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Research Article

Characterisation and classification of valley-bottom soils in Southwestern Nigeria: implications for land degradation neutrality

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Abstract: Valley-bottom (hydromorphic) soils in southwestern Nigeria support vital ecosystem services but remain poorly characterised for sustainable use. This study examined nine pedons from three sites (Iwofin, Osuru, and Debjik) near Ogbomoso, Oyo State, to a depth of 1.5 m and analysed their morphological, physical, and chemical properties following FAO protocols. Soils were predominantly sandy (surface sand: 69.5 – 77.9 %), with bulk density 1.41 – 1.54 g cm^{-3} and porosity above 40 %, indicating minimal compaction. The soils were slightly acidic to near-neutral (pH 5.49 – 6.20), with low organic carbon (0.97 – 1.85 g kg^{-1}) and total nitrogen (0.11 – 0.20 g kg^{-1}). Available phosphorus and cation-exchange capacity were low to moderate, dominated by calcium. Principal component analysis identified organic carbon, clay, and available phosphorus as key fertility determinants. These results provide baseline data for land-use planning in Oyo State. Overall, low organic matter and nutrient reserves highlight the need for integrated soil fertility management (ISFM), organic-matter restoration, and conservation-based practices to enhance productivity and support Nigeria's Land Degradation Neutrality targets.

Keywords: hydromorphic soils, soil conservation, physical properties, chemical properties, tropical soil management

1. Introduction

Understanding and classifying soils based on their physical and chemical properties provides the foundation for sustainable land-use decisions. Soil characterisation helps identify similarities and differences among soils, supports accurate classification, and guides the prediction of soil behaviour under different management systems (Akhtaruzzaman et al.,2014; Lufega & Msanya, 2017). Effective soil classification enables the exchange of knowledge, technology transfer, and adaptive management across landscapes, especially in regions where soil variability influences agricultural productivity.

Soils in tropical environments, such as Nigeria, exhibit considerable variability due to the interplay of climate, parent material, relief, organisms, and time (Fawole et al., 2016; Weil & Brady, 2017). These interactions produce marked differences along topographic gradients, from well-drained uplands to hydromorphic valley bottoms. Consequently, valley-bottom soils (also called *fadama* or *inland valley soils*) occupy unique landscape positions characterised by periodic waterlogging, fine-textured deposits, and variable fertility potential (Ogban & Obi, 2014). Their physical and chemical heterogeneity distinguishes them from the surrounding uplands, often making them more fertile yet fragile ecosystems (Dickson *et al.,* 2020). According to Weil & Brady (2017), iron (Fe) and manganese (Mn) segregation, structural instability under tillage, and nutrient retention patterns are typical of these environments.

In northern Nigeria, *fadama* soils have long supported dry-season irrigation farming due to organised schemes and relatively shallow groundwater (Ojobor & Aimufia, 2022). In contrast, southwestern Nigeria, including Oyo State, has not fully harnessed the agricultural potential of its valley-bottom landscapes. This could

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be linked to the state lying within the derived savanna agroecological zone, characterised by a bimodal rainfall pattern, moderate to high annual precipitation, and increasing land-use pressure around peri-urban centres such as Ogbomoso, coupled with rainfall variability associated with climate change, which heightens the need for detailed soil information to prevent degradation and optimise resource use efficiency.

Despite the recognised importance of inland valleys for food security and climate-resilient agriculture, and the pressure of expansion of cultivation into marginal and hydromorphic environments, there is limited pedon-level morphological and fertility data for valley-bottom soils in the Ogbomoso area. The absence of detailed soil classification and property assessment constrains evidence-based fertiliser recommendations, integrated soil fertility management, conservation agriculture planning, and soil health monitoring aligned with Nigeria's Land Degradation Neutrality commitments under SDG 15.

According to Ogban & Babalola (2009), the valley bottoms of southwestern Nigeria remain underutilised despite favourable rainfall and extended growing seasons; meanwhile, constraints such as poor drainage, limited accessibility, and inadequate characterisation have hindered their integration into sustainable production systems (Ogban & Obi, 2014). As population growth drives the expansion of cultivation into marginal lands, these hydromorphic environments represent potential frontiers for intensified yet sustainable agricultural use. Depending on pedogenic characteristics, they are often classified as Fluvisols, Gleysols, or related reference soil groups under the World Reference Base system. Their periodic sediment deposition and shallow water tables can enhance nutrient availability and moisture retention, making them attractive for dry-season cultivation (Dickson et al., 2020). However, prolonged waterlogging, compaction risk, structural degradation, and nutrient imbalances can constrain productivity if management is not adapted to their hydrological regime.

The productive utilisation of valley-bottom soils requires a clear understanding of their morphological, physical, and chemical properties, which determine management options, fertiliser needs, and resilience to degradation. Poorly characterised soils can lead to inappropriate land use, nutrient depletion, and secondary salinization, undermining Nigeria's progress toward Land Degradation Neutrality (LDN) and the Sustainable Development Goals (SDG 2 and SDG 15) as expressed by Hannam (2022). Existing studies have addressed inland-valley soils in other regions of Nigeria but have rarely provided pedon-level descriptions for the Ogbomoso area of Oyo State, where increasing land pressure and rainfall variability threaten soil quality and food security.

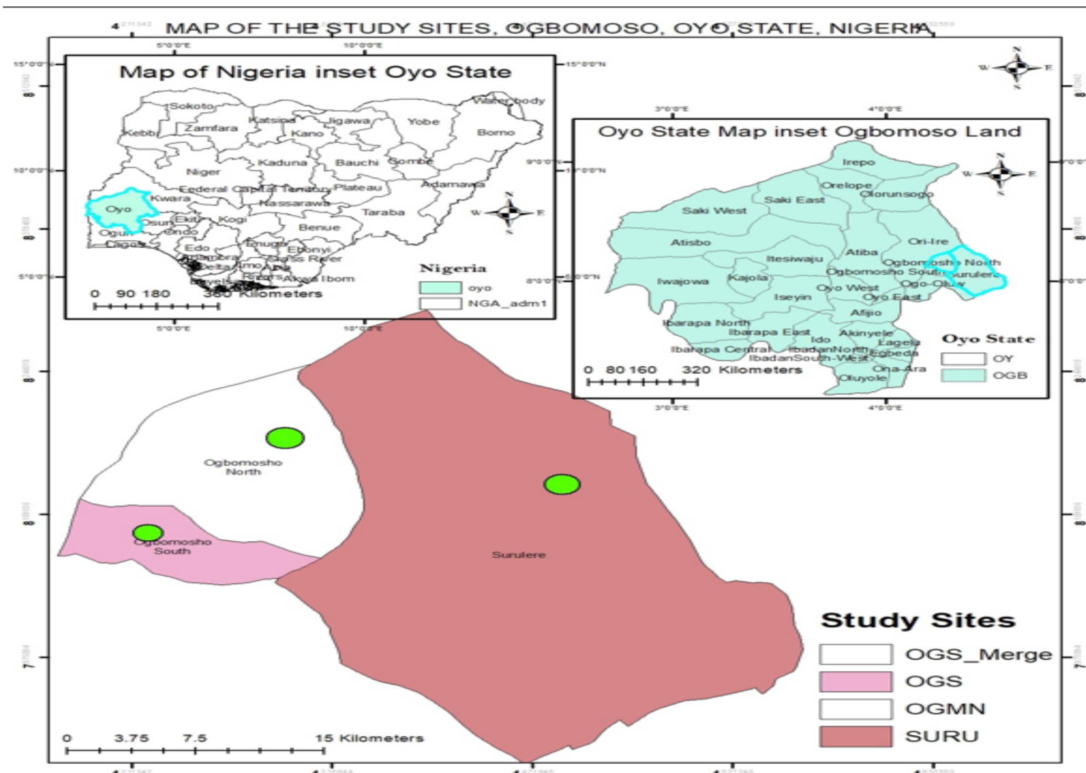

Fig 1: Map of the study

Table 1: Morphological and physical properties of some selected soils in the study area

Horizon	Depth	Colour	Texture	Drainage	%Sand	%Silt	%Clay	BD (g cm^{-3})	Porosity%	Saturation
	Iwofin profile									
AP	0-50	5YR 7/3	LS	WD	84.28	1.58	14.14	1.54	41.88	0.42
AB	51-70	10YR 6/2	SL	PD	74.34	9.4	16.26	1.50	43.39	0.43
B	71-90	10YR 7/2	SL	PD	77.74	5.94	16.32	1.51	43.02	0.43
BC	91-147	10YR 8/1	SL	PD	73.26	8	18.74	1.48	44.15	0.44
Min					73.26	1.58	14.14	1.48	41.88	0.42
Max					84.28	9.4	18.74	1.54	44.15	0.44
Mean					77.86	5.98	16.39	1.51	43.08	0.43
	Osuru profile									
AP	0-5	5YR 4/6	SCL	PD	55.26	20	24.74	1.41	46.79	0.47
AB	6 -19	10YR 10/8	SL	PD	75.5	7.64	16.86	1.50	43.4	0.43
B	20-42	10YR 6/4	SL	PD	77.68	5.34	16.98	1.50	43.4	0.43
BC	42-76	10YR 10/8	SL	PD	75.74	7.1	17.16	1.50	43.4	0.43
Min					55.26	5.34	16.86	1.41	43.4	0.43
Max					77.68	20	24.74	1.50	46.79	0.47
Mean					69.52	10.9	19.56	1.47	44.53	0.44
Debjik profile										
AP	0-20	5YR 4/3	SL	PD	73.38	9.28	17.34	1.49	43.77	0.44
AB	21-39	5YR 7/2	SL	PD	75.26	5.34	19.4	1.48	44.15	0.44
B	40-83	5YR 4/4	SL	PD	74.62	8.16	17.22	1.50	43.4	0.44
Min					73.38	5.34	17.22	1.48	43.4	0.44
Max					75.26	9.28	19.4	1.50	44.15	0.44
Mean					74.38	7.48	18.12	1.49	43.77	0.44

Source: - Field work 2022.

Therefore, addressing this knowledge gap is crucial for evidence-based soil management and policy formulation. Pedon-level classification and fertility assessment of these valley-bottom soils will enhance the understanding of their potential for sustainable cropping, guide soil fertility management strategies such as integrated soil fertility management (ISFM) and conservation agriculture (CA), and contribute to land degradation neutrality (LDN) monitoring frameworks within Oyo State. This study aimed to describe, classify, and evaluate the fertility status of representative valley-bottom soils in the Ogbomoso area of Oyo State, to determine their suitability for sustainable agricultural use and their contribution to Land Degradation Neutrality planning. Specifically, the objectives of this study are to describe the morphological characteristics of selected valley-bottom soil pedons, classify the soils using FAO-WRB criteria, determine selected physical and chemical fertility indicators across horizons and locations, and evaluate management implications for sustainable cropping systems and LDN monitoring in Oyo State, southwestern Nigeria.

2. Materials and methods

The study was conducted at 3 different valley bottom locations, namely: Iwofin (Surulere LGA, Ogbomoso), Osuru (Ogbomoso South) and Debjik farm (Ogbomoso North) in Ogbomoso. Their locations were recorded as latitude 8 ˚ 9 ΄N and longitude 4 ˚ 25΄ 7 ¨E, 8 ˚ 6΄ 9 ¨N and 4º 13΄ 25 ¨E, and latitude 8˚ 11΄ 37 ¨N and 4˚ 18΄ 12 ¨E, respectively, in Oyo state (Figure 1). The Climate is equatorial, with dry and wet seasons, and relatively high humidity. The state lies within the derived savanna agroecological zone, characterised by a bimodal rainfall pattern, moderate to high annual precipitation, and increasing land-use pressure around peri-urban centres such as Ogbomoso. The mean average temperature is 28°C, while the mean annual rainfall is about 1200 mm, with an average range of 786.2 to 1513 mm. The dry season starts in November and terminates in February, with associated harmattan (Ogban & Babalola, 2009).

Nine soil profile pits (three per site: Iwofin, Osuru, Debjik) were dug to approximately 1.5 m (1.5 × 1.5 × 1.5 m) and described in situ following FAO (2006) guidelines. Horizon depths were recorded, and a representative sample was collected from each identifiable horizon. Samples were air-dried, sieved (<2 mm) and analysed in duplicate. Laboratory analyses: particle size by Bouyoucos hydrometer (texture reported as % sand, silt, clay) as described by Huluka & Miller, 2014; bulk density via core method (g cm^{-3}), as described by Al-Shammary et al. (2018); pH (1:2.5 soil: water and 1 M KCl); organic carbon by Walkley–Black (report in g kg^{-1}); total N by Kjeldahl (g kg^{-1}); available P by Bray-1 (mg kg^{-1}); exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) by NH_4OAc (pH 7.0) and expressed as $cmolkg^{-1}$; exchangeable Al by 1M KCl; CEC by summation method ($cmolkg^{-1}$). All methods were run against standard laboratory blanks and certified reference material; analytical replicates (n=2) were used, and mean ± SD reported.

2.1. Statistical analyses

The parameters described on the site were coded for statistical analyses, and the set of data from the laboratory was also analysed statistically. The mean ($\bar{X}$). Standard deviation (S.D.) and Coefficient of variation (CV%) were calculated. Tests for normality (Shapiro–Wilk), two-way ANOVA (Site × Horizon) with Tukey HSD post-hoc (α=0.05), Pearson correlation, and Principal Component Analyses were also performed..

Table 2: Chemical properties of the soils across the study area

Horizon	Depth (Cm)	pH	OC (g/kg)	TN (g/kg)	Avail P (mg kg^{-1})	Ca →	Mg	K (cmolkg⁻¹)	Na →	CEC
	Iwofin profile									
Ap1	0-50	5.75	0.83	0.09	11.4	1.36	0.3	0.05	0.17	2.06
AB	51-70	5.91	1.47	0.16	13.88	2.56	0.56	0.06	0.31	3.03
B	71-90	5.49	0.7	0.08	11.84	1.13	0.26	0.05	0.18	2.05
BC	91-147	5.49	0.93	0.1	10.6	1.8	0.42	0.1	0.2	2.84
Mean		5.67	1.02	0.11	11.93	1.76	0.39	0.07	0.22	2.51
Stdev		0.17	0.29	0.03	1.21	0.54	0.11	0.02	0.05	0.44
CV(%)		3.16	28.77	28.31	10.14	31.00	29.99	29.62	25.43	17.73
	Osuru profile									
Ap1	0-5	6.07	3.32	0.37	10.6	5.81	0.41	0.09	0.29	5.91
AB	6 -19	6.1	1.28	0.14	10	2.5	0.38	0.05	0.27	3.13
B	20-42	0	0.89	0.1	9.48	2.97	0.41	0.06	0.31	3.84
BC	42-76	6.2	1.38	0.15	9.68	2.58	0.38	0.05	0.28	3.1
Mean		4.1	1.85	0.2	9.97	3.7	0.4	0.07	0.29	4.17
Stdev		2.66	0.95	0.11	0.42	1.37	0.02	0.02	0.01	1.15
CV(%)		64.90	51.08	52.84	4.25	37.01	3.79	23.90	5.11	27.51
	Debjik profile									
Ap1	0-20	5.86	1.66	0.18	10.48	3.38	0.71	0.05	0.27	3.82
AB	21-39	5.91	0.77	0.08	9.96	2.76	0.65	0.05	0.26	3.91
B	40-83	5.83	0.38	0.04	9.04	1.8	0.48	0.04	0.19	2.75
Mean		5.87	0.97	0.12	9.8	2.62	0.61	0.05	0.24	3.43
Sdev		0.03	0.54	0.06	0.60	0.65	0.10	0.01	0.04	0.53
CV(%)		0.56	55.25	49.77	6.08	24.81	15.97	10.00	14.83	15.39

Source: - Field work 2022.

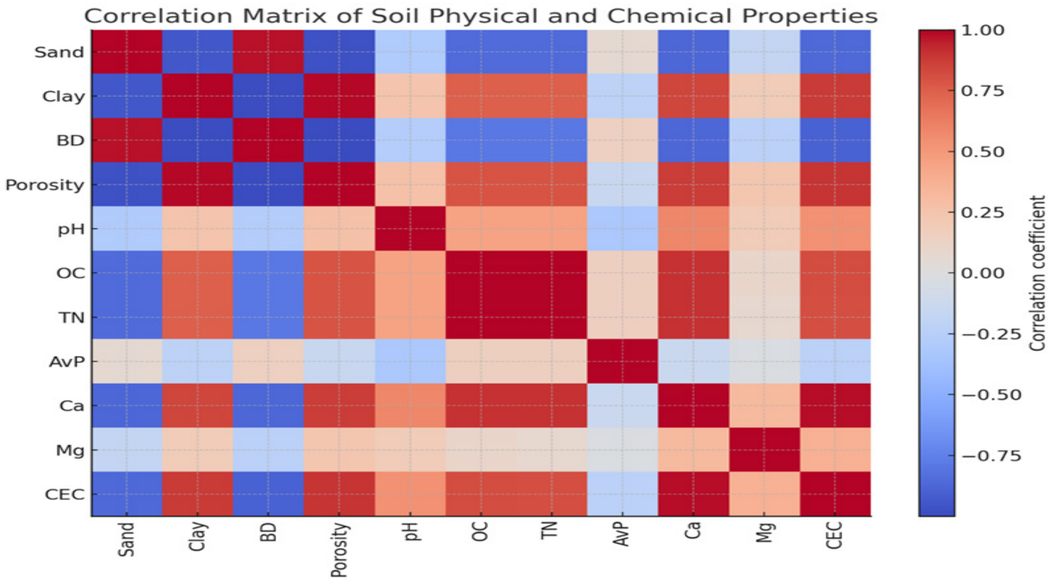

Fig. 2. Correlation matrix of soil physical and chemical properties

The heatmap shows strong positive associations between OC–TN (r ≈ 0.93), OC–CEC (r ≈ 0.81), and Clay–CEC (r ≈ 0.67), while Sand and BD exhibit negative correlations with most fertility-related variables (particularly OC and CEC).

3. Results

3.1. Morphology and physical properties of the valley-bottom soils

The morphological description of the studied valley-bottom pedons revealed distinct yet interrelated features influenced by drainage and depositional environment (Table 1). Surface horizons (Ap) across the three sites exhibited brown to yellowish-brown colours (5YR 4/3–7/3), whereas subsurface horizons were generally light yellowish or greyish brown (10YR 6/2–10YR 8/1), reflecting eluviation of organic materials and the influence of seasonal waterlogging. Drainage conditions varied from well-drained (WD) in the surface horizon of Iwofin to poorly drained (PD) in subsurface horizons of all sites, confirming intermittent hydromorphism typical of valley-bottom soils. The particle-size distribution showed dominance of sand fractions, ranging from 55.26 % to 84.28 % across horizons and sites. Mean sand contents were highest in Iwofin (77.86 %), followed by Debjik (74.38 %) and Osuru (69.52 %). Clay fractions varied between 14.14 % and 24.74 %, with a general increase with depth, indicating translocation of fine particles and moderate profile development. Silt content was comparatively low (1.58 – 20.0 %) across profiles.

Bulk density (BD) values ranged narrowly between 1.41 and 1.54 g cm^{-3}, averaging 1.49–1.51 g cm^{-3} across sites. Corresponding porosity values varied from 41.9 % to 46.8 %, implying adequate aeration and moderate compaction status. Saturation values (0.42–0.47) were highest in the surface horizons of Osuru (Ap: 0.47) and lowest in Iwofin (Ap: 0.42). Texturally, Iwofin pedons were loamy sand to sandy loam, Osuru ranged from sandy clay loam to sandy loam, while Debjik pedons were sandy loam throughout. The soils generally showed

Table 3: Profile characterisation across the study area

S/N	Location	Profile characteristics and classification
1	Iwofin	Deep, sandy loam, slightly acidic to neutral, Udic thermic, Ochpipedon, Oxic horizon, Alfisols, usdalf, plinthustalfs, typic plinthustalfs
2	Osuru	Shallow, loamy sand, slightly acidic, suborder aquerts, Great group, AridicEpiaquerts, Aendoaquerts.
3	Debjik	Shallow, loamy sand, slightly acidic, suborder aquerts, Great group, AridicEpiaquerts, Aendoaquerts.

Table 4: Summary of physical fertility indicators

Site	Mean Sand (%)	Mean Clay (%)	Mean BD (g cm⁻³)	Porosity (%)	Textural Class	Drainage Class
Iwofin	77.9	16.4	1.51	43.1	Loamy Sand–Sandy Loam	Well → Poorly Drained
Osuru	69.5	19.6	1.47	44.5	Sandy Clay Loam–Sandy Loam	Poorly Drained
Debjik	74.4	18.1	1.49	43.8	Sandy Loam	Poorly Drained

Table 5. Principal component loadings and variance explained

Variable	PC1	PC2	PC3
Sand	-0.35	-0.12	0.16
Clay	0.34	0.01	-0.32
BD	-0.35	-0.04	0.24
Porosity	0.35	0.04	-0.24
pH	0.17	-0.46	0.54
OC	0.33	0.22	0.23
TN	0.33	0.23	0.22
Avail P	-0.04	0.73	0.44
Ca	0.36	-0.08	0.17
Mg	0.10	-0.31	0.37
CEC	0.35	-0.16	0.05

moderate development with distinct horizonation and evidence of hydromorphic influence.

3.2. Chemical properties of the valley-bottom soils

The soils were generally slightly acidic to near-neutral, with pH values ranging from 5.49 to 6.20 (Table 2). Mean pH was lowest in Iwofin (5.67) and highest in Osuru (6.07), indicating weak acidity consistent with basement-complex parent materials and moderate leaching. Organic-carbon (OC) contents were low across all sites, averaging 1.02 g kg^{-1} (Iwofin), 1.85 g kg^{-1} (Osuru), and 0.97 g kg^{-1} (Debjik). Corresponding total-nitrogen (TN) values were similarly low (0.11 – 0.20 g kg^{-1}), yielding narrow C: N ratios typical of tropical mineral soils with rapid organic-matter turnover. The highest OC and TN concentrations occurred in Osuru's surface horizon (3.32 g kg^{-1} and 0.37 g kg^{-1}), declining sharply with depth. Available-phosphorus (P) contents ranged from 9.04 to 13.88 mg kg^{-1}, with means of 11.93 mg kg^{-1} (Iwofin), 9.97 mg kg^{-1} (Osuru), and 9.80 mg kg^{-1} (Debjik)—levels considered low to moderate for most arable crops.

Exchangeable-base cations showed clear dominance of Ca > Mg > Na > K across profiles. Calcium values averaged 1.76–3.70 $cmol_+$ kg^{-1}, while magnesium ranged 0.39–0.61 $cmol_+$ kg^{-1}. Potassium and sodium were generally ≤ 0.07 $cmol_+$ kg^{-1} and ≤ 0.29 $cmol_+$ kg^{-1}, respectively. Cation-exchange capacity (CEC) was low to moderate, averaging 2.51 $cmol_+$ kg^{-1} (Iwofin), 4.17 $cmol_+$ kg^{-1} (Osuru), and 3.43 $cmol_+$ kg^{-1} (Debjik). Coefficients of variation for OC and TN (28–55 %) were higher than for pH and CEC, suggesting greater spatial variability in organic-matter distribution.

3.3. Soil profile characterisation and physical-fertility indicators

Tables 3 and 4 provide the synthesis and classification backbone for the pedological interpretation, integrating the morphological, physical, and chemical data into a coherent taxonomic and management framework.

3.3.1. Profile characterisation

Profile descriptions (Table 3) revealed that the valley-bottom soils of Iwofin, Osuru, and Debjik differ in depth, drainage, and degree of development. Iwofin soils were deep (147 cm), sandy loam, and slightly acidic to neutral, with a diagnostic ochric epipedon over an oxic horizon. The pedon exhibited moderate horizon differentiation and was classified as Typic Plinthustalfs (Alfisols, Udic thermic) based on its clay illuviation, presence of plinthite, and moderately developed structure. Osuru and Debjik's profiles were shallow (76 cm and 86 cm, respectively), loamy sand, slightly acidic, and showed periodic water saturation. Both exhibited hydromorphic features (mottling, gleying, and poor drainage) and were classified within the Aquerts suborder, specifically Aridic Epiaquerts or Aendoaquerts, indicating Vertisol-

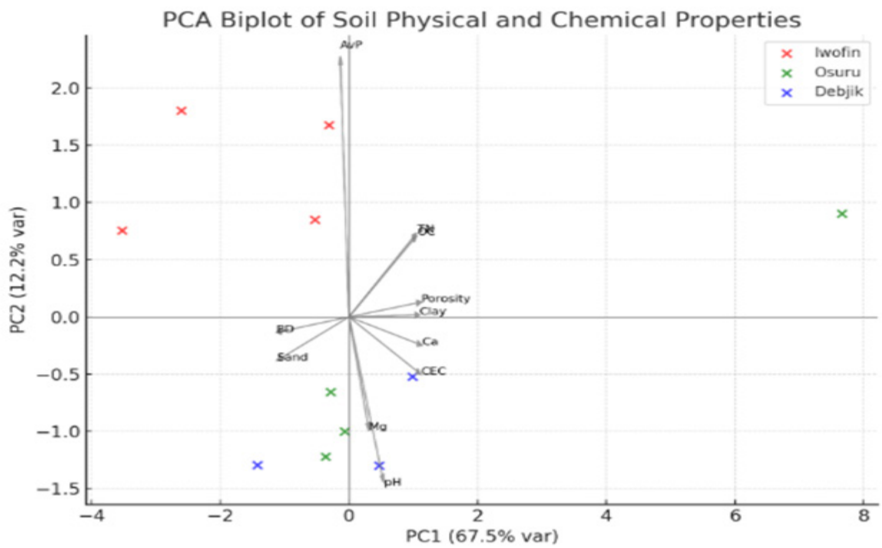

Fig. 2: **PCA biplot (PC1 vs. PC2)** showing the relationships among soil physical and chemical properties

like wetness regimes with seasonal cracking and shrink–swell tendencies. These taxonomic differences reflect variations in parent material, drainage status, and depositional history across the study area.

3.3.2. Physical fertility indicators

Mean values of the key physical indicators across sites are summarised in Table 4. Sand content dominated all soils (69.5 – 77.9 %), while clay content ranged from 16.4 % to 19.6 %. Mean bulk density values (1.47 – 1.51 g cm^{-3}) and corresponding porosities (43 – 45 %) indicate non-compacted, moderately porous profiles favourable for root growth and aeration. Texturally, Iwofin soils were loamy sand to sandy loam with well to moderately drained conditions, while Osuru and Debjik soils were sandy loam to sandy clay loam but poorly drained due to hydromorphic influence. These data confirm that all three valley-bottom soils are moderately coarse-textured, with slight structural differences controlled primarily by drainage and organic-matter dynamics.

3.4. Correlation and principal component analysis (PCA)

3.4.1. Correlation analysis of soil properties

Correlation analysis (Figure 2) revealed significant positive relationships among key fertility parameters across the three sites. Organic carbon (OC) correlated strongly with total nitrogen (TN) ($r = 0.93$, $p < 0.01$) and cation-exchange capacity (CEC) ($r = 0.81$, $p < 0.05$), indicating that organic matter is a major contributor to nutrient-holding capacity and nitrogen supply in these valley-bottom soils. Similarly, clay content showed a moderate positive correlation with CEC ($r = 0.67$) and exchangeable Ca ($r = 0.59$), suggesting that finer-textured soils retain more bases and exchange sites. Negative correlations were observed between sand content and most fertility parameters, particularly OC ($r = –0.79$) and CEC ($r = –0.70$), confirming that coarser-textured soils, such as those at Iwofin, are more prone to nutrient leaching and exhibit lower fertility retention. pH displayed weak-to-moderate positive correlations with exchangeable bases (Ca and Mg), implying that base saturation contributes to the near-neutral reaction observed in Osuru and Debjik profiles.

3.4.2. Principal component analysis (PCA)

Principal component analysis extracted three major components with eigenvalues > 1, cumulatively explaining approximately 88.75 % of the total variance among the measured soil attributes (Table 6). Principal Component 1 (PC1) explained 67.49 % of the total variance and loaded heavily on organic carbon, total nitrogen, available phosphorus, and CEC (Table 5). This component represents the organic-matter fertility axis, which captures nutrient reserves and retention capacity across sites. Principal Component 2 (PC2) accounted for 12.18 % of the variance, dominated by clay, bulk density, and porosity, representing the physical-structural quality axis that controls aeration, infiltration, and water-holding potential (Table 5). Principal Component 3 (PC3) contributed 9.08 % of the variance, driven mainly by exchangeable Ca and Mg, constituting the base-nutrient status axis (Table 5).

Table 6. PCA eigenvalues and variance explained

Principal component	% Variance explained
PC1	67.49
PC2	12.18
PC3	9.08

Cumulative variance explained: 88.75 %

Biplot projection (Figure 3) showed that soils from Osuru clustered around high OC, TN, and CEC loadings (PC1-positive region), reflecting improved organic status and higher fertility potential. Iwofin soils group on the negative PC1 side, associated with higher sand and bulk density but lower nutrient-retention parameters, reflecting coarse texture and poorer fertility, while Debjik soils occupy an intermediate position, showing moderate fertility and clay content. In all, the arrows represent the loadings of each variable: longer arrows (e.g., OC, TN, Ca, CEC) indicate a strong influence on soil fertility variation across sites. This visualisation supports the quantitative PCA Tables 5 and 6, reinforcing that organic matter content, nutrient bases, and CEC are the key drivers of fertility differentiation among valley-bottom soils in the study area.

4. Discussion

4.1. Morphological and physical characteristics

The observed colour variations from brown surface horizons to lighter or greyish subsoils reflect progressive oxidation–reduction dynamics associated with fluctuating water tables common in hydromorphic environments (Dickson et al*.,* 2020; Ojobor & Aimufia, 2022). Poor drainage in the lower horizons signifies restricted permeability, possibly due to finer-textured or compacted layers that retain water after heavy rainfall or flooding. The dominance of sandy textures (55 – 84 %) indicates derivation from coarse alluvial or colluvial deposits overlying basement complex materials. The relatively finer textures in Osuru suggest accumulation of transported silts and clays in less-drained micro-depressions. Such heterogeneity typifies valley-bottom soils of the Guinea savanna and reflects the combined effects of sediment sorting and periodic deposition (Nweke et al., 2025; Akhtaruzzaman et al., 2014).

Clay enrichment with depth (from ~14 % to ~24 %) across the profiles implies moderate illuviation, signifying weak pedogenic horizon differentiation. This pattern supports the classification of the soils as moderately developed Inceptisols or Entisols, consistent with hydromorphic landscapes where periodic saturation limits profile evolution (FAO, 2006). The recorded bulk density values (1.41–1.54 g cm^{-3}) fall within the critical range that permits adequate root growth and gas exchange as reported by (Francaviglia *et al.,* 2023). The lowest BD observed in Osuru (1.41 g cm^{-3}) corresponds with higher silt and clay contents, suggesting improved structural aggregation and organic-matter contribution. The porosity (42 – 47 %) complements these values, confirming moderately loose soil structure favourable for both aeration and moisture retention.

Across sites, Iwofin showed the coarsest texture and highest BD, implying greater drainage but lower nutrient- and water-holding capacity. Osuru displayed the most balanced physical attributes, with higher clay and porosity conducive to moisture retention, while Debjik represented a texturally stable but hydromorphic valley-floor environment with uniform sandy loam horizons. These findings collectively highlight that texture, organic matter, and drainage regime are the dominant factors controlling the physical quality of the studied soils. Their sandy nature enhances infiltration but increases vulnerability to leaching and structural instability. Management should therefore prioritise organic-matter enrichment, residue retention, and controlled tillage to improve aggregate stability and water-use efficiency (Stewart et al., 2020; Francaviglia et al., 2023). Moreover, given their moderate porosity and hydromorphic features, these valley-bottom soils have strong potential for dry-season vegetable and rice production if managed under Integrated Soil Fertility Management (ISFM) and appropriate drainage infrastructure. Such targeted interventions align with Nigeria's Land Degradation Neutrality (LDN) strategy and the broader SDG 15 goal of sustainable land use (FAO, 2022; UNCCD, 2020).

4.2. Chemical characteristics and fertility implications

The slightly acidic reaction (pH 5.5 – 6.2) observed across the sites reflects leaching of basic cations under high rainfall and low base saturation typical of hydromorphic soils in the southern Guinea savanna (Oku et al., 2020). Such pH conditions are still favourable for most tropical crops and nutrient availability, except phosphorus, which can become moderately fixed by Fe and Al oxides (Stewart et al., 2020). Low organic-carbon and nitrogen contents confirm the soils' weak fertility status and limited capacity for nutrient retention. Rapid organic-matter mineralisation under alternating wet–dry cycles and sparse residue return are key drivers of this depletion (Ojobor and Aimufia, 2022). The higher OC and TN values in Osuru's surface horizon suggest localised organic-matter accumulation where drainage is slower and biomass decomposition less intense. Similar patterns have been reported for fadama soils of Bayelsa State (Dickson et al., 2020).

Available phosphorus levels (≈ 9 – 13 mg kg^{-1}) fall below the agronomic optimum (> 15 mg kg^{-1}) for maize and most vegetables (FAO, 2022). Moderate P availability may be due to downward mobility under periodic flooding and strong sorption to Fe–Al oxides in slightly acidic environments. Hence, P fertilisation using soluble or organo-mineral sources is essential to sustain crop productivity. The dominance of Ca and Mg among exchangeable cations indicates moderate base status but generally low nutrient reserves. The very low K levels (< 0.1 $cmol_+ kg^{-1}$) highlight the need for K supplementation, as coarse-textured valley soils often experience rapid K leaching.

The CEC values (2–5 $cmol_+ kg^{-1}$) classify the soils as low-activity clays, implying limited buffering against acidification and nutrient loss (Lufega & Msanya, 2017). CEC correlated positively with OC and clay content (observed trend), underscoring the central role of organic-matter restoration in improving fertility. From a management standpoint, these results show that the valley-bottom soils possess moderate productivity potential but are constrained by low OC, TN, and CEC. Sustainable intensification should therefore emphasise Integrated Soil Fertility Management (ISFM), combining organic amendments (manure, compost, cover crops) with judicious mineral fertilisers and conservation-agriculture practices to rebuild organic pools, enhance nutrient cycling, and mitigate leaching losses (Stewart et al., 2020; Francaviglia et al., 2023). Improved nutrient management, coupled with controlled drainage, will enhance both agronomic performance and ecological resilience, supporting Nigeria's Land Degradation Neutrality (LDN) and SDG 15 targets (UNCCD, 2020; FAO, 2022).

4.3. Soil classification and physical-fertility interpretation

4.3.1. Taxonomic differentiation and landscape control

The classification results show a clear landscape–drainage relationship among the soils. The Iwofin profile (Typic Plinthustalfs) represents a relatively well-drained upland–valley transition where periodic wetness induces plinthite formation but does not dominate the pedogenic process. Its Udic moisture regime and oxic horizon indicate adequate aeration and moderate weathering intensity (FAO 2022; USDA 2022). In contrast, the Osuru and Debjik profiles (Aridic Epiaquerts/Aendoaquerts) are poorly drained valley-floor soils, where prolonged saturation promotes gleying and limited horizon differentiation. Their vertic characteristics, shrink–swell clays and seasonal cracking, align with the hydromorphic nature typical of inland-valley soils in humid and sub-humid zones of Nigeria (Oku et al., 2010; Lufega & Msanya, 2017). These taxonomic contrasts demonstrate how micro-topography and drainage gradients control soil formation and classification within short landscape distances, a hallmark of Guinea-savanna valley systems (Nweke et al., 2025).

4.3.2. Physical fertility implications

From a soil-quality standpoint, all pedons exhibited favourable bulk density (≤ 1.55 g cm^{-3}) and porosity greater than 40 %, signifying acceptable structural status and sufficient aeration for most arable crops. However, their coarse textures imply low water- and nutrient-holding capacity, particularly in Iwofin, where leaching risk is highest. The relatively finer textures in Osuru and Debjik improve moisture retention but, due to poor drainage, increase susceptibility to transient waterlogging and anaerobic stress (Francaviglia et al., 2023). Overall, the soils possess moderate to low inherent fertility and require management interventions such as organic-matter enrichment (compost, manure, cover crops) to enhance aggregation, CEC, and moisture storage; controlled drainage and raised-bed cultivation in poorly drained sites to mitigate waterlogging; and conservation-agriculture practices (reduced tillage, residue retention) to stabilise soil structure and minimise erosion. These measures are consistent with Integrated Soil Fertility Management (ISFM) and contribute to Nigeria's Land Degradation Neutrality (LDN) objectives and SDG 15 targets (UNCCD 2020; FAO 2022).

4.3.3. Synthesis

The integration of classification and physical-fertility results reveals a transition from moderately developed Alfisols in Iwofin to Osuru and Debjik. Such diversity within short spatial scales highlights the pedo-hydrological complexity of valley-bottom landscapes in southwestern Nigeria (Furlan et al., 2021). Although Furlan et al. (2021) work was done in Brazil, but it reflected similar happenings in the tropical regions; as such, this heterogeneity underscores the necessity of site-specific management planning and zonal fertility mapping for sustainable agricultural intensification.

4.4. Integrated soil-fertility interpretation and management zonation

The strong correlation between OC, TN, and CEC underscores the central role of organic matter as a fertility driver in valley-bottom soils. Low OC and TN levels in Iwofin confirm its sandy nature and rapid mineralisation losses, while the relatively higher values in Osuru correspond to finer texture and slower decomposition. Similar trends have been reported by Oku et al. (2010) and Ojobor (2022), who observed that soil fertility gradients in fadama ecosystems are primarily governed by organic matter accumulation and drainage status. The PCA results further differentiate the soils into three fertility management zones. These fertility zones reflect an ecological continuum driven by microtopographic control of drainage and sediment deposition. The physical and chemical relationships identified (e.g., OC ↔ CEC, Clay ↔ CEC) reinforce the need for integrated soil fertility management (ISFM) combining organic and mineral inputs to enhance nutrient retention, structure, and resilience (Stewart et al., 2020; Francaviglia et al., 2023). The following are distint features and suggested management for each zone: Zone I (Iwofin) – Coarse-textured, low organic matter, low CEC, and high sand fraction; requires organic-matter enrichment and controlled fertiliser application to prevent nutrient loss, Zone II (Osuru) – Moderately fine texture, high OC, TN, and CEC; suitable for intensified cropping under conservation-agriculture practices, with emphasis on residue retention, and Zone III (Debjik) – Intermediate texture and fertility, but constrained by periodic wetness; requires drainage improvement and balanced nutrient input to optimise productivity. These strategies, rooted in data-driven soil evaluation, will sustain productivity in the Ogbomoso valley-bottom ecosystems and contribute to climate-resilient agriculture in southwestern Nigeria.

4.5. Land degradation neutrality interpretation and indicator linkage

Land Degradation Neutrality, as defined by the United Nations Convention to Combat Desertification, is operationalised using three core global indicators: land cover change, land productivity dynamics, and soil organic carbon stocks (UNCCD, 2020; FAO, 2022). While this study did not directly assess land cover transitions, the measured physical and chemical properties provide baseline evidence relevant to the soil organic carbon and productivity indicators within the LDN monitoring framework. Soil organic carbon is the principal soil-based indicator under LDN because it integrates biological activity, structural stability, nutrient cycling, and long-term carbon sequestration potential (FAO, 2017; UNCCD, 2020). The low OC values recorded across Iwofin and Debjik indicate reduced soil carbon stocks and limited buffering capacity against nutrient depletion. In coarse-textured systems such as Iwofin, low OC combined with low CEC increases vulnerability to rapid mineralisation, nutrient leaching, and declining aggregate stability (Stewart et al., 2020; Francaviglia et al., 2023). Sustained cultivation without organic matter replenishment in such soils may result in negative productivity trends, directly affecting the land productivity dimension of LDN.

Hydromorphic conditions observed in Osuru and Debjik influence both carbon dynamics and productivity stability. Periodic saturation modifies redox conditions, affecting nutrient availability and root growth (Dickson et al., 2020). Although valley-bottom soils can support high biomass production under irrigated systems, prolonged anaerobic conditions may reduce nutrient-use efficiency and yield stability, thereby influencing land productivity trajectories (UNCCD, 2020). Controlled drainage is therefore essential to stabilise productivity and maintain neutrality status. Bulk density and porosity values across all pedons currently fall within acceptable ranges for root proliferation and aeration. However, sandy texture combined with low organic matter in Iwofin suggests susceptibility to erosion and structural decline under continuous tillage (Francaviglia et al., 2023). Physical degradation processes reduce effective rooting depth and diminish soil carbon protection mechanisms, potentially lowering soil carbon stocks over time, a key parameter monitored under LDN (FAO, 2017; UNCCD, 2020).

The PCA-derived fertility zonation offers a spatially explicit framework for LDN implementation in Oyo State. Zone I, characterised by coarse texture, low OC, and low CEC, represents a high-risk carbon-depletion zone requiring prioritised organic matter restoration and conservation agriculture. Zone II, with relatively higher OC and CEC, represents a maintenance zone where residue retention and balanced fertilisation can sustain soil functional capacity. Zone III, constrained primarily by hydromorphic conditions, requires drainage optimisation to prevent secondary degradation and productivity fluctuation. By translating pedon-level soil classification and fertility indicators into vulnerability and restoration priority classes, this study provides baseline data to support sub-national LDN monitoring in southwestern Nigeria. Integrating organic matter restoration, controlled drainage, and integrated soil fertility management can enhance soil carbon stocks, stabilise productivity, and maintain ecosystem functions, thereby contributing to Nigeria's commitments under SDG 15 and the UNCCD LDN framework (UNCCD, 2020; FAO, 2022).

5. Conclusion and recommendations

This study established baseline information on the morphology, physical, and chemical characteristics of valley-bottom soils in the Ogbomoso area of southwestern Nigeria. The soils were predominantly sandy to loamy sand, slightly acidic (pH 5.5–6.2), and low in organic carbon, total nitrogen, and cation exchange capacity, indicating weak inherent fertility. Bulk density and porosity values suggest good aeration but limited nutrient retention. Soil classification identified Iwofin as Typic Plinthustalfs (moderately drained), while Osuru and Debjik were hydromorphic Aquerts (poorly drained). Principal component analysis showed that organic carbon, clay, and available phosphorus accounted for over 80% of fertility variation, making them key soil-quality drivers. To enhance productivity and sustain ecosystem functions, integrated soil fertility management combining organic and mineral nutrient sources is recommended alongside improved drainage, residue retention, and conservation-agriculture practices. Fertility zoning based on the observed variations will support site-specific management and land-use planning. These interventions, if implemented, will promote sustainable intensification and align valley-bottom soil management with Nigeria's Land Degradation Neutrality and SDG 15 objectives.

References

Akhtaruzzaman, M., Haque, M. E., & Osman, K. T. (2014). Morphological, physical and chemical characteristics of hill forest soils at Chittagong University, Bangladesh. *Open Journal of Soil Science*, 4(01), 26. doi:10.4236/ojss. 2014.41004

Al-Shammary, A. A. G., Kouzani, A. Z., Kaynak, A., Khoo, S. Y., Norton, M., & Gates, W. (2018). Soil bulk density estimation methods: A review. *Pedosphere*, *28*(4), 581-596.

Blake, G. R., & Hartge, K. H. (1986). *Bulk density and porosity.* In A. Klute (Ed.), *Methods of Soil Analysis* (pp. 363–375). ASA, Madison.

Dickson, A. A., Tate, J. O., Ogboin, P. T., Payebo, C. O., & Agbai, W. P. (2020). Spatial variability of selected soil properties of the lower Niger River floodplains in Bayelsa state, Nigeria. *Science*, *4*(3), 14-27.

FAO (2022). *Guidelines for Soil Description* (6th ed.). Rome.

Fawole, O. A., Ojetade, J. O., Muda, S. A., & Amusan, A. A. (2016). Genesis and classification of soils on a toposequence underlain by mica schist in Ife area, southwestern Nigeria. *Global Journal of Science Frontier Research: D Agriculture and Veterinary*, *16*(7), 31-42.

Food and Agriculture Organisation (FAO) (2006). Guidelines for Soil Description.Fourth edition. Food and Agriculture Organisation of the United Nations, pp. 1-85

Francaviglia, R., Almagro, M., & Vicente-Vicente, J. L. (2023). Conservation agriculture and soil organic carbon: Principles, processes, practices and policy options. *Soil Systems*, *7*(1), 17.

Furlan, L. M., Rosolen, V., Moreira, C. A., Bueno, G. T., & Ferreira, M. E. (2021). The interactive pedological-hydrological processes and environmental sensitivity of a tropical isolated wetland in the Brazilian Cerrado. *SN Applied Sciences*, *3*(2), 144.

Hannam, I. (2022). Soil governance and land degradation neutrality. *Soil Security*, *6*, 100030.

Huluka, G., & Miller, R. (2014). Particle size determination by the hydrometer method. *Southern Cooperative Series Bulletin*, *419*, 180-184.

Kavianpoor, H. A. Esmali Ouri1, Z. Jafarian Jeloudar, and A. Kavian (2012). American Journal of Environmental Engineering 2(1): 34-44 DOI: 10.5923/j.ajee.20120201.06

Lufega, S. M., & Msanya, B. M. (2017). Pedological characterisation and soil classification of selected soil units of Morogoro District, Tanzania. *International Journal of Plant & Soil Science* 16(1): 1-12, 2017; Article no.IJPSS.32681 ISSN: 2320-7035.

Nweke IA, Uwoma CC, Nwankwo JE. (2025). Distribution of soil quality indicators in Fadama soils of Anambra State, Southeast, Nigeria. *Discovery*; 61, e13d3101 (2025) 1 - 19 doi: https://doi.org/10.54905/disssi.v61i337.e13d3101 pISSN 2278–5469; eISSN 2278–5450

Ogban, P. I., & Babalola, O. (2009). Characteristics, classification and management of inland valley bottom soils for crop production in subhumid southwestern Nigeria. *Agro-Science*, *8*(1).

Ogban, P. I., & Obi, J. C. (2014). Micro aggregate stability in seasonally wet soils on contrasting parent materials in southern Nigeria. *Journal of Applied Agricultural Research*, *6*(1), 225-235.

Ogunkunle A.O. (2005). Soil Survey and Sustainable Land Management. Invited paper at the 29th annual conf. of

SSSN held at the University of Nigeria, Abeokuta, from 6th to 10th Dec. 2004

Ojobor, S. A. (2022). *Fertility status of fadama soils in Asaba, Delta State, Nigeria. Nigerian Agricultural Journal*, 53(1), 25–36.

Ojobor, S. A., & Aimufia, P. N. (2022). Fertility status of fadama soils in Asaba, Delta State, Nigeria. *Nigerian Journal of Soil Science (NJSS)* 32 (1) 2022 72–76. https://www.soilsjournalnigeria.com

Oku, E., Essoka, A., & Thomas, E. (2010). Variability in soil properties along an Udalf toposequence in the humid forest zone of Nigeria. *Agriculture and Natural Resources*, *44*(4), 564-573.

Serrano, J., Shahidian, S., & Silva, J. M. D. (2014). Spatial and temporal patterns of apparent electrical conductivity: DUALEM vs. Veris sensors for monitoring soil properties. *Sensors*, *14*(6), 10024-10041.

Sivarajan, S.; M.Nagarajan and R.Sivasamy,2013.Spatial Variability analysis of Soil Properties using raster-based GIS Techniques, Asian Journal of Applied Science 6(2):68- 78

Stewart, Z. P., Pierzynski, G. M., Middendorf, B. J., & Prasad, P. V. (2020). Approaches to improve soil fertility in sub-Saharan Africa. *Journal of Experimental Botany*, *71*(2), 632-641.

UNCCD (2020). *Global Land Outlook: Nigeria LDN Target Setting Report.* Bonn, Germany.

Walkley, A., & Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), 29-38.

Weil, R.R. and Brady, N.C. (2017). The Nature and Properties of Soils. Pearson Education, Boston.