NJSS 35(2) 2026: 37-41 DOI: 10.67042/njss.2026.xxxxxxxxx

Nigerian Journal of Soil Science

Original Research

# Soil Physical Properties under Organic and Conventional Farming Systems in a Humid Tropical Environment

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**Keywords:**
aggregate stability, bulk density, humid tropics, organic farming, soil physical properties

**Manuscript History:**
Submitted: 01st March 2026
Accepted: 19th September 2026
Published:



## Abstract

Soil physical degradation remains one of the major constraints to sustainable agricultural productivity in humid tropical regions, where intensive conventional farming practice is one of the key factors that affects soil compaction and structural. It became necessary to study the effect of organic and conventional farming system on the soil properties of the Rivers State Teaching and Research Farm. This study evaluated the influence of organic farming practice on selected soil physical properties at the Rivers University Teaching and Research Farm, southern Nigeria. A randomized complete block design was used to compare organically and conventionally managed plots in three replicates. Composted materials and natural soil amendments without synthetic agro-chemicals were used for the organic farming practice while the plots were managed with the use of inorganic fertilizers and standard agronomic practices for conventional farming system. Soil samples were collected at 0–20 cm depth and analyzed for bulk density, total porosity, moisture contents, infiltration rate, aggregate stability, and texture using standard methods. Crop rotation was practiced on the organic plots to enhance soil fertility and reduce pest and disease incidence. Rotational sequences included cereal crops, legumes, and vegetables to promote nutrient balance and biological diversity. Results showed that organic farming significantly reduced soil bulk density and increased total porosity, moisture content, infiltration rate, and aggregate stability compared to conventional farming ($p \leq 0.05$). Improvements were attributed to continuous organic matter inputs and enhanced soil structural development. The findings demonstrate that organic farming practices may improve selected indicators of soil physical quality.

## 1. Introduction

The physical properties of soil play a critical role in determining soil productivity, water movement, aeration, root development and also play a major role in the sustainable productivity of the soil (Abebaw *et al.*, 2025). In tropical agricultural systems, soils are often subjected to intensive cultivation, high rainfall, and rapid organic matter decomposition, which collectively contribute to soil compaction, structural breakdown, and erosion (Qaswar *et al.*, 2020). Conventional farming systems that rely heavily on mineral fertilizers and frequent tillage have been widely associated with long-term deterioration of soil physical condition (Bronick and Lal, 2005).

Organic farming has emerged as a sustainable alternative that emphasizes the use of organic amendments, crop residue retention, crop rotation, and reduced dependence on synthetic inputs (Sonderegger and Pfister, 2021). Organic farming offers a wide range of benefits encompassing environmental preservation, social equity, and economic stability (Dadhick *et al.*, 2025). These practices are expected to improve soil physical properties by increasing soil organic matter content, enhancing aggregation, and promoting biological activity. Improved soil structure under organic management has been linked to better water infiltration, increased moisture retention, and reduced susceptibility to erosion (Lal, 2015).

Despite growing interest in organic agriculture, most studies on its effects on soil physical properties have been conducted in temperate regions. Although, organic farming has been investigated extensively in tropical humid environments, evidence from the specific location about the soil mineralogy, organic matter dynamics and response to management practices in limited. Therefore, there is need for region-specific field studies that evaluate the physical soil benefits of organic farming under tropical conditions.

This study aims to assess the influence of organic farming practices on selected soil physical properties under humid tropical conditions. Specifically, the study compared soil bulk density, porosity, moisture content, infiltration rate, and aggregate stability between organic and conventional farming systems.

## 2 Materials and Methods

### 2.1 Study Area

The study was conducted at the Rivers University Teaching and Research Farm located in Port Harcourt, southern Nigeria on the latitude of 4° 49′ 27″ N, and longitude of 7° 2′ 1″ E. The area lies within the humid tropical rainforest zone, characterized by high annual rainfall exceeding 2,000 mm and mean annual temperatures ranging from 25 to 30 °C. The soils are predominantly sandy loam to loamy sand, highly weathered, and prone to structural degradation under intensive cultivation.

### 2.2 Experimental Design and Plot Management

A randomized complete block design was employed with two treatments: organic farming and conventional farming. For the organic farming system, the plots were managed using composted materials and natural soil amendments without synthetic agro-chemicals while the plots were managed with the use of inorganic fertilizers and standard agronomic practices for conventional farming system. Each treatment was replicated three times. Individual plots measured 10 m × 10 m and were separated by buffer zones to prevent cross-contamination.

Organic plots received composted plant residues and animal manure, practiced crop residue retention and reduced tillage, and received no synthetic fertilizers or pesticides. Conventional plots were managed using inorganic fertilizers and standard agronomic practices commonly adopted on the farm.

### 2.3 Application of Organic Amendments

The compost consisted mainly of decomposed plant residues, crop wastes, and organic household materials, while the animal manure was primarily poultry and cattle manure that had undergone adequate composting to reduce pathogen load and stabilize nutrients. Organic amendments were applied uniformly to the organic plots at agronomically recommended rates prior to planting and were incorporated lightly into the topsoil to enhance nutrient availability and reduce nutrient losses (Lori *et al.*, 2017). Leguminous cover crops were grown during the off-season and incorporated into the soil at the vegetative stage. Crop residues from previous harvests were retained on the soil surface or incorporated into the soil rather than removed or burned. In addition, organic mulch materials such as dried grasses and crop residues were applied to the soil surface.

### 2.4 Soil Sampling

Soil samples were collected at a depth of 0 - 20 cm using a soil auger. A stratified random sampling technique was employed to account for spatial variability. Each plot was subdivided into equal sections, and sampling points were randomly selected within these sections. A total of five soil cores were collected per plot using a hand-held soil auger. The cores from each plot were thoroughly mixed in a clean container to form a composite soil sample, which represented the average soil condition of that plot. Undisturbed core samples were collected separately for bulk density determination.

### 2.5 Determination of Soil Physical Properties

Bulk density was determined using the core method and calculated as the ratio of oven-dry soil mass to core volume. The bulk density was derived using the following;

$$\text{Bulk Density (g cm}^{-3}) = \frac{W_d}{V} \quad (1)$$

where:
$W_d$ = oven-dry weight of soil (g)
V = volume of the core sampler (cm³)

The total porosity was calculated from bulk and particle density. The soil particle density was calculated using;

$$\text{Particle density} = \frac{W_s}{V_w - V_{sw}} \quad (2)$$

where:
$W_s$ = weight of oven-dried soil (g)
$V_w$ = volume of water in the pycnometer (cm³)
$V_{sw}$ = volume of water in the pycnometer after adding the soil sample (cm³)

A typical particle density value for mineral soils is approximately 2.65 g cm⁻³.

Total soil porosity was calculated from bulk density and particle density values using the relationship:

$$\text{Total Porosity} = \left(1 - \frac{Bulk\ Density}{Particle\ Density}\right) \times 100 \quad (3)$$

Soil moisture content was determined using the gravimetric method. Fresh soil samples were weighed, oven-dried at 105 °C for 24 hours, and reweighed. Soil moisture content was calculated as:

$$\text{Moisture Content (\%)} = \frac{W_f - W_d}{W_d} \times 100 \quad (4)$$

where:
$W_f$ = fresh weight of soil (g)
$W_d$ = oven-dry weight of soil (g)

Soil infiltration rate was measured in situ using a double-ring infiltrometer. Water was applied simultaneously to the inner and outer rings, and the rate of water infiltration into the soil was recorded over time. Infiltration rate was calculated as:

Infiltration rate (cm $h^{-1}$) = $\frac{\Delta d}{\Delta t}$ (5)

where:
$\Delta d$ = depth of water infiltrated (cm)
$\Delta t$ = time interval (hours)

Infiltration rate reflects soil structure, pore continuity, and compaction status and is strongly influenced by organic matter management.

Soil texture was determined using the hydrometer method, which quantifies the proportions of sand, silt, and clay based on sedimentation rates. Firstly, the hydrometer reading was initially corrected using Equation (6);

$(R_c) = R_o - C_t - C_m$ (6)

$R_c$ = corrected hydrometer reading
$R_o$ =observed hydrometer reading
$C_t$ = temperature correction
$C_m$ =meniscus correction

The percentage of each soil fraction was calculated as:

$$\% \text{ Clay} = \frac{\text{corrected hydrometer reading}}{\text{Oven-dry mass of soil used}} \times 100 \quad (7)$$

$$\% \text{ Silt + Clay} = \frac{\text{corrected hydrometer reading}}{\text{Oven-dry mass of soil used}} \times 100 \quad (8)$$

All analyses followed standard soil science procedures (Blake and Hartge, 1986; Kemper and Rosenau, 1986).

Soil aggregate stability was determined using the wet sieving method, which measures the resistance of soil aggregates to disintegration when exposed to water. Air-dried soil aggregates of a specific size range were placed on a set of sieves and oscillated in water.

Aggregate stability was expressed as Mean Weight Diameter (MWD) using the formula:

$$\text{MWD} = \sum(xi + wi) \quad (9)$$

where:
$xi$=mean diameter of each size fraction (mm)
$wi$ = proportion of total sample weight retained on each sieve

Higher MWD values indicate greater aggregate stability, which is associated with improved soil structure and reduced erosion risk (Six *et al.*, 2004).

### 2.6 Statistical Analysis

Data were subjected to descriptive statistics and analysis of variance (ANOVA) to test for significant differences between farming systems. Mean separation was performed using the least significant difference test at $p \leq 0.05$. Statistical analyses were conducted using standard statistical software.

## 3. Results

### 3.1. Soil Bulk Density and Porosity

Table 1 shows the effect of bulk density and total porosity on soil under organic and conventional farming system. Soils under organic farming exhibited significantly lower bulk density values compared to soils under conventional farming ($p \leq 0.05$). Correspondingly, total soil porosity was significantly higher in organic plots, indicating improved pore space distribution, as shown in Figure 1 and 2.

**Table 1.** Effect of Organic and Conventional Farming Systems on Bulk Density and Total Porosity

| Farming system | Bulk density (g $cm^{-3}$) | Total porosity (%) |
|---|---|---|
| Organic | $1.29 \pm 0.05^a$ | $52.03 \pm 2.1^a$ |
| Conventional | $1.47 \pm 0.05^b$ | $45.07 \pm 1.8^b$ |
| p-value | 0.013 | 0.019 |

Different superscripts within a column indicate significant difference at $p \leq 0.05$.

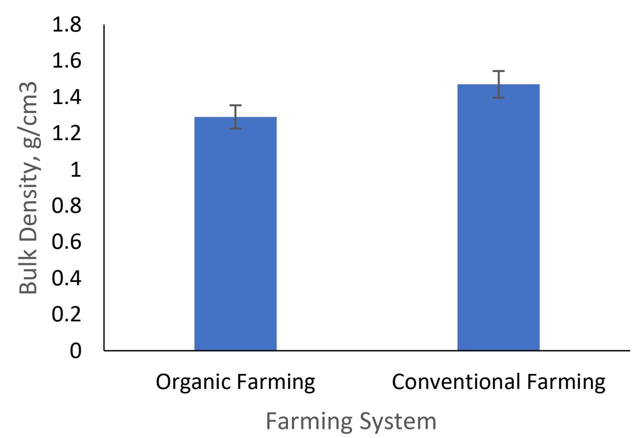


**Figure 1.** Effect Organic and Convention Farming Systems on Bulk Density

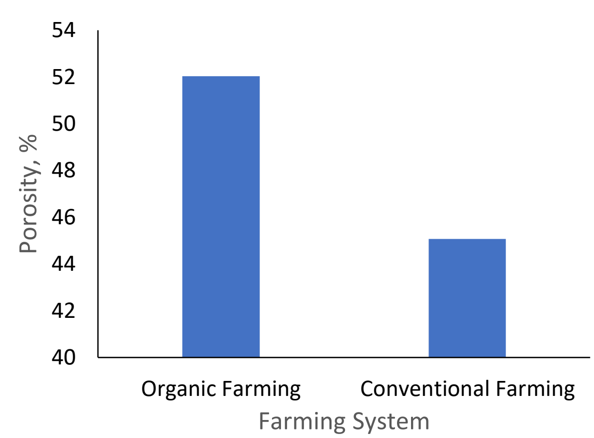


**Figure 2.** Effect Organic and Convention Farming Systems on Porosity

### 3.2 Soil Moisture Content and Infiltration Rate

Table 2 shows that both methods of farming have a significant effect on the moisture content and infiltration rate of soil. Organic farming significantly increased soil moisture content and infiltration rate relative to conventional farming (Figure 3). Higher infiltration rates under organic management suggest improved soil structure and reduced surface sealing (Figure 4).

**Table 2.** Effect of Organic and Conventional Farming Systems on Moisture Content and Infiltration Rate

| Farming system | Moisture Content (%) | Infiltration Rate (cm h$^{-1}$) |
|---|---|---|
| Organic | 23.9 ± 1.2$^{a}$ | 9.5 ± 0.5$^{a}$ |
| Conventional | 17.7 ± 1.0$^{b}$ | 3.9 ± 0.4$^{b}$ |
| p-value | 0.008 | 0.003 |

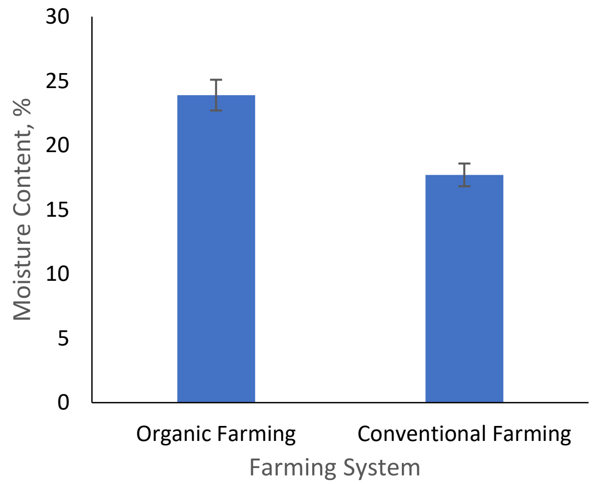


**Figure 3**. Effect Organic and Convention Farming Systems on Moisture Content

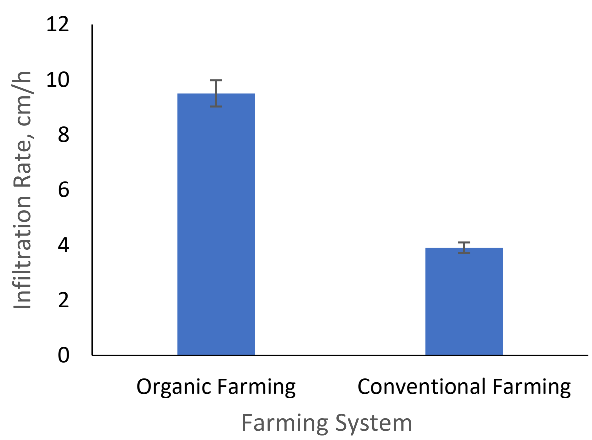


**Figure 4**. Effect Organic and Convention Farming Systems on Infiltration Rate

### 3.3 Aggregate Stability (Mean Weight Diameter)

Result shown in Figure 5 shows that mean weight diameter (MWD) values were significantly greater in organically managed soils than in conventionally managed soils, indicating enhanced aggregate stability and resistance to structural breakdown. Table 3 shows that both organic and conventional farming system has significant effect on the mean weight diameter of soil.

**Table 3.** Effect of Organic and Conventional Farming Systems on Aggregate Stability (Mean Weight Diameter)

| Farming system | Mean Weight Diameter (MWD, mm) |
|---|---|
| Organic | 1.79 ± 0.13$^{a}$ |
| Conventional | 1.07 ± 0.12$^{b}$ |
| p-value | 0.005 |

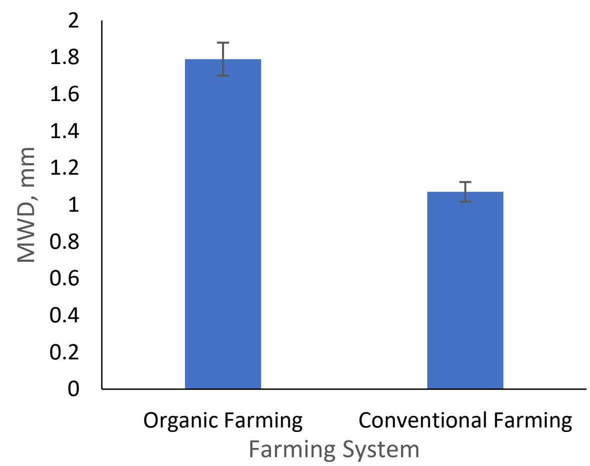


**Figure 5.** Effect Organic and Convention Farming Systems on Mean Weight Diameter

### 3.4 Soil Textural Characteristics of the Study Area

Table 5 shows the soil particle of various sizes, including sand (81.57%), silt (9.78%) and clay (8.65%). This result shows that the soil classification is loamy sand according to USDA textural classification of soil.

**Table 5.** Soil Textural Class (Particle Size Distribution)

| Depth, d (cm) | Percentage, % by Mass | | | Textural Class |
|---|---|---|---|---|
| | Sand | Silt | Clay | (USDA) |
| 0 – 20 | 81.57 | 9.78 | 8.65 | Loamy sand |

### 4. Discussion

The reduced bulk density observed under organic farming reflects the positive effect of organic matter inputs on soil structure. This indicates a strong resistance to compaction which is in tandem with the report of Williams *et al.* (2017) but can also be affected by the treatment differences (Blanco-Canqui *et al.* (2024). Organic amendments act as binding agents that enhance aggregation and reduce soil compaction which in turn lowers the soil's resistance to penetration (Blanco-Canqui *et al.*, 2015). Improved porosity under organic management further supports better aeration and root penetration which may also be influenced by the type of tillage and soil type (Sánchez de Cima *et al.*, 2015).

Higher soil moisture content in organic plots can be attributed to improved water-holding capacity associated with increased organic matter (Meena *et al.*, 2020). Mulching and residue retention likely contributed to reduced evaporation losses. These findings are consistent with previous studies reporting enhanced moisture retention in organically managed soils (Blanco-Canqui and Lal, 2009).

Enhanced infiltration rates and aggregate stability under organic farming indicate improved structural resilience, which is critical for reducing erosion in high-rainfall environments. This is in consonance with the findings of Nima *et al.* (2020) who reported 60.7% increase of hydraulic conductivity under organic farming when compared to conventional systems and Williams *et al.* (2017) report on better infiltration with organic system than conventional system.

Microbial by-products and organic binding agents play a key role in stabilizing aggregates, thereby improving soil physical quality. Overall, the results confirm that organic farming practices influences soil quality by improving its physical, chemical, and biological properties (Dadhick *et al.*, 2025) and promote favorable soil physical conditions in humid tropical environments.

## 5. Conclusion

The study demonstrates that organic farming practices significantly improve soil physical properties compared to conventional farming under humid tropical conditions. Organic management reduced soil compaction, enhanced porosity, increased moisture retention, improved infiltration, and strengthened aggregate stability. These improvements highlight the potential of organic farming as a sustainable soil management strategy for tropical agro-ecosystems. Adoption of organic farming practices can contribute to improved soil health, reduced land degradation, and enhanced long-term agricultural productivity.

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