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Research Article

Comparative Analysis of Soil Physical Properties under Cultivated Vegetation in Ogun State

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Abstract
Soil physical quality is an important component of land productivity and environmental stability. This study compares selected physical properties of topsoil (0–10 cm) under cassava cultivation, vegetable cultivation, and natural vegetation in Obafemi Owode Local Government Area, Ogun State, Nigeria. Fifteen samples were collected, comprising five samples from each land-use category, and analyzed for sand, silt, clay, bulk density, water-holding capacity, total porosity, natural water content, and specific gravity. Descriptive statistics and property-specific inferential tests were used rather than pooling the eight soil properties into a single score. One-way analysis of variance with Tukey's HSD post-hoc comparison was used for the three land-use groups, while independent-samples t-tests were used for the cassava-versus-vegetable comparison and for cultivated (cassava + vegetable) versus natural-vegetation soils. Because of the small sample size, Kruskal–Wallis tests were also used as a robustness check. The soils were predominantly sandy loam. The reanalysis indicates that clay content, reported total porosity, and natural water content differed among land uses, with cassava soils generally having higher clay, porosity, and water content than vegetable and natural-vegetation soils. The cassava-versus-vegetable comparison was significant for clay, total porosity and natural water content. By contrast, the cultivated-versus-natural-vegetation comparison showed no significant difference in bulk density, water-holding capacity, reported porosity, natural water content, sand, silt or specific gravity, although clay content differed significantly. A data-consistency check also identified a material discrepancy between reported porosity and porosity recalculated from bulk and particle density. Consequently, conclusions about soil physical quality and cultivation effects should remain cautious until the original laboratory records are used to verify the porosity values and the status and land-use history of the control sites. The findings provide a more defensible basis for interpreting soil physical conditions in the study area.

Keywords

Soil physical properties; cultivated land; natural vegetation; bulk density; porosity; land use; Ogun State

Introduction

1. Introduction

Soils are essential to terrestrial life. They provide vital ecosystem services that sustain agricultural production, biodiversity, and environmental quality as the interface between the lithosphere, atmosphere, hydrosphere, and

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biosphere. Soils provide plants with air, water, temperature regulation, nutrients, and protection from toxins in agricultural settings. Soils sustain ecosystem fertility and productivity by turning plant and animal wastes into plant-available nutrients (Ogunwole et al., 2019).

Cultivation can alter soil physical conditions through tillage, traffic, residue removal, repeated harvesting and changes in organic-matter inputs. These processes may increase bulk density, reduce pore space and modify water retention. However, the direction and magnitude of change are not uniform: management intensity, soil texture, parent material, cropping history and conservation practices can moderate or even reverse the expected pattern. Recent studies in Nigeria illustrate this variability. Ojo et al. (2022) found measurable differences in soil quality among land-use types in Ibadan, while a 2024 study in Ebonyi State reported that land-management systems significantly influenced bulk density, hydraulic conductivity and aggregate stability. Research in Ogun State has also shown that soil physical properties vary across contrasting land-use settings (Ganiyu et al., 2025).

Against this background, a comparison of cultivated and natural-vegetation soils in Obafemi Owode LGA is useful because local evidence is needed to determine whether the general pattern reported elsewhere is reproduced in this landscape. The scientific value of the study therefore lies less in establishing that land-use studies are absent from southwestern Nigeria and more in testing whether the expected cultivation-related changes are detectable in this specific setting.

An additional consideration is the interpretation of the control sites. The original manuscript labels them “uncultivated” and “natural vegetation”, but the land-use history of those sites was not documented. A control that is actually long-fallow or recently abandoned farmland may not represent natural vegetation in the strict sense. This distinction is essential when attributing observed differences to cultivation.

2. Literature Review

Soil physical qualities are extremely important for crop productivity. Texture, bulk density, porosity, and moisture retention affect water infiltration, aeration, drainage, and root penetration (Akinola et al., 2021). These traits affect how soils respond to rainfall and cultivation and how they support different crops under different land-use regimes. Physical property changes can have major effects on sustainable crop production in intensively cultivated soils like cassava and vegetable farms in Obafemi Owode LGA, Ogun State. Understanding soil physical characteristics is essential for soil fertility and agricultural output. Compaction, crusting, and inadequate water-holding capacity can limit crop development and production even with adequate chemical fertilization. Conversely, good soil physical properties improve root development, nutrient usage efficiency, and climate resistance (Osunde et al., 2019).

Cassava (Manihot esculenta) and Amaranthus cruentus (African Spinach) dominate smallholder farming in Obafemi Owode LGA. Both crops depend on soil structure. Vegetables develop quickly in soils with good tilth, aeration, and moisture retention, but cassava needs friable soils with low bulk density for root expansion and tuber bulking (Ezui et al., 2017). In southwestern Nigeria, persistent cultivation of these crops increases bulk density and decreases porosity compared to neighbouring natural vegetation or fallow fields (Oke et al., 2020).

This study is justified by three primary points. First, Obafemi Owode LGA is emblematic of the derived savanna agroecology where land demand is growing, but site-specific soil physical quality study is sparse. Second, comparing cultivated and natural vegetation soils reveals structural degradation and its effects on sustainable land management. Third, correlating these physical features to crop production requirements gives farmers, extension workers, and policymakers’ actionable knowledge to improve soil stewardship and assure long-term productivity.

Numerous studies in Nigeria have revealed that land-use practices can significantly influence soil physical quality. In Odeda Local Government Area of Ogun State, Alabi et al. (2019) reported variations in soil properties under different land-use systems, demonstrating the influence of land use on soil characteristics. Cultivated soils in Odeda LGA, which is similar to Obafemi Owode, had higher bulk density and lower porosity than natural soils (Oke et al., 2020). Due to frequent tillage, farm machinery, and decreasing organic matter inputs, aggregates changed. Water-holding capacity and nutrient retention depend on texture, which is influenced by sand, silt, and clay proportions. Texture does not vary with cultivation, but functional expression can. Continuous farming causes sandy soils to build crusts, reducing infiltration and increasing runoff (Ogunwole et al., 2019). Organic residue-enriched natural vegetation soils had improved structure, infiltration, and aggregate stability (Akinola et al., 2021).

Similarly, Akinde et al. (2020) observed that continuous cultivation in Ile-Ife was associated with higher soil bulk density and reduced soil quality compared with some other land-use systems. Ogban and Ibitt (2018) also found significant differences in soil physical and hydrological properties among forest, fallow and cultivated lands in Akwa Ibom State. These findings suggest that agricultural activities and land-management practices can alter soil structure, compaction, water movement and other physical properties, with implications for long-term soil productivity and sustainable agricultural production.

Soil compaction, measured by bulk density, affects root penetration and porosity. Cultivated soils with high bulk density hinder root growth, aeration, and water infiltration. High bulk density harms cassava, which has bulky storage roots (Ezui et al., 2017). Root exploration is limited on compacted soils, stunting vegetable development. Uncultivated soils with more organic matter have lower bulk density and better porosity and root penetration (Lawal, Akinola, & Olabode, 2021).

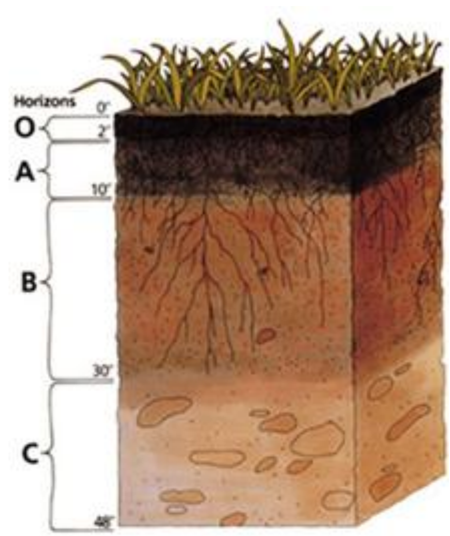

Figure 1: *Darkened topsoil and reddish subsoil [layers](#) are typical in [some regions.](#)*

Moisture and porosity are related. Porous soils store and move air and water. Studies in southwestern Nigeria demonstrate that cultivated soils have lower overall porosity and water-holding capacity, exposing crops to drought stress (Fashola, Lawal, & Olaniyan, 2019). The protective impact of litter cover and constant organic matter intake keeps natural vegetation soils more porous and wet. These discrepancies show how agriculture affects crop resilience and soil hydrology.

Soils decompose toxins, destroy disease agents, and eliminate impurities. Clay and humus help soils retain plant-accessible minerals. The general soil composition is 50% solids (45% mineral stuff and 5% organic matter) and 50% pore space, half of which is air and half water, for optimal plant growth. Soil structure is important because pore distribution controls air and water infiltration and movement, two critical aspects of soil life. Biochemical influences on soil qualities are largest near the surface, while geochemical affects increase with depth. In temperate climates, soils have three master horizons (A, B, and C), with the living component mostly in A and B (UCC, 2012). In tropical areas like southwestern Nigeria, severe weathering and biological activity can thin profiles to a single horizon.

Comparative studies of cultivated and uncultivated soils emphasize differences in soil physical properties. In southwestern Nigeria, soils under arable agriculture have higher bulk density (1.55 gcm^{-3}) than soils under forest vegetation (1.25 gcm^{-3}), according to Akinola et al. (2021). Cultivated soils have far lower overall porosity, limiting water retention and transmission. Due to surface crusting and limited penetration, Oke et al. (2020) discovered that cultivated soils had lower moisture content than natural vegetation soils.

These findings match global soil physical process understandings. Due to reduced porosity, farming disrupts this balance, denying crops air and water. Natural vegetation systems have stronger biological influences on soil qualities, such as roots and soil fauna that form pores, while continual farming reduces them (UCC, 2012). Soil structure changes due to cultivation effect long-term productivity. Cassava harvesting uproots plants, disturbing soil aggregates and accelerating erosion. Infiltration decreases as compaction increases (Lawal et al., 2021). For seedbed preparation, vegetable production requires periodic ploughing, which loosens the soil but compacts and loses organic matter (Ezekiel et al., 2020). Three primary patterns emerge from empirical studies. Initially, developed soils in southwestern

Nigeria consistently demonstrate elevated bulk density and decreased porosity relative to soils under natural vegetation. The moisture retention capacity in cultivated soils is markedly diminished, hence increasing the vulnerability of crops to drought. The physical demands of cassava and vegetables frequently surpass the capabilities of degraded agricultural soils, elucidating yield disparities in smallholder systems. These tendencies warrant a comparison analysis in Obafemi Owode LGA, where cassava and vegetables predominate in the agricultural landscape.

Materials and methods

2.1 Study Area

The study was conducted in Obafemi Owode Local Government Area of Ogun State, Nigeria. The study identified cassava farms, vegetable farms and areas described as uncultivated natural vegetation as the three land-use categories. This study analyses the physical qualities of soils beneath farmed land (cassava and vegetables) and wild vegetation in Obafemi Owode LGA, Ogun State, Nigeria, using field and laboratory methods. The methodology examined soil texture, bulk density, porosity, water-holding capacity, moisture content, and specific gravity to meet the research goals.

2.2 Sampling Design and Sample Collection

Fifteen (15) topsoil samples were collected from three land-use categories: five from cassava farms, five from vegetable farms and five from natural-vegetation sites. Sampling depth was 0–10 cm. Disturbed samples were air-dried, gently crushed and passed through a 2-mm sieve before laboratory analysis. Random sampling was used to reduce selection bias and represent soil heterogeneity.

2.3 Laboratory Analysis

Bulk density was evaluated with core samples dried at 105 °C (Campbell & Henshall, 1991), and porosity from bulk and particle density. Water-holding capacity and natural water content were assessed gravimetrically by saturation and oven-drying. Pycnometers measured specific gravity (Blake & Hartge, 1986).

2.4 Statistical Analysis

Each soil property was treated as a separate response variable; the eight properties were not pooled because they have different units and are not commensurable measurements. Means and standard deviations were calculated for each land-use group. One-way ANOVA was used to compare cassava, vegetable and natural-vegetation soils, with Tukey's HSD used for post-hoc comparisons. Independent-samples t-tests were used for the two-group cassava-versus-vegetable comparison and for cultivated (cassava + vegetable) versus natural-vegetation soils. Because $n = 5$ per land-use group is small, Shapiro - Wilk and Levene tests were examined as assumption diagnostics, and Kruskal–Wallis tests were used as non-parametric robustness checks. Effect sizes are reported using eta-squared for the three-group comparison and Cohen's d for two-group comparisons.

Results

3.1 Descriptive Statistics and Soil Texture in Obafemi Owode Local Government Area of Ogun State, Nigeria.

The descriptive statistics show that sand was the dominant fraction in all three land-use categories. Mean sand content was 75.0% under cassava, 77.0% under vegetables and 78.4% under natural vegetation. Mean clay content was 14.0%, 9.6% and 8.8%, respectively. Using these particle-size distributions, all three group means fall within the sandy-loam textural class. Thus, the soils were texturally similar at the group level, although clay content was higher under cassava.

Table 1: *Physical Properties in the Study Area*

Land use	Sand (%)	Silt (%)	Clay (%)	Bulk density (g cm⁻³)	WHC (%)	Porosity (%)	Water content (%)	Specific gravity
Cassava	75.0 ± 4.3	11.0 ± 3.4	14.0 ± 2.4	1.892 ± 0.046	35.0 ± 6.9	21.34 ± 2.15	10.26 ± 1.35	2.652 ± 0.008
Vegetable	77.0 ± 2.1	13.4 ± 2.1	9.6 ± 1.8	1.917 ± 0.012	30.4 ± 4.0	15.40 ± 2.31	6.88 ± 1.22	2.658 ± 0.004
Natural vegetation	78.4 ± 3.9	12.8 ± 4.2	8.8 ± 1.1	1.933 ± 0.050	27.9 ± 6.9	15.39 ± 3.11	6.92 ± 1.67	2.648 ± 0.013

Source: *(Laboratory Analysis) Summary of Physical Properties of Soil (Test Results).*

Note. Values are mean ± SD (n = 5). The porosity column reproduces the reported Table 1 porosity values after converting the fractions to percentages; these values require laboratory verification, as discussed in Section 3.5.

3.2 Differences in soil physical properties between cassava and vegetables cultivated farmlands in Obafemi Owode Local Government Area of Ogun State, Nigeria.

Table 2: *T-Test Statistics for Physical Properties of Farmland*

Property	T	p	Cohen's d	Decision
Sand	-0.93	0.378	-0.59	Not significant
Silt	-1.35	0.214	-0.85	Not significant
Clay	3.23	0.012	2.04	Significant
Bulk density	-1.15	0.282	-0.73	Not significant
WHC	1.29	0.234	0.81	Not significant
Porosity	4.21	0.003	2.66	Significant
Water content	4.16	0.003	2.63	Significant
Specific gravity	-1.41	0.195	-0.89	Not significant

The property-specific t-tests show that cassava and vegetable soils were not statistically different for sand, silt, bulk density, water-holding capacity or specific gravity. However, significant differences were detected for clay ($t = 3.23$, $df = 8$, $p = .012$), reported total porosity ($t = 4.21$, $df = 8$, $p = .003$) and natural water content ($t = 4.16$, $df = 8$, $p = .003$). Cassava soils had higher means for all three variables.

3.3 Three-Group Comparison

One-way ANOVA identified significant land-use effects for clay content, reported total porosity and natural water content. Clay content produced $F(2,12) = 11.20$, $p = .002$, $eta^2 = .651$; reported total porosity produced $F(2,12) = 9.03$, $p = .004$, $eta^2 = .601$; and natural water content produced $F(2,12) = 9.26$, $p = .004$, $eta^2 = .607$. Sand, silt, bulk density, water-holding capacity and specific gravity were not significant at $\alpha = .05$.

Table 3: Three-Group Comparison

Property	F(2,12)	ANOVA p	Kruskal–Wallis p	Eta²
Sand	1.14	0.351	0.347	0.160
Silt	0.70	0.516	0.539	0.104
Clay	11.20	0.002	0.009	0.651
Bulk density	1.37	0.291	0.310	0.186
WHC	1.77	0.213	0.242	0.227
Porosity	9.03	0.004	0.009	0.601
Water content	9.26	0.004	0.011	0.607
Specific gravity	1.46	0.270	0.285	0.196

The results support the principal ANOVA findings: clay (Kruskal–Wallis $H = 9.48$, $p = .009$), reported porosity ($H = 9.41$, $p = .009$) and natural water content ($H = 9.05$, $p = .011$) remained significant.

3.4 Cultivated Versus Natural-Vegetation Soils

When cassava and vegetable samples were combined to represent cultivated land and compared with natural-vegetation sites, only clay content differed significantly (Welch $t = 2.75$, $p = .017$; Cohen's $d = 1.14$). The cultivated mean clay content was 11.8%, compared with 8.8% under natural vegetation. Differences in sand, silt, bulk density, water-holding capacity, reported porosity, natural water content and specific gravity were not statistically significant at the 5% level. These results indicate that the evidence for a broad cultivation effect is mixed rather than uniformly null.

Table 4: *Cultivated Versus Natural-Vegetation Soils*

Property	Welch t	p	Cohen's d	Decision
Sand	-1.17	0.279	-0.68	Not significant
Silt	-0.29	0.784	-0.18	Not significant
Clay	2.75	0.017	1.14	Significant
Bulk density	-1.18	0.284	-0.73	Not significant
WHC	1.35	0.220	0.78	Not significant

Property	Welch t	p	Cohen's d	Decision
Porosity	1.63	0.136	0.83	Not significant
Water content	1.63	0.133	0.82	Not significant
Specific gravity	1.12	0.311	0.75	Not significant

3.5 Data-Consistency and Plausibility Checks

The cassava bulk-density total was 7.608; the vegetable porosity total was 0.6035; and the natural-vegetation silt mean was 12.80%, The Table 1 means were 21.34%, 15.40% and 15.39%, respectively. Bulk density values range from 1.852 to 1.972 g cm⁻³, which are high for many agricultural topsoil's. Because the same high values occur in the natural-vegetation samples.

Discussion

The strongest contrast occurs between cassava and vegetable soils for clay, reported porosity and natural water content. Cassava soils have higher mean clay content (14.0%) than vegetable soils (9.6%), together with higher reported porosity (21.34% versus 15.40%) and natural water content (10.26% versus 6.88%). The pattern is therefore not adequately described as "no effect of crop type". At the same time, bulk density and water-holding capacity do not differ significantly between the two crop systems. The observed pattern may reflect differences in site characteristics, management history or sampling locations rather than a direct causal effect of crop identity.

An important and initially counterintuitive pattern is that the mean bulk density increases from cassava (1.892 g cm^{-3}) to vegetable (1.917 g cm^{-3}) to natural vegetation (1.933 g cm^{-3}), while reported water-holding capacity decreases from cassava (35.02%) to vegetable (30.42%) to natural vegetation (27.88%). This is opposite to the common expectation that natural vegetation will have lower bulk density and greater pore space. More plausibly, it signals the need to establish whether the natural-vegetation sites are genuinely undisturbed, whether their land-use history differs from the farms, and whether spatial variation or parent material explains the pattern.

The cultivated-versus-natural-vegetation comparison provides a more cautious result. Clay content is significantly higher in cultivated soils, but the other measured properties do not differ significantly. This may indicate that the selected topsoil layer does not capture the full structural response to cultivation. Tillage-related compaction can occur below the sampled 0–10 cm layer, so sampling only the surface layer limits the study's ability to assess subsurface compaction. Future sampling should extend at least into the 10–30 cm layer, the objective is to evaluate plough-pan or subsoil effects.

The findings are broadly consistent with recent Nigerian literature in showing that land-use effects on soil quality can be property-specific and context-dependent. Ojo et al. (2022) reported differences in soil-quality indicators among land uses in Ibadan, while Ugbaja et al. (2024) found significant land-management effects on several soil physical indicators in Ebonyi State. Ganiyu et al. (2025) further demonstrated variation in soil physical properties across land-use patterns in Ogun State. These studies support a cautious interpretation rather than a universal assumption that every cultivated site must be more compacted than every natural-vegetation site.

Conclusions

This study demonstrates that the soil physical properties examined in Obafemi Owode LGA do not respond uniformly to land use. The soils are predominantly sandy loam, but significant differences occur in clay content, reported total porosity and natural water content among the three land-use groups. Cassava and vegetable soils differ significantly in these properties, whereas the broader cultivated-versus-natural-vegetation comparison shows a significant difference only in clay content.

Limitations

Only fifteen (15) samples were available (five per land-use category), limiting statistical power and the generalizability of the findings.

Sampling was restricted to 0–10 cm, which may miss subsurface compaction and plough-pan development commonly associated with cultivation.

Organic matter, aggregate stability, hydraulic conductivity and other mechanistic indicators were not measured.

Land-use history, duration of cultivation, tillage intensity, residue management and the fallow history of the natural-vegetation sites were not documented in the source manuscript.

Yield data were not collected; therefore, statements about crop productivity or yield improvement cannot be directly supported.

The reported porosity values are inconsistent with porosity calculated from the reported bulk density and specific gravity and must be verified from the laboratory records.

The correlation and remote-sensing analyses, and corresponding results were not reported.

Recommendations

Repeat or extend sampling into the 10–30 cm layer in future studies to assess subsurface compaction and possible plough-pan development.

Document the land-use history of every sampling site, including years under cultivation, tillage practice, residue management and the age of any fallow period.

Include organic matter, aggregate stability and hydraulic conductivity in future studies to strengthen the mechanistic interpretation of soil physical quality.

Use property-specific statistical analysis in future studies and report means, standard deviations, test statistics, p-values, effect sizes and assumption diagnostics.

Maintain residue incorporation, mulching, crop rotation and reduced-tillage practices where appropriate, but frame these as soil-conservation recommendations rather than as proven effects of the present dataset.

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