soil Survey Staff, 2014; Esu, 2010).

The relatively high sand content may favour infiltration and soil workability but can reduce water and nutrient retention. Conversely, increased clay in the subsurface may enhance water and nutrient retention while restricting permeability and root penetration where accumulation is substantial. The variation in particle-size distribution is also consistent with the depositional nature of floodplain soils.

Bulk Density and Moisture Content

Bulk density ranged from 1.84 to 2.10 g cm⁻³, with generally higher values in the subsurface horizons. These values indicate relatively compact soil conditions and may be associated with low organic matter, repeated cultivation, and natural consolidation of subsurface materials (Meek et al.,

1992; Ojeniyi, 2000). High bulk density can restrict root penetration, pore continuity, aeration, and water movement. Gravimetric moisture content ranged from 13.78 to 19.17%. Variations among horizons were associated with differences in texture, bulk density, and pore characteristics. Horizons with greater clay content generally have greater potential for water retention, whereas dense layers may restrict water movement and root-zone aeration. Thus, the interaction between texture and compaction is an important consideration for soil management in the study area.

Electrical Conductivity

Electrical conductivity ranged from 0.62 to 0.97 dS m⁻¹, indicating non-saline conditions. The observed values are below levels generally associated with salinity constraints for most crops. Slight differences among horizons may reflect variations in soluble salt distribution, decomposition of organic materials, and seasonal water movement. Therefore, salinity does not appear to constitute a major limitation to crop production in the studied soils (Brady & Weil, 2016).

Overall Assessment of Physical Properties

The soils were generally coarse to moderately fine textured, non-saline, and characterized by relatively high bulk density, particularly in subsurface horizons. The increase in clay and bulk density with depth indicates pedogenic differentiation and possible compaction of the subsoil. While the texture and low electrical conductivity are generally favourable for agricultural use, high bulk density may constrain root growth, infiltration, and aeration. Appropriate soil management, particularly practices that improve aggregation and organic matter status, is therefore important for sustaining rice production in the study area.

Table 2: Physical Properties of Soils of the Study Area

Horizon	Depth (cm)	% Sand	% Silt	% Clay	Textual Class	BD (g/cm ³)	GMC (%)	EC (ds/m)
Pedon 1								
Ap	0-36	60	26	14	Sandy Loam	1.94	19.17	0.66
B	36-75	60	18	22	Sandy Clay Loam	1.97	18.32	0.77
C	75-120	44	18	38	Sandy Clay	1.87	17.97	0.68
PEDON 2 :								
AP	0-15	43	45	12	Loam	1.84	14.02	0.97
E	15-35	58	32	10	Sandy Loam	1.98	13.98	0.70
B	35-65	47	18	35	Sandy Clay	2.10	13.78	0.74
C	65-145	41	46	13	Loam	1.89	15.84	0.62
R	145-150	48	18	34	Sandy Clay	2.00	15.38	

Chemical Properties of the Soils

The chemical properties of the soils are presented in Table 3. The two pedons differed considerably in soil reaction, organic carbon, exchangeable bases, acidity, and nutrient status, reflecting variations in parent material, leaching intensity, and organic matter dynamics.

Soil Reaction, Organic Carbon and Nitrogen

Soil pH ranged from 6.00–6.20 in Pedon 1 and 7.23–7.38 in Pedon 2, indicating slightly acidic and neutral to slightly alkaline conditions, respectively. The lower pH and base status of Pedon 1 may reflect greater leaching of basic cations, whereas the higher pH of Pedon 2 suggests comparatively greater base retention (Brady & Weil, 2016; Esu, 2010).

Organic carbon (OC) ranged from 1.00–1.33% in Pedon 1 and 0.02–0.59% in Pedon 2, with generally higher concentrations in surface horizons. The decline with depth reflects the concentration of organic residues and biological activity near the soil surface. Low OC throughout the profiles indicates limited organic matter accumulation and may contribute to weak aggregation and reduced nutrient retention (Lal, 1997; Ojeniyi, 2000).

Total nitrogen was generally low in both pedons and followed a pattern similar to OC, indicating a strong association between soil nitrogen and organic matter. The low nitrogen status suggests that nitrogen availability may constrain crop productivity and may require supplementation through appropriate organic or inorganic nutrient sources.

Available Phosphorus and Exchangeable Bases

Available phosphorus ranged from 1.18–3.41 mg kg⁻¹ in Pedon 1 and 1.54–7.37 mg kg⁻¹ in Pedon 2. The generally low values, particularly in Pedon 1, indicate limited phosphorus availability. Under acidic conditions, phosphorus can become strongly associated with iron and aluminium compounds, reducing its availability to plants (Brady & Weil, 2016).

Exchangeable calcium and magnesium were substantially higher in Pedon 2 (Ca: 3.80–13.60 cmolc kg⁻¹; Mg: 1.02–3.67 cmolc kg⁻¹) than in Pedon 1 (Ca: 1.08–1.44 cmolc kg⁻¹; Mg: 0.05–0.14 cmolc kg⁻¹). Potassium and sodium were also generally higher in Pedon 2. The greater abundance of exchangeable bases indicates a comparatively higher base status and nutrient reserve in Pedon 2, probably associated with differences in parent material and leaching conditions (Esu, 2010; Ogunwale et al., 2002).

Exchangeable Acidity and ECEC

Exchangeable acidity ranged from 4.21–5.56 cmolc kg⁻¹ in Pedon 1 compared with 1.20–2.20 cmolc kg⁻¹ in Pedon 2. The higher acidity of Pedon 1 corresponds with its lower pH and exchangeable base status and may restrict the availability of some essential nutrients.

Effective cation exchange capacity (ECEC) varied considerably between the pedons. Pedon 2 recorded values of 6.53–21.24 cmolc kg⁻¹, indicating moderate nutrient-retention capacity associated with its clay and organic matter contents. The unusually high ECEC values reported for Pedon 1 should be verified against the laboratory measurements and calculation procedure before publication.

Overall Assessment of Chemical Properties

The soils exhibited clear chemical differentiation between the two pedons. Pedon 1 was characterized by slightly acidic reaction, lower exchangeable bases, greater exchangeable acidity, and generally low nutrient status, whereas Pedon 2 had near-neutral to slightly alkaline reaction and a comparatively higher base status. These differences indicate contrasting soil fertility conditions within the floodplain. Management should therefore emphasize organic matter improvement and balanced nutrient application, with acidity correction considered where required by soil-test results.

Table 3: Chemical Properties of Soils of the Study Area

Horizon	Depth (cm)	pH (H ₂ O)	OC	OM (%)	TN	AP (mg/kg)	K	Na	Ca	Mg (cmol/kg)	H+Al	ECEC
$\longleftrightarrow$ $\longleftrightarrow$ $\longleftrightarrow$ $\longleftrightarrow$												
PEDON 1 (9°05'46.26"N, 11°16'27.85"E)												
Ap	0-36	6.20	1.04	1.31	9.34	2.03	0.30	0.54	1.44	0.12	4.43	97.29
B	36-75	6.05	1.00	0.82	7.91	1.18	0.29	0.72	1.08	0.14	4.21	95.49
C	75-120	6.00	1.33	0.10	10.15	3.41	0.32	0.65	1.13	0.05	5.56	99.10
PEDON 2 (9°05'46.26"N, 11°16'27.85"E)												
AP	0-15	7.23	0.100	0.172	0.015	7.37	0.08	0.24	3.80	1.02	1.80	6.94
E	15-35	7.37	0.219	0.378	0.031	1.54	0.10	0.34	4.60	1.24	1.40	7.68
B	35-65	7.38	0.319	0.550	0.046	2.23	0.92	1.17	9.60	2.59	2.20	16.48
C	65-145	7.30	0.020	0.035	0.004	2.74	0.06	0.19	4.00	1.08	1.20	6.53
R	145-150	7.28	0.587	1.012	0.084	2.92	0.97	1.60	13.60	3.67	1.40	21.24

Land Suitability Evaluation for Rice Production

Land suitability for rice production was evaluated by integrating the physical and chemical properties of the soils (Tables 2 and 3) using the FAO land evaluation framework (FAO, 1976). The major factors influencing suitability were soil texture, bulk density, soil reaction, organic carbon, nutrient status, exchangeable bases, and acidity. Pedon 1 was classified as marginally suitable (S3), mainly because of its relatively high bulk density, low organic carbon and nutrient status, and greater exchangeable acidity. Its slightly acidic reaction was within the generally acceptable range for rice but, together with low base status and phosphorus availability, may reduce nutrient supply and crop performance. Pedon 2 was classified as moderately suitable

(S2). Its near-neutral to slightly alkaline reaction, higher exchangeable bases, and comparatively better nutrient status provide more favourable conditions for rice production. However, relatively high bulk density and low organic carbon remain important limitations that may restrict root development and nutrient availability. Overall, the soils possess moderate potential for rice cultivation, with soil compaction and low fertility status constituting the principal limitations. Sustainable production would benefit from the incorporation of organic materials, balanced nutrient management, and practices that reduce soil compaction and improve soil structure. These interventions could enhance water movement, nutrient availability, and root development, thereby improving the productivity of the floodplain soils.

Table 4: Suitability Evaluation of Rice

Pedon	Suitability Class	Limiting Factors
Pedon 3	S3 (Marginally Suitable)	Low fertility, acidity, low OM
Pedon 5	S2 (Moderately Suitable)	High bulk density, moderate fertility
Pedon 6	S2 (Moderately Suitable)	Compaction, moderate OM deficiency

This classification aligns with FAO (1976, pp. 17–25) guidelines, which consider soil physical and chemical limitations in determining land suitability.

CONCLUSION

The study showed that the soils of the study area exhibit distinct morphological, physical, and chemical characteristics associated with floodplain soil development, parent material variation, and hydrological conditions. The soils were mainly sandy loam to sandy clay, with increasing clay content with depth. However, relatively high bulk density (1.84–2.10 g cm⁻³) represents an important physical constraint to root development, aeration, and water movement. The chemical properties revealed marked differences between the pedons. Pedon 1 was slightly acidic and characterized by relatively low organic carbon, exchangeable bases, and nutrient status, whereas Pedon 2 had near-neutral to slightly alkaline reaction and comparatively higher base status and nutrient-retention capacity. Organic carbon and nitrogen were generally low in both pedons, while available phosphorus ranged from low to moderate.

Based on the FAO land evaluation framework, Pedon 1 was classified as marginally suitable (S3) and Pedon 2 as moderately suitable (S2) for rice production. The major limitations were soil compaction, low organic matter, and nutrient deficiencies, with acidity constituting an additional limitation in Pedon 1. Overall, the soils have potential for rice cultivation, provided appropriate soil fertility and physical-condition management practices are adopted.

Recommendations

Organic matter management: Regular incorporation of farmyard manure, compost, crop residues, and other suitable organic materials should be encouraged to improve soil structure, reduce compaction, and enhance nutrient retention. **Balanced fertilization:** Soil-test-based application of nitrogen and phosphorus fertilizers is recommended to address the major nutrient limitations. Potassium should be applied where indicated by soil-test results, with nitrogen preferably applied in split doses. **Management of soil acidity:** Where soil testing confirms acidity-related constraints, appropriate liming should be considered, particularly for Pedon 1. **Reduction of compaction:** Reduced tillage and avoidance of heavy machinery when soils are excessively wet should be encouraged to improve soil porosity, root penetration, and water movement. **Water management:** Appropriate irrigation and drainage management should be maintained to regulate soil moisture and minimize prolonged waterlogging while supporting rice production. **Integrated soil fertility management:** Crop residues, organic amendments, and suitable crop rotations, including leguminous crops, should be incorporated into production systems to improve long-term soil fertility and sustainability. **Regular soil monitoring:** Periodic soil testing should be undertaken to monitor changes in soil fertility, acidity, salinity, and physical condition and to guide site-specific management decisions.

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