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Research Article

Assessment of Soil Fertility Status and Nutrient Distribution in Agricultural Soils of Gusau Local Government Area, Zamfara State, Nigeria

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ABSTRACT
Soil fertility assessment is a prerequisite for sustainable agriculture in semi-arid regions, where continuous cultivation often leads to nutrient depletion. This study evaluated the fertility status and nutrient distribution of agricultural soils in the Wanke and Magami Districts of Gusau, Zamfara State, Nigeria. One hundred and twenty (120) soil samples were systematically collected from two depths (0–20 cm and 20–50 cm) and analyzed for key physicochemical properties using standard laboratory procedures. The results indicated that soil pH ranged from 6.01 to 6.16, reflecting slightly acidic conditions suitable for most tropical crops. Organic carbon (1.00–1.23%) and total nitrogen (0.09–0.11%) levels were low to moderate, suggesting a need for organic matter stabilization. Notably, available phosphorus (7.04–8.57 mg kg^{-1}) fell below critical thresholds, identifying it as a primary limiting factor. The exchange complex was dominated by calcium (Ca^{2+}) and magnesium (Mg^{2+}), with an effective cation exchange capacity (ECEC) of 5.63–6.20 cmol (+) kg^{-1} and a high base saturation (75–82%). While the soils demonstrate moderate nutrient retention capacity, the deficiencies in nitrogen and phosphorus pose risks to long-term productivity. To mitigate these constraints and ensure food security in the region, the study recommends integrated soil fertility management, specifically the incorporation of organic amendments and balanced inorganic fertilizer application.

Keywords: Effective cation exchange capacity; Nutrient distribution; Savanna soils; Soil chemical properties; Soil fertility assessment

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INTRODUCTION

Soil fertility remains one of the most critical determinants of agricultural productivity and environmental sustainability, particularly in developing regions where crop production largely depends on the inherent nutrient status of soils. Soil fertility refers to the capacity of soil to supply essential nutrients in adequate quantities and appropriate proportions required for plant growth and crop yield. In tropical and semi-arid agroecosystems, soil fertility is strongly influenced by soil organic matter dynamics, nutrient cycling processes, and management practices. Declining soil fertility has become a major challenge in many parts of sub-Saharan Africa, largely due to continuous cultivation, nutrient mining, erosion, and inadequate nutrient replenishment (Lal, 2018; Vanlauwe *et al.*, 2019).

Tropical soils are often characterized by low organic matter content, limited nutrient reserves, and poor structural stability resulting from prolonged weathering and high decomposition rates. These conditions contribute to rapid nutrient losses and reduced nutrient retention capacity. As a result, many agricultural soils in West Africa exhibit deficiencies in key nutrients such as nitrogen, phosphorus, and potassium, which ultimately constrain crop productivity (Bationo *et al*., 2018; Chivenge *et al*., 2021). In Nigeria, several studies have reported declining soil fertility associated with intensive land use, inadequate organic matter inputs, and limited adoption of integrated nutrient management practices (Adesodun *et al*., 2020; Olorunfemi *et al*., 2022).

Assessment of soil fertility status is therefore essential for understanding soil productivity potential and for developing appropriate soil management strategies. Soil fertility evaluation commonly involves the determination of key soil chemical indicators such as soil pH, soil organic carbon, total nitrogen, available phosphorus, exchangeable bases, and cation exchange capacity. These properties influence nutrient availability, soil buffering capacity, and nutrient retention processes that regulate plant growth. Detailed information on the distribution of these soil properties provides a scientific basis for site-specific soil fertility management and sustainable agricultural planning (Adekiya *et al*., 2020; FAO, 2022).

In semi-arid regions of northern Nigeria, increasing population pressure and agricultural expansion have intensified land use and placed considerable stress on soil resources. Farmers in these areas often rely on traditional cropping systems with limited fertilizer inputs, which gradually leads to nutrient depletion and declining soil productivity. The sustainability of agricultural production in such environments therefore depends on accurate assessment of soil fertility conditions and identification of major nutrient limitations (Nwite *et al*., 2019; Chivenge *et al*., 2021).

Gusau Local Government Area of Zamfara State lies within the Sudan savanna ecological zone of north-western Nigeria where agriculture constitutes the primary livelihood for the majority of rural households. Major crops cultivated in the area include maize, millet, sorghum, groundnut, and cowpea. Despite the importance of agriculture in the region, detailed information on the fertility status and nutrient distribution of agricultural soils in the area remains limited. Such information is essential for identifying soil fertility constraints and for developing appropriate nutrient management practices that can enhance crop productivity and maintain soil health.

Therefore, this study was conducted to assess the fertility status and nutrient distribution of agricultural soils in Gusau Local Government Area, Zamfara State, Nigeria. Specifically, the study evaluates selected soil chemical properties and provides baseline information that can support sustainable soil fertility management and improved agricultural productivity in the region.

Materials and Methods

2.1 Study Area Description

The study was conducted in Gusau Local Government Area, located in the north-western part of Zamfara State. The area lies approximately between latitudes 12°00′–12°15′ N and longitudes 6°30′–6°45′ E**.** Gusau serves as the state capital and is situated within the Sudan savanna agro-ecological zone of northern Nigeria. The climate of the region is characterized by a distinct wet and dry season controlled largely by the movement of the Inter-Tropical Convergence Zone (ITCZ). Annual rainfall ranges from 700 to 900 mm, with most precipitation occurring between May and September**,** while the dry season extends from October to April**.** Mean annual temperature ranges from 27 to 34 °C, with higher temperatures typically recorded during the late dry season.

The vegetation of the area is typical Sudan savanna, dominated by scattered shrubs, grasses, and drought-tolerant tree species. Agricultural activities constitute the primary livelihood of rural households in the region. Major crops cultivated include maize (*Zea mays*), sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), groundnut (*Arachis hypogaea*), and cowpea (*Vigna unguiculata*). Farming is largely rain-fed and characterized by continuous cultivation with limited use of organic amendments. These practices often contribute to nutrient depletion and declining soil fertility.

The soils of the area are predominantly derived from basement complex parent materials and are generally classified as sandy loam to loamy sand in texture, reflecting the dominance of coarse particles in the savanna environment. Such soils typically exhibit low organic matter content, weak structural stability, and moderate to low nutrient retention capacity**,** which may limit crop productivity without appropriate soil fertility management practices.

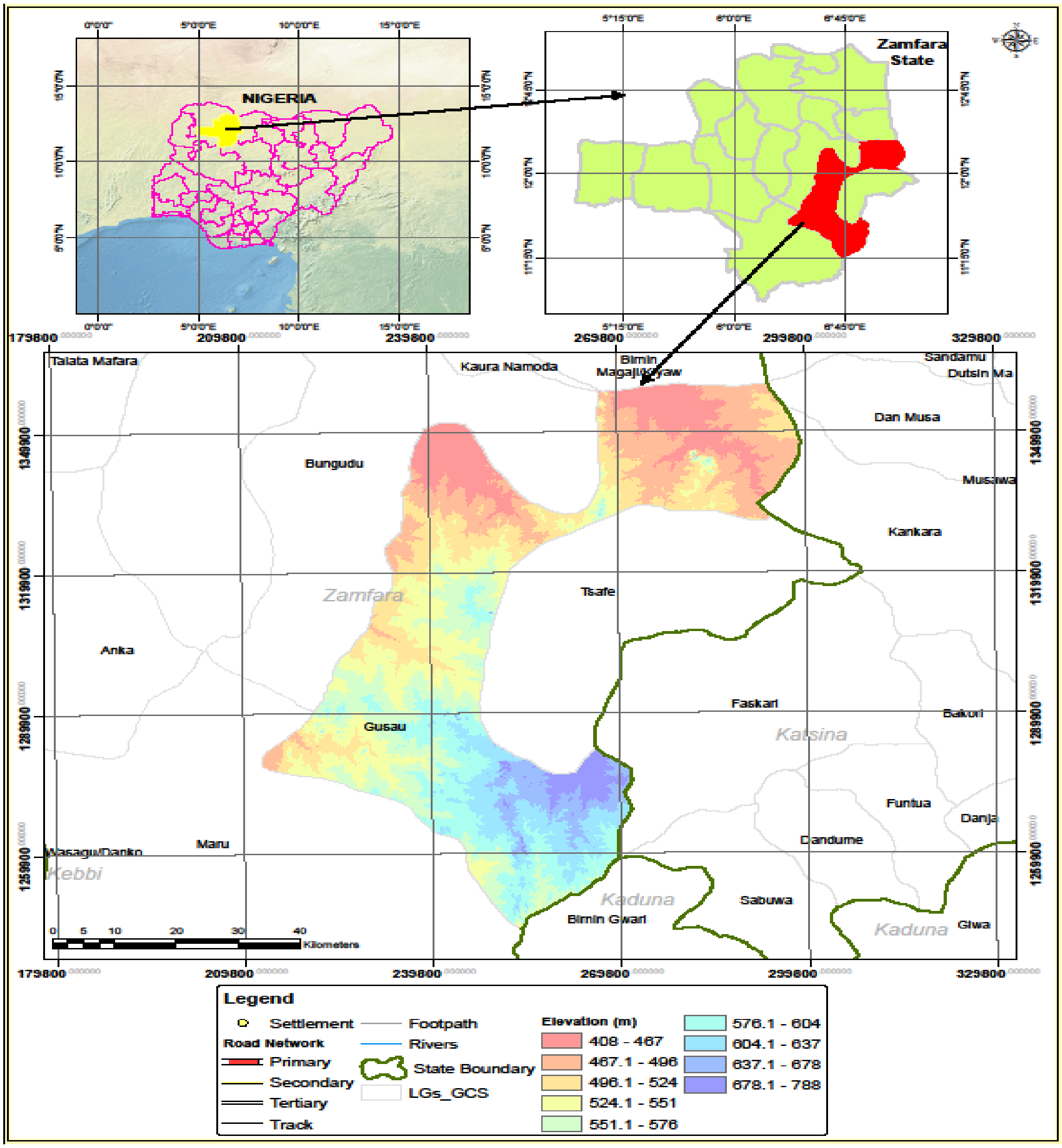

Figure 1: Map of Gusau Local Government Area

Soil Sampling Design

A field survey was conducted across two representative agricultural locations within Gusau Local Government Area, namely Wanke and Magami. These locations were selected due to their active agricultural use and their representativeness of the dominant farming systems in the area.

At each location, thirty (30) auger sampling points were established using a systematic sampling approach to capture variability in soil fertility conditions across cultivated fields. Soil samples were collected at two depth intervals: surface soil (0–20 cm) and subsurface soil (20–50 cm)**.** These depths represent the active root zone and the underlying soil layer influencing nutrient distribution and soil fertility dynamics.

At each auger point, soil samples were collected using a hand auger and placed in labeled polyethylene bags indicating the sampling location, depth, and sample identification number. In total, 60 sampling points were established across the two locations, resulting in 120 soil samples when both surface and subsurface depths were considered**.**

The collected soil samples were transported to the laboratory where they were air-dried, gently crushed, and sieved through a 2-mm mesh to remove plant residues and coarse fragments prior to chemical analysis.

Laboratory Analysis

Soil organic carbon (SOC) was determined using the Walkley–Black wet oxidation method, which involves the oxidation of soil organic carbon with potassium dichromate and sulfuric acid followed by titration of the residual dichromate. This method is widely used for estimating organic carbon in tropical soils because of its reliability and suitability for soils with relatively low organic matter content (Burt, 2018; Hazelton & Murphy, 2019). Soil total nitrogen (TN) was determined using the macro-Kjeldahl digestion method**,** where soil samples were digested with concentrated sulfuric acid in the presence of a catalyst mixture, followed by distillation and titration of the released ammonia (Bremner, 2018).

Available phosphorus (P) was extracted using the Bray and Kurtz No. 1 extraction method, which is commonly applied to acidic and slightly neutral soils in tropical environments (Bray & Kurtz, 1945; Burt, 2018). The extracted phosphorus was determined colorimetrically using a spectrophotometer after developing the phosphomolybdate blue complex (Murphy & Riley, 1962).

Exchangeable bases, including calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+), were extracted using 1 N ammonium acetate solution at pH 7.0 (Thomas, 1982; Burt, 2018). Calcium and magnesium were determined using atomic absorption spectrophotometry, while potassium and sodium were measured using a flame photometer (Burt, 2018). The effective cation exchange capacity (ECEC) was estimated as the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+) and exchangeable acidity (Al^{3+} and H^+). Exchangeable acidity was extracted using 1 N potassium chloride (KCl) and determined by titration with standardized sodium hydroxide solution (McLean, 1982). The ECEC provides an estimate of the soil's capacity to retain nutrient cations under natural soil conditions and is widely used in fertility evaluation studies of tropical soils where variable charge minerals dominate (FAO, 2022; Hazelton & Murphy, 2016).

Soil Fertility Rating

The fertility status of the soils was evaluated using established critical nutrient levels and rating scales commonly applied in tropical soil fertility studies. Key soil chemical properties including soil pH, soil organic carbon (SOC), total nitrogen (TN), available phosphorus (P), exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+), and effective cation exchange capacity (ECEC) were interpreted using standard fertility rating criteria. These parameters are widely used as indicators of soil nutrient availability, soil buffering capacity, and overall soil productivity potential.

Soil test values obtained from laboratory analysis were categorized into low, medium, and high fertility classes based on critical limits reported in previous tropical soil studies. Such classification helps to identify nutrient deficiencies and provides a scientific basis for recommending appropriate soil fertility management practices. In particular, organic carbon and total nitrogen are commonly used as indicators of soil organic matter status, while available phosphorus and exchangeable bases provide information on plant-available nutrients essential for crop growth.

The rating criteria adopted in this study are presented in Table 1, which summarizes the threshold values used for interpreting soil fertility levels in the study area. These thresholds are widely applied in tropical agricultural soils and provide a useful framework for evaluating soil fertility constraints and nutrient management requirements (Hazelton & Murphy, 2019; FAO, 2022; Chivenge *et al*., 2021).

Table 1: Soil Fertility Rating Criteria Used for Interpretation

Soil Property	Low	Medium	High
pH	<5.5	5.5–7.0	>7.0
Organic Carbon (%)	<1.0	1.0–2.0	>2.0
Total Nitrogen (%)	<0.10	0.10–0.20	>0.20
Available P (mg kg^{-1})	<10	10–20	>20
Exchangeable K (cmol(+) kg^{-1})	<0.20	0.20–0.40	>0.40
Exchangeable Ca (cmol(+) kg^{-1})	<2.0	2.0–5.0	>5.0
Exchangeable Mg (cmol(+) kg^{-1})	<0.50	0.50–1.50	>1.50
ECEC (cmol(+) kg^{-1})	<6	6–12	>12

RESULTS AND DISCUSSION

Soil Reaction and Electrical Conductivity

The results presented in Tables 2–4 indicate that soil pH ranged from 6.01 to 6.16, reflecting slightly acidic conditions across the study area. Although the narrow pH range suggests apparent uniformity, this condition is better explained by soil buffering processes governed by mineralogical composition and pedogenic history rather than true chemical homogeneity. In tropical savanna environments, soil acidity is primarily driven by intense weathering and leaching of base cations (Ca^{2+}, Mg^{2+}, K^+) under high rainfall conditions, which progressively increases the relative dominance of H^+ and Al^{3+} ions on the exchange complex. This process leads to moderate acidification even in cultivated systems (Lal, 2018; Minasny *et al*., 2019). The relatively stable pH observed in this study suggests that buffering mechanisms involving soil colloids and organic matter are maintaining equilibrium despite ongoing leaching processes. From a mineralogical perspective, tropical soils are commonly dominated by low-activity clays such as kaolinite and sesquioxides (Fe and Al oxides) formed through advanced weathering. These minerals possess variable charge surfaces, where protonation–deprotonation reactions regulate soil pH and prevent drastic fluctuations (Lehmann *et al*., 2020; Fageria *et al*., 2021). However, such soils typically exhibit low cation exchange capacity (CEC) and limited ability to retain base cations, which explains the persistence of slightly acidic conditions.

The implications of this pH range for nutrient dynamics—particularly phosphorus (P)—are significant. Although pH values between 6.0 and 6.5 are generally considered optimal for nutrient availability, in highly weathered tropical soils phosphorus availability is often controlled more by mineral interactions than by pH alone. Phosphate ions ($H_2PO_4^-$ and HPO_4^{2-}) are strongly adsorbed onto Fe and Al oxides through ligand exchange reactions, forming stable inner-sphere complexes that reduce their bioavailability (Hinsinger *et al*., 2018; Penn and Camberato, 2019). In addition, phosphorus may precipitate as Fe–P and Al–P compounds under slightly acidic conditions, further limiting its availability to plants (Bünemann *et al*., 2018). This process is particularly pronounced in soils dominated by kaolinite and oxide minerals, which provide abundant reactive surfaces for phosphorus sorption. Consequently, even when soil pH falls within the agronomically favorable range, P deficiency may still occur due to strong fixation processes inherent in tropical soils (Kochian *et al*., 2020; Tully *et al*., 2020). The role of parent material further reinforces this interpretation. Soils derived from highly weathered basement complex rocks are typically depleted in primary minerals capable of releasing base cations, resulting in low inherent fertility and enhanced susceptibility to nutrient fixation. This geochemical limitation contributes to the observed uniformity in soil reaction across the study area (Minasny *et al*., 2019). Electrical conductivity (EC) values recorded across the study area were low, indicating non-saline conditions. This reflects the dominance of leaching and eluviation processes, which remove soluble salts from the soil profile under humid tropical conditions (Lal, 2018). While low EC is favorable for crop growth in terms of salinity risk, it also suggests low concentrations of soluble nutrients in the soil solution, implying that nutrient availability depends largely on mineral weathering and external nutrient inputs rather than inherent soil reserves. Furthermore, the slightly acidic pH and low EC observed in the study area are characteristic of highly weathered tropical soils controlled by leaching intensity, oxide-rich mineralogy, and strong phosphorus fixation processes. These interacting factors highlight the need for integrated soil fertility management strategies, particularly those aimed at improving phosphorus availability through organic amendments, liming, or phosphorus-solubilizing inputs (Fageria *et al*., 2021; Tully *et al*., 2020).

Organic Carbon and Total Nitrogen

Soil organic carbon (SOC) content varied between 1.00 and 1.23%**,** while total nitrogen ranged from 0.09 to 0.11% across the two locations and soil depths. In both Wanke and Mada, the surface soils (0–20 cm) recorded slightly higher organic carbon and nitrogen values compared with the subsurface soils (20–50 cm). This vertical distribution pattern reflects the concentration of plant residues, root biomass, and microbial activity near the soil surface where organic materials accumulate. The gradual decline of organic carbon with depth is a common characteristic of cultivated tropical soils due to reduced organic matter inputs and increased mineralization processes in deeper soil layers.

Although the organic carbon levels recorded in the study area fall within the moderate range for tropical agricultural soils, the corresponding nitrogen values suggest relatively low nitrogen fertility. Nitrogen availability in soils is largely controlled by the decomposition of organic matter; therefore, soils with moderate organic carbon often exhibit limited nitrogen supply when continuous cultivation and low organic residue return occur. This condition is typical of savanna agroecosystems where rapid decomposition rates and nutrient mining through crop harvest contribute to gradual soil fertility decline (Vanlauwe *et al*., 2019; Lal, 2018). Consequently, the relatively low nitrogen content observed in the soils indicates that nitrogen supplementation through fertilizer application or organic amendments may be necessary to sustain crop productivity.

Available Phosphorus Distribution

Available phosphorus values ranged from 7.04 to 8.57 mg kg^{-1}**,** with slightly higher concentrations observed in surface soils compared with subsurface soils. Despite this variation, the overall phosphorus levels remained below the critical threshold of approximately 10 mg kg^{-1} commonly required for optimal crop growth in tropical soils. The low phosphorus availability observed in the study area therefore indicates that phosphorus deficiency may constitute a major limitation to crop production.

Low phosphorus availability in tropical soils is frequently associated with strong phosphorus fixation reactions involving iron and aluminum oxides present in highly weathered soils. These reactions reduce phosphorus solubility and limit its availability for plant uptake. In addition, continuous cropping without adequate phosphorus fertilization can gradually deplete soil phosphorus reserves. Similar findings have been reported in savanna agroecosystems of sub-Saharan Africa where phosphorus deficiency remains one of the most widespread soil fertility constraints affecting crop productivity (Bationo *et al*., 2018; Chivenge *et al*., 2021). The results therefore highlight the need for appropriate phosphorus management strategies to enhance nutrient availability and improve crop performance in the study area.

Exchangeable Bases and Effective Cation Exchange Capacity

The distribution of exchangeable bases showed that calcium (Ca^{2+}) was the dominant cation, followed by magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+). Exchangeable calcium ranged from 2.41 to 3.04 cmol kg^{-1}, while magnesium varied between 1.34 and 1.60 cmol kg^{-1}. The predominance of divalent cations, particularly Ca^{2+} and Mg^{2+}, is characteristic of savanna soils derived from weathered basement complex materials, where these bases are released through mineral weathering and retained under moderate leaching conditions (Lal, 2018; Tully *et al*., 2020). Despite this dominance of basic cations, the effective cation exchange capacity (ECEC) ranged from 5.63 to 6.20 cmol kg^{-1}, indicating only a moderate capacity for nutrient retention. This moderate ECEC can be mechanistically explained by the combined influence of clay mineralogy, organic matter content, and degree of weathering. In Sudan savanna soils, the clay fraction is typically dominated by low-activity minerals such as kaolinite and Fe/Al oxides, which possess limited permanent charge and therefore contribute less to cation exchange compared to 2:1 clay minerals (Lehmann *et al*., 2020; Fageria *et al*., 2021). Consequently, even where base cations are relatively abundant, the total number of exchange sites remains constrained, resulting in moderate ECEC values. In addition, soil organic matter—another key contributor to CEC through its high density of functional groups—was only moderate in the study area, further limiting the overall exchange capacity. This explains why high base saturation (75.20–81.94%) coexists with moderate ECEC: although a large proportion of exchange sites are occupied by Ca^{2+} and Mg^{2+}, the absolute number of exchange sites is relatively low. Similar observations have been reported in Sudan savanna soils of northern Nigeria and parts of sub-Saharan Africa, where moderate ECEC values are linked to low-activity clays and organic matter depletion under continuous cultivation (Kochian *et al*., 2020; Tully *et al*., 2020).

The observed variations between locations (e.g., Wanke and Magami) can be further interpreted in relation to land-use history and management intensity. Areas subjected to prolonged cultivation, such as Wanke, are likely to experience progressive depletion of organic matter and base cations due to continuous cropping and residue removal, which reduces both CEC and nutrient reserves. In contrast, locations such as Magami, where fallowing or less intensive land use may occur, tend to retain relatively higher organic matter levels and improved exchange capacity. These differences highlight the role of land-use legacy effects in controlling soil chemical properties, particularly in fragile savanna ecosystems (Bünemann *et al*., 2018; Minasny *et al*., 2019).

Although the study provides valuable insights into exchangeable bases and ECEC, it does not include micronutrient analysis, which represents an important limitation. In highly weathered tropical soils, iron (Fe) and aluminum (Al) oxides play a dual role—they not only influence cation exchange processes but also strongly control phosphorus availability through sorption reactions. Furthermore, micronutrients such as Fe, Mn, Cu, and Zn are essential for plant metabolic functions, and their availability is often influenced by soil pH, redox conditions, and mineral composition (Alloway, 2018; Fageria *et al*., 2021). The absence of these parameters limits a comprehensive assessment of soil fertility, particularly given the increasing recognition of micronutrient deficiencies in sub-Saharan African soils (Kochian *et al*., 2020). Future studies should therefore integrate micronutrient evaluation to provide a more holistic understanding of soil fertility status.

Comparatively, the ECEC values obtained in this study fall within the range reported for Sudan savanna soils across northern Nigeria, Niger, and parts of West Africa, where ECEC typically ranges between 4 and 8 cmol kg^{-1} depending on land use and soil texture (Lal, 2018; Tully *et al*., 2020). This suggests that the soils of the study area are representative of typical savanna agro-ecosystems rather than exceptional cases, characterized by moderate nutrient retention capacity and vulnerability to fertility decline under continuous cultivation.

Generally, the combination of moderate ECEC, high base saturation, low-activity clay mineralogy, and the effects of sustained land-use pressure suggests that, although the soils currently exhibit reasonable fertility status, their capacity to support long-term productivity remains constrained. This limitation arises because the soils possess a relatively small number of exchange sites due to low-activity clays and moderate organic matter levels, making them vulnerable to nutrient depletion under continuous cultivation. Consequently, without appropriate management interventions, essential nutrients may be progressively lost through crop uptake, leaching, and erosion. To mitigate these constraints, practices such as organic matter incorporation, residue retention, and integrated nutrient management are critical for enhancing cation exchange capacity, improving nutrient retention, and sustaining soil productivity (Bünemann *et al*., 2018; Fageria *et al*., 2021).

Implications for Soil Fertility Management

The overall evaluation of soil fertility parameters indicates that, although soil reaction and base saturation are moderately favorable for crop production, nitrogen (N) and available phosphorus (P) constitute the primary limiting nutrients in the study area. Given the moderate ECEC and low organic matter status, these soils exhibit limited nutrient buffering capacity, making them susceptible to rapid nutrient depletion under continuous cultivation. From an agronomic efficiency perspective, nitrogen should be prioritized first, followed by phosphorus. Nitrogen deficiency directly constrains vegetative growth and yield formation, while phosphorus limitation affects root development and nutrient uptake efficiency. However, due to the presence of Fe and Al oxides in these soils, phosphorus use efficiency is inherently low, necessitating careful management of P inputs (Hinsinger *et al*., 2018; Fageria *et al*., 2021). To address these limitations, a combined organic–inorganic nutrient management strategy is recommended. For cereal-based systems typical of the Sudan savanna, an application rate of approximately: 60–90 kg N ha^{-1} (e.g., urea or NPK formulations) and 20–40 kg P ha^{-1} (e.g., single superphosphate or NPK) is considered appropriate for moderate fertility soils under rainfed conditions (Lal, 2018; Tully *et al*., 2020). Nitrogen should be applied in split doses (e.g., at planting and 3–5 weeks after emergence) to minimize losses through leaching and volatilization, while phosphorus should be applied at planting and band-placed to reduce fixation and improve uptake efficiency. For resource-constrained smallholder farmers, reliance solely on mineral fertilizers may not be economically sustainable. Therefore, cost-effective alternatives and complementarities are essential. The incorporation of 5–10t ha^{-1} of farmyard manure or compost can significantly improve soil organic matter, enhance cation exchange capacity, and increase nutrient retention. In addition, integrating crop residues and adopting legume-based rotations can contribute to biological nitrogen fixation, reducing dependence on synthetic N fertilizers (Bünemann *et al*., 2018; Minasny *et al*., 2019). From a cost–benefit standpoint, targeted fertilizer application (micro-dosing)—such as applying small quantities of NPK (e.g., 2–4 g per planting hole)—has been shown to improve fertilizer use efficiency and yield response in smallholder systems, while minimizing input costs and financial risk (Tully *et al*., 2020). This approach is particularly suitable for farmers with limited access to capital. Generally, nutrient management in the study area should follow a priority-based and efficiency-driven approach, where nitrogen is addressed first to stimulate crop growth, followed by phosphorus to enhance root development and nutrient use efficiency. The integration of organic inputs with judicious fertilizer use is critical to improving soil fertility, increasing nutrient use efficiency, and ensuring the long-term sustainability of agricultural production systems in the Sudan savanna.

Table 2: Descriptive Statistics of Selected Soil Chemical Properties in the Study Area

Property	Mean	Min	Max	SD	CV (%)
pH	6.09	5.1	7.4	0.45	7.39
EC (dS m^{-1})	0.35	0.14	1.1	0.18	51.43
Organic C (%)	1.1	0.57	1.64	0.23	20.91
Organic Matter (%)	1.89	0.98	2.82	0.39	20.63
Total N (%)	0.1	0.05	0.15	0.02	20.00
Available P (mg kg^{-1})	8.11	1.64	13.76	1.59	19.61
Ca (cmol kg^{-1})	2.65	1.23	5.99	0.91	34.34
Mg (cmol kg^{-1})	1.47	0.21	3.11	0.72	48.98
Na (cmol kg^{-1})	0.21	0.04	2.12	0.29	138.1
K (cmol kg^{-1})	0.31	0.01	0.92	0.23	74.19
H (cmol kg^{-1})	0.42	0.02	0.96	0.22	52.38
Al (cmol kg^{-1})	0.76	0.23	1.94	0.29	38.16
TEB (cmol kg^{-1})	4.64	2.16	8.19	1.2	25.86
TEA (cmol kg^{-1})	1.18	0.39	2.71	0.46	38.98
ECEC (cmol kg^{-1})	5.82	3.27	9.7	1.22	20.96
PBS (%)	79.25	44.34	93.33	8.09	10.21
ESP (%)	3.5	0.48	28.15	4.78	136.57

Data source 2025

Table 3: Effect of Location on Soil Chemical Properties

Location	pH	OC (%)	TN (%)	Av.P (mg kg^{-1})	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	ECEC (cmol/kg)
Wanke	6.16	1.08	0.1	8.55	2.57	1.52	0.3	0.22	5.72
Mada	6.02	1.12	0.1	7.67	2.74	1.42	0.33	0.21	5.92

Data source 2025

Table 4. Effect of soil depth on selected soil chemical properties

Depth (cm)	pH	OC (%)	TN (%)	Av.P (mg kg^{-1})	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	ECEC (cmol/kg)
0–20	6.09	1.18	0.11	8.44	2.88	1.47	0.31	0.25	6.01
20–50	6.08	1.02	0.09	7.79	2.42	1.47	0.31	0.18	5.63

Data source 2025

CONCLUSION

This study evaluated the fertility status of agricultural soils in Gusau Local Government Area of Zamfara State using selected soil chemical properties. The results revealed that the soils are generally slightly acidic, with pH values within the favorable range for crop production. Organic carbon contents were moderate but declined with increasing soil depth, reflecting the influence of surface organic matter inputs and biological activity. Total nitrogen levels were relatively low, indicating limited nitrogen availability in the soils. Similarly, available phosphorus concentrations were below the commonly accepted critical level for tropical soils, suggesting that phosphorus deficiency may constrain crop productivity in the area.

Exchangeable bases were dominated by calcium and magnesium, while potassium and sodium occurred in smaller quantities. The effective cation exchange capacity indicated moderate nutrient retention capacity, and base saturation values were generally high, reflecting the dominance of basic cations in the exchange complex.

Generally, the soils possess moderately favorable chemical conditions for crop growth; however, nitrogen and phosphorus remain the major limiting nutrients. Sustainable crop production in the area will therefore require improved soil fertility management practices, including organic matter addition and balanced fertilizer application.

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