

SCIENTARA JOURNAL

Journal of Agricultural, Environmental and Life Sciences

ARTICLE TYPE	VOLUME / ISSUE	PUBLICATION DATE
Research Article	Vol. 2, Issue 2	16 October 2026

COMPARATIVE ANALYSIS OF LABLAB, MUCUNA, PUMPKIN AND COWPEA COVER CROPS FOR ENHANCING SOIL QUALITY IN SUDAN SAVANNAH OF NIGERIA

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ABSTRACT

Soil quality problem in Nigerian sudan savannah plays critical role and negatively affecting agricultural production. This research evaluated the comparative effectiveness of Mucuna, Lablab, Pumpkin, and Cowpea cover crops in enhancing soil quality. The Experiment was conducted at Center for Dryland Agriculture (CDA) Training and Research Farm, Bayero University Kano, the study utilized a Randomized Complete Block Design (RCBD) with four treatments which are replicated four times. Soil moisture content (SMC), particle size analysis (PSA), bulk density and soil temperature of base-line and end-lines data were compared and analyzed. The Results indicated that Mucuna substantiated the most significant long-term impact, by achieving the highest end-line, but reduction was logged in soil temperature (-6.67°C) and the highest moisture retention (1.94%) at 72 days after planting. However, Cowpea was identified as the second most effective treatment in enhancing soil quality, predominantly, during the early growth stages. Reduction in bulk density (-0.26 Mg/m³) was recorded in all treatments, therefore improved soil structure, while Mucuna still recording the preeminent. The study concludes that while Cowpea is ideal for rapid early-season, Mucuna is the most ideal cover crop for enhancing soil quality in the region.

Keywords: Sudan Savannah; Soil Quality; Cover Crops.; Soil Moisture

How to Cite: Musa, Y. H., Lawan, A. B., Atiku, A. A., Adamu, U. M., Abdullahi, A., & Yahaya, U. (2026), Comparative Analysis of Lablab, Mucuna, Pumpkin and Cowpea Cover Crops for Enhancing Soil Quality in Sudan Savannah of Nigeria, *Scientara Journal*, 2(2), 1-7.

1. INTRODUCTION

Cover crops play a crucial role in improving soil health, particularly in semi-arid regions where soil degradation and moisture retention are significant concerns (Abayomi *et al.*, 2001). In the Nigeria savannah, legume cover crops like cowpea and lablab have shown promise in enhancing soil fertility and structure (Tarfa, *et al.*, 2007). Research has demonstrated that cover crops can improve soil moisture retention, reducing the need for irrigation and minimizing soil erosion (Njiti *et al.*, 2018). For instance, cowpea cultivars have been found to exhibit varying levels of water use efficiency when grown on residual soil moisture in northeast Nigeria (Njiti *et al.*, 2018). Organic amendments, such as cow dung and poultry litter, have been shown to significantly enhance soil organic carbon and available phosphorus (Asiegbu & Oikeh, 1995; Anikwe, 2002). Furthermore, legume cover crops like cowpea and groundnut can fix nitrogen in the soil, improving soil fertility and structure (Tarfa, *et al.*, 2007). Cover Crops may include leguminous species such as cowpea, Mucuna and lablab or

non-leguminous species like pumpkin, which provide physical soil cover, improve infiltration, and reduce evaporation losses (Mbuthia *et al.*, 2015; Chouhan *et al.*, 2022). Their root systems enhance soil porosity and biological activity, further increasing the water-holding capacity of soils (Tariq *et al.*, 2023). Cover crops also contribute to improved soil quality by increasing organic carbon levels, total nitrogen, and available phosphorus (Ogunwole *et al.*, 2006).

Many studies Provides numerous examples of the positive impact of cover crops on soil quality indicators. Studies by Wiesmeier (2015), Juan *et al.* (2017), Cerdà *et al.* (2022), Gao *et al.* (2022), Mrunalini *et al.* (2022), Quin tarelli *et al.* (2022), and Schön *et al.* (2024) highlighted their beneficial effects on bulk density, aggregate stability, water retention capacity, organic matter content, and microbial activity in the soil. Studies have also shown that ground cover plants reduce nutrient leaching, thereby protecting groundwater quality. Cover crops are cultivated not for harvest but to improve soil health and preserve biodiversity. Cover crops can be used as catch crops or green manure and can be classified into the following groups: legumes (e.g alfalfa, vetches, clover), nonlegumes (spinach, canola and flax), grasses (e.g. ryegrass and barley) and brassicas (e.g. radishes and turnips) (Abdalla *et al.*, 2019). The positive impact of cover crops on soil health has been recognized since ancient times. Historical evidence suggests that cover crops were cultivated to improve soil fertility in China nearly 3,000 years ago (Pieters, 1927). Using cover crops is a nature-based solution that enhances soil structure throughout the soil profile, protects soil organic matter, and promotes nutrient cycling and biological activity in the soil (Lal, 2015).

2. MATERIALS AND METHODS

2.1 Land Preparation and Sowing

The experimental site was plowed and harrowed to a depth of approximately 30 cm to create a uniform seedbed. Seeds were sown manually at a spacing of 60 cm inter-row and 60 cm intra-row. Weed control was done manually to avoid the chemical interference of herbicides on soil biological activity.

The experiment utilized a Randomized Complete Block Design (RCBD) with four replicates. The treatments consisted of four cover crop species, totaling 16 experimental units

2.2 Soil samples preparation

The soil samples for laboratory Analysis were collected and labeled Appropriately from the Experimental sites using Auger, and core sampler in a sealed polythene bag.

2.3 Baseline and End-line parameters

Baseline and End-line parameters for assessing soil quality change before and after the experiment were:

Soil bulk density: Bulk density was determined using undisturbed core sampling method. The soil samples collected were oven dried at 105°C for 24hrs so as to remove the entire moisture content to constant weight and expressed as mass of dry soil per unit volume (Campbell and Henshall, 1991).

$BD = \text{Mass of Dry soil} / \text{Volume of soil.}$

Particle density: The Particle Density was determined using the Pycnometer method as described by Blake and Hartage (1986).

$PD = \text{Mass/volume.}$

Soil temperature: Soil Temperature of different cover crops was determined using Thermometer, inserted at a depth of 30 cm within each treatment plot.

Soil Moisture: Soil moisture content for base and end-lines level was analyzed at the beginning and end of the experiment. Samples were collected by Core sampler and analyzed using Gravimetric method as follow;

Fresh Weight (w_{wet}): Moist soil was weighed immediately in a pre-weighed Can.

Dry Weight (w_{dry}): Samples were oven-dried at 105°C for 24 hours and weighed after cooling in a desiccator.

Calculation:

$$\%M_{wt} = \frac{W_{wet} - W_{dry}}{W_{dry}} * 100$$

3. RESULTS AND DISCUSSION

3.1 Assessment of Soil Quality Changes (Baseline vs. End-line)

The impact of cover crops on soil quality was assessed by comparing baseline data (August) with end-line data (November).

All treatments exerted a negative change (reduction) on soil temperature. Mucuna demonstrated the most pronounced cooling effect (-6.67°C), significantly outperforming Cowpea (-2.74°C), which is attributed to the high thermal insulation provided by its dense biomass.

A reduction in bulk density was observed across all plots. The most significant structural improvement occurred in Mucuna plots (-0.26 Mg/m³), suggesting that biological root action and increased organic matter deposition enhanced soil porosity.

there were no significant differences in Soil moisture levels across the plots (averaging 1.30 to 1.32 %). This uniformity was expected as the experimental site had been subjected to the same environmental conditions and land preparation prior to the introduction of treatments

End-line Results and Treatment Effects: By the end of the 72 DAP, a significant divergence in SMC was observed among the treatments ($p < 0.05$). Mucuna pruriens: Recorded the highest end-line moisture content (1.60 %), representing a substantial increase from its baseline level.

Positive change detection was recorded for SMC and Particle Size Analysis (PSA) and Negative Effect on Soil Temperature and Bulk Density as shown in Table 4. While cover crops do not alter primary mineral textures, the increase in mean weight diameter (PSA) indicates an improvement in aggregate stability.

The Treatments has Negative Effect on Soil Temperature and Bulk Density while Increasing Soil Moisture Content and Aggregate Stability (particle Size) soil physical Parameters As shown in Table 3 and Fig 6.

The soil physical parameters tested both in Baseline and End-lines level were Compared and presented in Fig 6 below.

Table 1: Base and End lines data under different Cover crop both during the 2025/2026 raining season.

Treatment	Soil Temp (°C)	Bulk Density (Mg/m ³)	Soil Moisture Content (m ² /m ²)	Particle Size Analysis (um)
	Base – End	Base – End	Base -End	Base - End
Mucuna	22.17 - 15.5 a	1.91 -1.65 a	1.30 - 1.60 b	0.65 - 1.67 a
Lablab	21- 16.20 a	1.85 -1.69ab	1.32 - 1.54 a	0.64 - 1.46 ab
Pumpkin	22 - 18.63 a	1.84 - 1.73 ab	1.30- 1.40a	0.58 - 1.58ab
Cowpea	22.07 -19.33b	1.88 - 1.80 b	1.3 - 1.49b	0.59 - 1.74 b

Treatment	Soil Temp (°C)	Bulk Density (Mg/m ³)	Soil Moisture Content (m ² /m ²)	Particle Size Analysis (um)
	Base – End	Base – End	Base -End	Base - End
SE (±)	P<0.05			

Table 2: Change Detection from Base and End lines Data under Different Cover Crop.

Treatment	Soil Temp (°C)	Bulk Density (Mg/m ³)	Soil Moisture Content (m ² /m ²)	PSA (um)
Mucuna	-6.67 a	-0.26 a	0.30 b	1.02 a
Lablab	-4.80 a	-0.16 ab	0.22 a	0.82 ab
Pumpkin	-3.37 a	-0.11 ab	0.10a	1.0 ab
Cowpea	-2.74 b	-0.88 b	0.19b	1.15 b
SE (±)	P<0.05			

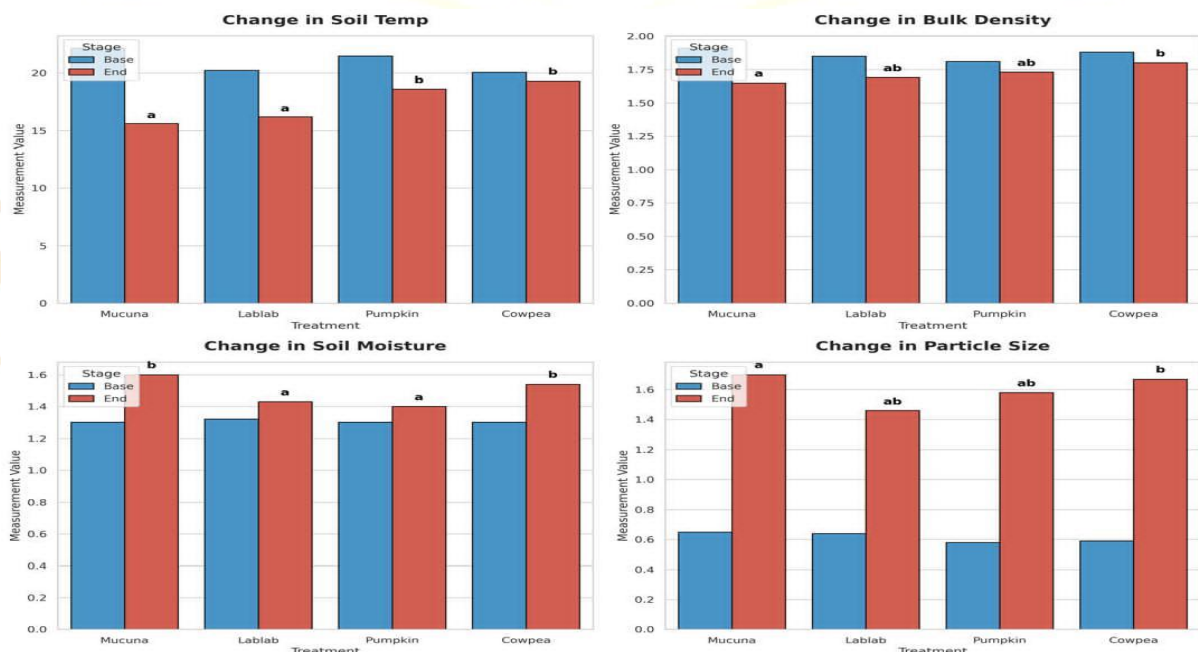


Figure 1: Base and End lines data comparison of Cover Crops Before and After the Experiment.

3.2 Discussion

3.2.1 Soil Quality as affected by Lablab, Mucuna, Pumpkin and Cowpea Cover crops.

The impact of cover crops on soil quality was assessed by comparing baseline data (August) with end-line data (November).

The Baseline – End-line approach was used to assesses the changes in soil quality. Soil samples for soil moisture content, particle size analysis, bulk density and soil temperature parameters were taken and analyzed during the planting period (3rd August) which was referred to as the Baseline data.

The above soil parameters for the assessing soil quality changes were analyzed again at 72 DAP (Days after Planting) (Early November).

Bulk density: The reduction in bulk density was most pronounced in Mucuna plots (decreasing from 1.91 Mg/m³ in Baseline to 1.65 Mg/m³). This improvement in soil structure is credited to increased organic matter and enhanced macro-fauna activity (e.g., earthworms), which improved the soil's capacity to hold water within its pores. Boateng, (2009).

Soil temperature: Soil temperature showed a significant decrease at the end-line, following the order: Mucuna > Lablab > Pumpkin > Cowpea. While soil temperature under Cowpea and Pumpkin Treatment Were Observed to have slightly higher soil Temperature at the End-line. Mucuna plots was recorded the lowest end-line temperatures (15.5°C) due to the dense canopy preventing solar radiation from penetrating the soil surface. This moderating effect protects soil microbes and preserves capillary water. Ziblim, (2013).

Soil Moisture Content (Baseline vs. End-line): The comparative analysis of soil moisture content between the baseline (pre-planting) and end-line (post-harvest) periods revealed a significant impact of cover crop species on moisture preservation.

Baseline status: At the onset of the experiment (Baseline), there were no significant differences in soil moisture levels across the plots (averaging 1.30 to 1.32 %). This uniformity was expected as the experimental site had been subjected to the same environmental conditions and land preparation prior to the introduction of treatments

End-line results and treatment Effects: By the end of the 72 DAP, a significant divergence in SMC was observed among the treatments ($p < 0.05$). Mucuna pruriens: recorded the highest end-line moisture content (1.60 %), representing a substantial increase from its baseline level. Mucuna mulch can increase available soil moisture content from baseline levels (9.54%) to significantly higher levels (11.40%) by reducing evaporation (Boateng, 2005). Lablab: followed closely with an end-line moisture content of 1.43%. Cowpea and Pumpkin showed a moderate increase compared to baseline, but were significantly lower than Mucuna at the end of the trial (1.54 % and 1.40 % respectively) due to their effect on the soil before senescence.

Soil Particle Density: As shown on Fig.6 while cover crops do not alter the mineral texture (sand/silt/clay ratio), they significantly influence aggregate stability. there was significant change between the Base and End lines level, Mucuna was found to influence the soil aggregates stability more by the addition of organic "glues" from decomposing Mucuna and Lablab vines binds smaller particles into stable macro-aggregates. Boateng, (2005). Mucuna recorded the highest increase in effective aggregate size, improving the soil's resistance to disintegration and erosion. Research shows that cover crops like Mucuna, Cowpea, and Lablab use root exudates and fungal hyphae to bind small particles (silt and clay) into larger, water-stable "macro-aggregates" Hulugalle *et al.*, (1986).

4. SUMMARY AND CONCLUSION

This Research evaluated the effectiveness of Mucuna, Lablab, Pumpkin and Cowpea Cover crops in enhancing soil quality in Nigerian Sudan Savannah. Mucuna significantly outperforms other cover crops in

enhancing soil quality by reducing soil temperature, bulk density and increasing particle size (Aggregates stability) and soil moisture.

5. CONCLUSION

Cover crops effectively improve soil physical quality over a single growing season. Dense canopies, particularly that of *Mucuna*, act as thermal buffers, significantly reducing soil temperatures compared to the early-maturing Cowpea and Pumpkin plots. Significant reduction in soil bulk density was observed across all cover crop treatments, with *Mucuna* recording the lowest values, indicating soil porosity and structure improvement. Significant differences between baseline and end-line data suggest that Cover crops, especially *Mucuna*, promote soil aggregation and structural stability by increasing effective particle size through organic matter binding.

The study concludes that while all cover crops improve soil moisture relative to bare soil, temporal consistency varies with species. *Mucuna* is the most effective species for long-term moisture conservation. The transition from a baseline of 1.30 % to an end-line of 1.60 % under *Mucuna* even after rainfall had ceased, proves its high efficiency in buffering the soil against the harsh evaporative demands of the Sudan Savanna region.

4.2 Conflicts of interest

The authors had no conflict of interest to declare.

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