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EFFECT OF ORGANIC AMENDMENT ON SOIL COMPACTION UNDER OPEN GRAZING SYSTEM

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ABSTRACT

The system of open grazing common in Northern Nigeria, leaves traces of soil compaction along the route of grazing. This trampling by livestock compacts agricultural soil, leading to degradation. This research investigated the effectiveness of organic amendments in mitigating soil compaction under open grazing conditions in Birnin Kebbi, Nigeria. A split-plot experiment compared compost, farmyard manure, and a control over six months (at zero month, after three months, and after six months). Results obtained showed that organic amendments significantly reduced bulk density (1.87–1.57 g cm^{-3}) and penetration resistance (0.41–0.35 MPa), while increasing porosity (29.31%–40.63%), aggregate stability (39.45%–68.85%), and soil moisture retention (3.97–6.40%). Compost consistently produced the greatest improvements, with optimal effects observed after six months. Structural properties such as bulk density, porosity, and aggregate stability exhibited strong interaction effects between amendment type and observation time, indicating progressive soil improvement due to organic matter decomposition. The findings of the research demonstrate that organic amendments, particularly compost, enhance soil resilience to trampling by improving its physical structure and hydraulic properties. This highlights the incorporation of amendment potential as sustainable management strategies for restoring soil quality and productivity in lands under open grazing system.

Keywords: Observation time, Soil compaction, Bulk density, Penetration resistance, Porosity

INTRODUCTION

Northern Nigeria is well-known for its agricultural activities, including the cultivation of crops and the rearing of animals. The rearing of animals especially cattle is basically through open grazing. This system of animal husbandry involves the movement of large herds of cattle from one place to another in search of greener pasture. The movement of the cattle leads to trampling of the soil which leads to compaction of the soil along the route. This practice has led to rapid soil degradation, threatening agricultural sustainability (Li et al., 2024).

Soil compaction is defined as an increase in the soil bulk density due to an external factor, such as the passage of herds of animal, hence it reduces soil porosity. Soil compaction creates a hard layer in the soil that prevents the penetration of water, air and nutrients into the soil and plant root, and then restricts the root growth and prevents the plant to get required water and nutrients (Abbaspour-Gilandeh and Sedghi 2015). Therefore, it reduces plant growth and eventually yield.

Pore spaces between soil particles are reduced when the particles are compressed close together. This leads to difficulty in root development and nutrients uptake, as a result of increase in bulk density and penetration resistance, which restricts the movement of water and air within the soil profile (Hamza and Anderson, 2005). For instance, Compaction has been demonstrated to significantly impedes maize root growth and nutrient absorption by strengthening the soil (higher penetration resistance), which in turn reduces crop yield (Olubanjo & Yessoufou, 2019).

Organic materials derived from plants and animals might possess many features that can improve soil fertility, quality of the environment and enhance crop performance. restoration to sustaining soil fertility and agricultural production, Organic amendments play an important role due to their ability for the improvement of physical, chemical and biological properties of soils. The application of organic materials as soil amendment has received more attention in recent years for agronomic applications as well as soil reclamation projects and seen as serving as a means to improve physical, chemical and biological soil properties, which in turn promotes improved crop yield and sound environment (Aytenew and Bore, 2020).

In many areas with pastoralist, like Northern Nigeria, open grazing system put constant pressure on the soil surface because animals are always trampling on them. This often causes more compaction, especially when the soil is wet, there isn't much vegetation cover, or the organic matter level is naturally low because of constant grass removal or overgrazing (Greenwood & McKenzie, 2001). It is thought that organic soil amendments can improve the structure of the soil, which will help it resist compaction better when animals graze on it. This will help land use and vegetation re-establishment in a sustainable way. This gap, connecting the use of organic amendments to reducing compaction in open grazing situations, needs more research, especially in places where compaction hurts soil health and productivity of grazing land.

The introduction of organic amendment as a means of improving physical properties and reduction of compaction risk is widely reported. Compost, farmyard manure and biochar are examples of organic amendments that has been reported to improve the structure of soil, enhance aggregate stability and reduce bulk density (Blanco-Canqui & Lal, 2009; Tejada & Gonzalez, 2007).

Because open grazing exposes the soil to frequent cattle trampling, it becomes compacted, which limits root growth, decreases infiltration, and decreases pasture productivity. There is little soil management intervention to prevent compaction in many grazing areas, especially in developing nations. Although organic additions are known to enhance soil structure, it is still unclear how well they work to reduce compaction during vigorous grazing.

Additionally, there is a dearth of site-specific experimental data assessing how well various organic supplements work to reduce soil compaction, particularly under open grazing

pressure. Therefore, the purpose of this study is to determine how much soil compaction and related physical characteristics in grazed lands are affected by organic amendments.
Thus, this study assesses how different organic amendments affects the degree of soil compaction at various times during open grazing.

MATERIALS AND METHODS

Study Area

The investigation was carried out in an open grazing field with constant animal activity in Birnin Kebbi. The experiment was conducted between October 2025 and April 2026. The location lies between Latitude 12.4318 ° N and Longitude 4.1956 ° E, with an average highest temperature of 41.4 °C and a lowest temperature of 18.6 °C, and receives approximately 787.53 ± 25.31 mm of precipitation annually. Birnin Kebbi has a steeped climate so therefore the major soil found in this area are the sandy clay type of soil and has characteristic red color enriched with a clay sub-soil noticeable in the landscape. There are two climatic regimes in the area; the distinct dry season, which occurs from November to March and wet season which occurs from June to September. The wet season typically peaks between July and September, when precipitation is at its maximum, whereas the dry season typically peaks in March, when evapotranspiration is at its highest. The region is home to short grasses that develop quickly during the rainy season and dry up during the dry season due to the extreme heat and high evapotranspiration (NiMet 2020).

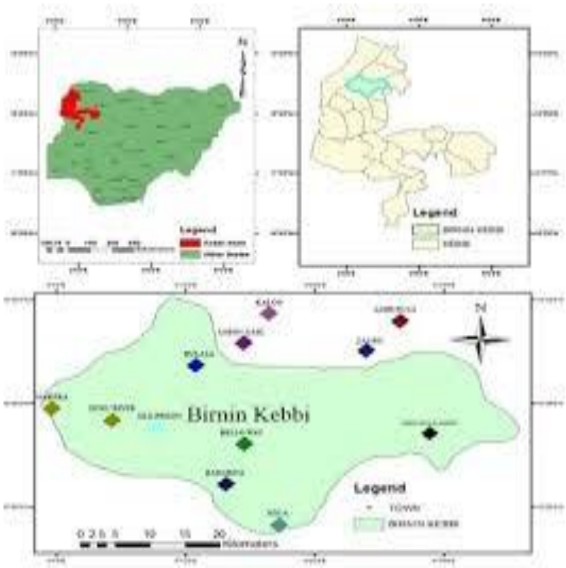

Figure 1: Map of Birnin Kebbi

Figure 2: Location of the Study

Experimental Design

The experiment was laid out using a Split Plot Design structured within a Randomized Complete Block Design (RCBD) with three amendments (factor A); 0 amendment T_0 (control), compost T_1 and farmyard manure T_2, with each amendment observed (factor B) at baseline A (0 months), after three months B, and after six months C. This gives a total of nine (9) treatments combination with three (3) replications. The amendment serves as the main plot, while the observation time serves as the sub-plot.

Treatments

The treatments comprised of the control plot T_0 (no amendment), T_1 (Compost) T_2 (Farmyard manure) as main plot, while the time of observation and measurement of soil compaction indicators (zero months A, three months B, and six months C) represent the sub-plot. This treatment factors were combined in a split plot design. Each main plot was measured 10 m × 10 m with buffer zones between plots as shown in figure 3.

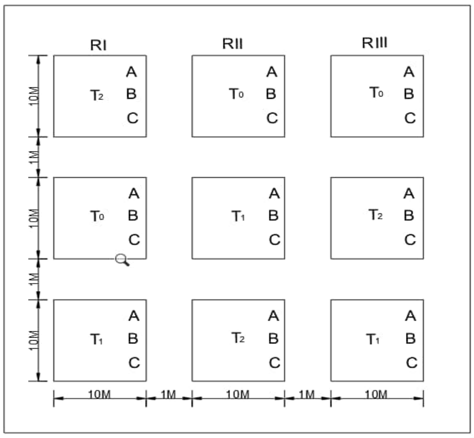

Figure 3: Expermental Layout

Amendment Application

Organic amendments were applied at a uniform rate (10 tons/ha). Amendments were incorporated into the top 0–15 cm soil layer before grazing began.

Grazing Management

The plots were subjected to controlled open grazing at uniform stocking density to simulate natural trampling pressure. Grazing was done with the herd making 10 passes on each grazing day.

Data Collection

Soil Compaction Indicators

Bulk Density (g/cm³):

The bulk density was determine using the core sampling method (0-15 cm depth). Soil sample from the core was oven dried at 105°C for 24 hours. The bulk density was determine using the formular in equation 1;

$$\text{Bulk density} = \frac{m}{v} \text{ (g/cm}^3\text{)} \quad (1)$$

Where

m = mass of the oven dried soil

V= Total volume of soil in the core

Penetration Resistance (MPa)

The penetration resistance was measured using a cone penetrometer with readings taken at multiple points in each plot in MPa.

Total Porosity (%):

Porosity was determined using the equation 2 below from values of bulk density and particle density.

$$\text{Porosity} = (1- \frac{bulk\ density}{particle\ density}) \text{x } 100\%. \quad (2)$$

Aggregate Stability (%)

The wet sieving method was used to assess soil aggregate stability, i.e., how well soil aggregates resist disintegration when exposed to water. This was based on the principle that stable soil aggregates resist breakdown when wetted, while unstable ones disperse. The method measured the proportion of aggregates that remain intact after controlled wetting and agitation. The mass distribution of aggregates across sieve sizes was used to compute indices such as mean weight diameter (MWD) or percentage of water-stable aggregates using the formula;

$$\text{MWD} = \sum(Xi - Wi) \quad (3)$$

Where:

Xi = mean diameter of each size fraction

Wi = proportion of total sample weight in that fraction

Soil Water Retention

The soil moisture content is usually expressed as a percentage of the oven dried soil. The soil moisture depends on the type of the soil. Water holding capacity is the waster held in the soil between its field capacity and permanent wilting point. Field capacity is the water remaining in the soil after it has been thoroughly saturated and allowed to drain freely, usually for 24/48 hours. Permanent wilting point is the moisture content of the soil at which plants wilt and fail to recover when supplied with sufficient water.

The 0 bar, 0.3 bar and 15 bars moisture extractor were used to determine the moisture content at saturation, field capacity (FC) and permanent wilting point (PWP) respectively. The soil samples were placed inside the pressure plate extractor calibrated at various levels as the moisture was been extracted at 0 bar, 0.3 bar and 15 bars, with the weights recorded. The moisture content was determined using equation 4;

$$Moisture\ content\ (MC) = \frac{moist\ soil\ weight - oven\ dried\ weight}{oven\ dried\ weight}\ x\ 100\% \quad (4)$$

The WHC was determined using the equation 5 below;

$$WHC = FC - PWP. \quad (5)$$

WHC = water holding capacity

FC = moisture content at field capacity

PWP = moisture content at permanent wilting point

Sampling Schedule

The sampling and measurement of parameters were done three times; immediately after the amendment (Baseline), 3 months after application and 6 months after application.

Data Analysis

Data was subjected to Analysis of Variance (ANOVA) using statistical software (SAS). Mean separation was done using Duncan Multiple Range Test (DMRT) at 5% probability level.

RESULTS AND DISCUSSION

The result of the statistical analysis in Table 1 presents the effect of organic amendment and the observation time on soil compaction indicators as measured from the field. Organic amendment (a) and observation time (b) significantly influenced soil compaction indicators (Table 1). Bulk density decreased from 1.84 to 1.70 g cm^{-3} with increasing amendment level, indicating reduced compaction due to improved soil structure and pore development. Penetration resistance showed a similar decline, reflecting enhanced soil friability. These findings agree with recent studies reporting reduced soil strength following organic inputs (Olubanjo & Yessoufou, 2019).

Porosity, aggregate stability, and soil moisture retention increased significantly with amendment application. Peak values for compost amendment T_1 suggest an optimal rate beyond which benefits diminish. Improved aggregation (38.96–58.07%) and moisture retention are linked to enhanced microbial activity and organic binding agents (Sun et al., 2024; Zhang et al., 2025).

Observation time revealed progressive improvements, characterized by a decrease in bulk density and an increase in porosity and aggregate stability from zero-month A to six-month C, indicating the cumulative effects of organic matter decomposition (Li et al., 2024).

The interaction effect was significant ($P \leq 0.01$) for bulk density, porosity, and aggregate stability but not for penetration resistance and moisture retention. Overall, organic amendments improved soil physical quality, with optimal effects at moderate application rates over time.

Table 1: Effect of Organic Amendment and Observation Time on Soil Compaction Indicators

Treatment	Bulk Density	Penetration Resistance	Porosity	Aggregate Stability	Soil Moisture Retention
Organic Amendment, a					
T_0	1.84a	0.41a	30.61c	38.96c	3.97c
T_1	1.75b	0.35b	35.81a	58.07a	6.40a
T_2	1.70c	0.36b	33.84b	52.51b	6.10b
SE±	0.01	0.004	0.29	0.08	0.06
Observation time, b					
A	1.84a	0.39a	30.65c	39.71c	5.07b
B	1.78b	0.37b	32.75b	54.00b	5.58a
C	1.67c	0.35c	36.86a	55.83a	5.82a
SE±	0.01	0.003	0.18	0.19	0.08
Interaction					
a x b	**	NS	**	**	NS

Means followed by the same letter within a treatment group are not statistically different at 5% level of probability using DMRT. NS = Not Significant * = Significant at 5% probability level ** =Significant at 1% probability level

Effects of Organic Amendment and Observation Time (ANOVA Results)

The analysis of variance (ANOVA) results (Tables 2–6) show that organic amendment and observation time exerted strong and consistent effects on soil physical properties. organic amendment significantly influenced all measured parameters—bulk density (F = 209.95), penetration resistance (F = 107.20), porosity (F = 209.64), aggregate stability (F = 2588.53), and soil water retention (F = 250.16)—all at $P < 0.0001$. Similarly, observation time significantly affected all variables, with particularly high F-values for bulk density (303.64), porosity (303.15), and aggregate stability (2086.98), indicating that temporal changes played a major role in improving soil structure.

The interaction effect (a × b) was highly significant ($P < 0.0001$) for bulk density, porosity, and aggregate stability, demonstrating that the influence of organic amendments on these structural properties depended on time after application. This suggests that improvements in soil aggregation and pore distribution are progressive and closely linked to organic matter decomposition and stabilization processes. Similar trends have been reported in recent studies, where time-dependent improvements in soil structure followed organic amendment incorporation (Sun et al., 2024; Zhang et al., 2025).

In contrast, the interaction effect was not significant for penetration resistance ($P = 0.5479$) and soil water retention ($P = 0.5440$), indicating that these properties responded independently to type of amendment and time. This implies that while structural attributes such as porosity and aggregation are strongly influenced by combined effects, soil strength and water retention may stabilize more rapidly or respond directly to individual factors.

Replication effects were generally non-significant across most parameters, except for bulk density and porosity, suggesting minimal experimental variability and good reliability of treatment effects.

Table 2: ANOVA for Bulk Density

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.00495556	0.00247778	11.95	0.0014
Organic Amendment (a)	2	0.08708889	0.04354444	209.95**	<.0001
Error(a)	4	0.00208889	0.00052222	2.52	0.0965
Observation Time (b)	2	0.12595556	0.06297778	303.64**	<.0001
a*b	4	0.02788889	0.00697222	33.62**	<.0001
Error	12	0.00248889	0.00020741		

**= Significant at (P≤ 0.01) *= Significant at (P≤ 0.05)

Table 3: ANOVA for Penetration Resistance

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.00062222	0.00031111	3.73	0.0549
Organic Amendment (a)	2	0.01786667	0.00893333	107.20 **	<.0001
Error(a)	4	0.00064444	0.00016111	1.93	0.1695
Observation Time (b)	2	0.00726667	0.00363333	43.60 **	<.0001
a*b	4	0.00026667	0.00006667	0.80	0.5479
Error	12	0.00100000	0.00008333		

**= Significant at (P≤ 0.01) *= Significant at (P≤ 0.05)

Table 4: ANOVA for Porosity

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	7.0749852	3.5374926	11.96	0.0014
Organic Amendment (a)	2	124.0446296	62.0223148	209.64**	<.0001
Error(a)	4	2.9768815	0.7442204	2.52	0.0968
Observation Time (b)	2	179.3771185	89.6885593	303.15**	<.0001

Source	DF	Anova SS	Mean Square	F Value	Pr > F
a*b	4	39.6750815	9.9187704	33.53**	<.0001
Error	12	3.5502667	0.2958556		

**= Significant at (P≤ 0.01) *= Significant at (P≤ 0.05)

Table 5: ANOVA for Aggregate Stability

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	2.436956	1.218478	3.62	0.0587
Organic Amendment (a)	2	1740.271400	870.135700	2588.53**	<.0001
Error(a)	4	0.226244	0.056561	0.17	0.9505
Observation Time (b)	2	1403.079800	701.539900	2086.98**	<.0001
a*b	4	847.239267	211.809817	630.11**	<.0001
Error	12	4.033800	0.336150		

**= Significant at (P≤ 0.01) *= Significant at (P≤ 0.05)

Table 6: ANOVA for Soil Water Retention

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.32666667	0.16333333	2.58	0.1170
Organic Amendment (a)	2	31.68666667	15.84333333	250.16**	<.0001
Error(a)	4	0.13333333	0.03333333	0.53	0.7187
Observation Time (b)	2	2.67555556	1.33777778	21.12**	0.0001
a*b	4	0.20444444	0.05111111	0.81	0.5440
Error	12	0.76000000	0.06333333		

**= Significant at (P≤ 0.01) *= Significant at (P≤ 0.05)

Interaction Effects of Organic Amendment and Observation Time on Soil Compaction Indicators

The table 7, 8 & 9 shows the interaction effects of organic amendment and Observation time on soil compaction indicators. For bulk density (Table 7), the interaction effects showed a consistent decline in bulk density across all treatment combinations, with the lowest value (1.57 g cm^{-3}) recorded under compost amendment observed after six months. The control treatment remained relatively high across all times. The results confirm that organic amendment effects intensify over time, likely due to progressive decomposition and stabilization of organic matter, which enhances soil aggregation and reduces compaction (Wu et al., 2024; Alencar et al., 2024).

Porosity increased significantly with both amendment level and time (Table 8). The highest porosity (40.63%) was observed under compost amendment observed after six months, while the control showed consistently low values. This improvement reflects enhanced pore formation and continuity driven by organic matter incorporation and microbial activity. Similar findings have been reported, where organic amendments increased macro- and total porosity through improved aggregation processes (Liu et al., 2024; Sun et al., 2024).

Aggregate stability exhibited the strongest interaction response (Table 9), increasing from 39.45% in the control to 68.85% under compost amendment observed after six months. The progressive improvement indicates that organic amendments enhance soil aggregate formation and stabilization over time through microbial binding agents, organic carbon accumulation, and mineral-organic interactions. Recent studies confirm that aggregate stability improves with time following organic amendment due to enhanced biological activity and carbon stabilization mechanisms (Zhang et al., 2025; Tao et al., 2024).

Table 7: Interaction between Organic Amendment and Observation Time on Bulk Density

Organic Amendment	Observation Time		
	A	B	C
T_0	1.87a	1.84ab	1.80c
T_1	1.82bc	1.71d	1.57f
T_2	1.82bc	1.79c	1.65e
SE±		0.01	

Means followed by the same letter (s) are not statistically different at 5% level of probability using DMRT.

Table 8: Interaction between Organic Amendment and Observation Time on Porosity

Organic Amendment	Observation Time		
	A	B	C
T_0	29.31f	30.44ef	32.08d
T_1	31.19de	35.59c	40.63a
T_2	31.45de	32.20d	37.86b
SE±		0.31	

Means followed by the same letter (s) are not statistically different at 5% level of probability using DMRT.

Table 9: Interaction between Organic Amendment and Observation Time on Aggerated Stability

Organic Amendment	Observation Time		
	A	**B**	**C**
T_0	39.45e	39.45e	37.97f
T_1	40.05e	65.32b	68.85a
T_2	39.62e	57.24d	60.67c
SE±		0.33	

Means followed by the same letter (s) are not statistically different at 5% level of probability using DMRT.

CONCLUSION

Across all parameters, compost amendment consistently produced better results than the farmyard manure, across three months and six months post amendment observation time. Suggesting that the significant interactions observed for key structural indicators confirm that soil improvement is not immediate but develops progressively over time. Organic amendments therefore act as slow-release agents of soil structural enhancement, with maximum benefits observed at later stages of decomposition.

This study therefore demonstrates that organic amendments significantly improve soil physical quality by reducing bulk density and penetration resistance while increasing porosity, aggregate stability, and water retention. These improvements are strongly time-dependent and, in several cases, synergistic. The findings emphasize that both organic amendment (preferably compost) and sufficient time after amendment are critical for achieving optimal soil structural restoration

REFERENCES

Abbaspour-Gilandeh, Y. Sedghi, R. (2015). Prediction soil fragmentation during tillage operation using fuzzy logic approach. J Terramech. 57(2): 61-69. https://doi.org/10.1016/j.jterra.2014.11.002

Alencar, L. M., Silva, A. P., & Santos, R. J. (2024). Effects of organic amendments on soil physical quality and carbon dynamics in tropical soils. *Scientific Reports*, *14*, Article 75771 https://doi.org/10.1038/s41598-024-75771-w

Aytenew M. and Bore G., (2020). Effects of Organic Amendments on Soil Fertility and Environmental Quality: A Review. Journal of Plant Sciences. Vol. 8, No. 5, pp. 112-119. https://doi.org/10.11648/j.jps.20200805.12

Blanco-Canqui, H., & Lal, R. (2009). Crop residue removal impacts on soil productivity and environmental quality. *Critical Reviews in Plant Sciences*, 28, 139–163. https://doi.org/10.1080/07352680902776507

Greenwood, K. L., & McKenzie, B. M. (2001). Grazing effects on soil physical properties and the consequences for pastures: A review. *Australian Journal of Experimental Agriculture*, 41, 1231–1250. https://doi.org/10.1071/EA00102

Hamza, M. A., & Anderson, W. K. (2005). Soil compaction in cropping systems: A review of causes, effects, and control. *Soil & Tillage Research*, 82, 121–145. https://doi.org/10.1016/j.still.2004.08.009

Li, X., Zhang, H., Wang, X., & Li, J. (2024). Soil organic carbon enhancement via aggregate stabilization under organic amendments. *Soil & Tillage Research*, *245*, 105912. https://doi.org/10.1016/j.still.2024.105912

Nigerian Meteorological Agency (NiMet). (2020). Overview of the 2020 seasonal rainfall prediction. https://fscluster.org/sites/default/files/documents/2020_srp_fss_abuja.pdf

Olubanjo, O. O. & Yessoufou, M. A. (2019). *Effect of Soil Compaction on the Growth and Nutrient Uptake of Zea mays L.* Sustainable Agriculture Research. *8*(3), 1–10. https://doi.org/10.5539/sar.v8n3p1

Pan, Y., Wang D., Tan T., An J., Jin X., Zou H., Zang Y., Yu N., & Siddique K.H.M., (2025). *Effect of organic amendments on soil organic carbon fractions, water retention, and mechanical properties in a Chinese Alfisol.* Soil & Tillage Research, 254:106723. https://doi.org/10.1016/j.still.2025.106723

Sun, R., Chen, Y., & Zhao, L. (2024). Effects of organic matter inputs on soil aggregation and structure stability: A field-based evaluation. *CATENA*, *238*, 107774. https://doi.org/10.1016/j.catena.2024.107774

Tao, J., Li, F., & Zhang, W. (2024). Organic amendments and soil aggregate stabilization: Mechanisms and microbial mediation. *Plants*, *13*(21), 3064. https://doi.org/10.3390/plants13213064

Tejada, M., & Gonzalez, J. L. (2007). Application of different organic wastes in soil restoration: Effects on soil biological properties. *Bioresource Technology*, 98, 2802–2806. https://doi.org/10.1016/j.biortech.2006.09.019

Wu, X., Chen, H., & Zhang, Y. (2024). Long-term effects of organic amendments on soil bulk density and structure in agricultural systems. *Scientific Reports*, *14*, Article 41231. https://doi.org/10.1038/s41598-024-41231-w

Zhang, Y., Li, X., & Wang, Q. (2025). Organic amendments as improvement for soil aggregation and carbon sequestration in agricultural soils. *Field Crops Research*, *328*, 109946. https://doi.org/10.1016/j.fcr.2025.109946