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Pedological Characterization and Taxonomic Classification of Soils for Sustainable Agricultural Land Management in Ikere-Ekiti, Southwestern Nigeria

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Abstract

Soil classification and characterization play a critical role in sustainable land management, agriculture, environmental protection research and enriching our ability to use soil resources wisely. This study focused on analyzing and classifying soils from three locations in Ikere Ekiti: Ayewa Farm, Oke-Otin Farm, and Ayodele Farm. Soil samples were excavated from each site to assess their physical, chemical, and morphological properties. The classification followed the Soil Classification Guideline legend. At Ayewa Farm, the soils were identified as Alfisols, Kandiustalf, and Typic Kandiustalf, featuring a well-developed illuvial horizon with significant clay accumulation. Soils at Oke-Otin Farm were classified as Alfisols, Kanhaplustalf, and Typic Kanhaplustalf, also marked by clay-rich horizons. Meanwhile, at Ayodele Farm, the soils were categorized as Alfisols, Kandiudalf, and Avenic Plinthic Kandiudalf, characterized by a thick, dark surface horizon and high base saturation. These findings highlight the diverse soil types across the study area, emphasizing the need for detailed soil profiling to inform land management and use and also a foundation for future soil conservation strategies in the region.

Keywords

Soil Classification, Alfisols, Horizon, Land Management, Soil Conservation

Introduction

Soil characterization and classification are vital components of sustainable agricultural land management, particularly in regions with diverse soil types and environmental conditions, such as southwestern Nigeria. Soil properties directly influence crop production, water management, and soil conservation, making the accurate assessment of soil types essential for optimal land use and long-term agricultural sustainability (1, 2). In areas like Ikere Ekiti, where agriculture is a significant part of the local economy, understanding soil variations is crucial for making informed decisions about land use and resource management (3).

The soils of Ikere Ekiti are influenced by the region's climatic conditions, which include alternating wet and dry seasons typical of the humid tropics. These soils exhibit a range of physical and chemical properties that affect their suitability for different crops. For instance, soil texture, organic matter content, and mineral composition can determine a soil's fertility, moisture retention capacity, and susceptibility to erosion, all of which are critical for crop growth (4). Despite the agricultural potential of these soils, there remains a lack of comprehensive soil data for the region, which hinders effective land management and planning (5, 6).

Soil classification systems, such as the USDA Soil Taxonomy and the World Reference Base for Soil Resources (WRB), are widely used to categorize soils based on their genetic and morphological characteristics (4) (WRB, 2022). These systems provide a structured approach to identifying soil types and understanding their suitability for different agricultural practices. Recent studies have emphasized the importance of soil surveys in southwestern Nigeria, highlighting their role in guiding crop selection, improving soil fertility, and implementing effective conservation strategies (8).

This study aims to characterize and classify the soils of Ikere Ekiti, focusing on three farms: Ayewa Farm, Oke-Otin Farm, and Ayodele Farm. By analyzing the physical, chemical, and morphological properties of these soils, the study seeks to provide a comprehensive understanding of the soil types in the region. This research will inform sustainable land management practices, enhance agricultural productivity, and support soil conservation efforts in the area.

Methodology

Study Area

The study was conducted in Ikere Ekiti, a region located in southwestern Nigeria, characterized by a humid tropical climate. The area experiences distinct wet and dry seasons, impacting soil characteristics that are crucial for agricultural productivity. Ikere Ekiti lies on the Precambrian Basement Complex, contributing to the variability in the region's soil types (9). The study was carried out at three agricultural farms: Ayewa Farm, Oke-Otin Farm, and Ayodele Farm, chosen based on their diverse agricultural practices and land uses.

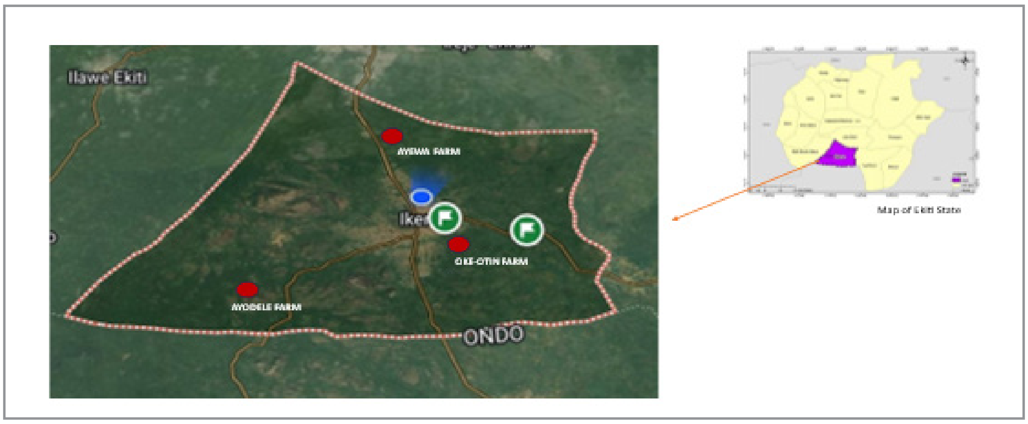

Figure 1: Location Map of the Study Area

Soil Sampling and Analysis

Soil samples were collected through the excavation of profile pits at each site, where a total of three pits were dug at each farm. The excavation depths varied slightly across the sites: Ayewa Farm (1.1 m), Oke-Otin Farm (1.05 m), and Ayodele Farm (1.4 m). Soil samples were taken from distinct horizons identified in each profile, ranging from the surface to the maximum depth of excavation, ensuring the representation of the soil profile's vertical variability (10). The profile pits were carefully described following soil morphological features such as color, horizon structure, texture, and the presence of specific diagnostic horizons like plinthite (4).

The soil samples were air-dried, sieved, and analyzed for both physical and chemical properties. Soil texture was determined by the hydrometer method (11), and bulk density was measured using the core method (12). These properties are vital for understanding water retention capacity and compaction levels, which are key to land management decisions. Soil pH was determined in a 1:1 soil-water suspension (13), organic carbon was measured using the Walkley-Black method (14), and available phosphorus was analyzed using the Bray-1 method (15). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) were extracted with ammonium acetate and analyzed via atomic absorption spectrophotometry.

Soil Classification

Soil classification followed the USDA Soil Taxonomy (2022) framework, where the soils were assigned to appropriate soil orders and suborders based on their physical, chemical, and morphological characteristics. This approach provided a comprehensive understanding of the soil types across the study area and their suitability for agricultural use (4).

Data Analysis

Descriptive statistics were employed to analyze the soil data, including the mean, standard deviation, and range for each of the soil properties. This helped summarize the variability in soil characteristics across the three farms, providing insights into the soil suitability for various agricultural practices.

Results and Discussions

Physical Properties

The physical properties of soils at the three study sites reveal significant variability that influences their agricultural potential (as seen in Table 1). At Ayewa Farm, the profile exhibited predominantly sandy textures (82.5% sand in the A horizon), transitioning to loamy sand and loam at depth. Bulk density ranged from 1.59 to 1.83 g/cm³. The high sand content indicates good drainage but poor water-holding capacity, necessitating organic amendments to improve moisture retention (9, 16). At Oke-Otin Farm, soils were also sandy at the surface (85% sand), with loam appearing deeper (28% clay in the Ei horizon). Bulk density was consistent (1.63-1.77 g/cm³). Poor drainage in lower layers, indicated by mottling, suggests potential waterlogging, which may require drainage improvements (10). The profile at Ayodele farm showed a mix of sand and loam, with higher bulk density (up to 1.95 g/cm³) at depth. While good drainage supports deeper-rooted crops, the dense lower layers may restrict root penetration, suggesting the need for soil loosening.

Table 1: Physical Properties of soils across the study area

Profile	Horizon	Sand (%)	Silt (%)	Clay (%)	Si:Cl	Textural Class	Bulk Density
Ayewa Farm	O	82.2	15.8	2	7.90	Sand	1.59
	A	82.5	14.8	2.7	5.48	Sand	1.75
	Bi	76	16.5	7.5	2.20	Loamy sand	1.59
	Bii	76	9	15	0.60	Loamy sand	1.83
	E	63	9	28	0.32	Loam	1.76
Oke-Otin Farm	O	85	14	1	14.00	Sand	1.7
	A	80.1	16.3	3.6	4.53	Sand	1.63
	Bi	78	6	16	0.38	Loamy sand	1.74
	Bii	61.7	12.3	26	0.47	Loam	1.74
	Ei	57.5	14.5	28	0.52	Loam	1.77
	Eii	57.5	14.5	28	0.52	Loam	1.77
Ayodele Farm	O	83.8	12	4.2	2.86	Sand	1.66
	A	65	29	6	4.83	Loamy sand	1.83
	Bi	69.5	18	12.5	1.44	Loamy sand	1.83
	Bii	59	17.5	23.5	0.74	Loam	1.95
	Ei	61.5	14.5	24	0.60	Loam	1.95

The distribution of the silt–clay (Si:Cl) content across the three soil profiles provides valuable insight into pedogenic processes, structural development, and the functional behaviour of the soils in relation to agricultural use. At Ayewa Farm, the Si:Cl ratio showed a progressive decrease with depth, indicating a gradual enrichment of clay in the subsurface horizons. This pattern aligns with typical eluviation–illuviation processes where fine particles, particularly clay, are translocated downward from the surface horizons (17). The declining ratio suggests increasing clay dominance, which may enhance nutrient retention in deeper horizons but could also lead to reduced permeability with depth, affecting root penetration and aeration.

At Oke-Otin Farm, the Si:Cl trend similarly decreased from the surface horizon down to the Bi horizon, reflecting clay accumulation in the subsurface. However, a slight and statistically insignificant increase in the lower horizon (Eii) suggests minimal reworking of silt content or a weak eluviation zone at depth, possibly influenced by fluctuating moisture regimes. The minor increase may also indicate partial clay removal or slowed illuviation; a behaviour commonly associated with soils experiencing intermittent wetness or seasonal hydrological shifts (10, 18, 19). Despite this slight fluctuation, the overall trend still reflects a predominantly clay-enriched subsoil.

At Ayodele Farm, the surface O horizon exhibited a lower Si:Cl content compared to the overlying A horizon, reflecting limited silt incorporation in the organic-rich layer. From the A horizon onward, the Si:Cl ratio decreased markedly through Bi and Bii horizons, suggesting strong clay accumulation in the subsurface—likely the result of advanced pedogenic differentiation and sustained eluviation processes. In the Ei horizon, the ratio maintained an insignificant difference relative to preceding horizons, implying a stabilized fine-fraction distribution at deeper depth. This stabilization often indicates the lower boundary of active eluviation–illuviation dynamics, marking a zone where clay movement becomes less pronounced (20).

Across the three sites, the consistent downward decrease in Si:Cl ratio underscores the dominance of clay illuviation, a hallmark of Alfisol-like pedogenesis common in humid tropical landscapes. Agriculturally, this vertical redistribution influences soil workability and root exploration: while surface horizons remain favourable for tillage due to higher silt proportions, the increasingly clayey subsoil may impose physical limitations on deep-rooted crops. Incorporating organic amendments and adopting controlled-traffic farming could mitigate compaction and improve structural stability, supporting sustainable land management in Ikere-Ekiti.

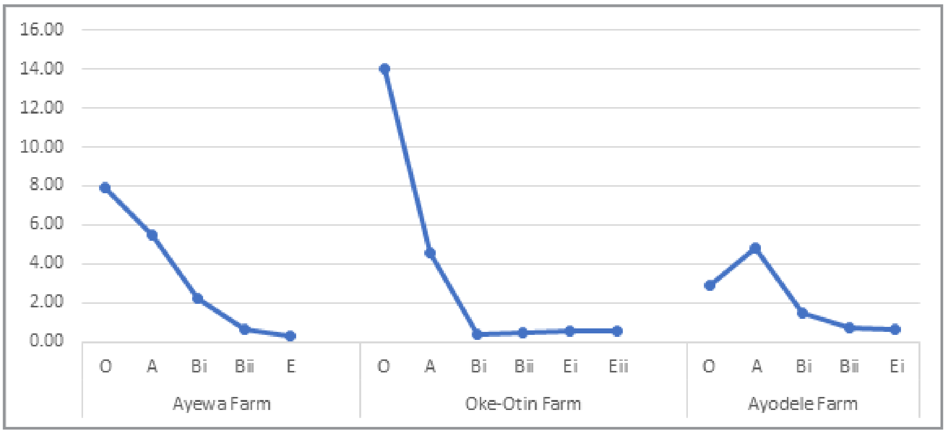

Figure 2: Si:Cl across the study area

Chemical Properties

The chemical properties of soils from Ayewa, Oke-Otin, and Ayodele Farms (as shown in Table 2) revealed distinct characteristics influencing their agricultural suitability. At Ayewa Farm, soil pH ranged from slightly acidic to near-neutral (5.11-6.74) with high base saturation (87-98%), indicating nutrient availability. The cation exchange capacity (CEC) was moderate (3.63-4.19 cmol/kg) across horizons. However, organic carbon content dropped significantly with depth (from 3.1% in the surface to 0.93% in deeper layers), which, along with low levels of exchangeable potassium (K) and magnesium (Mg), suggests a need for nutrient supplementation (Smith et al., 2020; 9). In contrast, Oke-Otin Farm displayed near-neutral pH (6.13-6.85) and high base saturation (88-100%), with CEC ranging from 3.84 to 4.77 cmol/kg. While organic carbon content was low (peaking at 1.25%), available phosphorus levels were higher in surface layers but declined with depth, indicating potential phosphorus limitations for deeper-rooted crops (10, 21).

At Ayodele Farm, the soils were slightly acidic to neutral (pH 6.06-6.96) with consistently high base saturation (89-98%) and moderate CEC values (3.59-4.54 cmol/kg). However, the organic carbon content remained low throughout the profile (max 0.7%), accompanied by low nitrogen and available phosphorus, highlighting a reduced fertility status that may affect crop productivity unless supplemented (22). Overall, while all sites exhibited good nutrient availability due to high base saturation, the low organic carbon and inconsistent phosphorus levels indicate a need for soil amendments, particularly organic matter additions and targeted fertilization, to improve soil fertility and support sustainable agricultural practices (FAO, 2019; 4).

Table 2: Chemical Properties of soils across the study area

PROFILE	HORIZON	pH H20	Ca	Mg	K	Na	H+	C.E.C	C.E.C CLAY	OC	O.M	Total N.	Available P	Base sat.	ESP	Zn	Fe	Mn
			.....[cmol/kg]………..						[%]	[mg/kg]	[%]	[%]						
AYEWA	O	6.05	2.59	0.69	0.35	0.27	0.1	4.01	20	3.1	5.332	0.2	22.2	98	6.92	0.3	0.2	11.1
	A	6.46	2.57	0.66	0.17	0.2	0.1	3.69	13.6	2.82	4.8504	0.15	20	88	5.55	0.1	0.2	10.7
	Bi	6.74	2.56	0.69	0.19	0.12	0.1	3.63	48.4	0.51	0.8772	0.04	8.24	95	3.37	0.1	0.2	5.4
	Bii	5.11	2.67	0.83	0.25	0.14	0.2	4.04	26.9	0.98	1.6856	0.06	9.27	87	3.59	0.1	0.2	7.1
	E	5.38	2.7	0.96	0.25	0.14	0.1	4.19	14.9	0.93	1.5996	0.06	18.7	98	3.45	0.1	0.1	0.501
OKE-OTIN	O	6.13	2.64	0.79	0.33	0.25	0.1	4.12	41.2	1.25	2.15	0.11	22.3	100	6.23	0.4	0.3	11.7
	A	6.29	2.59	0.73	0.25	0.16	0.1	3.84	10.6	1.26	2.1672	0.11	20.6	97	4.28	0.2	0.2	7.6
	Bi	6.36	2.69	0.76	0.29	0.15	0.1	3.98	24.8	0.21	0.3612	0.02	19.9	98	3.85	0.1	0.2	4.4
	Bii	6.61	3.1	0.89	0.66	0.13	0.1	4.77	18.3	0.19	0.3268	0.04	9.18	89	2.71	0.3	1.4	2.1
	Ei	6.85	2.99	0.79	0.66	0.16	0.1	4.67	16.7	0.21	0.3612	0.07	10.64	88	3.47	0.2	0.2	1.3
	Eii	6.85	2.9	0.76	0.65	0.13	0.1	4.6	16.6	0.21	0.3612	0.01	10.71	98	2.92	0.2	0.2	1.2
AYEWA	O	6.96	2.91	0.06	0.33	0.46	0.1	4.42	44.2	0.35	0.602	0.02	20.34	97	12.23	0.4	0.3	20.9
	A	6.23	2.78	0.1	0.25	0.21	0.4	3.9	39	0.16	0.2752	0.01	11.7	89	6.28	0.3	0.6	24.7
	Bi	6.78	2.79	0.07	0.14	0.13	0.1	3.59	17.9	0.46	0.7912	0.02	11.6	88	4.15	0.2	0.5	16.1
	Bii	6.19	2.8	0.1	0.17	0.13	0.1	3.76	47	0.7	1.204	0.03	23.4	98	4.06	0.1	0.4	14.7
	Ei	6.06	2.96	0.11	0.14	0.54	0.1	4.54	19.7	0.7	1.204	0.02	10.7	97	14.4	0.2	0.3	3

Morphological Properties

The soil profiles from Ayewa, Oke-Otin, and Ayodele Farms revealed significant variations in morphological properties that affect their agricultural potential (as presented in Table 3). The profile at Ayewa Farm, extending to 1.1 meters, displayed a dark reddish-brown (2.5YR 4/2) surface horizon with loose consistency, indicating good organic matter content and aeration. However, deeper horizons showed increased stoniness and hardness, which could restrict root growth and water movement. Despite moderate drainage, the hard layers suggest limitations for deep-rooted crops, emphasizing the need for soil loosening practices to enhance root penetration (4). The moderate drainage and compact subsoil suggest suitability for crops like maize, with potential improvements needed for deeper soil management (9).

The profile at Oke-Otin Farm, reaching 1.05 meters, showed a dark yellowish-brown (10YR 4/4) surface with good aeration but transitioned into poorly drained subsurface horizons with frequent mottles, indicating periodic waterlogging. The compacted deeper layers limit water infiltration, making the soil less suitable for crops sensitive to excess moisture (10). Improving drainage through soil amendments could enhance the soil's suitability for agriculture, particularly for crops like cassava that are moderately tolerant of moisture (4, 23).

The deepest profile (1.4 meters) at Ayodele Farm was well-drained, with a pale yellow (2.5Y 7/3) surface horizon. The presence of stony, hard layers at depth indicates advanced soil development with plinthite accumulation, which may limit rooting depth. These soils are ideal for deep-rooted crops but may benefit from organic matter additions to improve nutrient retention (24). The well-drained profile supports crops with deep root systems; however, periodic deep tillage may enhance crop performance (4).

Table 3: Morphological Properties of soils across the study area

Profile	Horizon Designation	Profile Thickness	Slope	Depth [cm]	Colour	Mottles	Stoniness (Abundance)	Soil Water State	Soil Structure	Concretions	Consistences	Root (Abundance)	Drainage	Boundary Form
AYEWA	O	1.1 m	FLAT	0-25	2.5YR 4/2	Few	No stone	Wet	Fine	Few	Dry Loose	Many	FAIRLY DRAINED	Smooth
	A			25-37	7.5YR 5/6	Many	No stone	Wet	Fine	Few	Soft	Common		Smooth
	Bi			37-54	7.5YR 6/6	Few	Fairly stony	Moist	Fine	Common	Slight Hard	Few		Irregular
	Bii			54-73	7.5YR 5/6	Few	Stony	Moist	Coarse	Many	Hard	Few		Wavy
	E			73-110	7.5YR 5/6	Few	Very stony	Moist	Coarse	Many	Very Hard	Very Few		Smooth
OKE-OTIN	O	1.05 m	FLAT	0-21	10YR 4/4	Many	No stone	Wet	Fine	Few	Dry loose	EX. Many	POORLY DRAINED	Wavy
	A			21-30	2.5YR 5/6	Many	No stone	Wet	Fine	Common	Soft	Many		Wavy
	Bi			30-40	10YR 5/4	Common	No stone	Wet	Fine	Few	Soft	Few		Smooth
	Bii			40-60	10YR 5/8	Common	Stony	Moist	Medium	Common	Hard	Few		Irregular
	Eti			60-80	10YR 5/6	Few	Stony	Moist	Coarse	Many	Hard	Few		Irregular
	Etii			80-105	7.5YR 6/8	Few	Very stony	Moist	Coarse	V.Many	V.Hard	V. Few		Wavy
AYODELE	O	1.4 m	FLAT	0-10	2.5Y 7/3	Few	No stone	Dry	Fine	Few	Dry Loose	Few	WELL DRAINED	Wavy
	A			10-35	2.5Y6/4	Few	Stony	Moist	Fine	Common	Hard	Few		Wavy
	Bi			35-65	2.5Y 8/3	Few	Fairly stony	Moist	Coarse	Few	Hard	Few		Irregular
	Bii			65-100	2.5Y 7/4	Few	Fairy stony	Moist	Coarse	Common	V.Hard	Few		Irregular
	E			100-140	2.5Y 8/4	Many	Very stony	Dry	Coarse	Many	V.Hard	V.Few		Wavy

Characterization and Classification

The classification results provided in Table 4 below represents the soil taxonomy of three study locations, and they are classified according to the USDA Soil Taxonomy system (2022).

The soil at Ayewa Farm is classified as Typic Kandiustalf under the Alfisol order, characterized by a well-developed argillic horizon and typical of humid tropical regions with moderate weathering and clay illuviation (4). This classification indicates well-drained soils with moderate acidity, commonly found in areas with seasonal moisture fluctuations. Although such soils are generally suitable for agriculture, they can be prone to nutrient leaching, requiring proper soil management practices like the application of organic matter and fertilizers to maintain soil fertility (4, 9). Therefore, Ayewa Farm's soil is conducive to farming, but fertility management is necessary to avoid long-term nutrient depletion, which can limit crop productivity.

The soil at Oke Otin Farm is classified as Typic Kanhaplustalf, a subgroup of Alfisol, and is characterized by strong leaching, low pH, and nutrient depletion due to its well-drained conditions (4, 6). This type of soil is highly acidic and often low in essential nutrients, making it less suitable for crops unless amended (6, 23). Given these conditions, soil management practices, such as the application of lime to reduce acidity and the addition of organic fertilizers to replenish nutrients, are essential for maintaining agricultural productivity (4). Thus, while the soil at Oke Otin Farm can support agriculture, it requires significant amendments and management interventions to optimize soil fertility and ensure sustainable farming practices.

The soil at Ayodele Farm is classified as Avenic Plinthic Kandiudalf, part of the Alfisol order, and features a shallow surface horizon with a plinthic horizon that restricts water movement and root growth (FAO, 2019). The plinthic horizon, which consists of hard, iron-rich layers, leads to poor drainage and fluctuating moisture conditions, which are detrimental to crop growth. This makes the soil more challenging for agricultural use, particularly in wet seasons when water infiltration is limited. To improve its suitability for agriculture, interventions such as deep tillage to break the plinthic layer and enhance root penetration, along with improved drainage systems, are necessary (4, 23). Therefore, while the soil at Ayodele Farm can support crops under certain conditions, its potential can be significantly improved with targeted soil management techniques.

Table 4: Soil classification and characterization across the study area following USDA (2022)

STUDY LOCATIONS	ORDER	SUB ORDER	GREAT GROUP
Ayewa Farm	Alfisol	Kandiustalf	Typic Kandiustalf
Oke Otin Farm	Alfisol	Kanhaplustalf	Typic Kanhaplustalf
Ayodele Farm	Alfisol	Kandiudalf	Avenic Plinthic Kandiudalf

Conclusion and Recommendations

The soil characterization and classification in Ikere Ekiti revealed that all study locations belong to the Alfisol order, with variations in suborders and great groups reflecting differences in drainage, nutrient levels, and soil management needs. Ayewa Farm, classified as Typic Kandiustalf, exhibits moderate fertility and drainage, requiring nutrient management to sustain productivity. Oke Otin Farm, with its Typic Kanhaplustalf soils, is highly acidic and nutrient-depleted, necessitating lime application and organic amendments to improve fertility. The Avenic Plinthic Kandiudalf at Ayodele Farm indicates poor drainage and root restriction due to plinthic horizons, demanding deep tillage and improved drainage. To optimize agricultural productivity, site-specific soil management practices are crucial. It is recommended that farmers implement nutrient management and soil amendment strategies, especially lime application in acidic soils, along with enhancing drainage where plinthic layers are present. Conservation practices, like crop rotation and cover cropping, will support long-term soil health, while future studies should explore precision agriculture and digital soil mapping to enhance sustainable land use.

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