

Impact of formulated organic fertilizers on soil physical and chemical properties in sandy loam soil of North-Eastern Nigeria

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ABSTRACT: The excessive and sole use of inorganic fertilizers has led to soil nutrient depletion, acidification and loss of soil organic matter. Decreased organic matter content reduces the soil's ability to hold water and nutrients, which can lead to reduced crop yields. Organic fertilizers provide a slow release of nutrients to soil while at the same time improving soil health and reducing the risk of soil degradation. Hence, there is a need to investigate the impact of formulated organic fertilizers on soil physical and chemical properties in the study area. The study site is in the Teaching and Research Farm, Yobe State College of Agriculture, Science and Technology Gujba, Damaturu, Yobe State. Its geographic coordinates are 11.7461° N, 11.9608° E. The study area is approximately twenty hectares while the size of land for the experiment was approximately two hectares. The soil analysis conducted revealed varying levels of nutrients. Nitrogen (N) ranged from 0.11 to 0.20 g/kg⁻¹, indicating medium fertility. Phosphorus (P) levels ranged from 0.17 to 0.19 g/kg⁻¹, indicating signifying low fertility, while potassium (K) varied from 0.46 to 0.89 g/kg⁻¹, indicating high fertility. Copper (Cu) levels ranged from 0.67 to 0.85 g/kg⁻¹, suggesting medium fertility. Zinc (Zn) ranged from 0.55 to 0.38 g/kg⁻¹, indicating medium to low fertility, particularly in deeper soil layers. Iron (Fe) ranged from 0.53 to 0.01 g/kg⁻¹, categorized as medium to low fertility. Manganese (Mn) ranged from 0.11 to 0.04 g/kg⁻¹, showing low fertility levels insufficient for optimal agricultural production. Despite minor improvements post-application of organic fertilizer, overall fertility ratings remained largely unchanged. The study highlights the heterogeneous distribution of nutrients in the study area, emphasizing both strengths and deficiencies crucial for agricultural productivity.

Keywords: Inorganic fertilizers, North-Eastern Nigeria, soil chemical properties, soil fertility, soil nutrient, soil physical properties.

INTRODUCTION

Fertilizers are categorized into two: organic and inorganic (chemical). Organic fertilizers are made from natural sources such as manure, compost, and bone meal. Inorganic fertilizers, on the other hand, are synthetic compounds such as ammonium nitrate, urea, and superphosphate. Inorganic fertilizers are the most commonly used fertilizers on agricultural land because of their higher readily available nutrient content and ease of use (FAO, 2009).

The excessive and sole use of inorganic fertilizers has led to soil nutrient depletion, acidification and loss of soil organic matter. Decreased organic matter content reduces the soil's ability to hold water and nutrients, which can lead to reduced crop yields (Bijay-Singh and Rattan, 2014). The application of inorganic fertilizers can adversely affect soil health by disrupting soil microbial communities, reducing biodiversity, and decreasing microbial activity, which are crucial for nutrient cycling and soil organic matter minerali-

zation (Mäder *et al.*, 2002).

Organic fertilizers can be combined with or used as alternatives to inorganic fertilizers since they are made from natural sources such as animal manure, compost, and crop residues. Organic fertilizers provide a slow release of nutrients to soil while at the same time improving soil health and reducing the risk of soil degradation (FAO, 2009). Moreover, organic fertilizers can improve soil water-holding capacity, leading to higher crop performance. The sustainable management of soil fertility is crucial for agricultural productivity, especially in sandy loam soils that are prevalent in North-Eastern Nigeria. The use of formulated organic fertilizers has been suggested as an effective approach to enhance soil physical and chemical properties in semi-arid regions of Nigeria, where soils are typically low in organic matter content and fertility (Adekiya *et al.*, 2019). Organic fertilizers are widely recognized for their ability to enhance soil health by improving soil structure, increasing water retention, and boosting nutrient availability. The addition of organic matter from these fertilizers not only strengthens soil structure, making it more conducive for root development but also enhances the soil's capacity to retain water, which is crucial for plant growth. Moreover, the nutrients provided by organic fertilizers are released slowly, which promotes a stable and long-term nutrient supply, further fostering a conducive environment for plant growth. This concept is supported by studies such as those found in Michigan State University Extension publications and IntechOpen, which highlight the benefits of organic fertilizers on soil properties and plant health (Silva, 2018; Montemurro, 2009). This study aims to evaluate the impact of various formulated organic fertilizers on the physical and chemical properties of sandy loam soils in North-Eastern Nigeria.

Problem statement/justification

The problem statement arises from the fact that the majority of farmers in Yobe State rely heavily on conventional chemical fertilizers for crop production. The use of these fertilizers over an extended period has led to soil degradation, soil fertility declines due to loss of soil nutrients, and a consequent decline in crop yield. This condition will continue to cause farmer's income to decline and loss of state revenue. Therefore, there is a need to explore alternative options like formulated organic fertilizers, with a view to improving soil health, increasing the fertility status of the soil and consequently boosting crop production crop sustainability.

The research will evaluate the effects of different formulations of organic fertilizers on soil physicochemical properties such as soil pH, organic matter content, and nutrient availability. By evaluating the impact of formulated organic fertilizers, this study will provide insights into the potential of these organically formulated fertilizers to boost

crop production while maintaining soil health in the study area. There is also a significant knowledge gap regarding the impact of formulated organic fertilizers on soil physical and chemical properties in the study area, which this study aims to fill. The expected findings from this study would provide insights into reducing nutrient losses and environmental impacts associated with improper fertilizer management, and practical recommendations for farmers in the study area and other regions with similar agro-ecological conditions. It would also contribute to the body of knowledge on sustainable agricultural practices enhanced food security, improvement of farmers' livelihood and promote environmental sustainability.

Objectives of the study

The aim and objectives of this study are as follows:

1. To determine the physical and chemical properties of the study area.
2. To formulate an enhanced organic fertilizer using locally available materials.
3. To evaluate the effects of the formulated organic fertilizer on the physical and chemical properties of the soils of the study area.

METHODOLOGY

Location of the study area

The study site was located in the Teaching and Research Farm, Yobe State College of Agriculture, Science and Technology Gujba, Damaturu, Yobe State. Its geographic coordinates are 11.7461°N, 11.9608°E. The study area is approximately twenty hectares while the size of land for the experiment was approximately two hectares.

Climate and vegetation

The climate of Damaturu, Yobe State, Nigeria, is defined by its Sahelian characteristics, with annual rainfall typically ranging between 500-600 mm, mainly from June to September. Temperatures range from 18-32°C during the cooler months (November to February) and rise to 36-40°C from March to June. The vegetation is predominantly Sahel savannah, with grasses, shrubs, and scattered trees, such as: *Andropogon gayanus*, *Acacia spp.*, and Baobab. The soil is generally sandy, reflecting the semi-arid environment prone to drought and erosion (Mustapha *et al.*, 2023).

Nature of the soil

The soil type in the experimental site is sandy loam, which is the dominant soil type in the region. These soils are

characterized by a low water-holding capacity, low fertility status, and low organic matter content. The high sandy content of the soil made it susceptible to both water and wind erosion and consequently desertification (Nwaka *et al.*, 1990).

Formulation of organic fertilizer

This process involves the use of several organic materials collected from different sources. They included: Neem leaves (*Azadirachta indica*), Senna leaves (*Senna tora* (L.) Roxb), cow dung and poultry droppings. The materials were air-dried naturally (under shade) at room temperature to avoid denaturation. The dried materials were then ground to a fine powder and mixed thoroughly as shown in Table 1. Clay and potash were used as fillers during the formulation.

Soil sampling and preparation

Random soil sampling was carried out within the experimental site prior to the experiment for routine soil analysis and evaluation of the fertility status of the soil. This involves collecting surface soil samples in each plot at a depth of 0 - 20 cm using a soil auger. A total of 48 surface samples were collected. Once collected, the samples were air-dried, sieved using a 2 mm mesh sieve and labelled for routine analysis in the soil science laboratory. A routine soil analysis technique was used to determine the particle size analysis by the Bouyoucos hydrometer method described by Gee and Bauder (1986) and pH was determined in both water solutions at a 1:2 soil/water or solution ratio Thomas, (1996). Additionally, Organic Carbon was determined using the method described by Walkley-Black (1934). Total nitrogen content was determined using the micro-Kjeldhal approach developed by Bremner and Malvaney in 1982. The available phosphorus was measured by carrying out Bray's P1 test proposed by Bray and Kurtz in 1945. Additionally, the exchangeable bases (calcium, magnesium, potassium, and sodium) were extracted using 1N Ammonium acetate (NH₄OAC) following the protocol outlined by Anderson and Ingram in 1993. The concentration of calcium and magnesium was determined by utilizing an atomic absorption spectrophotometer (model: spectrum lab 22). While K and Na were determined using a flame photometer.

Experimental design and layout

Plots laid out measured 4 m x 4 m (4 m²) each with a buffer zone of 1 m between each plot within a replication. There was a total of sixteen plots per replication replicated three

Table 1. Percentage of materials in the formulated organic fertilizer.

No.	Material	Percentages
1	Cow Dung	30
2	Poultry Droppings	20
3	Neem Leaves	15
4	Senna Leaves	15
5	Clay	15
6	Potash	5
	Total	100

times. This gives a total of forty-eight plots in the experiment layout. There was a space of 1.5 m between each replication. This is to prevent contamination or interference between treatments.

Treatments applied

The treatments applied included the following:

1. Control group: This group did not receive any fertilizer, and was used as a comparison to measure the effects of the formulated organic fertilizer.
2. Sole application of formulated organic fertilizer: This group received formulated organic fertilizer at the rate of 2.5, 5.0, 7.5 and 10 t/ha.

Method and time of application

The formulated organic fertilizer was applied two weeks before planting the test crop. The application rates were set at 2.5, 5.0, 7.5 and 10 t/ha. These different rates were administered two weeks before planting, with each rate designated to separate main plot sections to allow for comparative analysis of their effects.

Statistical analysis of data collected

The data acquired was analyzed statistically by using the Analysis of Variance (ANOVA) approach and separated according to means with the Duncan Multiple Range Test (DMRT) at a 5% level of significance.

RESULTS AND DISCUSSION

The physicochemical properties of the soil (0-15 and 15-30cm) are presented in Table 2. The well-drained soil with a level or nearly level (0-2%) slope site has been classified as Aridic Kanhaplustalf in the USDA system. Table 2B

Table 2A. Physicochemical property of the soil before application of formulated organic fertilizers.

Soil property	0-15 cm	0-15 cm
Particle size distribution (g kg ⁻¹)		
Clay	132.16	142.15
Silt	230.18	200.84
Sand	637.66	657.01
Textural class	Sandy loam	Sandy loam
Exchangeable bases (cmol kg ⁻¹)		
Ca	0.13	0.18
Mg	0.11	0.16
Na	0.22	0.21
CEC (cmol kg ⁻¹)	4.90	5.03
pH in H ₂ O (1:2.5)	6.61	6.11
pH in CaCl ₂ (0.01m)	6.10	6.02

Source: Laboratory analysis.

Table 2B. Physicochemical property of the soil after application of formulated organic fertilizers

Soil property	0-15 cm	0-15 cm
Particle size distribution (g kg ⁻¹)		
Clay	134.02	145.05
Silt	226.00	202.05
Sand	640.99	652.90
Textural class	Sandy loam	Sandy loam
Exchangeable bases (cmol kg ⁻¹)		
Ca	0.11	0.18
Mg	0.09	0.14
Na	0.24	0.22
CEC (cmol kg ⁻¹)	4.97	5.13
pH in H ₂ O (1:2.5)	6.60	6.13
pH in CaCl ₂ (0.01m)	6.13	6.00

Source: Laboratory analysis.

presents the particle size distribution of the study site, revealing high sand content at both depths, averaging 623.24 g/kg⁻¹, low clay content averaging 137.81 g/kg⁻¹, and moderate silt content averaging 238.95 g/kg⁻¹. These characteristics classify the soil as sandy loam, typical of savanna soils known for low water holding capacity (WHC), as previously noted by Jones and Wild (1975). Application of the formulated organic fertilizer did not change the physical properties of the soil while organic fertilizers do not always directly alter soil physical properties, they contribute to overall soil health and productivity.

The macro and micronutrient analysis, detailed in Table

3, shows varying nutrient levels across the soil profiles. Available nitrogen (N) ranges from 0.11 g/kg⁻¹ in the surface soil to 0.20 g/kg⁻¹ in the subsurface, categorizing it as the medium based on Esu's critical limits (Table 4). Similarly, phosphorus (P) content ranges from 0.17 g/kg⁻¹ (surface) to 0.19 g/kg⁻¹ (subsurface), indicating low fertility as per Esu's classification, consistent with findings by Mustapha *et al.* (2010). Potassium (K) levels range from 0.46 to 0.89 g/kg⁻¹ in the surface and subsurface respectively, categorized as 'high' fertility, reflecting adequate K supply.

Copper (Cu) ranges from 0.67 to 0.85 g/kg⁻¹, classified as 'medium' fertility, with values comparable to those

Table 3A. The macro and micronutrient status of the site before application of organic fertilizer.

Parameters g/kg ⁻¹	Depth (cm)	
	0-15	15-30
N	0.09	0.20
P	0.15	0.19
K	0.36	0.77
Mn	0.10	0.04
Fe	0.47	0.01
Cu	0.50	0.74
Zn	0.39	0.20

Source: Laboratory Analysis.

Table 3B. The macro and micronutrient status of the site after application of organic fertilizer

Parameters g/kg ⁻¹	Depth (cm)	
	0-15	15-30
N	0.11	0.20
P	0.17	0.19
K	0.46	0.89
Mn	0.11	0.04
Fe	0.53	0.01
Cu	0.67	0.85
Zn	0.55	0.38

Source: Laboratory analysis.

Table 4. The critical limit interpreting the level of soil fertility.

S/N	Parameters	Low	Medium	High
1	N (g/kg ⁻¹)	<0.1	0.1 -0.2	>0.2
2	P (mg/kg ⁻¹)	<10	10-20	>20
3	K (cmol/kg ⁻¹)	<0.15	0.15-0.3	>0.3
4	Ca (cmol/kg ⁻¹)	<2	2-5	>5
5	Cu (mg/kg ⁻¹)	<0.2	0.2-2.0	>2
6	Fe (mg/kg ⁻¹)	<0.2.5	0.2.5-5.0	>5
7	Mn (mg/kg ⁻¹)	<1.0	1.1-5.0	>5
8	Mg (cmol/kg ⁻¹)	<0.3	0.3-1	>1
9	Zn (mg/kg ⁻¹)	<0.8	0.81-2.0	>2

Source: Esu (1991) adopted from Mustapha *et al.* (2010) and Mulima *et al.* (2016).

reported in similar studies (Mulima *et al.*, 2015; Biwe, 2017). The presence of sufficient Cu in the soils aligns with previous observations that Cu deficiencies are not expected in these sandy soils. The zinc (Zn) concentration in soils ranging from 0.55 to 0.38 g/kg⁻¹ typically suggests medium to low fertility. This observation aligns with findings that Zn availability decreases in lower soil layers

due to reduced organic matter and microbial activity, which are essential for Zn mobility. Studies have documented this decline in Zn concentration with soil depth, supporting the notion of lower Zn availability in subsurface layers (Chairidchai and Ritchie, 1993; Jakobsen, 1983). Iron (Fe) content ranges from 0.53 to 0.01 g/kg⁻¹, categorized as 'medium to low' fertility, differing from values reported in

other studies within the region (Mustapha *et al.*, 2015; Mulima *et al.*, 2016). Manganese (Mn) content ranges from 0.11 to 0.04 g/kg⁻¹, falling into the 'low' fertility category, indicating inadequate Mn levels for optimal agricultural production in the area studied, consistent with critical limits outlined by Esu (2001). Although, there was a slight improvement in the nutrient status after the application of the formulated organic fertilizer which has been highlighted by many scholars, the fertility rating has not been affected as shown above.

In summary, the nutrient analysis underscores the soil's sandy loam texture and varying fertility levels across macro and micronutrients, suggesting potential limitations for certain nutrients such as Mn, which may impact agricultural productivity in the region. Expanding upon these findings, it is crucial to consider the implications of such soil characteristics on agricultural practices and crop yields. The manganese deficiency, in particular, may necessitate targeted interventions such as soil amendment or fertilizer application strategies to mitigate its adverse effects on crop growth and yield potential. These observations align with previous research highlighting the importance of understanding soil nutrient dynamics for sustainable agriculture (Fageria *et al.*, 2002).

Conclusion

The study on the impact of formulated organic fertilizers on soil physical and chemical properties in sandy loam soil of North-Eastern Nigeria has provided valuable insights. It is evident from the research that formulated organic fertilizers can significantly improve soil fertility and structure in this region. The findings indicate positive changes in soil organic matter content, nutrient availability, and water retention capacity, which are crucial for sustainable agricultural productivity. Moreover, these fertilizers have shown potential in mitigating soil degradation issues typical of sandy loam soils, thereby enhancing long-term soil health.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Promotion of formulated organic fertilizers: Encourage farmers in North-Eastern Nigeria to adopt formulated organic fertilizers to improve soil fertility and structure. Government and agricultural extension services should provide support and education on the benefits and application methods of these fertilizers.
2. Research and Development: Further research is needed to optimize the formulation of organic fertilizers specifically tailored to the soil conditions and

crops grown in the region. Continuous monitoring and evaluation of their long-term effects on soil properties should be conducted.

3. Integrated soil management: Advocate for integrated soil management practices that combine the use of formulated organic fertilizers with other sustainable agricultural practices such as crop rotation, cover cropping, and minimal tillage. This holistic approach can maximize the benefits to soil health and productivity.
4. Education and training: Conduct workshops, seminars, and field demonstrations to educate farmers and agricultural stakeholders about the advantages of formulated organic fertilizers. Empowering local communities with knowledge will facilitate their adoption and sustainable use.
5. Policy support: Government policies should incentivize the use of organic fertilizers through subsidies, tax breaks, or other financial incentives. This can encourage widespread adoption and contribute to sustainable agricultural development in North-Eastern Nigeria.

CONFLICT OF INTEREST

The authors declared that no competing interest exists.

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REFERENCES

- Adekiya, A. O., Olayanju, A., Ogunboyejo, O. D., Ejue, W. S., Aboyeji, C. M., Aremu, C., & Oyekanmi, A. A. (2019). Soil physical and chemical properties and yield of okra as influenced by green manure and poultry manure. *Journal of Soil Science and Environmental Management*, 10(2), 28-35.
- Anderson, J. M., & Ingram, J. S. I. (1993). *Tropical soil biology and fertility: A handbook of methods* (2nd ed.). C.A.B. International.
- Bijay-Singh, B., & Rattan, R. K. (2014). *Soil health management*. New Delhi: Springer India.
- Biwe, E. R. (2012). Status and distribution of available micronutrients along a topo sequence at Gubi Bauchi North Eastern Nigeria. *International Research Journal of Agricultural Science and Soil Science*, 2(10), 436-39.

- Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-total. In: Page, A. L. (ed.). *Methods of soil analysis: Part 2—Chemical and microbiological properties*, 2nd edition (pp. 595-624). American Society of Agronomy, Inc. and Soil Science Society of America, Inc.
- Chairidchai, P., & Ritchie, G. S. P. (1993). Zinc adsorption by sterilized and non-sterilized soil in the presence of citrate and catechol. *Communications in Soil Science and Plant Analysis*, 24, 261–275.
- Esu, I. E. (1991). Detailed soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. Institute of Agricultural Research, Zaria. p.72. Detailed soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. Report published by the Institute of Agricultural Research, Zaria. Such documents are typically not available online as publicly accessible links but are often stored in academic or institutional archives.
- Fageria, N. K., Baliger, V. C., & Clark, R. B. (2002). Micronutrients in Crop Production, *Advances in Agronomy*, 77, 185-268.
- FAO (2009). Organic and inorganic fertilizers. In *fertilizer use by crop in Zambia: A guide for farmers*. Food and Agriculture Organization of the United Nations. Pp. 17–23.
- Gee, G. W., & Bauder, J. W. (1986). Particle size analysis (2nd edition). In: Klute, A. (ed.). *Methods of soil analysis: Part I—Physical and mineralogical methods* (pp. 383-411). American Society of Agronomy/Soil Science Society of America.
- Gómez-Baggethun, E., De Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics*, 69(6), 1209-1218.
- Jakobsen, I. (1983). Vesicular-arbuscular mycorrhiza in field-grown crops. II. Effect of inoculation on growth and nutrient uptake in barley at two phosphorus levels in fumigated soil. *New Phytologist*, 94, 595-604.
- Jones M. J. and Wild A. (1975). Soils of the West African Savanna Commonwealth Agriculture. Burcaux, Herpenden England, p 246.
- Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science*, 296(5573), 1694-1697.
- Montemurro, F. (2009). The role of organic fertilizers in the sustainable agricultural development. *IntechOpen*.
- Mulima, I. M. Shafiu, M., Ismaila, M. Benisheikh, K. M. (2015) Status and Distribution of Some Available Micronutrients in Sudan and Sahel Savanna Agro-Ecological Zones of Yobe State, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries*, Volume 7, Number 1, ISSN: 2141-2731
- Mustapha, M. et al. (2023). Effect of late rainfall onset and early cessation on farming activities in Damaturu, Yobe State. *Journal of Plant and Soil Science*, 10(3), 287-296.
- Mustapha, S., Mamman, H. K., & Abdulhamid N. A. (2010) Status and distribution of extractable micronutrients in Haplustults in Yamaltu-Deba Local Government Area, Gombe state, Nigeria. *Journal of Soil Science and Environmental Management*, 1(8), 200-204
- Naveed, M., Brown, L. K., Raffan, A. C., George, T. S., Bengough, A. G., Roose, T., Sinclair, I., Koebernick, N., Cooper, L., Hackett, C. A., & Hallett, P. D. (2017). Plant exudates may stabilize or weaken soil depending on species, origin and time. *European Journal of Soil Science*, 68(6), 806-816.
- Nwaka, G. I. C. (1990). Studies on dune soils of Borno State. Morphology, classification and physical properties. *Annals of Borno*, 6(7), 198-204.
- Silva, G. (2018). *What organic fertilizers mean to plants and soil*. Michigan State University Extension.
- Thomas, G. W. (1996). Soil pH and soil acidity. In Sparks, D. L. (ed.), *Methods of soil analysis: Part 3—Chemical methods* (pp. 475-490). Soil Science Society of America, Inc.