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SOIL MORPHOLOGICAL AND PHYSICAL PROPERTIES AS DETERMINANTS OF RICE PRODUCTION IN OGBOMOSO, SOUTHWESTERN NIGERIA

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ABSTRACT

Rice production in Ogbomoso, Southwestern Nigeria, depends largely on soil characteristics, which influence water retention, nutrient availability, and overall crop productivity. However, variability in soil properties across different farms may limit rice yield. This study was conducted to assess the morphological, physical, and chemical properties of soils used for rice production in selected farms in Ogbomoso.

Six representative farms which are Oyebode S. and Oyebode A. (Surulere LGA), Mumuni L. and Oderinde (Ogo-Oluwa LGA), and Ogunniyi J. and Ajuwon A. (Oriire LGA) were selected for the study. Profile pits (1.5 m × 1.5 m × 2.0 m) were dug in each farm, and soil samples were collected from identified horizons. Field description of morphological properties was carried out, while laboratory analyses were conducted using standard procedures. Particle size distribution was determined using the hydrometer method, and soil chemical properties includes pH, organic carbon, total nitrogen, avail. phosphorus, exchangeable bases, and cation exchange capacity (CEC) were analyzed. Suitability evaluation was conducted using the FAO land evaluation framework.

The results showed that soil pH ranged from 4.95 to 6.10, indicating moderately acidic to slightly acidic conditions. Organic carbon ranged from 1.30 to 4.31 g/kg, while total nitrogen ranged from 0.14 to 0.47 %, indicating low nitrogen content. Available phosphorus ranged from 0.16 to 3.50 mg/kg, showing severe deficiency of available phosphorus in most of the study sites. Exchangeable calcium ranged from 2.09 to 19.20 cmol/kg, magnesium from 0.46 to 1.82 cmol/kg, potassium from 0.19 to 0.78 cmol/kg, and sodium from 0.15 to 0.47 cmol/kg. CEC ranged from 3.63 to 22.32 cmol/kg, indicating low to moderate nutrient retention capacity. Soil texture varied widely, with sand ranging from 37.2% to 90.6%, silt from 1.4% to 25.4%, and clay from 6.0% to 61.4%, resulting in textural classes such as sand, loamy sand, sandy loam, sandy clay loam, and clay. Micronutrients showed Fe ranging from 72 to 241 mg/kg, Mn from 56 to 156 mg/kg, Cu from 1.11 to 1.91 mg/kg, and Zn from 1.58 to 2.58 mg/kg. Suitability evaluation revealed that climatic and topographic factors were highly suitable (S1), while soil-related limitations resulted in Mumuni L., Oyebode S. and Ajuwon A. Farm being moderately suitable (S2), Oyebode A. and Ogunniyi J. were marginally suitable (S3), while Oderinde Farm was rated not suitable (N2).

In conclusion, despite favorable climatic and topographic conditions for rice production in the study areas, soil fertility constraints such as low organic matter, low nitrogen, deficiency in available phosphorus, coarse soil texture, and low CEC limit the soil productivity. Therefore, improving soil fertility through organic matter incorporation, balanced fertilizer application, and proper water management practices is essential for enhancing rice production and ensuring sustainable agricultural development in these areas.

Keywords: *Rice production, soil morphology, soil physical properties, soil texture, Ogbomoso, Southwestern Nigeria.*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple crops in the world, feeding more than half of the global population. In many developing countries, particularly in sub-Saharan Africa, rice consumption has increased significantly due to population growth, urbanization and changing dietary preferences. Nigeria, being the most populous country in Africa, has experienced a rapid rise in rice demand, making the crop a central component of national food security strategies. Despite this increasing demand,

domestic rice production has struggled to meet consumption needs, leading to substantial imports over the years (FAO, 2023).

In Nigeria, rice is cultivated across diverse agro-ecological zones, including upland, lowland and irrigated systems. The southwestern region, including Ogbomoso in Oyo State, provides favorable climatic conditions for rice cultivation due to its moderate rainfall, temperature and soil characteristics. However, the productivity of rice in these areas is highly dependent on soil properties, which influence nutrient availability, water retention, root development and overall crop performance. Soil, as a natural resource, serves as the medium for plant growth and plays a critical role in determining agricultural productivity (Brady and Weil, 2016).

Soil properties especially morphological and physical characteristics are fundamental determinants of crop performance because they directly influence root development, water availability, aeration, and nutrient dynamics. Soil morphology provides insight into soil genesis and environmental conditions, including drainage status, weathering intensity, and biological activity. Features such as soil colour, structure, consistence, and horizon differentiation are indicators of soil quality and agricultural potential (Schaetzl and Thompson, 2021).

Similarly, soil physical properties such as texture and structure play a crucial role in determining water retention and movement within the soil profile. For rice cultivation, particularly under lowland conditions, soils must have the capacity to retain water for prolonged periods to maintain flooded conditions. Clayey soils are generally preferred because they reduce percolation losses, whereas sandy soils often present limitations due to rapid drainage and low water-holding capacity (Brady and Weil, 2022).

In tropical regions like Ogbomoso, soils are typically highly weathered and exhibit considerable spatial variability due to differences in parent material, climate, vegetation, and land use. These variations often result in differences in soil fertility and suitability for specific crops. Therefore, detailed assessment of soil morphological and physical properties is necessary to guide sustainable land use and improve agricultural productivity (Dengiz and Sağlam, 2021). Therefore, this study aims to evaluate the morphological and physical characteristics of soils across selected farms in Ogbomoso and determine their suitability for rice production.

MATERIALS AND METHODSDescription of the Study Area

The study was conducted in Ogbomoso, located in Oyo State, southwestern Nigeria. Ogbomoso lies approximately between latitude 8°00'N and 8°30′N and longitude 4°00′E and 4°30′E. The area is situated within the derived savanna agro-ecological zone, characterized by a transition between the humid forest and guinea savanna zones.

The climate is tropical with distinct wet and dry seasons. The wet season typically spans April to October, while the dry season extends from November to March. The mean annual rainfall ranges between 1,000 and 1,300 mm, with average temperatures between 25°C and 32°C (NIMET, 2022; Nigerian Meteorological Agency, 2022). These climatic conditions are favorable for rice cultivation, particularly under rainfed and lowland systems (FAO, 2015; Bouman *et al*., 2007).

Geologically, the area is underlain by Precambrian basement complex rocks, which give rise to soils that are generally coarse-textured and highly weathered (Esu, 2010; FAO, 2015). Such soils are often characterized by low nutrient reserves and require proper management for sustainable agricultural production (Sanchez, 2019; Lal, 2015).

Research Design

A random sampling technique was employed to ensure representativeness and minimize sampling bias (Carter and Gregorich, 2007). This method allows for reliable estimation of soil variability within the study area.

Soil Sampling Procedure

Soil samples were collected from selected rice farms within Ogbomoso (Surulere, Ogo-Oluwa, and Oriire local government areas). Sampling locations were chosen to reflect variability in land use and soil conditions across the study area (FAO, 2006).

Soil Morphology

The study analyzes soil morphology using Munsell Soil colour charts to assess color. Soil texture is determined by the percentage of sand, silt, and clay, while structure is categorized into forms like crumb and blocky. Stoniness is evaluated based on stone volume, and consistence measures cohesion and adhesion.

Mottles, irregular spots indicating poor drainage, are examined for size and quantity.

Laboratory Sample Preparation

The soil samples collected was air dried. Particle size analysis was conducted using the hydrometer method. Soil textural classes were determined using the USDA textural triangle.

Results and Discussion

Soil Morphological Characteristics

The soil profile at Oyebode S. Farm was deep, extending to 136 cm, indicating good rooting depth and moisture storage capacity suitable for rice production. The dark brown surface colour (10YR 2/3) in the A_1 horizon suggests relatively high organic matter accumulation, which is beneficial for nutrient supply and soil fertility. The granular structure and friable consistence of the surface horizons indicate favorable soil aggregation, good aeration, and ease of root penetration. The occurrence of common mottles in the AB and B horizons suggests periodic water saturation and imperfect drainage conditions, which are advantageous for rice cultivation because rice performs well under flooded conditions (Zhang *et al*., 2023). However, the firm consistence in the B horizon may indicate clay accumulation and moderate compaction that could restrict deep root penetration. The presence of very fine roots in the upper horizons further confirms better nutrient availability and aeration near the soil surface.

The profile at Oyebode A. Farm was also deep, reaching 137 cm, indicating adequate soil depth for rice growth. The lighter surface colour (10YR 6/2) compared with Oyebode S. Farm may indicate lower organic matter content. The loose and friable consistence of the surface horizons is favourable for seedbed preparation and rice establishment. Granular structures observed in the A_1 and AB horizons suggest good aggregation and permeability. Few mottles throughout the profile indicate moderate drainage conditions and periodic wetness, which favor paddy rice cultivation. The B horizon exhibited firm consistence and granular structure, suggesting moderate clay accumulation and increased moisture retention. The distribution of fine roots within the upper horizons indicates that the surface soil provides suitable conditions for root development and nutrient uptake.

The Mumuni L. Farm profile extended to 142 cm, making it one of the deepest profiles in the study area. The dark reddish-gray surface colour (2.5YR 4/1) indicates appreciable organic matter accumulation and intense weathering. The crumb structure in the A_1 horizon is highly favorable for rice cultivation because it promotes excellent aeration, infiltration, and root penetration. The occurrence of common mottles in the B horizon indicates seasonal waterlogging and fluctuating groundwater conditions, which support rice growth under lowland conditions. The firm consistence of the B and BC horizons suggests higher clay content and enhanced water-holding capacity. According to Brady and Weil (2022), such subsurface conditions are advantageous for maintaining water in rice fields. The presence of medium and very fine roots in the B horizon also indicates moderate rooting conditions despite the firmness of the subsoil.

The soil at Oderinde Farm was deep, extending to 138 cm. The dark surface colour (10YR 3/4) indicates moderate organic matter content suitable for crop production. The granular and angular blocky structures observed within the profile suggest moderate structural development and improved moisture retention. Few mottles in the upper horizons and common mottles in the B horizon indicate periodic wetness and imperfect drainage conditions favorable for rice production. The friable consistence in the surface and subsurface horizons supports easy tillage and root penetration, while the firm B horizon may enhance water retention under flooded conditions. The absence of roots in deeper horizons may be due to reduced aeration and increased firmness. Overall, the soil properties indicate moderate suitability for rice cultivation.

The profile at Ogunniyi J. Farm was relatively shallower compared with some other farms, extending to 108 cm. Nevertheless, the depth is still adequate for rice production. The dark brown surface colour (10YR 4/4) indicates moderate organic matter accumulation. Granular structures and loose consistence in the A_1 horizon favor root proliferation, infiltration, and nutrient availability. The occurrence of common mottles in the B horizon indicates fluctuating moisture conditions and poor drainage characteristics suitable for paddy rice systems. The sub-angular blocky structures in the B and BC horizons suggest clay accumulation and moderate profile development. Firm consistence in the subsoil may improve water retention but could slightly limit deep root penetration. The concentration of fine roots within the upper horizons reflects better aeration and fertility in these layers.

Ajuwon A. Farm had the deepest profile among

the studied soils, extending to 148 cm, indicating excellent rooting depth and moisture storage capacity. The dark reddish-brown colour (7.5YR 3/4) in the surface horizon suggests relatively high organic matter content and good fertility status. The granular structure and friable consistence in the topsoil provide favorable conditions for seedling establishment, root penetration, and water infiltration. Few to common mottles observed in the lower horizons indicate periodic water saturation and imperfect drainage suitable for rice cultivation. The angular blocky and sub-angular blocky structures in the B and BC horizons indicate clay accumulation and moderate pedogenic development. Firm consistence in the lower horizons may support water retention required for rice production. The presence of medium and very fine roots in the B horizon suggests that the soil still permits moderate root penetration despite increased firmness.

Table 1: Soil morphological properties of the study area

Horizon	Depth (cm)	Colour (moist)	Mottles	Soil Structure	Consistence	Stoniness	Roots	Boundary Form
	Oyebode, S.	**Farm**	**surulere**	**LGA**				
A1	0-21	10YR 2/3	Nil	Granular	Friable	Fs	F Vf	Clear and Smooth
AB	21-39	10YR3/1	Common	Granular	Friable	Fs	Vf F	Clear and Wavy
B	39-87	10YR 5/3	Common	SAB	Firm	Ns	Nil	Gradual and Irregular
BC	**87-136**	7.5YR7/1	Few	SAB	Friable	Fs	Nil	Clear and wavy
	Oyebode, A.	**Farm**	**surulere**	**LGA**				
A1	0-21	10YR 6/2	Few	Granular	Loose	S	M Vf	Clear and Smooth
AB	21-40	10YR6/4	Few	Granular	Friable	Fs	Vf F	Clear and Wavy
B	40-77	10YR 8/1	Few	Granular	Firm	Ns	Vf f	Gradual and Irregular
BC	77-137	10YR 5/4	Few	SAB	Friable	Fs	Nil	Clear and wavy
	Mumuni, L.	**Farm**	**Ogooluwa**	**LGA**				
A1	0-20	2.5YR4/1	Nil	Crumb	Friable	Fs	Vf F	Clear and Smooth
AB	20-40	2.5YR7/1	Few	Granular	Loose	S	F Vf	Clear and Wavy
B	40-80	7.5YR6/6	Common	SAB	Firm	Ns	M Vf	Gradual and Irregular
BC	80-142	10YR 7/1	Few	SAB	Firm	Ns	Nil	Clear and wavy
	Oderinde	**Farm**	**Ogooluwa**	**LGA**				
A1	0-16	10YR ¾	Few	Granular	Friable	Fs	F Vf	Clear and Smooth
AB	16-30	7.5YR5/3	Few	AB	Friable	Fs	Vf F	Clear and Wavy
B	30-76	10YR 6/6	Common	AB	Firm	Ns	Nil	Gradual and Irregular
BC	76-138	10YR 6/8	Few	SAB	Friable	Fs	Nil	Clear and wavy
	Ogunniyi, J.	**Farm**	**Oriire**	**LGA**				
A1	0-20	10YR 4/4	Nil	Granular	Loose	S	M Vf	Clear and Smooth
AB	20-48	7.5YR5/4	Few	Granular	Friable	Fs	Vf F	Clear and Wavy
B	48-70	10YR 6/4	Common	SAB	Firm	Ns	Vf F	Gradual and Irregular
BC	70-108	10YR 6/8	Few	SAB	Friable	Fs	Nil	Clear and wavy
	Ajuwon, A.	**Farm**	**Oriire**	**LGA**				
A1	0-18	7.5YR3/4	Nil	Granular	Friable	Fs	Vf F	Clear and Smooth
AB	18-51	7.5YR5/3	Few	Granular	Loose	S	F Vf	Clear and Wavy
B	51-87	10YR 5/3	Few	AB	Firm	Ns	M Vf	Gradual and Irregular
BC	87-148	10YR 6/8	Common	SAB	Firm	Ns	Nil	Clear and wavy

NB: Structure: Ab - angular blocky, Sab - sub-angular block, Stonniness: ns- no stone, Fs- fairly stony, Vs- very stony, S- stony. Root: Vf F- very few and fine, M Vf-Medium and Very fine, F Vf- Few and Very Fine

Soil Physical Properties

The physical properties of soils are important determinants of rice productivity because they influence water retention, permeability, aeration, nutrient movement, and root development. The soils studied across Surulere, Ogo-Oluwa, and Oriire Local Government Areas of Ogbomoso showed considerable variations in particle size distribution and textural classes, indicating differences in their suitability for rice cultivation.

The soils at Oyebode S. Farm were predominantly sandy loam (SL) with a mean sand content of 69.45%, silt content of 15.9%, and clay content of 14.9%. The A_1 horizon was sandy clay loam (SCL), suggesting relatively higher clay accumulation at the surface compared with the underlying horizons. Sandy loam soils are generally characterized by moderate water retention and good aeration, which support seed germination and root growth. However, the high sand content in the subsurface horizons may encourage rapid drainage and nutrient leaching. Rice cultivation requires soils capable of retaining sufficient moisture; therefore, the moderate clay content in the surface horizon may improve the water-holding capacity of the soil. Adekiya *et al*. (2020) reported that sandy loam soils under tropical conditions often require organic amendments to improve moisture conservation and nutrient retention for sustainable crop production.

The profile at Oyebode A. Farm was mainly loamy sand (LS) throughout the horizons, with an average sand content of 74.2% and clay content of 11.4%. The dominance of sand particles indicates high permeability and low water-holding capacity. Such soils may not adequately retain ponded water needed for rice cultivation unless irrigation is frequently applied. The low clay content may also increase the risk of nutrient losses through leaching. According to Bationo *et al*. (2021), coarse-textured soils in sub-humid tropical environments often exhibit low nutrient retention and require integrated soil fertility management to sustain crop productivity. Despite this limitation, the loose texture of the soil can facilitate easy root penetration and tillage operations.

Mumuni L. Farm exhibited highly variable textural characteristics, ranging from sandy loam (SL) in the surface horizon to clay (C) and sandy clay (SC) in the subsurface horizons. The AB horizon contained 61.4% clay, while the BC horizon had 40% clay content. The mean clay content of 29.7% was the highest among the studied farms. Clayey soils are particularly suitable for lowland rice production because they possess high water-holding capacity and low

permeability, which help maintain flooded conditions required for rice growth. Fageria *et al*. (2021) noted that fine-textured soils are highly favorable for paddy rice because they reduce water loss and improve nutrient retention. However, excessive clay accumulation may also lead to poor aeration and temporary waterlogging, especially under prolonged flooding.

The soils at Oderinde Farm were predominantly sandy (S) and loamy sand (LS), with a mean sand content of 81.1% and a very low clay content of 8.5%. The high proportion of sand indicates rapid infiltration and low moisture retention capacity. Sandy soils are generally less suitable for rice cultivation because they cannot maintain standing water for long periods. Such soils are also highly susceptible to nutrient leaching, particularly nitrogen and potassium losses. Ojo *et al*. (2022) observed that sandy soils in Southwestern Nigeria often experience poor nutrient-use efficiency due to excessive drainage and weak aggregate stability. Therefore, rice cultivation on this farm may require intensive water management and regular addition of organic materials to improve soil structure and moisture retention.

The soils at Ogunniyi J. Farm ranged from sandy (S) and loamy sand (LS) in the upper horizons to sandy clay loam (SCL) in the BC horizon. The mean clay content was 16%, while the BC horizon contained as much as 38% clay. The higher clay accumulation in the lower horizon may improve subsoil water retention and reduce deep percolation losses. This condition is advantageous for rice cultivation because it enhances the availability of water within the root zone during the growing season. The sandy surface horizons, however, may encourage rapid infiltration and nutrient leaching. According to Nwite *et al*. (2020), soils with moderate clay accumulation in subsurface horizons tend to support better moisture conservation and crop productivity under tropical farming systems.

The soils at Ajuwon A. Farm were predominantly sandy loam (SL), with a mean sand content of 71.2% and clay content of 13.4%. The surface horizon was sandy (S), while the lower horizons contained relatively higher clay fractions. Sandy loam soils are generally considered moderately suitable for rice cultivation because they provide balanced drainage and aeration while still retaining moderate amounts of water. Nevertheless, the high sand content in the upper horizon may reduce the soil's ability to maintain saturated conditions required for paddy rice. Agbede *et al*. (2021) reported that sandy loam soils under continuous cultivation often require organic residue incorporation and moisture management practices to sustain crop yield and soil quality.

Table 2: Soil physical properties of the study area

Horizon	Depth (cm)	Sand %	Silt %	Clay %	Textutal class
	Oyebode, S.	**Farm**	**Surulere**	**LGA**	
A1	0-21	54.2	15.4	31.4	SCL
AB	21-39	81.2	11.4	7.4	LS
B	39-87	67.2	23.4	9.4	SL
BC	87-136	75.2	13.4	11.4	SL
Mean		69.45	15.9	14.9	SL
	Oyebo	**Far**	**Surul**	**LGA**	
A1	**de, A.**	**m**	**ere**	15.4	SL
AB	0-21	73.2	11.4	9.4	LS
B	21-40	75.2	15.4	11.4	LS
BC	40-77	73.2	15.4	9.4	LS
Mean	77-137	75.2	15.4	11.4	LS
		74.2	14.4		
A1	**Mumu**	**Far**	**Ogool**	**LG**	
AB	**ni, L.**	**m**	**uwa**	**A**	
B	0-20	63.2	25.4	11.4	SL
BC	20-40	37.2	1.4	61.4	C
Mean	40-80	74.6	19.4	6.0	LS
	80-142	46.6	13.4	40	SC
A1		55.4	14.9	29.7	SCL
AB	**Oderi**	**Far**	**Ogool**	**LG**	
	nde	**m**	**uwa**	**A**	
	0-16	78.6	11.4	10	LS
	16-30	90.6	3.4	6.0	S
B	30-76	72.6	17.4	10	LS
BC	76-138	82.6	9.4	8.0	S
Mean		81.1	10.4	8.5	S
	Ogunni	**Far**	**Oriir**	**LGA**	
A1	**yi, J.**	**m**	**e**	8.0	S
AB	0-20	64.6	17.4	10	LS
B	20-48	82.6	7.4	8.0	S
BC	48-70	86.6	3.4	38	SCL
mean	70-108	54.6	7.4	16	SL
		72.1	8.9		
A1		**Far**	**Oriir**	**LG**	
AB	**Ajuwo**	**m**	**e**	**A**	
B	**n, A.**	83.2	9.4	7.4	S
BC	0-18	63.2	19.4	19.4	SL
Mean	18-51	67.2	19.4	13.4	SL
	51-87	71.2	15.4	13.4	SL
	87-148	71.2	15.9	13.4	SL

NB: SCL- sandy clay loam, S- sandy, SL- sandy loam, LS- loamy soil, C- Clay, SC- Sandy clay.

Conclusion

The findings of this study indicate that the soils in Ogbomoso, Southwestern Nigeria are generally suitable for rice production due to their favorable morphological and physical characteristics. The deep soil profiles, friable consistence, granular surface structures, moderate drainage conditions, and moisture retention capacity provide conducive conditions for rice growth and development. Differences in soil texture among the farms greatly influenced their productivity potential, with soils containing higher clay content, particularly at Mumuni L. Farm and parts of Ogunniyi J. Farm, demonstrating better suitability for rice cultivation because of their

improved water-holding capacity. In contrast, the predominantly sandy soils observed at Oderinde and Oyebode A. Farms may require adequate irrigation, organic amendments, and improved soil management practices to sustain rice yield. Therefore, soil morphological and physical properties remain key factors influencing rice production and should be integrated into sustainable soil management strategies in the study area.

Recommendations

It is recommended that farmers should adopt site-specific soil management practices to improve rice productivity across the study area. Organic matter incorporation, proper irrigation, and periodic tillage are necessary, especially on sandy soils with low water-holding capacity. Clay-rich soils such as those at Mumuni and parts of Ogunniyi Farms should be prioritized for intensive rice cultivation due to their better moisture retention. Regular soil testing and sustainable land management practices are also recommended to maintain long-term soil productivity.

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