UNIZIK JOURNAL OF AGRICULTURAL AND BIOSYSTEMS ENGINEERING

Journal homepage: https://journals.unizik.edu.ng/ujabe/

UJABE

April (2026), 1(2): 117-125

ISSN: 3141-2912

COMPARATIVE EVALUATION OF CHICKEN AND TURKEY MANURE ON SOIL HYDRAULIC PROPERTIES IN SANDY LOAM SOIL

***[1]Erewari Ukohua-Onuoha, [2]Raymond Alex Ekemube, [1]Nyenweaizi Fyne-Akah**

[1]Department of Agricultural & Environmental Engineering, Rivers State University, Port Harcourt, Nigeria

[2]Department of Agricultural & Biosystems Engineering, University of Benin, Benin City, Nigeria

**Corresponding Author's E-mail: erewari.ukoha@ust.edu.ng*

Received: 17th January 2026; **Accepted:** 26th January 2026; **Available Online:** 30th April 2026

ABSTRACT

This study described the response of soil hydraulic parameters to chicken and turkey manure. A soil-manure mix ratio of 5:1 was used for the experiment. Samples were labelled CMM for chicken manure and TMM for turkey manure. A third sample without manure was labelled control. All soil samples were kept under a controlled environment for 12 weeks. Soil samples were collected and analyzed at intervals of 4 weeks for bulk density, saturated hydraulic conductivity (Ksat), water retention capacity (WHC), and total organic carbon (TOC). Soil textural properties and manure nutrient composition were also analyzed. Standard methods were used for all analyses. Results show that the soil is of loamy sand textural classification and that both amendment materials improved bulk density significantly ($p < 0.001$) relative to the control. The mean bulk densities (CMM – 1.25 g/cm^3; TMM – 1.19 g/cm^3) were found to be within the recommended values for loamy soils. Although the amendments changed WHC and Ksat values, the difference compared to the reference soil was not significant ($p > 0.05$). Mean values of bulk density, WHC ($<$ 90%), and Ksat (22.06 cm/day) of the amended soils indicate that both manures improve soil hydraulic and organic matter properties, and selection between the them will depend on availability.

Keywords: Food Security, soil hydraulic properties, Soil Amendment, Sustainable Agriculture, Total Organic Carbon

1.0 INTRODUCTION

With the teaming global population amidst increasing demand for food and limited land and water resources, the importance of sustainable agriculture cannot be overemphasized. A major factor responsible for limited land resources is soil degradation, and a typical indicator of soil degradation is soil hydraulic properties deterioration (Indoria et al., 2020; FAO, 2021). Soil hydraulic properties determine plant, water, and nutrient uptake as well as crop growth and yield. This is because these physical properties control the rate of water flow, water retention, and the availability of nutrients in soil (García-Gutiérrez et al., 2018). Also, valuable information about nutrient leaching, contaminant transport within the vadose zone, and drainage characteristics is obtainable from soil hydraulic properties (Seema et al., 2019). Soil amendment is the application of special materials to soils with the intent of enhancing soil properties for improved crop growth and yield. Some of these materials are organic materials often obtained from agricultural activities, while others are inorganic. Common organic materials for soil amendment include compost and animal dung because of their availability, cost-effectiveness, and high nutritional value. The poultry industry is an important industry. This industry directly addresses two sustainable development goals (SDGs) – SDGs 2 and 8 relating to zero hunger and employment, respectively, and indirectly addresses SDGs 1 and 3 relating to no poverty and good health and well-being, respectively. Also, the industry generates large volumes of poultry dung (Okai, 2019) for soil amendment. According to Adewumi et al. (2011), the Nigerian poultry industry generates

about 932.5 metric tons of poultry dung annually, and this figure could increase exponentially.

Poultry dung/manure constituents vary depending on the type of poultry bird (Mukhtar, 2005; Hamid et al., 2019). For example, for the same live weight (445 kg), broilers have the highest daily production of total manure, total solids (TS), VS, N, P, and K, whereas turkeys produce the lowest amount for all these properties (Mukhtar, 2005). This implies that the type of poultry manure used in soil amendment may influence the soil nutrient and hydraulic properties. Most works on the use of manure as soil amendments have focused on improving soil nutrients, and even when soil physical properties are considered there is dearth of reports comparing the effects of the type of poultry bird manure on soil physical properties (Mamman, 2020, Adebayo et al., 2019; Brust, 2019, Obi and Ebo, 1995;). Considering the important functions of these properties and the common use of poultry manure as soil amendment materials, this study investigated the effect of chicken and turkey manures on soil hydraulic parameters.

2.0 METHODOLOGY

2.1 Study Area

The experiment was carried out at the farm workshop of the Department of Agricultural and Environmental Engineering, Rivers State University, which is situated in Port Harcourt, Rivers State, Nigeria. Geographically, the site is located between latitude 4°49′27′N and longitude 7°2′1′E in southern Nigeria's humid tropical rainforest zone. This area has a moist tropical climate with significant rainfall and somewhat consistent year-round temperature trends. Rainfall in Port Harcourt averages between 2,300 and 3,000 mm per year, with the wettest months usually falling between March and October. September often records the highest rainfall, which averages between 350 and 400 mm. On the other hand, the harmattan wind, which impacts many regions of West Africa, has a minor influence on the short dry season, which primarily lasts from December to February (NIMET, 2021). Average annual temperature and relative humidity of the study area are 28℃ and $>$ 85% respectively.

2.2 Soil Sample Analyses

Soil samples were collected from the research farm at Rivers State University, Port Harcourt, at a depth of 0-30cm with the aid of a shovel. The soil sample was sun-dried, homogenized, and divided into three equal weights. Each portion of soil was transferred into a well-labeled experimental pot, including control, CMM (chicken manure mixture), and TMM (Turkey manure mixture). Moderately weathered chicken and turkey manure were applied by broadcasting and uniformly mixed with the soil in a soil-manure mix ratio of 5:1. The mixing of the CMM and TMM with soil was for rapid degradation of the degradable carbon by microbes since the experiment time was only for 12 weeks. This process is similar to the report by Okparanma et al. (2022). Experimental pots were kept in a controlled environment to avoid leaching by rainfall and samples were collected for analyses at, 4, 8, and 12 weeks after initial application (WAIA) to determine bulk density,

water holding capacity (WHC), saturated hydraulic conductivity (Ksat) and total organic carbon (TOC). Table 1 presents the analytical methods used.

Table 1: Analytical Methods of Soil Parameters

Parameter	Analytical Method	APHA Number (s)
WHC	Gravimetric moisture content method	9040D
Bulk Density	Core method	9035A
Saturated Hydraulic Conductivity	Constant head method	9100
TOC	Walkley-Black Wet Oxidation as modified by Juo (1979)	-

3.0 RESULTS AND DISCUSSION

3.1 Characterization of Soil and Poultry Manure

An initial soil particle size analysis was carried out to characterize the soil. Results of the particle size characterization showed that the soil was 85.5% sand, 4.4% silt, 11.0% clay, giving a textural property of loamy sand. The amendment materials (chicken manure and turkey manure) were also characterized. The nutrient composition of chicken and turkey manure is presented in Table 2. The result shows that the chicken manure differs from turkey manure, as observed by Mukhtar (2005), who highlighted that the NPK contents of poultry manure were different for different types of poultry birds. The soil sample used for this study was not physically degraded; however, it was expected that the application of poultry manure would affect the soil hydraulic properties.

Table 2: Characteristics of Poultry manure

Parameters	**Chicken Manure**	**Turkey Manure**	**Percentage Difference**
Nitrogen %	0.044	0.038	14%
Phosphorus mg/ka	19.652	11.33	42%
Potassium cmol/k	12.45	8.182	34%

3.2 Bulk Density

Figure 1 displays the effect of the different types of poultry manure on bulk density. The control sample maintained comparatively steady and higher bulk density values than the manure-treated soils (CMM and TMM), like other works (Rivenshield and Bassuk, 2007; Ewulo et al., 2008; Al-Omran et al., 2019; Agbede, 2025). The decline shows a sharp decrease within the first 4 weeks after initial application (WAIA), followed by a minimal decrease in the weeks following (8 and 12 WAIA). Chenu et al. (2000) explained that the presence of organic matter in soil stimulates microbial activities that enhance soil aggregation and pore stabilization, that decrease the bulk density. The characteristic organic carbon of the soil samples in this work corroborates the report of Chenu et al. (2000).

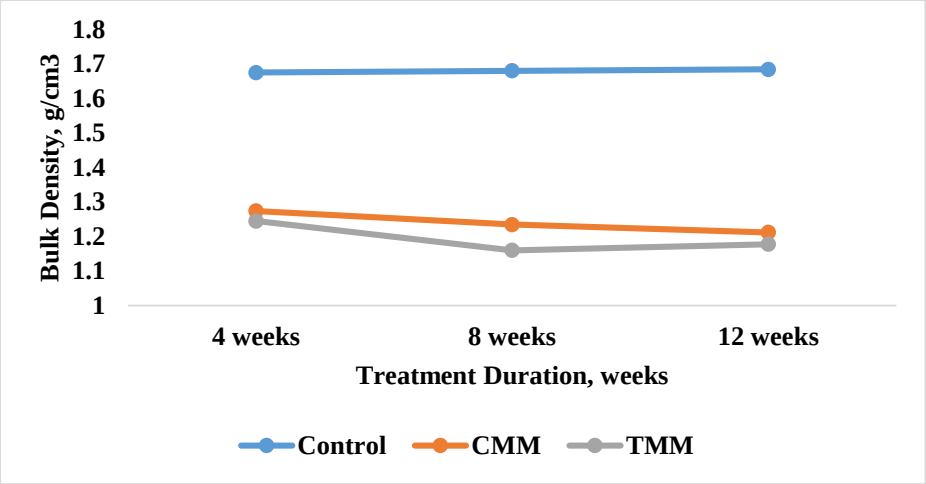


Figure 1: Effect of Poultry Manure on Soil Bulk Density

Table 3 shows the average total organic carbon (TOC) of the soil samples. TOC of CMM and TMM were higher than the control. It was observed that TOC decreased with time for the first 8 weeks and increased by the 12th week for both the control and the amended soils. This characteristic trend is explained by microbial activities on organic materials. Microbes degrade organic materials for energy, which results in the decrease of TOC in the soil. However, when microbes exhaust the degradable carbon in the soil which is a function of time, the recalcitrant and inert carbon fractions such as humic substances start to build up while microbial biomass and waste increase resulting in the increment of TOC after the initial decrease (Lal, 2015; Said-Pullicino et al., 2007).

Table 3: TOC Content of Soil Samples with Time

Duration	Control	CMM	TMM
4 weeks	0.234	2.808	1.794
8 weeks	1.17	2.574	2.106
12 weeks	1.304	2.617	5.00
Average	0.903	2.666	2.967

The results of the sample t-Test in Table 4 imply that soil amendment with both manures caused a highly significant difference ($p < 0.001$) in soil bulk density with reference to the baseline. However, no significant difference was noticed between the amended soils (CMM and TMM) with $p > 0.05$. This suggests that the type of poultry manure may not play a significant role in influencing bulk density, like the report of Veettil et al. (2024) for chicken manure and dairy manure.

Table 4: Group Comparative Independent Sample t-Test for Bulk Density

	Control and CMM	Control and TMM	CMM and TMM
T-test	1.77848E-05	4.84233E-05	0.21874
p-value	$p < 0.001$	$p < 0.001$	$p > 0.05$

The average bulk densities of CMM (1.24 g/cm3) and TMM (1.19 g/cm^3) are within the ideal bulk densities of loamy soil ranging from 1.1 to 1.4 g/cm^3 (Hillel, 2003, USDA-NRCS, 2008). The control with an average bulk density of 1.68 g/cm^3 falls outside of this range meaning that the bulk density of the control is too high. When bulk density gets too high (usually above 1.6–1.8 g/cm^3), the bigger pores break down, and the total pore space shrinks. This really cuts down soil water for plant use and makes it harder for roots to spread out (Lal and Shukla, 2004; Reynolds et al., 2008).

3.2 Water Holding Capacity

The changes in water retention capacity over time is displayed in Figure 2. Similar to the bulk density, the water retention capacity at 4 WAIA for the control was higher than that of the poultry manure-amended soils. The control soil's water holding capacity remained steady throughout the period of the experiment. With the amendments (CMM and TMM), an initial 25% decrease in water holding capacity was observed in the 4 WAIA, followed by a steady increase in the weeks following (8 and 12 WAIA).

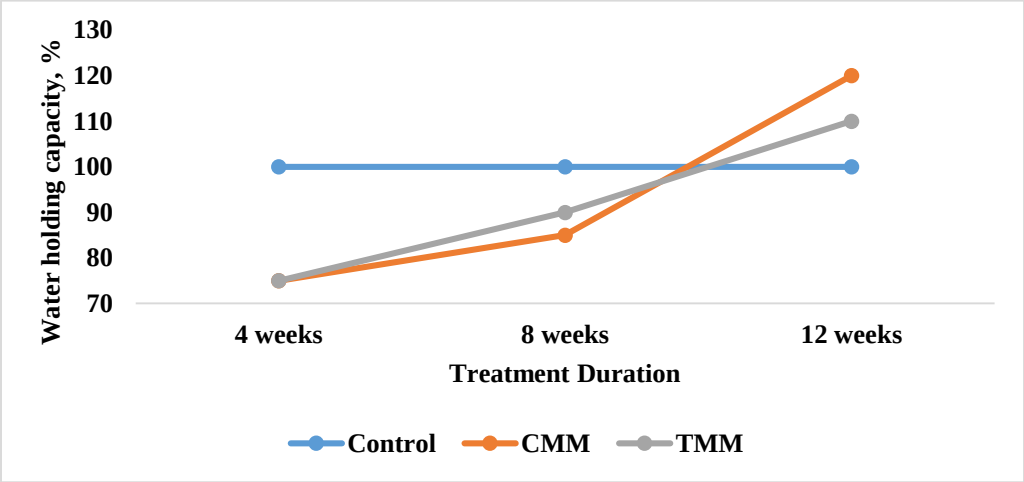


Figure 2: Effect of Poultry Manure on Water Holding Capacity

Although the initial decline is a deviation from the inverse nonlinear connection between soil water holding capacity and bulk density, this initial decline is explained by increased macro-porosity brought on by the addition of manure that is consistent with the decrease in bulk density, which tends to decrease capillary water retention (Lashermes et al., 2009). The steady, sharp increase at 8 WAIA suggests a partial repair of water-retaining micropores, probably because of aggregate formation and microbial breakdown of organic waste. By 12 WAIA, both manure treatments outperformed the control with TMM at 110% WHC and CMM at 120%. Poultry manure's organic residues probably created stable humic compounds that enhanced the soil's microporosity and structure, allowing for greater moisture retention (Amadji et al., 2013; Al-Omran et al., 2019). This demonstrates how organic matter decomposition is time-dependent and how soil water dynamics gradually improve as a result.

The statistical difference between the control and the amended soils, as well as between the amended soils are presented in Table 5. The results explain that there was no significant difference

($p > 0.05$) between the control's water holding capacity and the amended soils, as well as between the amended soils (CMM and TMM).

Table 5: Group Comparative Independent Sample t-Test for Water Holding Capacity

	Control and CMM	Control and TMM	CMM and TMM
T-test	0.650652	0.457253	0.926603
p-value	$p > 0.05$	$p > 0.05$	$p > 0.05$

3.3 Saturated Hydraulic Conductivity (Ksat)

Saturated Hydraulic Conductivity (Ksat) is a key soil property that determines how fast water seeps into, flows through, and drains out of soil layers. It affects root development and aeration, nutrient leaching, and irrigation efficiency (Saunders et al., 2022; Sharma et al., 2021; Colmer and Voesenek, 2021). Lal and Shukla (2004) reported that the optimal Ksat for annual field crops ranges from 1.5 to 15 cm/day and that Ksat values less than 1 cm/day have the potential to cause waterlogging, while Ksat values greater than 20 cm/day might require frequent irrigation. In this work, the average Ksat values for the control, CMM, and TMM are 23.03, 22.06, and 22.06 cm/day, respectively. These values are similar to the values in the work of Demir and Dogan Demir (2019) but greater than the 20 cm/day guideline as reported by Lal and Shukla (2004). The results also show that with the chicken and turkey manure amendment, an initial decrease of the Ksat values occurred for the 4 WAIA, followed by a steady increase for the 8 and 12 WAIA (Figure 3).

This observation confirms the earlier observations of Khalid et al. (2014), who reported that hydraulic conductivity decreased with increasing level of poultry manure. This indicates that the effect of poultry manure on Ksat is time-dependent and that when it comes to improving saturated hydraulic conductivity in loamy sandy soils, chicken manure may be marginally more stable. The values of the bulk density, WHC, and Ksat for CMM and TMM are consistent. Soil with an average bulk density ranging from 1.19 to 1.24 g/cm^3, WHC of over 90%, and Ksat of over 20 cm/day suggests that the soil is very porous and well-structured. The soil holds water well and drains fast, suggesting good physical condition with correct handling.

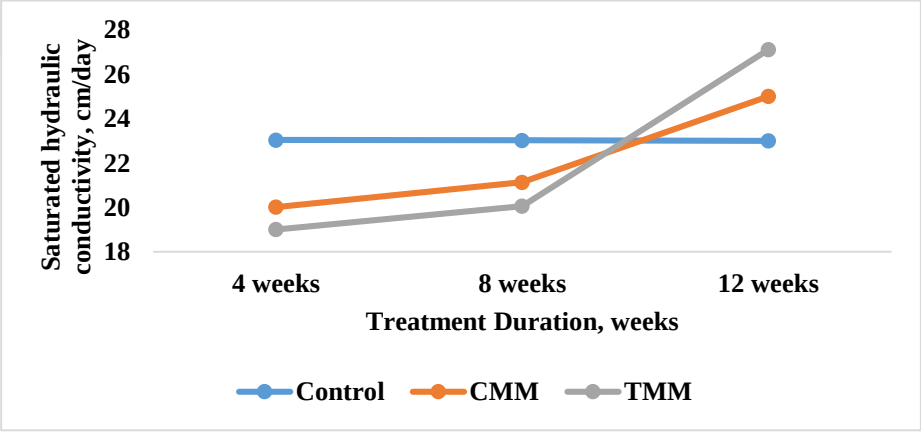


Figure 3: Effect of Poultry Manure on Saturated Hydraulic Conductivity

Table 6 reveals that the Ksat values of the amended soils (CMM and TMM) were different from the reference sample, but this difference was not significant. Similarly, between the amended soils (CMM and TMM), the difference was not significant with $p > 0.05$ between all groups.

Table 6: Group Comparative Independent Sample t-Test for Saturated Hydraulic Conductivity

	Control and CMM	**Control and TMM**	**CMM and TMM**
T-test	0.650652	0.457253	0.926603
p-values	$p > 0.05$	$p > 0.05$	$p > 0.05$

4.0 Conclusion

The use of poultry manure as a soil amendment can change soil hydraulic properties. Chicken and turkey manures had different amounts of nitrogen, phosphorus, and potassium. Chicken and turkey manures are good for bulk density improvement while maintaining good water retention capacity (WHC) and saturated hydraulic conductivity (Ksat). Organic matter decomposition is time-dependent, and soil water dynamics improve gradually.

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To cite this article:
Ukohua-Onuoha Erewari, Ekemube Raymond Alex and Fyne-Akah Nyenweaizi, 2026. Comparative Evaluation of Chicken and Turkey Manure On Soil Hydraulic Properties in Sandy Loam Soil. 1(2): 117-125. https://journals.unizik.edu.ng/ujabe/