



RESEARCH PAPER

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Carbon sequestration potential of napier (*Pennisetum purpureum*) grass applied with varying classifications of livestock excrement

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ABSTRACT

This study evaluated the carbon sequestration potential of napier grass (*Pennisetum purpureum*) applied with varying classifications of livestock excrement under a combined inorganic–organic fertilization system. The experiment was conducted at the RDE Complex, College of Agriculture, Central Mindanao University from June to August 2025 using a Randomized Complete Block Design (RCBD) with five treatments: control (recommended rate of inorganic fertilizer), and combinations of inorganic fertilizer with goat manure, chicken manure, cattle manure, and swine manure. Results revealed highly significant differences ($p < 0.01$) among treatments in soil organic matter, soil pH, soil organic carbon (SOC), soil organic carbon stocks (SOCS), and carbon sequestration of napier grass. Among treatments, cattle manure (T4) consistently showed the highest performance, recording the greatest organic matter content (4.01%), favorable soil pH (6.03), highest SOC (2.33%), highest SOC stocks (32.15 Mg/ha), and highest carbon sequestration potential (4.72 Mg/ha). Swine manure (T5) produced the highest bulk density (1.29 g/cm³), while the control treatment showed the lowest carbon storage values across parameters. Overall, organic amendments significantly improved soil carbon dynamics compared to the control, demonstrating the strong potential of integrated nutrient management in enhancing carbon storage in napier grass systems. The findings indicate that cattle manure is the most effective amendment for maximizing soil carbon sequestration and improving soil quality, thereby contributing to climate change mitigation and sustainable forage production systems.

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INTRODUCTION

The urgent need to address climate change has spurred interest in agricultural practices that not only enhance productivity but also contribute to carbon sequestration, thereby mitigating greenhouse gas emissions. Carbon sequestration, the process of absorbing and storing atmospheric carbon dioxide (CO₂), plays a critical role in reducing greenhouse gas concentrations major drivers of global warming. This process can occur naturally through biological mechanisms such as photosynthesis in forests, grasslands, and oceans, or artificially through technological methods like carbon capture and storage (CCS) in industrial settings (Piccolo, 2012).

One promising agricultural strategy involves the integration of livestock excrement into farming systems. Livestock waste categorized into solid manure, slurry, and composted residues possess distinct nutrient profiles and decomposition rates that can differently influence soil organic carbon dynamics. Beyond enhancing soil fertility and structure, the use of such organic amendments has the potential to significantly boost soil carbon storage and nutrient cycling (FAO, 2017), contributing to more sustainable land management.

Napier grass (*Pennisetum purpureum*), known for its high biomass yield and adaptability to diverse environments, emerges as an ideal forage crop for investigating the synergistic effects of livestock excrement on both carbon sequestration and forage quality (Yousuf *et al.*, 2019).

This study aims to assess the carbon sequestration potential of Napier grass when cultivated with varying classifications and application levels of livestock excrement. By quantifying soil carbon accumulation, this research seeks to illuminate the dual benefits of integrating livestock waste into forage production systems.

Understanding how different types and quantities of livestock excrement influence both carbon dynamics

and forage quality is vital for advancing sustainable agriculture. The outcomes of this research could improve soil fertility, reduce greenhouse gas emissions. Ultimately, by bridging agronomic practices with environmental sustainability, this study offers valuable insights for policymakers, agronomists, and farmers aiming to develop resilient, climate-smart agricultural systems.

MATERIALS AND METHODS

Place and duration of the study

The study was conducted in RDE Complex, College of Agriculture, Central Mindanao University, Musuan, Maramag, Bukidnon from June 2025 to August 2025. The analysis of soil properties planted with Napier (*Pennisetum purpureum*) grass applied with varying classifications of livestock excrement was conducted in the Soil and Plant Analysis Laboratory at Central Mindanao University.

Materials and equipment

Tillage tools for land preparation, planting materials, laboratory apparatus, chemical reagents, record book, and livestock excrement storage. A total of 100 sqm of land area was used and underwent soil sampling analysis. The study was laid out via a Randomized Complete Block Design (RCBD). The Napier grass was randomly selected and planted to experimental planting area with 3 replication each of the treatment. The soil and grass yield sample throughout harvest underwent certain laboratory analysis for further evaluation. The application rate of livestock excrement was as follows:

T1- 104kg/ha of complete (14-14-14) fertilizer and 0% of livestock excrement.

T2- 104kg/ha of complete (14-14-14) fertilizer and 104kg/ha livestock excrement (goat manure).

T3- 104kg/ha of complete (14-14-14) fertilizer and 104kg/ha (chicken manure).

T4- 104kg/ha of complete (14-14-14) fertilizer and 104kg/ha (cattle manure).

T5- 104kg/ha of complete (14-14-14) fertilizer and 104kg/ha (swine manure).

A total of 15 samples (5 treatments replicated into 3) were used and underwent laboratory analysis of soil chemical properties such as soil pH using Potentiometric Method (1:5) Soil: Water ratio, organic matter using Walkey- Black Method, nitrogen using Kjeldahl Method, extractable P via Bray P₂ Method/ UV-Vis Spectrophotometer, and exchangeable K through Extraction Method/Flame Photometer was conducted at the Soil and Plant Analysis Laboratory (SPAL) of Central Mindanao University (CMU).

Due to lack of equipment for carbon analysis, the derivation of soil organic carbon from soil organic matter was employed. Previous studies suggested the estimated percent of carbon in organic matter is about 58%. The percent soil organic carbon was calculated using the conversion factor of 1.72. The following formula was used.

$$\text{SOC} = \text{OM}\% / 1.72 \quad \text{Eq. 1}$$

Where:

SOC = Soil Organic Carbon

OM = Organic Matter

1.72 = conversion factor from (100/58) *100

Preparations of the treatment

The livestock excrement was gathered from the backyard piggery for the swine manure and livestock project for the other excrement at CMU-College of Agriculture-RDE Complex, Central Mindanao University, Musuan, Maramag, Bukidnon. Sun and air drying of excrement from 30 days will be done. Grinding the dried excrement was performed for the proper and accurate distribution of the amount of livestock excrement. It was stored into a clean and tidy storage to avoid any possibilities of adulteration and contamination from undesirable organisms and foreign objects.

Data collection

Bulk density

Calculate the bulk density of the mineral soil core: Dry bulk density soil samples in drying oven at 105°C for maximum of 48 hrs. The volume of the core

sample was measured and the fresh and oven dried weight of the soil samples will be weighed.

$$\rho_b = M_s / V_t \quad \text{Eq.2}$$

Where:

ρ_b = Bulk Density

M_s = Mass of Soil

V_t = Total Volume

Total carbon stocks of the soil planted with Napier grass per treatment

Using the obtained carbon concentration data obtained from equation 1, through the formula of the amount of carbon per unit area were given by:

$$\text{SOC (t/ha)} = (\rho_{b \text{ soil}}) * \text{depth}_{\text{soil}} * C \quad \text{Eq. 3}$$

Where:

C = Carbon Stock (t/ha)

$\rho_{b \text{ soil}}$ = Bulk Density

Depth_{soil} = Soil Depth

RESULTS AND DISCUSSION

This study assessed the carbon sequestration potential of Napier (*Pennisetum purpureum*) grass with a measurement of 100 sqm of the land area at the College of Agriculture RDE-Complex of Central Mindanao University with an open area, located at an elevation of 312 meters above sea level (masl). Table 1 shows the varying results of the soil properties particularly bulk density where there is no significant difference of the block was observed.

There is a highly significant difference among treatment means observed, where Treatment 5 had the highest mean of 1.29 g/cm³, followed by Treatment 4 with 1.25 g/cm³, Treatment 2 with 1.22 g/cm³, Treatment 3 with 1.19 g/cm³, and Treatment 1 with the lowest mean of 0.87 g/cm³.

Napier grass grows from cuttings or slips that requiring developing roots immediately. Bulk Density at around the volume of 1.29 g/cm³, means that there is virtually zero physical resistance, allowing the roots to penetrate deep into the soil early. This leads to faster tillering (more shoots) and higher biomass yield (Tamta *et al.*, 2023).

Table 1. Bulk density, soil pH, and organic matter content of the soil applied with organic and inorganic fertilizer

Treatment	BD (g/cm ³)	OM (%)	pH (n)
T1	0.87 ^{bc}	3.66 ^e	5.98 ^b
T2	1.22 ^{bc}	3.80 ^c	5.88 ^c
T3	1.19 ^a	3.94 ^b	5.81 ^d
T4	1.25 ^{ab}	4.01 ^a	6.29 ^a
T5	1.29 ^c	3.73 ^d	5.60 ^e
F-Test	**	**	**
CV (%)	2.61	0.20	0.20

** = highly significant, BD= Bulk Density, OM= Organic Matter, pH= Soil pH, LE= Livestock Excrement, RRIF= Recommended Rate of Inorganic Fertilizer, GM= Goat Manure, ChM= Chicken Manure, CM= Cattle Manure, SM= Swine Manure. Means with the same letter are not significantly different, while means with different letters are significant at 5% and 10% level of probability using HSD.

Swine manure is high in nitrogen and phosphorus, which Napier grass implores. The high porosity ensures these nutrients and oxygen reach the roots simultaneously, preventing the stunted growth often seen in compacted soils (Agbede, 2025).

Moreover, Table 1 also shows the different results among treatment means of other related soil characteristics such as organic matter and soil pH. In the portion of organic matter, where highly significant difference among treatment means were observed. Treatment 4 obtained the highest mean of organic matter with 4.01%, followed by Treatment 3 with 3.94%, Treatment 2 with 3.80%, Treatment 5 with 3.73%, and Treatment 1 with the lowest result of 3.66%.

In many tropical and subtropical areas where Napier grass is grown, soil organic matter often drops below 2% due to heat and frequent harvesting. Reaching 4.01% through the application of cattle manure place the soil in a production advantage. This is critical for Napier grass, which requires consistent moisture to produce high biomass (Borisoot *et al.*, 2025).

In specification of soil pH, where highly significant difference among treatment means were also noticed. Treatment 4 obtained the highest mean of 6.03, followed by Treatment 1 with 5.98, Treatment 2 with 5.88,

Treatment 3 with 5.81, and Treatment 5 with the lowest rate of 5.60.

A soil pH around 6.03 noticed in Napier grass plots is an excellent result for cattle manure application. It indicates that the soil is in a highly productive state, as this slightly acidic range is where nutrient availability is at its peak (Hermy and Reeza, 2025).

Table 2 shows the varying results of other sets of soil related characteristics such as soil organic carbon, soil organic carbon stocks, and amount of carbon sequestered by the Napier grass per treatment. Soil organic carbon, where there is highly significant difference among treatment means were observed. Treatment 4 has respectfully gained the highest mean of 2.33%, followed by Treatment 3 with 2.29%, Treatment 2 with 2.21%, Treatment 5 with 2.17%, and Treatment 1 with the lowest level of 2.13%.

Table 2. Soil organic carbon, soil organic carbon stocks, and carbon sequestered by the Napier (*Pennisetum purpureum*) grass applied with varying classifications of livestock excrement

Treatment	SOC (%)	SOCS (Mg/ha)	CSNG (Mg/ha)
T1	2.13 ^e	27.65 ^b	3.96 ^b
T2	2.21 ^c	28.68 ^b	4.21 ^b
T3	2.29 ^b	32.06 ^a	4.71 ^a
T4	2.33 ^a	32.15 ^a	4.72 ^a
T5	2.17 ^d	27.30 ^b	4.01 ^b
F-Test	**	**	**
CV (%)	0.17	2.47	3.24

** = highly significant, BD = Bulk Density, OM = Organic Matter, pH = Soil pH, LE = Livestock Excrement, RRIF= Recommended Rate of Inorganic Fertilizer, GM= Goat Manure, ChM= Chicken Manure, CM= Cattle Manure, SM= Swine Manure. Means with the same letter are not significantly different, while means with different letters are significant at 5% and 10% level of probability using HSD.

Based on the findings of Fosu-Mensah *et al.* (2025), a soil organic carbon (SOC) level of 2.33% is an excellent result for Napier grass establishment using cattle manure. This value confirms that the 4.01% Organic Matter is effectively delivering carbon stability to the soil.

Meanwhile, soil organic carbon stocks, where there is also an indication of highly significant difference among treatment means. Treatment 4 has revealed the highest mean of 32.15 Mg/ha, Treatment 3 with 32.06 Mg/ha, Treatment 2 with 28.68 Mg/ha, Treatment 1 with 27.65 Mg/ha, and Treatment 5 with the lowest mean of 27.30 Mg/ha.

A soil organic carbon (SOC) stocks of around 25-37 Mg/ha is an exceptionally high and impressive value for Napier grass, indicating highly effective management and carbon sequestration. Such levels are driven by the high biomass productivity of *Pennisetum purpureum*, particularly with high-rate organic inputs like cattle manure (Biazin *et al.*, 2018).

On the other hand, the carbon sequestered by the napier grass had also an indication of highly significant difference among treatment means. Treatment 4 repeatedly obtained the highest mean of 4.72 Mg/ha, followed by Treatment 3 with 4.71 Mg/ha, Treatment 2 with 4.21 Mg/ha, Treatment 5 with 4.01 Mg/ha, and Treatment 1 with 3.96 Mg/ha.

The carbon sequestration of around 4.72 Mg/ha in the cattle manure-treated plots indicates a high potential for carbon storage in napier grass systems. Conversely, this level of sequestration highlights the effectiveness of organic amendments in improving soil carbon stocks compared to traditional mineral fertilization (Huang *et al.*, 2022).

Cattle manure is a highly effective organic amendment for fostering soil organic carbon (SOC) and improving soil health over the long term. Unlike synthetic fertilizers that provide only immediate nutrients, cattle manure directly adds substantial organic carbon, improves soil physical structure, and promotes stable humus formation, as highlighted in studies on manure application (Khan *et al.*, 2024).

CONCLUSION

Based on the results presented in the manuscript, the study demonstrated that the application of livestock excrements significantly influenced the carbon sequestration potential of Napier grass through

improvements in key soil properties, including bulk density, organic matter, soil pH, soil organic carbon, soil organic carbon stocks, and carbon sequestration capacity. Among the organic amendments evaluated, cattle manure consistently produced the most favorable results, recording the highest organic matter content, soil organic carbon, soil organic carbon stocks, and carbon sequestration values. These findings indicate that integrating organic amendments with inorganic fertilizers enhances soil carbon accumulation and promotes better soil quality under Napier grass production systems.

Furthermore, the study confirms that the type of livestock excrement applied plays an important role in determining the extent of soil carbon storage and sequestration. The superior performance of cattle manure suggests its greater effectiveness in contributing stable organic carbon and improving soil conditions conducive to carbon retention. Overall, the integration of livestock manure, particularly cattle manure, into Napier grass cultivation represents a sustainable nutrient management strategy that can enhance soil fertility, increase carbon sequestration, and support climate change mitigation while maintaining productive forage systems.

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