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Pedogenic processes and fertility constraints across a Basement Complex toposequence in Southwestern Nigeria

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Abstract

Inadequate soil characterisation and classification remain a major constraint to agricultural development and sustainable land management in Nigeria. This study investigated and taxonomically grouped soils across an area of approximately 12.5 hectares at Olowogbo Village, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria, using the USDA Soil Taxonomy, the WRB framework, and the indigenous classification system of Smyth and Montgomery. Following reconnaissance surveys, five representative profiles (Profile 1 to 5) were identified, excavated, and described. Results showed that soil colour varied from dark yellowish brown (10YR 4/6) at surface horizons to strong brown (7.5YR 5/6) and very pale brown (10YR 7/4) in subsoil horizons. The soils have a high sand fraction, and textural classes ranged from sandy to sandy clay loam. Soil pH ranged from 4.69 to 5.66, organic carbon content from 9.43 to 48.24 g kg^{-1}, while total nitrogen (0.03–0.22 g kg^{-1}), available phosphorus (1.08–6.09 mg kg^{-1}), exchangeable potassium (0.16–0.43 cmol kg^{-1}), and effective cation exchange capacity (3.61–6.29 cmol kg^{-1}) were low. However, percentage base saturation was high (89.98 – 98.14%) and dominated by calcium and magnessium. The soils were classified as Alfisols, Inceptisols and Entisols in the USDA Soil Taxonomy, equivalent to Lixisols, Fluvisols and Leptosols respectively in the WRB system and to the Ibadan, Jago, Mamu, Iwaji, and Balogun series in the indigenous classification. An integrated soil fertility management strategy is recommended to enhance fertility and correct acidity. This study provides a baseline assessment of soil fertility, land use planning and sustainable agricultural management in study area and similar agroecological zones.

Keywords: soil characterisation, soil classification, profiles, soil fertility, sustainable agriculture

1. Introduction

Soils are fundamental natural resources that underpin food security, ecosystem stability, and sustainable land management [1-5]. In sub-Saharan Africa, where agriculture is the primary economic activity for the majority of the rural population, a thorough understanding of soil morphology and physicochemical behaviour is essential for sound land use planning and effective fertility management [6-9]. Despite the importance of soils to agricultural productivity, a significant proportion of tropical African soils remain poorly characterised at the local scale where management decisions are implemented [10-12]. Nigeria, with a land area of approximately 923,768 km², encompasses diverse agroecological zones and a corresponding diversity of soil types, ranging from Vertisols in the semiarid north to Ferralsols and Ultisols in the humid south [13-15]. Within the derived savannah and rainforest transition zones of southwestern Nigeria, soils are predominantly derived from the Precambrian Basement Complex, characterised by deep weathering profiles, light textures, low organic matter content, and inherently low fertility [6,16,17]. These soils present significant management challenges for smallholder farmers who depend on them for crop production.

A critical and long-standing challenge in Nigerian soil science is the absence of a consolidated national soil map and a unified, comprehensive soil classification system. Unlike countries such as the USA, Canada, UAE, Saudi Arabia and European nations, which have established authoritative national soil survey programmes and integrated soil classification databases, Nigeria lacks an equivalent resource that systematically covers the full range of its soil diversity. The soil classification literature for Nigeria is instead characterised by a series of landmark but geographically fragmented studies, each covering a distinct region and reflecting the knowledge, methods, and classification frameworks prevailing at the time of its publication. The foundational works in Nigerian soil classification include:

- Moss [18] surveyed soils of western and mid-western Nigeria on sedimentary parent materials;

- Smyth and Montgomery [19] characterised and classified the soils of central western Nigeria predominantly Basement Complex-derived soils using a combination of geographical and taxonomic approaches;
- Jungerius [20] focused on the soils of eastern Nigeria, largely underlain by sedimentary formations;
- Klinkenberg and Higgins [21] documented the soils of northern Nigeria, including both Basement Complex and sedimentary-derived soils; and
- Murdoch et al. [22] characterised the savannah soils of southwestern Nigeria.

Together, these works represent the historical backbone of Nigerian soil survey knowledge.

However, each of these classification systems is inherently limited in its geographical scope, covering only a part of the country, and none of them is sufficiently comprehensive to serve as a universally applicable national soil classification framework. No single publication provides a complete account of all Nigerian soils, and the absence of a consolidated national system means that soil information remains fragmented, making it difficult to transfer agronomic knowledge and management recommendations across regions. Furthermore, several of these seminal works predate the modern era of soil survey and classification. Since their publication, the international soil classification systems particularly the USDA Soil Taxonomy and the World Reference Base for Soil Resources (WRB) have undergone multiple revisions incorporating new diagnostic criteria, pedogenic concepts, and analytical techniques that were unavailable to earlier workers [23,24]. The indigenous classification schemes consequently lack comparability with modern international systems, limiting their utility for contemporary soil science and agricultural development.

The practical consequences of this fragmented and outdated soil knowledge base are evident at the farm level. Nigerian farmers have recurrently experienced crop failures, uneven crop growth patterns, and suboptimal yields even after following officially recommended input application rates for fertilisers, lime, and other soil amendments. These outcomes can be attributed, at least in part, to the application of generalised recommendations derived from obsolete or regionally unrepresentative soil data that fail to capture the actual properties and constraints of the specific soils on individual

farms. Without accurate, site-specific soil characterisation data informed by modern classification systems, it is not possible to develop reliable, locally appropriate fertiliser and management recommendations that address the true edaphic constraints farmers face. Several studies have documented soil properties and taxonomic groupings in comparable agroecological zones of southwestern Nigeria. Olasoji et al. [25] characterised soils derived from Basement Complex rocks in Osun State, reporting similar patterns of light texture, low ECEC, and strong acidity that constrain crop yields without external inputs. Adegbite et al. [26], Are et al. [27] and Adesemuyi et al. [28] demonstrated the importance of detailed profile-level investigations for understanding soil variability across short distances in the Basement Complex terrain.

It is therefore imperative that soils across Nigeria especially in agriculturally significant zones that have received limited attention since the original surveys, are resurveyed and reclassified using modern analytical methods and current international classification frameworks. Such efforts are essential for advancing soil knowledge, enabling evidence-based land use planning, and ultimately driving optimal agricultural productivity. The present study responds directly to this need by characterising the soils of Akinyele Local Government Area, Ibadan, a locality that falls within the central-western Nigeria zone originally surveyed by Smyth and Montgomery [19] but which lacks detailed, profile-level characterisation data based on contemporary methods. Systematic soil survey data at the profile level for this locality will give researchers, extension agents, and policymakers the ability to develop site-specific soil fertility management strategies. This study set out to characterise, classify, and evaluate the variability of soil properties across selected profiles in Akinyele Local Government Area, Ibadan, using internationally recognised soil classification systems.

Specifically, this study aims to:

1. Identify and describe the morphological properties of selected profiles in the study area;

2. Determine the physical and chemical characteristics of the soils across the selected profiles;

3. Classify the soils using the USDA Soil Taxonomy (13th edition), the IUSS World Reference Base (WRB) for Soil Resources (4th edition), and the indigenous classification system of Smyth and Montgomery; and

4. Assess the implications of the soil properties for sustainable land use and agricultural practices in the study area.

2. Materials and Methods

2.1 Description of the Study Site

This research was conducted in Olowogbo Village, located in Akinyele Local Government Area of Ibadan, Oyo State (Figure 1). The total land area covered by the site is approximately 12.5 hectares and lies between latitudes 7°38′10.72″ - 7°38′32.90″N and longitudes 3°53′25.86″ - 3°53′40.52″E. It falls within the mapped area of the Ibadan North-East Sheet 261, produced by the Federal Survey in 1964 [29]. The area is positioned within the tropical rainforest ecological zone. Farming and small-scale trading are the principal economic activities of inhabitants. The climate is characterised by a bimodal rainy season extending approximately eight months with mean annual rainfall ranges between 1,190mm and 1,342mm [30]; followed by a dry season of approximately four months that is intensified by the harmattan, a dry northeasterly trade wind originating from the Sahara Desert. The mean daily temperatures ranged from 21°C to 32°C, respectively. Afternoon temperatures decline during the major rainy season, reaching approximately 29°C in July, and rise again towards the end of the year. Night temperatures decrease to approximately 18°C in December, with absolute minimum temperatures of around 9°C recorded during the harmattan period. The study area is predominantly low-lying with gently to moderately undulating terrain. Oyo State is geologically divided into two distinct zones: the southern part underlain by sedimentary rocks, and the northern part dominated by crystalline Pre-Cambrian Basement Complex rocks. The Basement Complex is primarily composed of medium-grained, strongly foliated gneiss with alternating light and dark mineral bands with the lighter bands comprising feldspar and quartz, and the darker bands rich in biotite mica. Much of the region falls within the Guinea slope section of the broader Niger-Guinea watershed [14].

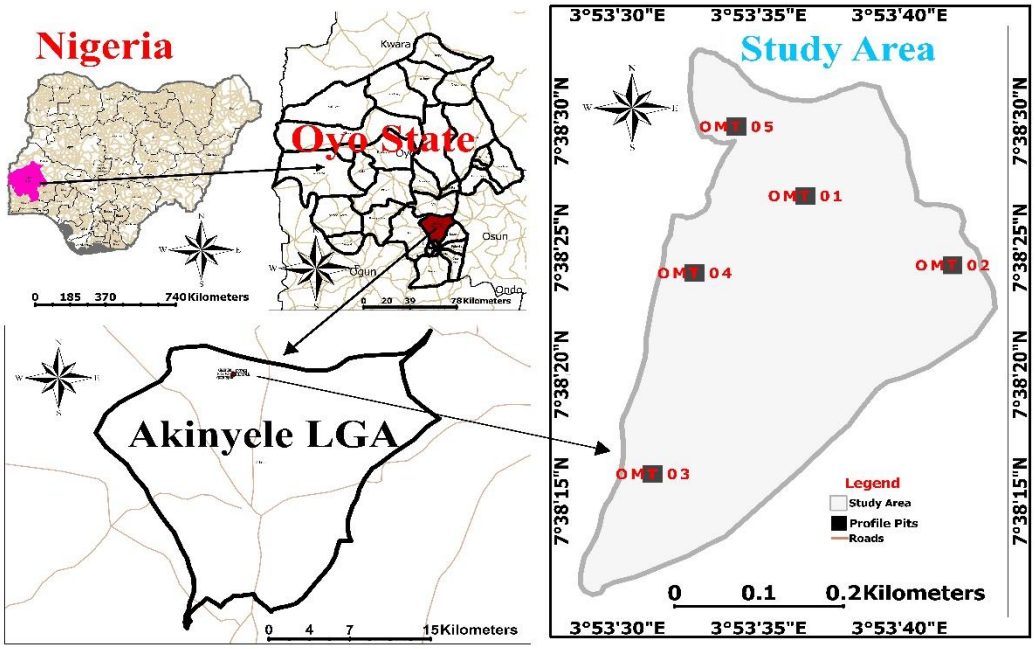


Figure 1 Location and boundary of the study area

2.2 Field Survey and Soil description

A preliminary reconnaissance survey was carried out in September 2024 to establish the site boundary and pinpoint locations for profile excavation across the landscape. A grid-based approach was employed for the soil survey, the boundary of the study area were delineated from the existing perimeter map. Transect lines were established at 80-m intervals, and auger observations were conducted approximately every 70 m along each transect. Fieldwork followed the profile-description guidelines of USDA [23] alongside the WRB classification manual [24]. Equipment comprised a Dutch soil auger, spade, profile description sheets, a Geographical Positioning System and Munsell soil colour Book (MSCB).

Sampling locations were fixed in advance using a Geographic Information System (GIS) and their coordinates loaded onto a handheld GPS unit for field navigation. At each stop, key soil traits such as texture, colour, consistency, and mottling were logged in situ at four depth bands (0–15, 15–30, 30–60, and 60–90 cm), following USDA [23] and WRB [24] field description manuals. Locations sharing similar traits were grouped into mapping units and subsequently investigated by excavating representative profile pits measuring 200 × 150 cm, extending to depths of 150–200 cm. Every profile was geo-referenced and its description recorded (Table 1). Colour was determined from the MSCB, applying the FAO [31] guidelines for that procedure. Other morphological characteristics determined for each profile pit are: horizon

designation, texture by feel, structure, consistency, presence and quantity of mottles, root distribution and density, stoniness or gravel content, and other significant features such as concretions and coatings. Site characteristics including geographic coordinates, elevation, land use history, slope, parent material, drainage, and biological activity were also documented.

2.3 Soil Sampling Procedure

Soil samples were taken from every identified horizon in all five profiles, working from the lowest layer upward with a hand trowel. These were bagged, labelled, and delivered to the soil consultancy laboratory in the Department of Soil Resources Management, Faculty of Agriculture, University of Ibadan, for physicochemical preparation and analysis. There, samples were air-dried in the shade, ground with a pestle and mortar, and passed through a 2.0 mm sieve, except for organic carbon (SOC) and total nitrogen (TN) samples, which were sieved at 0.5 mm to exclude coarser fragments. Standard analytical procedures, outlined below, were followed throughout.

2.4 Laboratory Analysis

Particle-size fractions were quantified using the Bouyoucos hydrometer method [32]. Hydrogen peroxide (H_2O_2) using sodium hexa-metaphosphate $(NaPO_3)^6$ as the dispersing agent were added to destroyed the Organic matter (OM). Textural classes were assigned via the USDA textural triangle, following the approach of [33]. The chemical properties examined comprised soil pH, organic carbon (Org. C), total nitrogen (TN), available phosphorus (Av. P), exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), and the micronutrients Fe, Cu, Zn, and Mn. A glass-electrode pH meter was used on a 1:1 soil-to-water suspension [34], while organic carbon followed the Walkley-Black wet-oxidation procedure [35] and total nitrogen the micro-Kjeldahl procedure [36]. Available phosphorus was extracted by the Bray-1 method [37], and exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) were extracted in Mehlich-3 solution, with readings taken by Atomic Absorption Spectrophotometry (AAS) and flame photometry. Effective cation exchange capacity (ECEC) was computed as the sum of exchangeable bases plus exchangeable acidity [38], and base saturation was expressed as a percentage of this ECEC value.

2.5 Soil Classification and Mapping

Pedons were first grouped under the indigenous series concept of Smyth and Montgomery [19], after which each series was correlated against the USDA Soil Taxonomy [23] and the WRB [24]. Correlation relied on identifying key diagnostic horizons and features, drawing on the morphological, physical, and chemical data collected; the resulting soil map combined the georeferenced field data with GIS layers (ArcGIS 10.5) and Google Earth imagery.

2.6 Statistical Analysis

Relationships among soil properties were assessed using Pearson's simple correlation coefficients. Statistical significance was accepted at $p < 0.05$ and $p < 0.01$. Coefficients of variation (CV) were used to assess variability within each profile, with CV < 15% classified as low, 15–35% as moderate, and > 35% as high. The mean and standard deviation were determined using the descriptive statistics. All of these analysis were carried out using the IBM SPSS Version 22.0 [39].

3. Results and Discussion

3.1 Morphological Characteristics of the Profiles

The morphological properties of the five profiles investigated in Akinyele Local Government Area reflect the combined influence of parent material, climate, and topographic position on soil profile development.

3.1.1 Soil depth

The horizon depths as seen in the soil profile shows that the soils of OMT-01, OMT-03, OMT-04 and OMT-05 were deep (150-200 cm). This is an indication of a well-developed soils according to the rating given by Dent and Young [40]. The Ap horizon of OMT-01 was seen to be 0 to 26 cm deep. The depth of the AB horizon was 26–46 cm. The horizons beneath the AB were Bc, BC1 and BC2 had depths of 46–56, 56–99 and 99–128 cm, respectively (Table 1, Figure 2). The Ap horizon of OMT-2 was 26 cm deep, followed by an AB horizon which was 53 cm deep (Figure 3). The Ap horizon of OMT-03 was 18 cm in thickness, followed by an AB horizon which was 33 cm deep then Bc which was 54 cm deep, BC1 which was 109 cm deep and BC2 which was 175 cm deep (Figure 4). The thickness of OMT-04 Ap horizon was 20 cm. The next horizon which was Cr1 was 46 cm thick and followed by Cr2 horizon was a 92 cm thick (Figure 5). The 5th profile (OMT-05) Ap horizon was 32 cm thick, the next horizon (B1) was a 64 cm thick, which lay above a 89 cm thick B2 horizon followed by a Bc horizon which

was 116 cm thick then BC1 horizon which was 147 cm thick and BC2 which was 175 cm thick (Figure 6). Although OMT-01, OMT-02 and OMT-04 (profiles 1, 2 and 4) were a well-developed soils yet their depths were a bit shallow because of seasonal waterlogging and the rise in the water table in OMT-02 coupled with the presence of stone lines impeding the depth of OMT-01 and OMT-04.



Location N: 05. 98553º E: 08.44696º

Elevation:270m

Slope: Gentle

Extent of Erosion: slight

Rock outcrop: Nil

Land use: Arable

Soil surface form: Flat

Profile Thickness: 128 cm

Lithology: Sedentary

Parent material: Quartzite Schist

moisture Condition: wet

Season of the year: Rainy

Evidence of biological activity: Nil

Hardness:Hard Drainage: well drained comment:

Farmland was used for cassava and plantain

SOIL CLASSIFICATION

USDA: Arenic Haplustalf

WRB: Ferric Lixisol (arenic)

LOCAL CLASSIFICATION: Ibadan Series.

Figure 2 Soil profile Pit OMT-01



Location N:05.98713 º08.44612E

Elevation: 257m

Slope: Flat

Extent of Erosion: High

Rock outcrop: Nil

Land use: Arable

Profile Thickness: 53 cm

Lithology: Sedimentary

Parent material: Transported and Sedimentary

moisture condition: wet

Season of the year: Rainy

Evidence of biological activity: Termite cast

Hardness: Hard

Drainage: poorly drained

Comment: Farmland was used for rice paddy

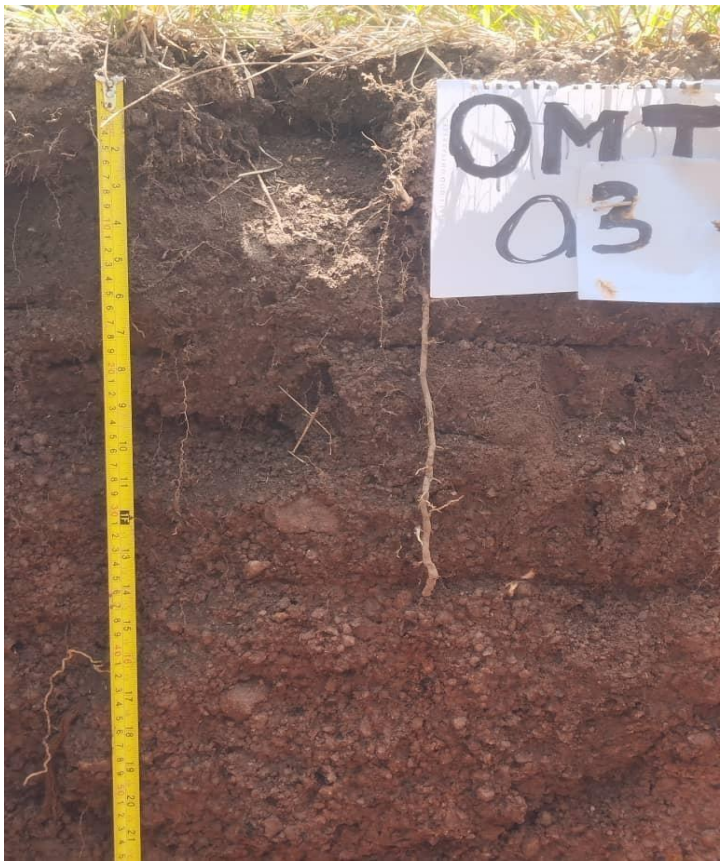
SOIL CLASSIFICATION

USDA: Aquic Dystrudept

WRB: Orthfluvic Fluvisol (humic oxyaquic)

LOCAL CLASSIFICATION: Jago Series.

Figure 3 Soil profile Pit OMT-02



Location N: 05. 98388 º08.44358 E

Elevation: 262m

Slope: Flat

Extent of Erosion: slight

Rock outcrop: Nil

Land use: Arable

Soil surface form: smooth

Profile Thickness:175cm

Lithology: Schist

Parent material: Sedentary moisture

Condition: wet

Season of the year: Rainy

Evidence of biological activity: Nil

Hardness: Hard

Drainage: well drained comment: Farmland was used for cassava and

plantain

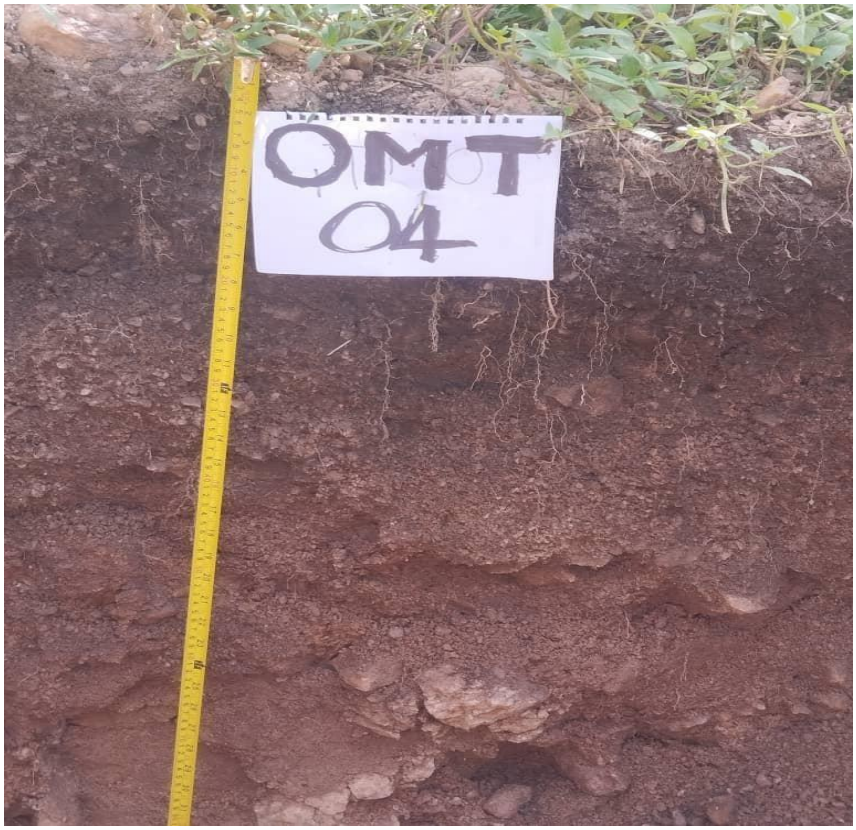
SOIL CLASSIFICATION

USDA: Typic Kandiustalf

WRB: Ferralic Lixisol (saprolithic)

LOCAL CLASSIFICATION: Mamu Series.

Figure 4 Soil profile Pit OMT-03



Location N: 05. 98433 º08.44602 Eº

Elevation:270m

Slope: Flat

Extent of Erosion: slight

Rock outcrop: Nil

Land use: oil palm

Soil surface form: smooth

Profile Thickness:92cm

Lithology: Quarzite Schist

Parent material: Sedentary

moisture condition: moist

Season of the year: Rainy

Evidence of biological activity: Animal burrow

Hardness: Hard

Drainage: well drained

comment: Farmland was used for oil palm production

SOIL CLASSIFICATION

USDA: Lithic Usthorthent

WRB: Skeletic Leptosol (Ochric)

LOCAL CLASSIFICATION: Iwaji Series.

Figure 5 Soil profile Pit OMT-04



Location N: 05. 98477 º08.44778 Eº

Elevation:267m

Slope: Flat

Extent of Erosion: slight

Rock outcrop: Nil

Land use: cassava plantation

Soil surface form: smooth

Profile Thickness:175cm

Lithology: Granite gneiss

Parent material: Sedentary mottled clay

moisture condition: moist Season of the year: Rainy

Evidence of biological activity: Animal burrow

Hardness: Hard

Drainage: well drained comment: Farmland was used for cassava production

SOIL CLASSIFICATION

USDA: Inceptic Haplustalf

WRB: Haplic Lixisol (hypereutric)

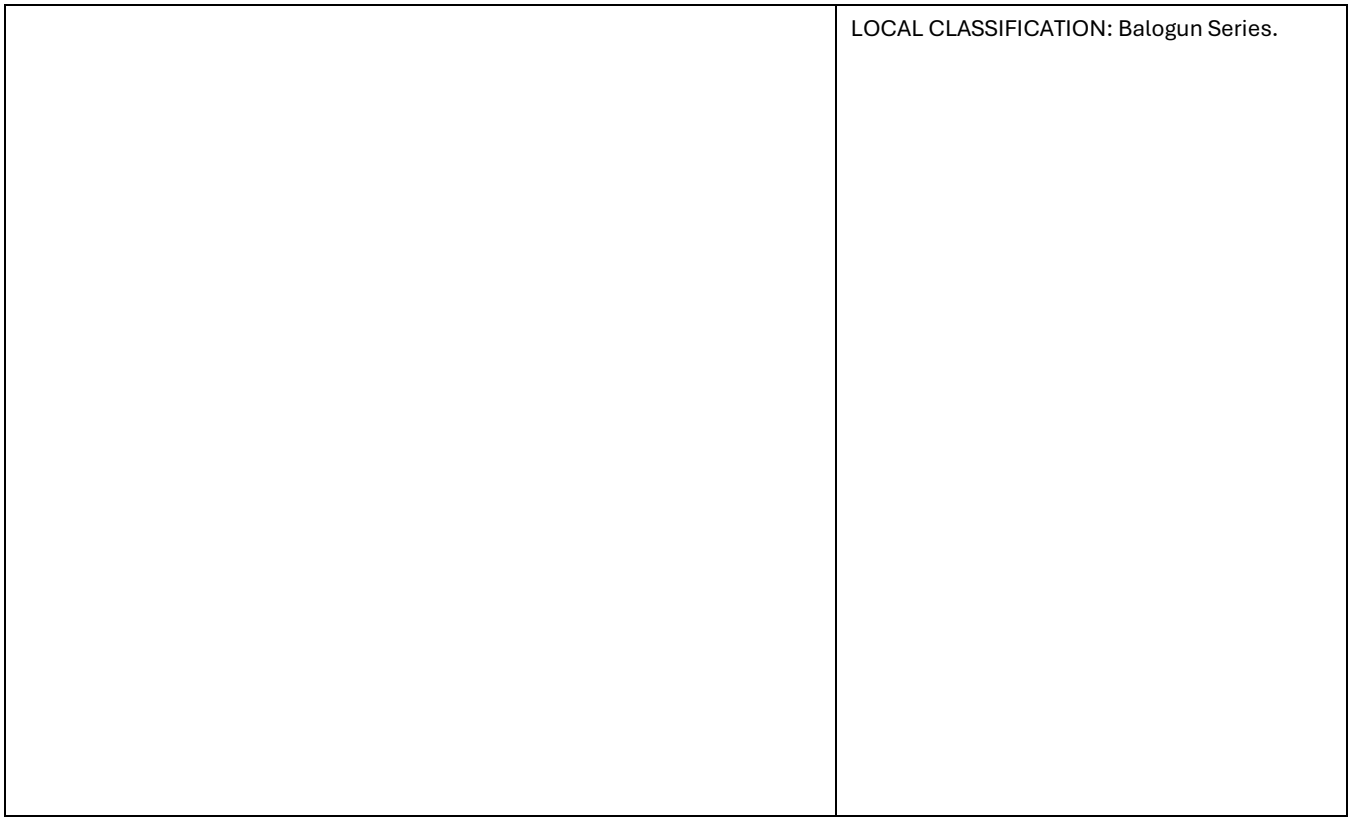


Figure 6 Soil profile Pit OMT-05

3.1.2 Soil colour

Colour is among the most diagnostic morphological attributes recorded during profile description, given its quantitative basis in soil classification systems [41], and it reflects organic matter status, drainage condition and iron mineralogy. In OMT-01, the Ap and AB horizons were both dark yellowish brown, differing only in chroma (10YR4/6 compared with 10YR/4/4), while the Bc and BC2 horizons were strong brown (7.5YR/5/6) and BC1 was also strong brown but changed only in value (7.5YR/4/6), the presence of good drainage and aeration is indicative of this pattern (Table 1). The Ap horizon of OMT-02 was dark yellowish-brown (10YR/4/4) and became pale brown (10YR/6/3) in the AB horizon. The OMT-03 had dark yellowish-brown (10YR/3/4) Ap horizon, shifting to brown at the AB horizon (7.5YR/4/4), then strong brown through the Bc and BC1 horizons (7.5YR/4/6), and finally very pale brown at BC2 (10YR 5/6) such changes attributable to organic matter and moisture content (Table 1). The OMT-04 profile Ap horizon was very dark greyish brown (10YR/3/2) moving to dark brown (7.5YR/3/4) in the next horizon which was the Cr1 horizon while the last horizon or Cr2 was brown (7.5YR/5/3). The OMT-05 Ap horizon was dark yellowish-brown (10YR/3/4) which was the same colour as the B1 horizon but differs in value and chroma (10YR/4/6) the next B2 horizon was yellowish brown (10YR/5/6), before turning strong

brown (7.5YR/5/8) at Bc, yellowish red (5YR/5/8) at BC1, and yellow (10YR/7/8) at BC2; a yellowing likely driven by goethite [42]. The overall lightening with depth across profiles can be traced to several interacting factors: SOM content, moisture status, and the oxidation-reduction behaviour of Fe and Mn oxides. This echoes reports elsewhere that mineralogical variation produces distinct colour patterns in soils [25,43].

3.1.3 Mottles, Stoniness and Concretion

The presence of mottles in OMT-02 (abundant, at AB horizon or 31–53 cm depth) and OMT-04 (moderate to very high, throughout the profile) indicates periodic waterlogging or fluctuating water tables. The poor drainage status of OMT-02, confirmed by its classification as an Aquic Dystrudept, is consistent with its low topographic position, shallow profile depth (53 cm), and sedimentary alluvial parent material, a conditions associated with hydromorphic soils along floodplain margins in the Ibadan region [14,19]. OMT-04, classified as a Lithic Usthorthent with a profile depth of only 92 cm, exhibits high stoniness and abundant mottles that reflect proximity to weathering rock and impeded internal drainage rather than a seasonally high water table (Table 1).

Stones were mostly absent in almost all the horizons in OMT-01, except in BC2 horizon where it is fairly stony. There is no stone in OMT-02. There was no stone in the Ap horizon of OMT-03 but AB, BC1 and BC2 horizons was found to be fairly stony while the Bc horizon was stony. The Ap and Cr2 horizons of OMT-04 were stony while the Cr1 horizon was fairly stony. All the horizons in OMT-05 were stony. Stoniness heavily dictates soil physical, thermal, and hydraulic properties. In Africa, the Sahara, Sahel, and most soils in the geological mantle in the west of the African continent are gravelly [44]. Although, excess stones hinder root growth and limit the overall volume available for water and nutrient storage, moderate stoniness can enhance soil aeration, reduce surface erosion, prevent heavy compaction, and moderate temperature fluctuations to protect crops [45-47].

There is a presence of Fe/Mn concretion in all the profiles. In OMT-01, it was restricted to subsoil (Bc and BC2 horizons) indicating a deeper, more stable water table or seasonally saturated zone, whereas in OMT-02 it was present in the AB horizon which is a transitional layer between the topsoil and subsoil and this mean, the water table is close to the topsoil and poorly drained. In OMT-03 and OMT-04, Fe/Mn was present in all the horizons except the Ap horizon, these indicated that the topsoil was well

aerated and too oxidized for the Fe/Mn formation but the consistent presence of Fe/Mn throughout the subsoils and deeper horizons is an indicated of widespread contemporary waterlogging and restricted drainage in the subsoil. Fe/Mn presence in the B1, B2, Bc and BC1 horizons in OMT-05 is an indication of fluctuating seasonal water table that rises into the B horizon during wet season and drops during the dry spell. Fe–Mn concretions are used as diagnostic indicators of soil redoximorphosis because they are mostly found in soils with restricted internal drainage as the result of alternating oxidation and reduction cycles [48,49].

3.1.4 Soil Structure

Structure graded from crumb aggregates at the surface to sub-angular blocky forms deeper in the profiles. OMT-01 retained a crumb structure throughout (Table 1). OMT-02's Ap horizon was crumb-structured, but its underlying AB horizon turned sub-angular blocky and held a water table that halted further digging. OMT-03 showed crumb structure at Ap and AB, shifting to sub-angular blocky in the Bc, BC1, and BC2 horizons below. OMT-04's Ap horizon was likewise crumb-structured before becoming massive at Cr1 and reverting to crumb at Cr2. OMT-05 began massive at Ap, turned crumb through B1, B2, and Bc, then sub-angular blocky at BC1 and BC2. Surface crumb structure is generally attributed to organic matter and biological activity stabilising aggregates [50], while the sub-angular blocky structure found in the subsoils of OMT-02, OMT-03, and OMT-05 points to clay accumulation and the development of argillic or cambic diagnostic horizons; the structural variation between profiles may also reflect uneven weathering of the parent material [51].

3.1.5 Soil Consistency

Consistency reflects how strongly soil particles cohere and resist rupture or disturbance. OMT-01 was friable throughout, while OMT-02 graded from firm at Ap to very firm in the AB horizon. OMT-03 stayed friable at Ap and AB but hardened to very firm at BC1 and BC2. OMT-04's Ap horizon was friable, its Cr1 firm, and its Cr2 very firm, whereas OMT-05 was friable at Ap and B1 but firm from B2 through BC2. This broad shift from friable topsoil to very firm subsoil, typical of well-drained upper horizons giving way to denser material below, could restrict root growth and water movement under intensive farming [52]. The Fe/Mn concretions noted across several profiles likely stem from redox cycling tied to seasonal wetting and drying [53] and are diagnostic of Plinthic or Petroplinthic WRB properties.

3.1.6 Horizon boundaries

All profiles showed distinct transitions between surface and sub-surface horizons (Table 1). OMT-01's Ap-to-AB boundary was wavy, sharpening to smooth-clear from Bc through BC2 — a pattern plausibly linked to repeated tillage disturbance [54]. OMT-02's Ap-AB boundary was clear and smooth. OMT-03 showed a clear, smooth Ap-A transition, a diffuse boundary at Bc, and clear-smooth again between BC1 and BC2. OMT-04 was clear and smooth at every boundary. OMT-05 ran wavy through Ap, B1, and B2, turned smooth-clear at Bc, wavy again at BC1, then smooth-clear at BC2. Collectively, this variability suggests a measurable human footprint on soil physical condition, most likely from farming activity [55].

Table 1: Morphological Properties of Some Profiles in Study Area

Profile	Horizon	Depth (cm)	Colour (moist)	Mottles	Stoniness	Structure	Consistency (Moist)	Concretion	Field Texture	Boundary Form
OMT-01	Ap	0-26	10YR 4/6	-	-	Crumbs	Friable	-	S	Wavy
	AB	26-46	10YR 4/4	-	-	Crumbs	Friable	-	S	Wavy
	Bc	46-56	7.5YR 5/6	Few	-	Crumbs	Friable	Fe/Mn	LS	Smooth clear
	BC1	56-99	7.5YR 4/6	-	-	Crumbs	Friable	-	LS	Smooth clear
	BC2	99-128	7.5YR 5/6	-	Fairly stony	Crumbs	Friable	Fe/Mn	LS	Smooth clear
OMT-02	Ap	0-31	10YR 4/4	-	-	Crumbs	Firm	-	SL	Smooth clear
	AB	31-53	10YR 6/3	Abundant	-	Sub-angular blocky	Very firm	Fe/Mn	SL	Smooth clear
OMT-03	Ap	0-18	10YR 3/4	-	-	Crumbs	Friable	-	LS	Smooth clear
	AB	18-33	7.5YR 4/4	-	Fairly stony	Crumbs	Friable	Few Fe/Mn	LS	Smooth clear
	Bc	33-54	7.5YR 4/6	-	Stony	Sub-angular blocky	Firm	Fe/Mn	SCL	Diffuse
	BC1	54-109	7.5YR 4/6	-	Fairly stony	Sub-angular blocky	Very firm	Fe/Mn	SL	Smooth clear
	BC2	109-175	10YR 7/4	-	Fairly stony	Sub-angular blocky	Very firm	Fe/Mn	SL	Smooth clear
OMT-04	Ap	0-20	10YR 3/2	Moderate	Stony	Crumbs	Fri	-	LS	Smooth clear
	Cr1	20-46	7.5YR 3/4	High	Fairly stony	Massive	Firm	Few Fe/Mn	S	Smooth clear

	Cr2	46-92	7.5YR 5/3	V high	Stony	Crumbs	Very firm	Fe/Mn	S	Smooth clear
OMT-05	Ap	0-32	10YR 3/4	-	Stony	Massive	Friable	-	S	Wavy
	B1	32-64	10YR 4/6	Few	Stony	Crumbs	Friable	Fe/Mn	S	Wavy
	B2	64-89	10YR 5/6	Few	Stony	Crumbs	Firm	Fe/Mn	LS	Wavy
	Bc	89-116	7.5YR 5/8	moderate	Stony	Crumbs	Firm	Fe/Mn	SL	Smooth clear
	BC1	116-147	5YR 5/8	Few	Stony	Sub-angular blocky	Firm	Fe/Mn	SL	Wavy
	BC2	147-175	10YR 7/8	Few	Stony	Sub-angular blocky	Firm	-	SL	Smooth clear

Concretion: Fe – Iron, Fe/Mn – Iron-Manganese; Field Texture: S-Sandy, LS-Loamy sand, SL-Sandy loam, SCL-Sandy clay loam.

3.2 Physical Properties of the Soil

3.2.1 Particle size distribution and Textural Class

The proportions of sand, silt, and clay across the size spectrum shape most other soil properties. Texturally, the pedons are predominantly light, with sandy and loamy sand textures dominant in OMT-01, OMT-04, and the upper horizons of OMT-05, whereas sandy loam occurred throughout OMT-02 and in the deeper horizons of OMT-03 and OMT-05 (Table 2). The sand fraction was generally high (700–883 g/kg), consistent with derivation from coarse-grained Basement Complex rocks in which quartz dominates the mineral skeleton after intensive tropical weathering [56,57]. In OMT-01 the mean and standard deviation of the sand was 838±52.63 g/kg with a CV of 6.28%, the mean and std. dev was 746.0±5.66 g/kg and CV = 0.76% in OMT-02. The mean, std. dev. and CV was 700.0±136.93 g/kg, CV = 19.56%; 883.0±40.34 g/kg, CV = 4.57% and 801.67±118.87 g/kg, CV = 14.83%, in OMT-03, 4 and 5, respectively. While workable, sandy soils are prone to nutrient leaching and erosion under heavy rainfall and wind exposure [58], and their large inter-particle pores drain quickly, leaving plants vulnerable to water stress. Down-slope movement of water further strips away finer particles, leaving behind coarser sand particles, which can lead to a higher sand content [59].

Silt fractions were generally low (72–177 g/kg). The mean and std. dev. of the silt was 108±22.89 g/kg with a CV of 59.43% in OMT-01, the mean and std. dev was 177±9.9 g/kg and CV = 5.59% in OMT-02. The mean, std. dev. and CV was 174.00±66.93 g/kg, CV = 38.47%; 72.33±25.42 g/kg, CV = 35.15% and 117.33±62.82 g/kg, CV = 53.54%,

in OMT-03, 4 and 5, respectively. This reflect advanced weathering and limited contribution of primary silicate minerals to the fine fraction. The clay content ranged from 10 to 137 g/kg in the surface and sub-surface horizons (Table 2). Clay contents were highest in OMT-02 and OMT-03, consistent with the occurrence of argillic or cambic horizons, and lowest in OMT-04 and OMT-01. Topsoils across the profiles were clay-deficient (< 100 g/kg), with clay content building up with depth in the sub-surface; a pattern likely reflecting clay eluviation and weathering processes. Because surface horizons hold so little clay, water-holding capacity is low and infiltration rapid, leaving these layers prone to drying out quickly once the rains begin, particularly early in the season. The comparatively low silt and clay fractions, paired with elevated sand content, most likely trace back to the parent material's weathering behaviour, echoing the pattern reported by Isola et al. [60] in Oyo state, Nigeria. Since the percentage of sand observed in this study was generally high (540–952 g/kg) in all the soil horizons of the profiles, the textural class of the soils were sand in the Ap, AB horizons of profile 1, Cr1 and Cr 2 horizons of profile 2; Ap and B1 horizons of profile 5. Then it was sandy loam in Ap and AB horizons of OMT-01, Cr1 and Cr 2 horizons of OMT-02; Ap and B1 horizons of OMT-05. Then it was sandy loam in Ap and AB horizons of OMT-02; BC1 and BC2 horizons of OMT-03 then Bc, BC1 and BC2 horizons of OMT-05. The texture was loamy sand in Bc, BC1 and BC2 horizons of OMT-01; Ap and AB horizons of OMT-03; Ap horizons of OMT-04 and B2 horizon of OMT-05 and it was sandy clay loam in the Bc horizon of OMT-03 (Table 2).

3.2.2 Silt-to-Clay Ratios

The silt-to-clay ratio (SCR) across all profiles ranged from 1.19 to 11.00 (Table 2). The SCR serves as an indicator of soil weathering intensity, decreasing irregularly down the profile. Surface horizons across all five profiles exhibited higher SCR values, indicating greater potential nutrient and water retention capacities in topsoils relative to underlying layers. The elevated silt content in surface horizons may also stem from recent depositions of eroded colluvial sediments. Furthermore, because the SCR was > 1.5 across all five profiles, these soils can be regarded as pedogenetically young with substantial remaining weathering potential [61]. These results align with findings by Babalola et al. [62] and Adeyemo et al. [63], who reported similar SCR trends in Basement Complex soils.

Table 2: Physical Properties of Soil

Profile	Horizon	Depth	Sand	Silt	Clay	Silt/Clay	Textural Class
			← g/kg →				
OMT-01	Ap	0-26	900	90	10	9	Sand
	AB	26-46	890	80	30	2.67	Sand
	Bc	46-56	800	130	70	1.86	Loamy Sand
	BC1	56-99	810	110	80	1.38	Loamy Sand
	BC2	99-128	790	130	80	1.63	Loamy Sand
	Mean		**838.00**	**108.00**	**54.00**	**2.00**	
	SD		**52.63**	**22.80**	**32.09**	**3.22**	
	CV		**6.28**	**21.11**	**59.43**	**97.30**	
OMT-02	Ap	0-31	742	184	74	2.48	Sandy loam
	AB	31-53	750	170	80	2.13	Sandy loam
	Mean		**746.00**	**177.00**	**77.00**	**2.30**	
	SD		**5.66**	**9.90**	**4.24**	**0.25**	
	CV		**0.76**	**5.59**	**5.51**	**10.74**	
OMT-03	Ap1	0-18	850	100	50	2.00	Loamy Sand
	AB	18-33	780	140	80	1.75	Loamy Sand
	B	33-54	540	250	210	1.19	Sandy clay loam
	BC1	54-109	570	240	190	1.26	Sandy loam
	BC2	109-175	760	140	100	1.40	Sandy loam
	Mean		**700.00**	**174.00**	**126.00**	**1.38**	
	SD		**136.93**	**66.93**	**70.21**	**0.34**	
	CV		**19.56**	**38.47**	**55.73**	**22.65**	
OMT-04	Ap	0-20	840	100	60	1.67	Loamy Sand
	Cr1	20-46	920	50	30	1.67	Sand
	Cr2	46-92	889	67	44	1.52	Sand
	Mean		**883.00**	**72.33**	**44.67**	**1.62**	
	SD		**40.34**	**25.42**	**15.01**	**0.09**	
	CV		**4.57**	**35.15**	**33.61**	**5.35**	
OMT-05	Ap	0-32	952	44	4	11.00	Sand
	B1	32-64	935	44	21	2.10	Sand
	B2	64-89	786	124	90	1.38	Loamy Sand
	Bc	89-116	776	124	100	1.24	Sandy loam
	BC1	116-147	679	184	137	1.34	Sandy loam
	BC2	147-175	682	184	134	1.37	Sandy loam
	Mean		**801.67**	**117.33**	**81.00**	**1.45**	
	SD		**118.87**	**62.82**	**56.42**	**3.90**	
	CV		**14.83**	**53.54**	**69.65**	**126.85**	

3.3 Chemical Properties

3.3.1 Soil pH and Exchangeable Acidity

Across all five profiles, soil pH ranged between 4.69 and 5.66, indicating strongly to moderately acidic conditions (Table 3). This is a characteristic feature of Alfisols, Inceptisols, and Entisols weathered from crystalline Basement Complex rocks under humid tropical conditions [64]. Leaching of basic cations under heavy rainfall, combined with the release of aluminium and hydrogen ions during mineral weathering, drives this acidity [65]. Repeated applications of inorganic fertilisers (such as urea,

DAP, and SSP) or organic acid release from organic matter decomposition can further compound soil acidification [66]; Guo et al. [67] noted that heavy fertiliser use combined with base-cation removal via crop harvests accelerates soil acidification, while Kousar et al. [68] linked declining agricultural soil pH to reduced base saturation and organic acid accumulation. Because these pH values fall below the optimal range of 6.0–7.0 preferred by most arable crops, correcting acidity through soil liming and organic amendments is warranted. The significant positive correlation between pH and total nitrogen (Figure 7; $r = 0.451$, $p < 0.05$) suggests that soil acidification suppresses nitrogen availability by inhibiting microbial nitrification [69]. Exchangeable acidity ranged from 0.1to 0.5 cmol kg^{-1}.

3.3.2 Soil Organic Carbon, Total Nitrogen and Available Phosphorus

Soil organic carbon (SOC) content ranged from 9.43 to 48.24 g kg^{-1} (Table 3). Surface horizons consistently exhibited higher SOC values than sub-surface horizons due to continuous litter deposition at the surface and rapid organic matter decomposition with depth under warm, humid conditions. Mean SOC values across all five profiles were high (> 15.0 g kg^{-1}) based on critical threshold limits [56]. Positive correlations (Figure 7) between organic carbon and exchangeable calcium ($r = 0.417$) as well as base saturation ($_r = 0.357$) confirm the role of organic matter in enhancing cation exchange capacity in low-activity clay soils [70,71].

Total nitrogen values were very low (0.03-0.22 g kg^{-1}), remaining consistently below the critical threshold of 2.0 g kg^{-1} established for tropical agricultural soils [72]. Wide C:N ratios suggest a predominance of recalcitrant, woody organic residues with slow mineralisation rates. The positive correlation between total nitrogen and exchangeable calcium ($r = 0.502$, $p < 0.01$) (Figure 7) indicates that liming—by increasing pH and calcium supply—indirectly enhances microbial activity and nitrogen mineralisation.

Available phosphorus concentrations (Table 3) were very low (profile means ranging from 1.37 to 4.32 mg kg^{-1}), falling far below the critical threshold of 10 mg kg^{-1} recommended for crop production in Nigeria [73]. Low phosphorus availability reflects strong P-fixation by iron and aluminium oxides under acidic conditions, a phenomenon typical of soils weathered from crystalline Basement Complex rocks [65]. This represents a major edaphic constraint to crop productivity, demonstrating that targeted phosphorus fertilisation—combined with organic matter application to block fixation sites—is essential. Isola et al. [60] and Ajayi et al. [6] similarly reported low available

phosphorus in comparable agroecological zones, attributing it to continuous crop harvesting, low organic matter levels, and high P-fixation capacity.

3.3.3 Exchangeable Cations, ECEC, ECEC/clay and Percentage Base Saturation

Exchangeable calcium (Ca^{2+}) was the dominant cation (2.25–4.94 cmol kg^{-1}), followed by magnesium (Mg^{2+}, 0.37–2.76 cmol kg^{-1}), sodium (Na^{+}, 0.13–0.32 cmol kg^{-1}), and potassium (K^{+}, 0.16–0.43 cmol kg^{-1}) (Table 3). Based on FAO rating [31], Ca^{2+} and Na^{+} were low, Mg^{2+} was medium, and K^{+} ranges from very low <0.2 cmo kg^{-1} to medium (0.3-0.6 cmo kg^{-1}). This confirms that the parent material was inherently rich in Ca^{2+} and Mg^{2+}. According to Brady and Weil [69], Ca^{2+}, Mg^{2+} and K^{+} compete for exchange sites and plant uptake is governed by their relative ratios. These findings align with previous observations on Basement Complex soils [74,75]. Effective cation exchange capacity (ECEC) values were very low to low (3.61–6.29 cmol kg^{-1}), reflecting the dominance of 1:1 kaolinitic clays and the light soil textures [72]. The strong positive correlation between ECEC and exchangeable magnesium ($r = 0.592$, $p < 0.01$) suggests that dolomitic limestone is preferable to calcitic limestone for acidity correction in these soils (Figure 7). Base saturation was uniformly high (89.94–98.01%), consistent with the Alfisol and Inceptisol criteria under the USDA Soil Taxonomy (Table 3).

3.3.4 Extractable Micronutrients

Table 3 presents DTPA-extractable concentrations of four micronutrients namely zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) across the five profiles (OMT-01 to OMT-05). The correlation matrix in Figure 7 details relationships between micronutrient availability and other soil chemical and physical properties.

Zinc (Zn)

Zn concentrations across the five profiles ranged from 0.7 to 2.6 mg kg^{-1}, with profile means of 1.24 (OMT-01), 1.80 (OMT-02), 1.32 (OMT-03), 1.27 (OMT-04), and 1.28 mg kg^{-1} (OMT-05). The highest single Zn concentration (2.6 mg kg^{-1}) occurred in the Ap horizon of OMT-02, matching the expectation that organic matter accumulation and biological activity concentrate zinc in topsoils. High coefficients of variation (29.33% to 62.85%) reflect substantial intra-profile variability, driven by variations in organic matter content, clay mineralogy, and redox conditions. The standard DTPA critical threshold for Zn deficiency is 0.6-1.0 mg kg^{-1}. Profile means across all five pedons

exceeded this threshold, indicating adequate profile-scale zinc supply. However, specific subsoil horizons notably the AB horizon of OMT-01 (0.7 mg kg^{-1}) and the Bc horizon of the OMT-03 (0.7 mg kg^{-1}) are below or near critical deficiency limits.

Iron (Fe)

Extractable iron ranged from 5 mg kg^{-1} (Bc horizon, OMT-04) to 77 mg kg^{-1} (Bc horizon, OMT-03), with the profile means of 42.00, 26.50, 32.80, 27.67 and 43.50 mg kg^{-1} for the profiles 1 to 5, respectively. High CV values (129.58% in OMT-04 and 87.21% in OMT-03) indicate an irregular vertical distribution of Fe, controlled by redox fluctuations, horizon ferruginisation, and mottling from water table movements. The DTPA critical threshold for Fe deficiency is 4.5 mg kg^{-1}; all horizon values were well above this threshold, indicating no risk of iron deficiency for crop production. This agrees with earlier appraisals of Nigerian Basement Complex soils [76]. Extractable Fe correlated positively and significantly with total nitrogen (r = 0.371, p < 0.05), exchangeable calcium (r = 0.346, p < 0.05), potassium (r = 0.390, p < 0.05), and base saturation (r = 0.416, p < 0.05) (Figure 7), showing that iron availability is linked to organic matter and exchangeable cation status. Conversely, Fe correlated negatively with extractable copper (r = -0.361, p < 0.05) and clay content (r = -0.345, p < 0.05), pointing to competitive adsorption mechanisms or textural controls on iron mobility.

Manganese (Mn)

Manganese concentrations ranged from 21.5 to 143.0 mg kg^{-1}. The Ap horizon of OMT-02 recorded an exceptionally high Mn value of 143.0 mg kg^{-1}, yielding a profile mean of 109.00 mg kg^{-1} which is far exceeding the other profiles (means of 25.68, 35.48, 23.73, and 23.73 mg kg^{-1} for OMT-01, -03, -04, and -05, respectively). This reflects localized conditions in OMT-02 that promote surface manganese accumulation, including poor drainage, low redox potential, or Mn-rich parent material. The DTPA critical deficiency threshold for Mn is 1.0-5.0 mg kg^{-1}, while toxicity limits range between 140.0 and 200.0 mg kg^{-1}. Most horizon values fell within safe agronomic limits, though the topsoil value in OMT-02 (143.0 mg kg^{-1}) approaches phytotoxic levels and warrants careful management. Manganese correlated positively with pH (r = 0.398, p < 0.05$), total nitrogen ($r$ = 0.504, p < 0.01$), calcium ($r$ = 0.445, p < 0.01), ECEC (r = 0.431, p < 0.05$), and silt content ($r$ = 0.461, p < 0.01), while displaying a negative correlation with sand (r = -0.402, p < 0.05$). The positive correlation between pH and Mn is noteworthy, as manganese solubility typically

increases under acidic and reducing conditions; this relationship suggests that Mn distribution in these soils is governed more by organic chelating agents and parent material composition in silty horizons than by pH-driven dissolution alone.

Copper (Cu}

Copper concentrations ranged from 0.3 to 8.4 mg kg^{-1}, with uniform profile means of 4.54, 4.65, 4.26, 4.87, and 4.62 mg kg^{-1} for OMT-01 through OMT-05, respectively. All Cu values exceeded the DTPA critical deficiency threshold of 0.2 mg kg^{-1}. While a few topsoil horizons recorded elevated levels (e.g., OMT-05 Ap at 8.4 mg kg^{-1}), none exceeded the phytotoxicity threshold of 17.0-25.0 mg kg^{-1}. Compared to earlier studies on Nigerian soils [62], these copper levels are slightly elevated. Copper correlated negatively with pH (r = -0.351, $p < 0.05$), available phosphorus (r = -0.385, $p < 0.05$), and extractable iron (r = -0.361, $p < 0.05$). The inverse relationship between pH and Cu aligns with geochemical principles, as copper solubility increases in more acidic media. The negative correlation between Cu and Fe points to competitive binding on soil sorption sites or antagonistic root uptake mechanisms.

General Micronutrient Trends

Most micronutrients exhibited higher surface concentrations that decreased with depth, consistent with organic matter **chelation** and surface retention. However, extractable Fe and Cu showed depth-wise fluctuations (such as the sharp drop in Fe in the AB horizon of OMT-01 compared to its Ap horizon), reflecting eluviation/illuviation dynamics and local redox patterning. High CV values for Fe in OMT-04 (129.58%) and Mn in OMT-05 (117.62%) highlight spatial heterogeneity caused by weathering gradients and alternating Fe^{2+}/Fe^{3+} and Mn^{2+}/Mn^{4+} redox transitions. Overall, supply of Fe, Mn, and Cu is adequate to abundant across all five profiles. Agronomic monitoring should focus primarily on Zn management for high-demand crops such as maize (*Zea mays*).

Table 3: Chemical Properties of Soil

Profile	Horizon	Depth	pH	TN	Org. C	Av P	Ca	Mg	Na	K	ECEC	BS	EA	Zn	Fe	Mn	Cu
			H_2O	g/kg	mg/kg			cmol/kg				%	cmol/kg		mg/kg		
OMT-01	Ap	0-26	5.34	0.03	31.9	4	2.65	1.37	0.27	0.32	5.0	92.00	0.4	1.2	74	30.6	6.4
	AB	26-46	5.28	0.03	24.30	-1	2.65	2.40	0.21	0.43	5.9	94.99	0.3	0.7	6	25.3	4.3
	Bc	46-56	4.69	0.06	19.95	0	3.19	1.18	0.13	0.35	5.1	94.17	0.3	2.1	71	21.5	2
	BC1	56-99	4.95	0.06	15.60	1	3.24	0.67	0.19	0.19	4.5	93.45	0.3	0.8	51	23.9	3.1
	BC2	99-128	5.09	0.11	16.32	2	2.79	2.76	0.21	0.18	6.1	96.74	0.2	1.4	8	27.1	6.9
	$\dot{X}$		**5.07**	**0.06**	**21.62**	**1**	**2.90**	**1.67**	**0.20**	**0.29**	**5.3**	**94.27**	**0.30**	**1.24**	**42.00**	**25.68**	**4.54**
	SD		**0.26**	**0.03**	**6.72**	**1**	**0.29**	**0.88**	**0.05**	**0.11**	**0.6**	**1.76**	**0.07**	**0.56**	**33.16**	**3.43**	**2.10**
	CV		**5.18**	**61.24**	**31.07**	**133**	**10.13**	**52.32**	**25.01**	**36.52**	**12.4**	**1.87**	**23.57**	**45.12**	**78.95**	**13.35**	**46.22**
OMT-02	Ap	0-31	4.92	0.08	38.81	5	3.39	2.00	0.24	0.22	6.0	96.70	0.2	2.6	25	143	4.2
	AB	31-53	5.21	0.08	19.23	3	3.79	1.20	0.32	0.34	5.9	94.96	0.3	1	28	75	5.1
	$\dot{X}$		**5.07**	**0.08**	**29.02**	**4**	**3.59**	**1.60**	**0.28**	**0.28**	**6.0**	**95.83**	**0.25**	**1.80**	**26.50**	**109.00**	**4.65**
	SD		**0.21**	**0.00**	**13.85**	**1**	**0.28**	**0.56**	**0.06**	**0.08**	**0.0**	**1.23**	**0.07**	**1.13**	**2.12**	**48.08**	**0.64**
	CV		**4.05**	**0.00**	**47.73**	**33**	**7.85**	**35.23**	**19.77**	**30.30**	**1.1**	**1.28**	**28.28**	**62.85**	**8.00**	**44.11**	**13.69**
OMT-03	Ap	0-18	5.47	0.11	37.72	2	4.39	0.67	0.18	0.18	5.7	94.76	0.3	0.9	8	58.5	5.6
	AB	18-33	5.66	0.14	26.12	1	4.94	0.72	0.17	0.16	6.2	95.23	0.3	2.4	9	37.8	6
	Bc	33-54	5.59	0.17	24.67	1	3.79	0.54	0.243	0.21	5.0	94.10	0.3	0.7	77	44.1	2.7
	BC1	54-109	5.58	0.11	28.29	3	4.04	0.75	0.304	0.23	5.6	94.66	0.3	1.3	27	20.1	0.8
	BC2	109-175	5.55	0.08	16.69	2	3.44	0.6	0.27	0.16	4.9	89.94	0.5	1.3	43	16.9	6.2
	$\dot{X}$		**5.57**	**0.12**	**26.70**	**2**	**4.12**	**0.65**	**0.23**	**0.19**	**5.5**	**93.74**	**0.34**	**1.32**	**32.80**	**35.48**	**4.26**
	SD		**0.07**	**0.03**	**7.56**	**1**	**0.57**	**0.09**	**0.06**	**0.03**	**0.5**	**2.16**	**0.09**	**0.66**	**28.60**	**17.26**	**2.40**
	CV		**1.24**	**25.91**	**28.33**	**39**	**13.93**	**13.24**	**24.94**	**16.57**	**9.6**	**2.30**	**26.31**	**49.79**	**87.21**	**48.64**	**56.28**
OMT-04	AP	0-20	5.37	0.17	48.24	3	3.69	0.81	0.19	0.24	5.03	98.01	0.1	2.1	69	49.5	6.5
	Cr1	20-46	5.51	0.14	26.12	2	3.49	0.75	0.18	0.21	4.93	93.91	0.3	0.8	5	14.2	2
	Cr2	46-92	5.54	0.17	13.06	3	3.09	1.00	0.30	0.32	5.02	94.02	0.3	0.9	9	7.5	6.1
	$\dot{X}$		**5.47**	**0.16**	**29.14**	**2**	**3.43**	**0.85**	**0.22**	**0.26**	**4.99**	**95.31**	**0.23**	**1.27**	**27.67**	**23.73**	**4.87**
	SD		**0.09**	**0.02**	**17.79**	**1**	**0.30**	**0.13**	**0.07**	**0.06**	**0.06**	**2.34**	**0.12**	**0.72**	**35.85**	**22.56**	**2.49**
	CV		**1.66**	**10.19**	**61.04**	**27**	**8.90**	**15.68**	**31.52**	**22.15**	**1.11**	**2.45**	**49.49**	**57.11**	**129.58**	**95.08**	**51.18**
OMT-05	Ap	0-32	5.56	0.08	22.49	2	3.34	1.21	0.24	0.26	5.25	96.19	0.2	1.4	7	25.2	8.4
	B1	32-64	5.53	0.11	24.67	2	3.19	0.37	0.30	0.21	4.23	96.45	0.15	0.9	62	79	0.3
	B2	64-89	5.49	0.11	24.67	2	3.59	0.95	0.27	0.16	5.23	95.22	0.25	1.6	77	10.9	7

Bc	89-116	5.34	0.22	21.76	4	3.64	1.00	0.19	0.23	5.25	96.19	0.2	1.1	32	13.3	2.1
BC1	116-147	5.29	0.06	15.60	6	3.19	0.94	0.18	0.27	4.78	95.82	0.2	1.8	74	8.8	4.2
BC2	147-175	5.2	0.06	9.43	2	2.25	0.58f	0.30	0.29	3.61	94.46	0.2	0.9	9	5.2	5.7
Ẋ		**5.40**	**0.11**	**19.77**	**3**	**3.20**	**0.84**	**0.25**	**0.24**	**4.73**	**95.72**	**0.20**	**1.28**	**43.50**	**23.73**	**4.62**
SD		**0.15**	**0.06**	**6.06**	**1**	**0.51**	**0.31**	**0.06**	**0.05**	**0.68**	**0.75**	**0.03**	**0.38**	**31.78**	**27.92**	**3.04**
CV		**2.70**	**58.14**	**30.65**	**49**	**15.81**	**36.62**	**22.41**	**19.94**	**14.35**	**0.79**	**15.81**	**29.33**	**73.05**	**117.62**	**65.92**

Note: Ẋ - Mean; SD – Standard Deviation; CV – Coefficient of variation; TN – Total Nitrogen; Avail P – Available Phosphorus; BS % - Percentage Base Saturation; EA – Exchangeable Acidity.

	pH	Total N	Org. Carbon	Avail P	Ca	Mg	Na	K	ECEC	ECEC/Clay	BS	Acidity	Zn	Fe	Mn	Cu	Sand	Silt	Clay
pH	1.00	0.45*	0.12	-0.06	0.43	-0.45*	0.32	-0.33	-0.01	0.30	-0.11	0.14	-0.27	-0.14	-0.22	0.13	0.03	-0.11	0.07
Total N	0.45*	1.00	0.20	0.12	0.50*	-0.29	-0.08	-0.42	0.10	0.04	0.32	-0.28	-0.01	-0.08	-0.02	-0.14	-0.10	0.01	0.20
Org. Carbon	0.12	0.20	1.00	0.13	0.42	0.02	-0.22	-0.16	0.34	0.10	0.36	-0.23	0.39	0.15	0.55**	0.02	0.14	-0.08	-0.20
Avail P	-0.06	0.12	0.13	1.00	-0.03	0.02	0.16	-0.11	-0.05	-0.22	0.30	-0.33	0.33	0.16	0.27	0.07	-0.17	0.22	0.11
Ca	0.43	0.50*	0.42	-0.03	1.00	-0.39	-0.25	-0.51*	0.49*	-0.10	0.12	0.08	0.30	-0.06	0.22	-0.09	-0.21	0.20	0.21
Mg	-0.45*	-0.29	0.02	0.02	-0.39	1.00	-0.11	0.36	0.59**	0.07	0.27	-0.10	0.18	-0.30	0.19	0.28	0.17	-0.08	-0.27
Na	0.32	-0.08	-0.22	0.16	-0.25	-0.11	1.00	0.11	-0.21	-0.03	-0.18	0.11	-0.34	-0.06	0.13	0.09	-0.14	0.16	0.12
K	-0.33	-0.42	-0.16	-0.11	-0.51*	0.36	0.11	1.00	-0.01	0.12	-0.02	0.03	-0.18	-0.06	-0.09	-0.04	0.18	-0.12	-0.24
ECEC	-0.01	0.10	0.34	-0.05	0.49*	0.59**	-0.21	-0.01	1.00	-0.03	0.22	0.13	0.36	-0.35	0.35	0.20	-0.03	0.12	-0.07
ECEC/Clay	0.30	0.04	0.10	-0.22	-0.10	0.07	-0.03	0.12	-0.03	1.00	0.15	-0.14	-0.24	-0.33	-0.02	0.10	0.86***	0.88***	0.80***
BS	-0.11	0.32	0.36	0.30	0.12	0.27	-0.18	-0.02	0.22	0.15	1.00	-0.94***	0.36	-0.09	0.35	-0.01	0.07	-0.06	-0.08
Acidity	0.14	-0.28	-0.23	-0.33	0.08	-0.10	0.11	0.03	0.13	-0.14	-0.94***	1.00	-0.25	-0.02	-0.24	0.06	-0.07	0.09	0.05
Zn	-0.27	-0.01	0.39	0.33	0.30	0.18	-0.34	-0.18	0.36	-0.24	0.36	-0.25	1.00	0.18	0.34	0.21	-0.10	0.19	0.00
Fe	-0.14	-0.08	0.15	0.16	-0.06	-0.30	-0.06	-0.06	-0.35	-0.33	-0.09	-0.02	0.18	1.00	0.00	-0.20	-0.23	0.22	0.24
Mn	-0.22	-0.02	0.55**	0.27	0.22	0.19	0.13	-0.09	0.35	-0.02	0.35	-0.24	0.34	0.00	1.00	-0.12	0.01	0.11	-0.15
Cu	0.13	-0.14	0.02	0.07	-0.09	0.28	0.09	-0.04	0.20	0.10	-0.01	0.06	0.21	-0.20	-0.12	1.00	0.26	-0.21	-0.30
Sand	0.03	-0.10	0.14	-0.17	-0.21	0.17	-0.14	0.18	-0.03	0.86***	0.07	-0.07	-0.10	-0.23	0.01	0.26	1.00	-0.98***	0.98***
Silt	-0.11	0.01	-0.08	0.22	0.20	-0.08	0.16	-0.12	0.12	-0.88***	-0.06	0.09	0.19	0.22	0.11	-0.21	-0.98***	1.00	0.92***
Clay	0.07	0.20	-0.20	0.11	0.21	-0.27	0.12	-0.24	-0.07	-0.80***	-0.08	0.05	0.00	0.24	-0.15	-0.30	-0.98***	0.92***	1.00

Figure 7 Pearson Correlation Matrix of the Physical and Chemical Properties of the Study Area (2-tailed); White – not significant, Yellow – significant negative, Green – Significant positive (*p<0.05, ** p<0.01, *** p<0.001).

3.4 Taxonomic Classification

The five soil profiles were classified into three USDA soil orders: Alfisols (OMT-01, OMT-03, and OMT-05), Inceptisols (OMT-02), and Entisols (OMT-04). This taxonomic diversity reflects the variable influence of parent material, landscape position, and local hydrological regimes across the study area.

3.4.1 Profile OMT-01: Arenic Haplustalf (USDA) / Lixic Arenosol (WRB) / Ibadan Series (Smyth and Montgomery)

Profile OMT-01 is characterized by a sandy topsoil texture extending past a depth of 50 cm before giving way to a subsoil horizon with increased clay accumulation, meeting the criteria for an argillic horizon under the USDA Soil Taxonomy [23]. High base saturation (> 50%) throughout the profile confirms its placement in the Alfisol

order and the Ustalfs suborder. Due to its sandy surface layer (> 50 cm thick), it classifies at the subgroup level as an Arenic Haplustalf. Under the WRB system [24], it correlates to a Lixic Arenosol (Coarsic) due to its coarse texture and low-activity clays. In the local classification of Smyth and Montgomery [19], it belongs to the Ibadan series, derived from fine-grained biotite gneiss on upper-slope topography.

The sandy upper horizons (arenic qualifier), argillic horizon with high base saturation, and abundant iron concretions (ferric properties) are the principal diagnostic criteria.

3.4.2 Profile OMT-02: Aquic Dystrudept (USDA) / Orthfluvic Fluvisol (WRB) / Jago Series (Smyth and Montgomery)

Profile 2 (Aquic Dystrudept / Orthifluvic Fluvisol, Humic, Oxyaquic / Jago series) has an alluvial origin along local drainage pathways and occupies 9% of the surveyed area. It is characterised by a shallow cambic horizon, periodic waterlogging (aquic conditions) and low base status, requiring artificial drainage management for arable cropping.

3.4.3 Profile OMT-03: Typic Kandiustalf (USDA) / Ferralic Lixisol (WRB) / Mamu Series (Smyth and Montgomery)

Profile 3 (Typic Kandiustalf / Ferralic Lixisol, Saprolithic / Mamu series; 21.45% of the area) is distinguished by a kandic horizon with low-activity kaolinitic clays and low ECEC/clay ratios.

3.4.4 Profile OMT-04: Lithic Usthorthent (USDA) / Skeletic Leptosol (WRB) / Iwaji Series (Smyth and Montgomery)

Profile 4 (Lithic Usthorthent / Skeletic Leptosol, Ochric / Iwaji series; 5.30% of the area) located on upper slope/crest positions; it is the least-developed profile, severely truncated or shallow with a hard bedrock or lithic contact occurring within 50 cm of the surface and absence of distinct pedogenic horizons. Restricted rooting depth limits its utility to forestry or agroforestry.

3.4.5 Profile OMT-05: Inceptic Haplustalf (USDA) / Haplic Lixisol (WRB) / Balogun Series (Smyth and Montgomery)

Profile 5 (Inceptic Haplustalf / Haplic Lixisol, Hypereutric / Balogun series; 16.23% of the area) shows an incipient argillic horizon representing an intermediate stage between Inceptisols and mature Alfisols and high base saturation (> 35%).

These classifications update and refine the legacy series descriptions of Smyth and Montgomery (1962) using current USDA Soil Taxonomy (12th edition) and WRB (2022) criteria, directly addressing the recognised deficiency of modern, internationally comparable soil classification data for this part of southwestern Nigeria (Figure 8).

Table 4: Soil classification of the profiles

Profile	USDA Soil Taxonomy [23]	WRB System [24]	Local Classification [19]	Area coverage	
				(Ha)	(%)
OMT 01	Arenic Haplustalf	Ferric Lixisol (arenic)	Ibadan series	5.71	48.02
OMT 02	Aquic Dystrudept	Orthfluvic Fluvisol (humic, oxyaquic)	Jago series	1.07	9.00
OMT 03	Typic Kandiustalf	Ferralic Lixisol (saprolithic)	Mamu series	2.55	21.45
OMT 04	Lithic Usthorthent	Skeletic Leptosol (ochric)	Iwaji series	0.63	5.30
OMT 05	Inceptic Haplustalf	Haplic Lixisol (hypereutric)	Balogun series	1.93	16.23

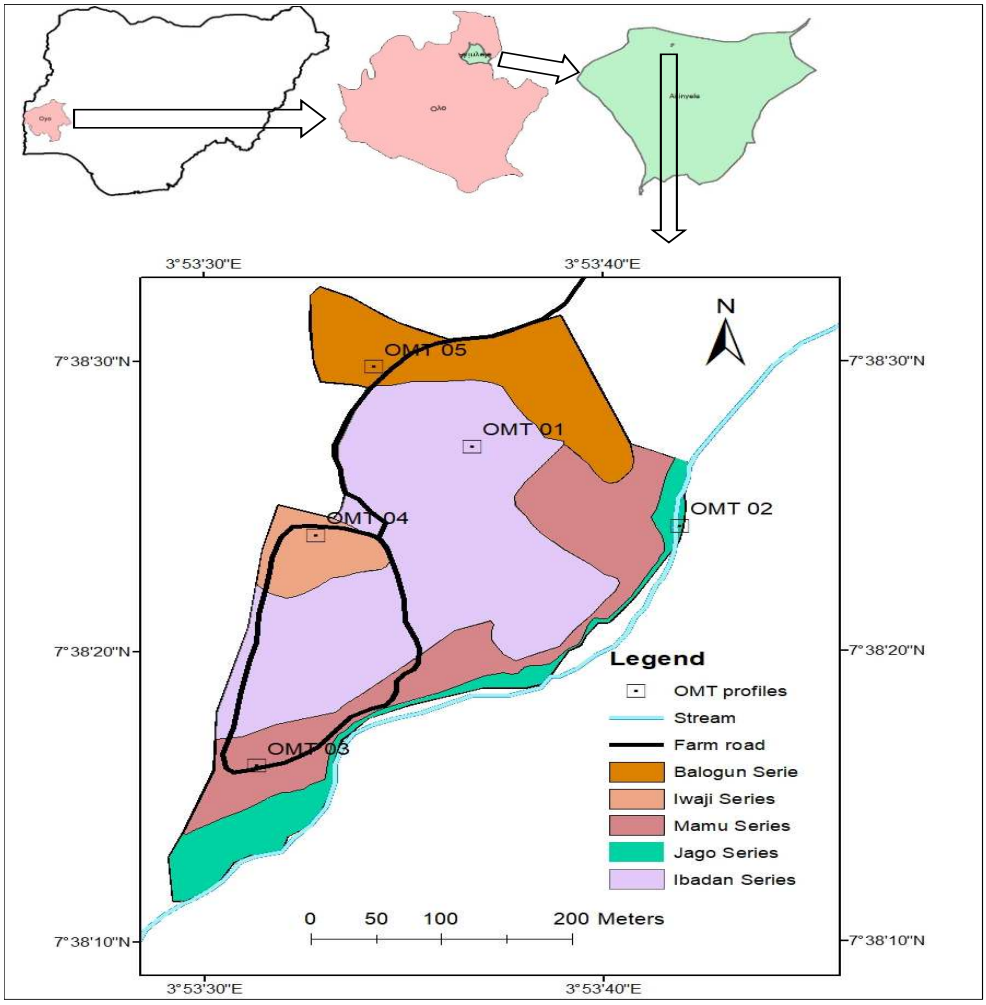


Figure 8 Spatial distribution of soil series across the study area

3.5 Implications for Soil Fertility Management and Land Use

Taken together, the recurring acidity, nutrient scarcity, light texture, and low ECEC across all five profiles underscore how vulnerable these soils are to productivity loss in the absence of active management, offering a plausible explanation for the crop failures and inconsistent yields farmers have reported when applying generic fertiliser guidance drawn from outdated or non-local soil data.

For profile 1 (Ibadan series, 48% of the study area), management should prioritise lime to lift pH above 5.5, organic manure to boost nutrient retention and moisture-holding capacity, and phosphorus fertiliser paired with organic matter to limit fixation losses. Crops tolerant of acidic, low-fertility soils such as cassava (*Manihot esculenta*), cowpea (*Vigna unguiculata*), and sorghum (*Sorghum bicolor*) are well-suited to this series under low-input conditions. For OMT-02 (Jago series), improving drainage is a precondition for arable use; growing rice (*Oryza sativa*) fits current land use well. OMT-04 (Iwaji series), being shallow, stony, and largely undeveloped pedogenically, is better suited to perennial tree crops or agroforestry buffers than arable farming.

Across all profiles, organic matter management through composting, green manuring, cover cropping, and conservation tillage represents the most cost-effective strategy for improving soil quality, as it simultaneously addresses soil pH, ECEC, water-holding capacity, and biological activity [3,70]. This quantitative characterisation gives Akinyele LGA a scientific basis for site-specific fertiliser guidance and land-suitability assessment grounded in its actual soil conditions, an improvement on the broad, regionally averaged recommendations still in use.

CONCLUSION

This study characterized and classified the soils of a 12.5-hectare study area in Olowogbo Village, Akinyele Local Government Area, Ibadan, Nigeria. Five representative profiles were identified and mapped as Ibadan, Jago, Mamu, Iwaji, and Balogun series. Under the USDA Soil Taxonomy, these profiles were classified as *Arenic Haplustalf, Aquic Dystrudept, Typic Kandiustalf, Lithic Usthorthent*, and *Inceptic Haplustalf*, respectively. Under the WRB system, they correspond to *Ferric Lixisol (Arenic), Orthifluvic Fluvisol (Humic, Oxyaquic), Ferralic Lixisol (Saprolithic), Skeletic Leptosol (Ochric),* and *Haplic Lixisol (Hypereutric)*.

The soils are predominantly light-textured, strongly to moderately acidic, and critically deficient in nitrogen, phosphorus, and available potassium, with very low effective cation exchange capacity. These traits track the advanced tropical weathering and low-activity clay mineralogy characteristic of Alfisols and related soils formed on crystalline Basement Complex rock in southwestern Nigeria. The findings confirm that the constraints earlier workers (notably Smyth and Montgomery) documented still hold, while adding an updated, internationally comparable characterisation that this locality previously lacked.

The findings directly address the prevailing problem of inadequate and fragmented soil knowledge in Nigeria, offering profile-level data aligned with current international classification systems. Sustainable management of these soils requires integration of lime application, organic manure, phosphorus fertilisation, appropriate crop selection, and where relevant, drainage improvement. These results provide essential baseline information for soil fertility research, precision agriculture, and evidence-based land use planning in Akinyele Local Government Area and comparable agroecological zones in southwestern Nigeria.

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