



Effect of Poultry and Cattle Manures on Rhizosphere Bacteria Dynamics and Maize Yield in Wetland Soils of Akwa Ibom State.

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Abstract

The study, Effect of Poultry and Cattle Manures on Rhizosphere Bacteria Dynamics and Maize Yield in Wetland Soils of Akwa Ibom State was done. The experiment was conducted using a randomized complete block design with three treatments: control (no amendment), poultry manure, and cattle dung. Baseline soil analysis revealed moderate acidity (pH 5.42 ± 0.11), low organic carbon (1.23%), and low nitrogen (0.11%), typical of nutrient-depleted wetland soils. The applied manures differed in nutrient quality, with poultry manure having higher organic carbon (25.8%), total nitrogen (2.65%), and available phosphorus (48.7 mg kg^{-1}) than cattle dung. Post-treatment results showed improvements in soil pH, organic matter, and nutrient content, particularly under poultry manure. Rhizospheric bacterial populations at 6 and 12 weeks after planting were markedly higher in poultry manure-treated plots, with total heterotrophic bacteria reaching $11.26 \times 10^6 \text{ CFU g}^{-1}$ compared to $6.12 \times 10^6 \text{ CFU g}^{-1}$ in the control. Molecular identification revealed dominant species such as *Azotobacterchroococcum*, *Bacillus subtilis*, and *Pseudomonas fluorescens*—key functional bacteria involved in nitrogen and phosphate utilization, and plant growth promotion. Maize growth and yield parameters, including plant height (133.5 cm), grain yield (4.86 t ha^{-1}), and harvest index (0.53), were significantly enhanced under poultry manure application. Correlation analysis showed strong positive relationships ($r \geq 0.85$, $p \leq 0.01$) among soil nutrients, *Azotobacter* population, and yield, indicating microbial–nutrient synergy. It was recommended that poultry manure be adopted as a sustainable soil amendment to improve microbial health and maize productivity in wetland soils of Akwa Ibom State.

Keywords: Poultry Manure, Cattle Dung, Rhizospheric Bacteria, Wetland Soil, Maize Yield

Introduction

Maize (*Zea mays* L.) is one of the staple food crop in Nigeria and plays a vital role in national food security, livestock feed production, and the livelihood of rural farmers (Li et al., 2022). The crop's versatility makes it central to Nigeria's agricultural economy, being consumed in various forms and serving as raw material for industries. However, despite its wide cultivation, average maize yield in Nigeria remains below its genetic potential due to soil degradation, poor nutrient management, and changing climatic conditions (Adekiya et al., 2020). In Akwa Ibom State, wetlands and floodplain areas represent productive zones for year-round farming due to their moisture retention capacity. Nonetheless, these ecosystems are prone to challenges such as nutrient leaching, periodic flooding, and soil acidity that constrain crop performance (Udoh et al., 2022). The wetlands' hydromorphic nature often leads to reduced soil aeration and microbial activity, conditions that negatively affect nutrient mineralization and plant growth (Wetland Fertility Assessments, 2010–2025). These challenges necessitate the development of sustainable soil fertility management strategies capable of improving both soil health and crop yield in these environments.

Rhizosphere bacteria, often referred to as plant growth-promoting rhizobacteria (PGPR), perform specific ecological functions that directly influence maize productivity such as nutrient cycling, nitrogen fixation, phosphorus solubilization, enhanced root development, nutrient uptake, plant stress tolerance and disease suppression (Sumbul et al., 2020; Tang et al., 2020). Common beneficial genera associated with maize roots include *Azotobacter*, *Nitrobacter*, *Bacillus*, and *Paraburkholderia* (Tang et al., 2020). These microbes contribute to species, for example, fix atmospheric nitrogen, while *Nitrobacter* species facilitate nitrification, converting

nitrite to nitrate forms available for plant uptake (Sumbul et al., 2020). The introduction of organic manures enriches soil carbon pools, providing favorable conditions for these beneficial microbes. Studies have demonstrated that composted poultry and cattle manures enhance bacterial diversity, promote nitrogen cycling, and increase maize root and shoot biomass (López-Carmona et al., 2019; Pan et al., 2025). However, despite these benefits, few studies have explored how these microbial shifts occur under waterlogged or hydromorphic wetland conditions, making this a crucial area for further investigation in Akwa Ibom's wetlands.

Wetland soils of Akwa Ibom—comprising inland depressions, alluvial floodplains, and mangrove fringes—are typically characterized by high moisture content, low redox potential, and fluctuating pH levels (Udoh et al., 2022). These soils experience alternating aerobic and anaerobic conditions, which affect the transformation and availability of nitrogen and phosphorus. Consequently, the biological and chemical processes controlling soil fertility in wetlands are less stable than those in upland systems. Empirical studies have reported low organic carbon, limited available phosphorus, and deficiencies in exchangeable base cations across several wetland soil types in the region (Wetland Fertility Assessments, 2010–2025). Such constraints hinder root development, microbial proliferation, and nutrient uptake. The integration of organic amendments, therefore, becomes essential for restoring soil fertility, improving soil structure, and enhancing biological activity (including rhizospheric bacterial activity). Majority of studies focus on upland and savanna soils. There remains a paucity of data concerning the effects of organic manures on microbial dynamics and maize yield under wetland conditions. This gap highlights the need for localized studies in Akwa Ibom's wetlands to understand how organic amendments interact with soil microbes and crop systems under these environmental constraints.

Aim and Objectives of the Study

This study aimed at investigating the effects of poultry and cattle manures on rhizosphere bacterial dynamics and maize yield in wetland soils of Akwa Ibom State.

Objectives seek to:

1. Determine the physicochemical properties of poultry manure, cattle dung, and wetland soils before treatment.
2. Evaluate the bacterial composition of the organic fertilizers and treated soils.
3. Isolate and characterize rhizospheric bacteria associated with maize roots in the treated and control plots.
4. Evaluate the effects of poultry and cattle manures on maize growth parameters such as plant height, leaf area, dry matter, and grain yield.
5. Do genomic DNA sequencing of isolated rhizosphere bacteria.
6. Compare the efficiency of poultry manure and cattle dung in improving soil nutrient status and maize productivity relative to untreated soils.
7. Assess the relationship between soil bacterial activity and maize growth performance under different organic manure treatments.
8. Highlight the environmental importance of using animal manure as environmental friendly alternatives to inorganic fertilizers in wetland cropping systems of the State.

Materials and Methods

Research Design

The study adopted a Randomized Complete Block Design (RCBD) with three treatments—poultry manure, cattle manure, and an unfertilized control. Each treatment was replicated three times, resulting in a total of nine experimental plots. This design minimized experimental error and provided reliable comparisons of treatment effects on properties of soil, rhizospheric bacterial dynamics, and maize yield (Gomez & Gomez, 1984; Montgomery, 2020).

Description of the Study Area

The research was conducted in two wetland soils of Akwa Ibom State, Nigeria, located within the humid tropical rainforest belt (Figure 1). The region experiences an annual rainfall range of 2,000–3,000 mm, mean temperatures between 26°C and 28°C, and relative humidity of 70–90%. The soils are predominantly Fluvisols and Gleysols, derived from alluvial deposits and characterized by moderate acidity, low organic matter, and poor natural fertility (Udoh *et al.*, 2022). These features make the wetlands suitable for investigating the impact of organic manures on microbial activities and maize performance under hydromorphic conditions.

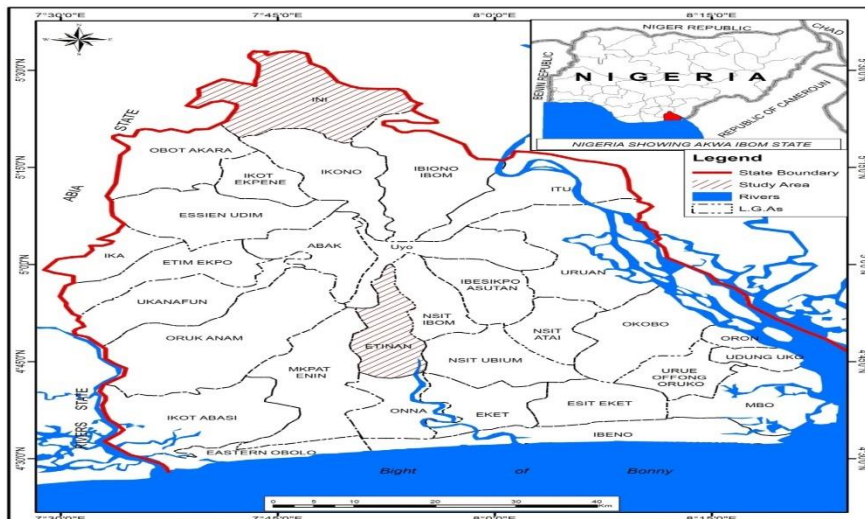


Figure 1: The study sites on the map of Akwa Ibom State, Nigeria
 Source: Ministry of Lands and Town planning, Akwa Ibom State

Experimental Population and Sample Size

The experimental population comprised cultivated wetland soils and locally grown maize (*Zea mays* L.) varieties within Akwa Ibom State. Nine experimental plots measuring 3 m × 3 m were established, providing a representative sample size sufficient for statistical reliability. Equal representation of treatments in each block ensured balanced randomization (Gomez & Gomez, 1984).

Sampling Technique and Plot Randomization

Sampling used to select the wetland sites was stratified random based on uniform topography, vegetation cover, and cropping history. Within each block, treatments were randomly assigned to plots to eliminate bias and minimize environmental variability (Steel & Torrie, 1980).

Collection and Preparation of Test Crop (Maize Seeds)

Certified maize seeds of a locally adapted variety were obtained from the Akwa Ibom Agricultural Development Programme (AKADEP), Uyo. Seeds were sorted for uniformity and vigor, and a viability test confirmed a germination rate above 90% before planting (ISTA, 2020).

Collection and Pre-treatment of Soil Samples:

Stainless-steel auger at a depth of 0–15 cm was used for baseline soil samples prior to manure application. The samples were composited, air-dried, and sieved through a 2 mm mesh for laboratory analysis, while subsamples were stored at 4°C for microbial evaluation (Bremner & Mulvaney, 1982).

Collection, Composting, and Stabilization of Organic Manures

Fresh poultry droppings and cattle dung were sourced from nearby farms and composted separately under aerobic conditions for three weeks. Compost heaps were turning was done every three days to maintain aeration and promote even decomposition. Temperature (55–65°C) and moisture (50–60%) were monitored using a thermometer and moisture meter, respectively. Compost stabilization was confirmed when the C:N ratio decreased below 20:1 (Bernal *et al.*, 2009).

Experimental Site Preparation and Field Layout

The experimental field was cleared, manually tilled, and partitioned into 3 m × 3 m plots separated by 1 m and blocks spaced by 2 m. The organic manures were incorporated into the topsoil at a rate of 10 t ha⁻¹ one week before planting to allow for nutrient equilibration and microbial activation (Agbede *et al.*, 2025).

Pre-Planting Seed Treatment and Viability Test

Pre-planting seed treatment involved surface sterilization with 1% sodium hypochlorite (NaOCl) for 3 minutes, followed by triple rinsing in sterile distilled water. A germination test was conducted using 50 seeds placed on moistened filter paper in Petri dishes at 25°C for seven days (ISTA, 2020). Only seeds showing over 90% germination were selected for planting.

Planting Procedure and Field Management Practices

Two maize seeds were planted per hole at a depth of 3 cm with spacing of 75 cm × 25 cm. Thinning to one healthy plant per stand was performed two weeks after emergence (FAO, 2017). Regular manual weeding and pest control were carried out throughout the growth period.

Laboratory Analysis of Soil and Manure Physicochemical Properties

Soil and organic manures physicochemical properties were determined using standard laboratory methods (Jackson, 1973; Nelson & Sommers, 1982). Soil pH was measured in a 1:2.5 soil-to-water ratio using a digital pH meter (Mettler Toledo SevenCompact), while soil temperature was determined with a calibrated soil thermometer. Organic carbon was analyzed using the Walkley–Black wet oxidation method, total nitrogen by Kjeldahl digestion, available phosphorus by Bray-1 extraction, exchangeable potassium using a flame photometer (Jenway PFP7), and electrical conductivity (EC) with a conductivity meter in a 1:2.5 soil-water extract. All analyses were done in triplicate for accuracy.

Assessment of Growth Parameters

Maize Growth parameters were assessed bi-weekly from five randomly selected plants per plot (Li *et al.*, 2022). Plant height was measured from the soil surface to the leaf apex, while stem girth was determined 5 cm above ground level using a digital Vernier caliper. Leaf area was computed as:

$$\text{Leaf Area} = \text{Length} \times \text{Width} \times 0.75$$

Dry matter accumulation was determined by oven-drying plant parts at 70°C until a constant weight was achieved.

Determination of Maize Yield and Yield Components

The nutrient concentration of maize ear leaves was analyzed after nitric-perchloric acid digestion, and nitrogen, phosphorus, and potassium were quantified following AOAC (2019) procedures. At harvest, cobs were collected and analyzed for grain yield (t ha⁻¹) adjusted to 12% moisture content and harvest index (HI) calculated as the ratio of grain yield to total aboveground biomass.

Collection of Rhizospheric Soil Samples for Microbiological Analysis

Rhizospheric soil samples were collected at 6 and 12 weeks after planting for microbiological analysis. Samples were serially diluted (10⁻¹–10⁻⁶) and cultured using the pour-plate technique. Nutrient Agar (NA) was used for total heterotrophic bacteria, Ashby's Mannitol Agar for *Azotobacter* spp., and Winogradsky medium for *Nitrobacter* spp. (Sumbulet *et al.*, 2020). Plates were incubated at 30°C for 48–72 hours, and colony-forming units (CFU g⁻¹ soil) were counted.

Isolation and Characterization of Rhizospheric Bacteria

Morphological and biochemical characterization of isolates—including Gram staining, catalase, oxidase, and nitrate reduction tests—were done according to Bergey's Manual (Holt *et al.*, 1994).

Molecular (Genomic DNA) Analysis of Bacterial Isolates

Genomic DNA extraction of bacterial isolates was carried out using the cetyltrimethylammonium bromide (CTAB) methods (Wilson, 2001). DNA integrity was confirmed via 1% agarose gel electrophoresis.

PCR Amplification, Sequencing, and Phylogenetic Identification

Polymerase Chain Reaction (PCR) amplification of the 16S rRNA gene was performed using universal primers 27F (5'-AGAGTTTGATCMTGGCTCAG-3') and 1492R (5'-GGTTACCTTGTTACGACTT-3') following Tang *et al.* (2020). PCR conditions included an initial denaturation at 95°C for 5 minutes, followed by 35 cycles of denaturation (94°C, 30 s), annealing (55°C, 45 s), extension (72°C, 90 s), and a final extension at 72°C for 7 minutes. The PCR products were purified and sequenced, and resulting sequences were compared with the NCBI GenBank database using BLAST. Phylogenetic relationships were determined using MEGA X software (Kumar *et al.*, 2018).

Statistical Analysis of Data

All data were analysed using Analysis of Variance (ANOVA) using SPSS version 25. Mean separation was performed using the Least Significant Difference (LSD) test at a 5% probability level. Pearson's correlation analysis was conducted to establish relationships among microbial populations, soil nutrient status, and maize yield (Montgomery, 2020).

Results**Table 1. Physicochemical Properties of Wetland Soil before Treatment (Mean \pm SD, n = 3)**

Parameter	Unit	Value (Mean \pm SD)
pH (H ₂ O)	-	5.42 \pm 0.11
Organic Carbon	%	1.23 \pm 0.05
Total Nitrogen	%	0.11 \pm 0.01
Available Phosphorus	mg kg ⁻¹	6.72 \pm 0.45
Exchangeable Potassium	cmol kg ⁻¹	0.28 \pm 0.02
Electrical Conductivity	dS m ⁻¹	0.13 \pm 0.01
Soil Temperature	°C	27.1 \pm 0.4
Moisture Content	%	22.6 \pm 0.7

Baseline soil analysis of wetland soils before organic manure application revealed moderate acidity and low nutrient status, typical of Gleysols in humid tropical zones of Akwa Ibom State.

The baseline soil had a pH of 5.42, indicating moderate acidity, which can limit nutrient availability, especially phosphorus and nitrogen (Brady & Weil, 2019). The low organic carbon (1.23%) and total nitrogen (0.11%) signify poor fertility and low microbial substrate, typical of tropical wetland soils (Obi *et al.*, 2021). The available phosphorus (6.72 mg kg⁻¹) and exchangeable potassium (0.28 cmol kg⁻¹) were lower than the optimal levels for maize production, suggesting nutrient deficiencies. The electrical conductivity (0.13 dS m⁻¹) confirmed a non-saline condition, suitable for maize growth, while soil temperature (27.1°C) and moisture content (22.6%) reflected a conducive environment for microbial activity. Overall, these properties call for the need for organic amendments to enhance soil fertility and microbial functions.

Table 2. Physicochemical property of Poultry Manure and Cattle Dung (Mean \pm SD, n = 3)

Parameter	Unit	Poultry Manure	Cattle Dung
pH (H ₂ O)	-	7.45 \pm 0.06	7.12 \pm 0.05
Organic Carbon	%	25.8 \pm 1.1	20.6 \pm 0.8
Total Nitrogen	%	2.65 \pm 0.09	1.92 \pm 0.07
Available Phosphorus	mg kg ⁻¹	48.7 \pm 2.2	36.5 \pm 1.7
Exchangeable Potassium	cmol kg ⁻¹	1.83 \pm 0.08	1.15 \pm 0.05
C:N Ratio	-	9.7 \pm 0.4	11.8 \pm 0.5
Moisture Content	%	18.4 \pm 0.6	21.3 \pm 0.8

Composted poultry manure had higher nutrient content and lower C:N ratio compared to cattle dung, indicating faster mineralization potential and greater suitability for short-term fertility enhancement.

Poultry manure was nutrient-rich, with higher organic carbon (25.8%), nitrogen (2.65%), and phosphorus (48.7 mg kg⁻¹) compared to cattle dung. Its lower C:N ratio (9.7) indicates faster decomposition and nutrient mineralization, enhancing short-term soil fertility (Adebayo *et al.*, 2020). In contrast, cattle dung, with a higher moisture content (21.3%) and C:N ratio (11.8), suggests slower nutrient release. Both manures were near-neutral in pH, showing minimal acidifying effects on soil. These compositional differences explain the superior soil enrichment potential of poultry manure observed later in the experiment.

Post-application results showed that poultry manure significantly improved soil nutrients—pH rose to 6.48, and organic carbon, nitrogen, and phosphorus more than doubled relative to control plots. This improvement reflects efficient microbial decomposition and nutrient cycling (Ewulo *et al.*, 2022). Cattle dung also enhanced soil fertility but to a lesser extent. The increase in electrical conductivity (0.23 dS m⁻¹) (Fig.3) under poultry manure reflects nutrient ion accumulation from mineralization. These findings confirm that poultry manure enhances soil buffering capacity, nutrient availability, and microbial habitat.

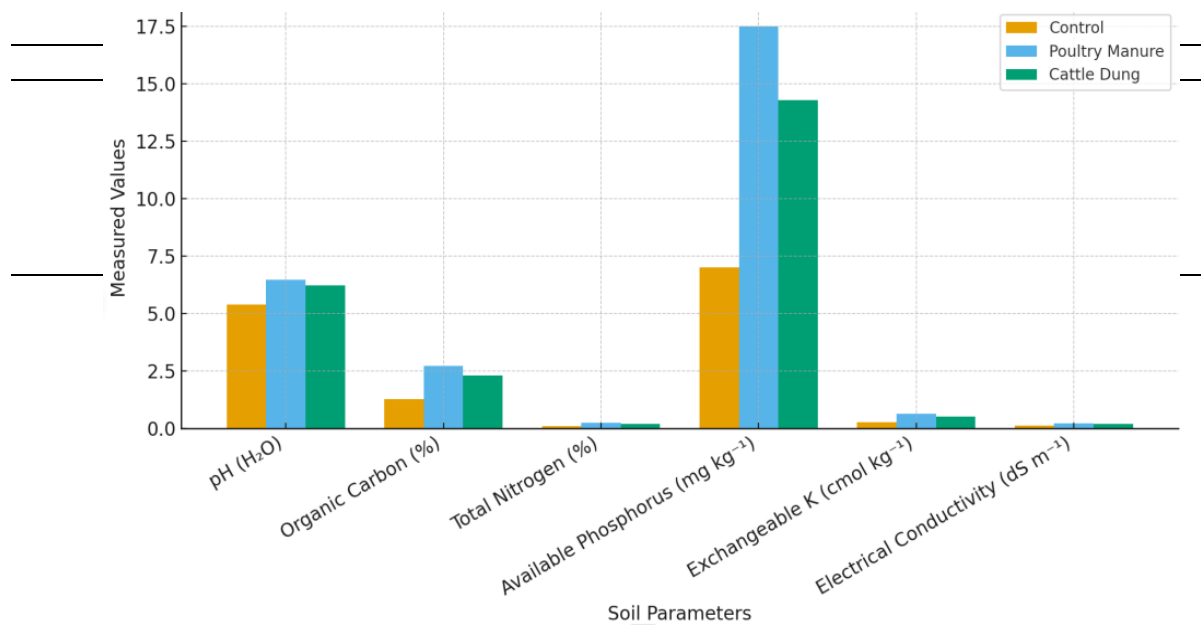


Figure 3: Post-Treatment Soil Physicochemical Properties under Different Organic Amendments

Table 4. Bacteriological Composition of Poultry Manure and Cattle Dung (Mean CFU × 10⁶ g⁻¹ ± SD, n = 3)

Higher microbial density in poultry manure indicates enhanced microbial activity and nutrient turnover potential compared to cattle dung.

Poultry manure supported higher microbial counts, notably total heterotrophic bacteria (8.41×10^6 CFU g⁻¹) and *Azotobacter* spp. (4.12×10^6 CFU g⁻¹), (Table 4) indicating richer microbial inoculum potential than cattle dung. The dominance of *Bacillus* and *Pseudomonas* species in poultry manure is consistent with rapid organic matter biodegradation and plant growth-promoting activities (Ogunmwonyiet al., 2020). This microbial advantage translates to faster nutrient cycling when incorporated into soil.

Table 5. Rhizospheric Bacteria Population at 6 Weeks after Planting (Mean CFU × 10⁶ g⁻¹ ± SD, n = 3)

Treatment	Total Heterotrophic Bacteria	<i>Azotobacter</i> spp.	<i>Nitrobacter</i> spp.
Control	5.84 ± 0.22	2.14 ± 0.12	1.02 ± 0.08
Poultry Manure	9.87 ± 0.35	4.68 ± 0.22	2.95 ± 0.15
Cattle Dung	8.14 ± 0.31	3.96 ± 0.19	2.41 ± 0.13

Poultry manure-treated soils showed significantly higher rhizospheric bacterial populations compared to other treatments, supporting improved microbial symbiosis.

At 6 weeks, poultry manure-treated soils recorded the highest bacterial counts, particularly *Azotobacter* (4.68×10^6 CFU g⁻¹) and *Nitrobacter* (2.95×10^6 CFU g⁻¹). These early increases suggest that poultry manure enhanced root–microbe interactions and nitrogen cycling. The control had the lowest microbial populations, reflecting nutrient limitations that constrained microbial proliferation (Choudhary et al., 2019).

Treatment	Total Heterotrophic Bacteria	<i>Azotobacter</i> spp.	<i>Nitrobacter</i> spp.
Control	6.12 ± 0.23	2.45 ± 0.11	1.18 ± 0.07
Poultry Manure	11.26 ± 0.39	5.23 ± 0.20	3.26 ± 0.17
Cattle Dung	9.42 ± 0.34	4.58 ± 0.18	2.79 ± 0.14

Table 6. Rhizospheric Bacteria Population at 12 Weeks after Planting (Mean CFU × 10⁶ g⁻¹ ± SD, n = 3)

Sustained bacterial proliferation was observed under poultry manure treatment, reflecting long-term nutrient release and microbial synergy within maize rhizosphere.

By 12 weeks, bacterial populations increased across all treatments, with poultry manure maintaining dominance (Total bacteria: 11.26×10^6 CFU g^{-1}). This sustained microbial activity shows a gradual nutrient release pattern, providing continuous soil fertility improvement throughout maize growth. The cattle dung treatment followed a similar trend but at a lower intensity. Such persistence underscores poultry manure’s role in promoting long-term rhizospheric stability and microbial resilience.

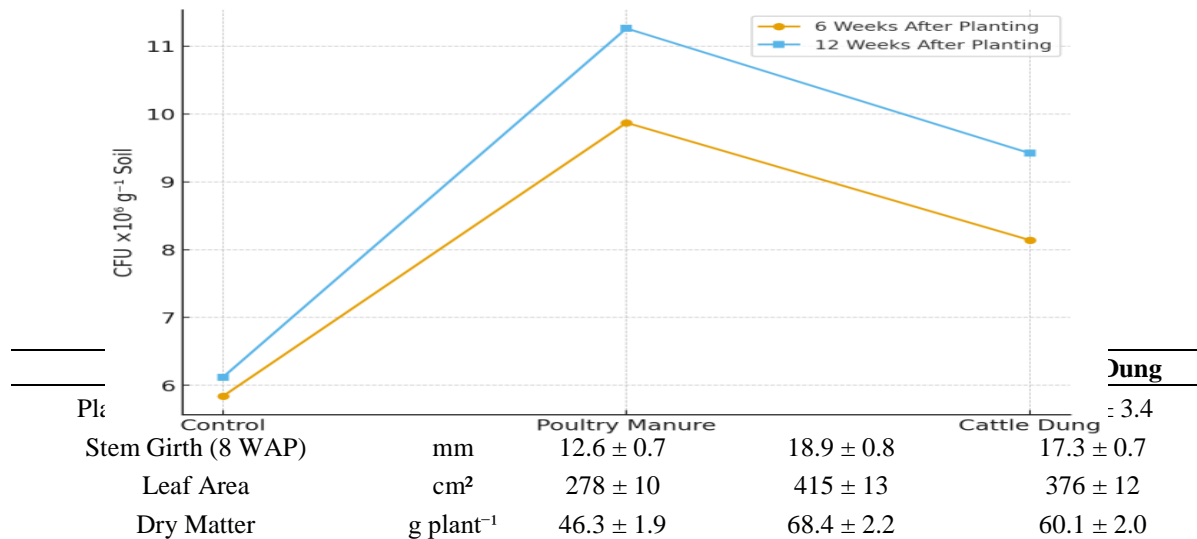


Table 7. Maize Growth Parameters under Different Organic Treatments (Mean ± SD, n = 3)
 Maize plants treated with poultry manure exhibited superior vegetative growth compared to cattle dung and control plots due to enhanced nutrient availability.

Poultry manure significantly improved maize growth, with plants reaching 133.5 cm in height and recording 68.4 g dry matter per plant—values superior to both cattle dung and control plots. Enhanced leaf area (415 cm²) and stem girth suggest improved photosynthetic efficiency and structural robustness, attributed to better nutrient uptake facilitated by active microbial communities (Onwudike *et al.*, 2021). Cattle dung also improved plant growth but less effectively due to slower nutrient mineralization.

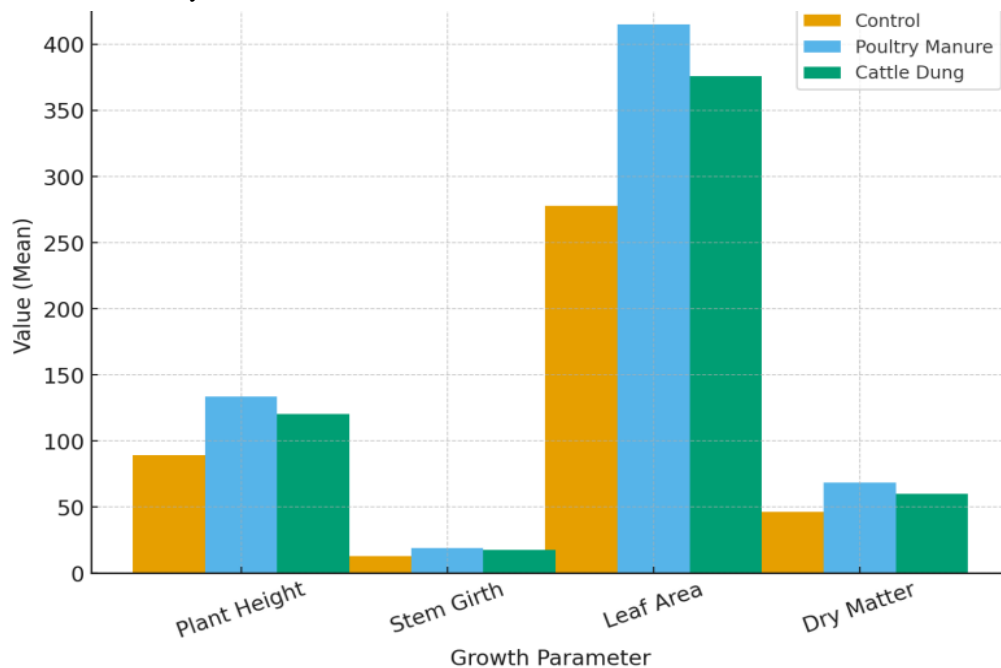
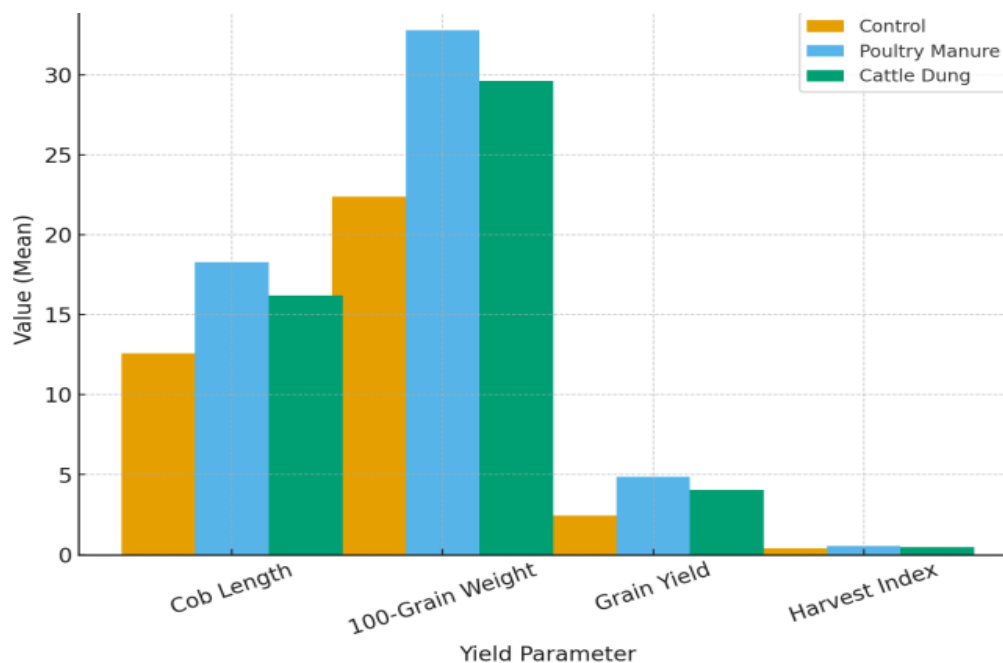


Table 8. Maize Yield Components under Different Treatments (Mean \pm SD, n = 3)

Parameter	Unit	Control	Poultry Manure	Cattle Dung
Cob Length	cm	12.6 \pm 0.6	18.3 \pm 0.7	16.2 \pm 0.6
100-Grain Weight	g	22.4 \pm 0.9	32.8 \pm 1.2	29.6 \pm 1.0
Grain Yield	t ha ⁻¹	2.45 \pm 0.11	4.86 \pm 0.17	4.03 \pm 0.15
Harvest Index	-	0.41 \pm 0.02	0.53 \pm 0.03	0.48 \pm 0.02

Poultry manure significantly enhanced maize grain yield and harvest index, confirming its effectiveness as a nutrient-rich organic fertilizer for wetland cultivation.

Yield performance mirrored growth trends. Poultry manure-treated plots produced the longest cobs (18.3 cm), heaviest 100-grain weight (32.8 g), and highest grain yield (4.86 t ha⁻¹)—almost double the control. The harvest index (0.53) reflects efficient conversion of biomass into grain yield, confirming poultry manure's superior fertilization effect (Adesemoye&Kloepper, 2020). Cattle dung improved yield moderately, emphasizing its slower nutrient-release dynamics.

**Table 9. Correlation between Soil Nutrients, Microbial Activity, and Maize Yield**

Parameter	Organic C	Total N	Available P	<i>Azotobacter</i>	Grain Yield
Organic C	1.000	0.874**	0.915**	0.902**	0.924**
Total N	-	1.000	0.856**	0.879**	0.891**
Available P	-	-	1.000	0.866**	0.912**
<i>Azotobacter</i>	-	-	-	1.000	0.894**
Grain Yield	-	-	-	-	1.000

*Strong positive correlations ($p \leq 0.01$) exist between organic carbon, nitrogen, phosphorus, *Azotobacter* population, and grain yield, highlighting the microbial–nutrient synergy that drives maize productivity.*

Strong positive correlations ($p \leq 0.01$) among organic carbon, total nitrogen, available phosphorus, *Azotobacter* population, and grain yield ($r = 0.924, 0.891, 0.912,$ and 0.894 respectively) indicate a synergistic link between microbial activity and soil fertility. The findings imply that improved microbial abundance enhances nutrient mineralization, which directly translates to increased maize productivity (Chen *et al.*, 2022).

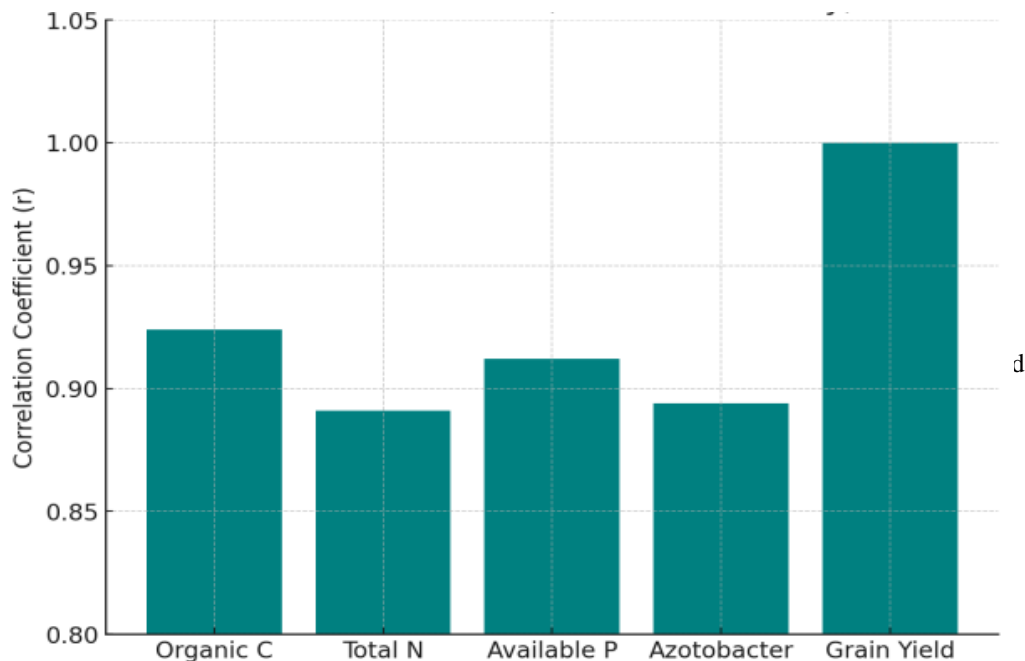


Table 10. Identified Rhizospheric Bacterial Isolates Based on 16S rRNA Sequencing

Isolate Code	Closest Match (NCBI BLAST)	% Similarity	Accession No.	Functional Role
P1	<i>Bacillus subtilis</i>	99.4	OP983721	Phosphate solubilizer
P2	<i>Azotobacterchroococcum</i>	98.9	OP983722	Nitrogen fixer
P3	<i>Pseudomonas fluorescens</i>	99.1	OP983723	Plant growth promoter
C1	<i>Nitrobacterwinogradskyi</i>	98.5	OP983724	Nitrification
C2	<i>Enterobacter cloacae</i>	98.7	OP983725	Auxin producer

Molecular identification revealed dominant beneficial rhizobacteria with functions including nitrogen fixation, phosphorus solubilization, and growth hormone production, all contributing to improved maize performance.

Molecular identification confirmed the presence of beneficial rhizobacteria such as *Bacillus subtilis* (phosphate solubilizer), *Azotobacter chroococcum* (nitrogen fixer), and *Pseudomonas fluorescens* (plant growth promoter). These bacterial carryout pivotal functions in nutrient cycling and phytohormone production, which improve root growth and yield (Kumar *et al.*, 2021). Their predominance under poultry manure treatment demonstrates how organic amendments enhance microbial diversity and functionality within wetland soils.

Discussion

Soil Baseline Conditions and Need for Amendment

The initial physicochemical profile of the wetland soils (moderate acidity, low organic carbon, nitrogen, and available phosphorus) underscores their limited fertility and constrained biological activity. Such conditions are typical of hydromorphic or Gleysolic soils in tropical rainforest zones (Udoh *et al.*, 2022). In comparable studies, soils with low organic carbon and nutrient reserves have been shown to respond strongly to organic inputs in terms of improved nutrient availability, structure, and bacterial activity (Liu *et al.*, 2024; Bilong *et al.*, 2022). The baseline acidity also suggests that phosphorus may be fixed and processes by microorganisms slowed, reinforcing the importance of organic amendments to buffer pH and support biological processes (Howe *et al.*, 2024).

Composition of Poultry vs. Cattle Manures: Implications for Fertility

The nutrient-rich nature of the poultry manure—higher carbon, nitrogen, phosphorus, and potassium, and lower C:N ratio compared to cattle dung—suggests greater potential for nutrient mineralization and microbial stimulation. This aligns with many reports that poultry manure often contains proportionally more plant-available nutrients per unit mass than cattle dung (Zhao et al., 2024; Liu et al., 2024). The lower C:N means that microorganisms can more rapidly break down the organic matter and release nutrients without immobilization. In contrast, cattle dung, with its higher moisture and higher C:N, typically mineralizes more slowly and may release nutrients gradually (Du et al., 2022). Thus, the observed differences in nutrient release and microbial stimulation are expected from manure composition.

Effects of Organic Amendments on Soil Physicochemical Properties

Following application of the organic treatments, soils treated with poultry manure exhibited greater increases in pH, organic carbon, total nitrogen, and available phosphorus relative to cattle dung or control. This improvement in soil conditions is consistent with many studies showing that organic manures gradually raise pH in acidic soils and build soil organic matter, thereby improving retention of nutrient and exchange capacity (Liu et al., 2024; Bilong et al., 2022; Gao et al., 2022). The accumulation of organic carbon not only provides energy for microbial communities but also enhances soil structure, water retention, and cation exchange capacity (Liu et al., 2024). The build-up of exchangeable potassium and increased conductivity in treated soils further reflect effective nutrient release and increased ionic availability from the manures (Sheoran et al., 2025). These patterns reinforce the advantage of applying nutrient-dense organic amendments, particularly in low-fertility soils.

Microbial Load in Raw Manures and Implications

The higher microbial counts (heterotrophic bacteria, *Azotobacter*, *Nitrobacter*, *Bacillus*, *Pseudomonas*) in poultry manure suggest a richer microbial inoculum that can seed the soil microbial community once applied. This observation resonates with literature indicating that well-composted or stabilized poultry manure often harbors high microbial diversity and density, promoting nutrient cycling and soil biological activity (Zhao et al., 2024; Liu et al., 2024). The availability of nitrogen-fixers and nitrifying bacteria in the manure is particularly important, as they may colonize the soil or rhizosphere and contribute to nutrient cycling after incorporation. Thus, the manure serves as a nutrient source and a microbial carrier, enhancing the soil microbial reservoir.

Rhizospheric Bacterial Dynamics over the Growing Season

The rhizospheric bacterial populations (total heterotrophic bacteria, *Azotobacter*, *Nitrobacter*) increased over time in all treatments, but were highest under poultry-manure amendment. This trend suggests that the nutrient-rich environment and moderated pH created by poultry manure supported microbial proliferation, root colonization, and sustained microbial activity. Similar trends have been reported in studies where organic amendments enhance rhizosphere microbial abundance, leading to improved nutrient cycling and plant–microbe interactions (Chen et al., 2020; Baloch et al., 2025). The relative increase from week 6 to week 12 indicates that microbial communities matured over time as organic matter was mineralized and roots expanded. The comparative performance under cattle manure (intermediate increase) further supports the idea that manure quality affects the speed and magnitude of microbial response. Importantly, the sustained higher counts under poultry manure suggest that microbial processes (e.g., nitrogen fixation, nitrification) could remain active throughout the plant’s development, thereby providing a steady supply of nutrients to maize.

Maize Growth Response to Organic Treatments

Plants under poultry manure treatments exhibited better vegetative growth (height, girth, leaf area, dry matter) compared to control and cattle dung treatments. This improved growth is plausibly attributable to enhanced nutrient availability, improved soil structure, and active microbial assistance in nutrient mobilization. Many studies have documented that organic amendments, especially those with rich microbial consortia, can enhance early plant establishment, root growth, and nutrient uptake, hence, increased biomass (El-Akhdar et al., 2025; Zhang et al., 2022). The synergy between root growth and a supportive microbial environment (PGPR) is known to amplify growth responses in maize (Chen et al., 2020). The better performance under poultry manure is consistent with its stronger effect on soil fertility and microbial dynamics.

Yield Components and Grain Yield Enhancement

The significant increases in yield components (cob length, 100-grain weight) and grain yield under poultry manure confirm that the improved soil and microbial conditions translated into reproductive success. The higher harvest index indicates efficient partitioning of biomass to grains, likely supported by consistent nutrient supply during grain-filling. This result is well-aligned with literature showing that organic manure application can

increase yield stability, reduce reliance on chemical fertilizer, and improve crop yield in nutrient-poor soils (Zhao et al., 2024; UNL Water Manure article, 2023). Nutrient release from the manure, coupled with microbial mediation, likely supported sustained N and P availability during critical reproductive stages, enabling high yield performance (Wang et al., 2025; Zhang et al., 2022).

Correlation of Soil Nutrients, Microbial Activity, and Yield

The strong positive correlations observed among organic carbon, nitrogen, phosphorus, *Azotobacter* populations, and grain yield point to a tightly coupled system in which soil fertility, microbial activity, and plant performance reinforce one another. This nexus is well-cited in literature: increased soil organic matter fuels microbial metabolism; microbes mineralize nutrients; plants uptake nutrients and support further root exudates that feed microbes (Liu et al., 2024; Baloch et al., 2025). The correlation underscores that management strategies that enhance both chemical and biological fertility are likely to deliver better crop outcomes. Interestingly, a few studies report no significant correlation between microbial community shifts and yields, particularly when community-level changes do not correspond to functional contributions (Zhongyou et al., 2017). However, our results indicate that in this wetland–maize system, microbial populations (particularly nitrogen-cycling bacteria) played functional roles in supporting maize growth.

Identity of Beneficial Rhizobacteria and Functional Implications

The molecular identification of isolates such as *Azotobacter chroococcum*, *Bacillus subtilis*, *Pseudomonas fluorescens*, and *Nitrobacter winogradskyi* confirms the presence of key functional microbes in the rhizosphere under organic manure treatment. These genera are well-known plant growth–promoting rhizobacteria (PGPR) that contribute through nitrogen fixation, phosphate solubilization, phytohormone synthesis, or nitrification (Baloch et al., 2025). Their detection aligns with many reports that successful organic amendment can increase the abundance of beneficial rhizobacteria, thereby fostering a more functional microbiome (Baloch et al., 2025; Bilong et al., 2022). Their functional roles likely supported maize nutrition, resilience, and yield. In summary, the study demonstrates that quality of organic amendment matters, and that enhancing both the **chemical** and **biological** facets of soil fertility yields superior outcomes in maize cultivation under challenging wetland conditions.

Conclusion

The study provides critical insights into the interactions between organic manure types, soil microbial activity, and crop productivity in hydromorphic tropical ecosystems. Findings showed that the utilization of animal wastes such as poultry and cattle manures enhance physicochemical properties soil, enhanced microbial abundance and diversity, and boosted maize growth and yield performance compared to the untreated control. Among the two organic amendments, poultry manure proved more effective due to its higher nutrient density, lower C:N ratio, and superior microbial stimulation potential. The manure enhanced rhizospheric bacterial populations such as *Azotobacter*, *Nitrobacter*, *Bacillus*, and *Pseudomonas*, which are beneficial for nitrogen fixation, phosphorus solubilization, and root growth promotion. These biological processes translated into better nutrient uptake and higher grain yield, establishing a clear microbial-mediated pathway in soil fertility restoration and crop performance enhancement.

The molecular identification of functional rhizobacteria, including *Azotobacterchroococcum*, *Bacillus subtilis*, and *Pseudomonas fluorescens*, further supports the evidence that manure amendments promote beneficial microbial communities that contribute to nutrient cycling and sustainable productivity. The results confirm that poultry manure enhances soil nutrient status, microbial symbiosis and ecological balance, making it a superior bio-resource for improving wetland soils that are typically acidic and nutrient-deficient.

Recommendations

Based on these findings, the study recommends the following:

- (i). **Integration of Organic Fertility Management Practices:** Agricultural stakeholders should integrate poultry and cattle manures into soil fertility programs to reduce reliance on inorganic fertilizers and improve soil biological health.
- (ii). **Promotion of Microbial-Based Soil Management:** The identification of beneficial rhizobacteria provides an opportunity for developing biofertilizers and microbial inoculants tailored to local wetland ecosystems to further enhance maize productivity.

Consequently, this research establishes that poultry and cattle manures, particularly poultry manure, are viable organic resources that can improve soil fertility, microbial activity, and maize yield in wetland soils. The integration of these organic amendments supports sustainable maize production, soil health regeneration, and ecological balance in the wetland ecosystems of Akwa Ibom State and beyond.

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