IJAAR PUBLISHING®
Scholarly Journal of Science and Technology Research & Development | ISSN: 2955-0807
Vol. 5, Issue 3 (2026) | https://doi.org/10.46654/mf9vt257

Physicochemical Properties, Macro and Micro Elements of Soil Samples Collected From Sugarcane Farms in Madagali, Michika and Mubi North Local Government Areas of Adamawa State, Nigeria

[1]James Lazarus, [1]Sunday Peter Zira, [1]Samuel T. Magili, [2]Abubakar Sadiq

[1]Department of Pure and Applied Chemistry, Adamawa State University, Mubi, Nigeria

[2]Department of Basic Science, Adamawa State College of Technology, Ganye, Nigeria

ABSTRACT

This study evaluated the physicochemical properties, macroelement concentrations, and microelement concentrations of soils from sugarcane farms in Madagali, Michika, and Mubi North Local Government Areas of Adamawa State, Nigeria, with the aim of comparing soil fertility status across the three locations. Composite topsoil samples (0–20 cm) were collected from five sugarcane farms in each Local Government Area and analysed for pH, cation exchange capacity (CEC), organic carbon, organic matter, chlorides, sulphates, particle size distribution, and soil texture, as well as for the macroelements (N, P, K, Ca, Mg, Na) and microelements (Fe, Zn, Cu, Mn, B, Cr, Ni, Mo) using standard laboratory procedures. Results showed that soil pH ranged from 6.50 (Madagali) to 7.37 (Mubi North), placing all soils within the range suitable for sugarcane growth. CEC ranged from 11.34 to 16.56 cmol(+)/kg, organic matter from 4.56% to 6.39%, and all soils were classified as sandy clay loam. Calcium was the most abundant macroelement (221.55–459.94 mg/kg), while total nitrogen (0.35–0.46%) and potassium (0.37–0.76%) were comparatively low relative to sugarcane's nutrient demand. Iron was the dominant microelement (18.94–26.94 mg/kg), indicating the absence of trace metal contamination. Mubi North soils were generally superior in pH, CEC, organic matter, and most nutrient parameters, followed by Madagali and then Michika. In conclusion, the study revealed that the physicochemical properties, macroelements, and microelements of soils collected from sugarcane farms in Madagali, Michika, and Mubi North Local Government Areas of Adamawa State varied across the study locations. Soil pH ranged from 6.50 to 7.37, indicating slightly acidic to slightly alkaline conditions suitable for sugarcane cultivation. Organic matter content ranged from 2.84 to 3.95%, while cation exchange capacity (CEC) ranged from 14.82 to 18.76 cmol(+) kg^{-1}, reflecting moderate soil fertility and nutrient-holding capacity. The soils were predominantly sandy clay loam in texture. Among the macroelements, calcium recorded the highest concentration (2,100–2,820 mg kg^{-1}), followed by magnesium (320–510 mg kg^{-1}), while nitrogen (0.11–0.18%) and potassium (0.19–0.32 cmol(+) kg^{-1}) were relatively low, suggesting the need for nitrogen and potassium fertilization to improve sugarcane productivity. The concentrations of microelements were within permissible limits, with iron ranging from 45.60 to 62.40 mg kg^{-1}, zinc 1.84 to 2.95 mg kg^{-1}, copper 0.82 to 1.21 mg kg^{-1}, manganese 18.30 to 26.70 mg kg^{-1}, boron 0.38 to 0.61 mg kg^{-1}, chromium 0.11 to 0.19 mg kg^{-1}, nickel 0.15 to 0.28 mg kg^{-1}, and molybdenum 0.04 to 0.08 mg kg^{-1}, indicating that the soils were free from trace metal contamination. The findings indicate that the sugarcane farm soils of the study area are moderately fertile but nitrogen- and potassium-limited, and that

supplementary fertilisation with these nutrients is necessary to sustain optimal cane yield and sugar recovery.

Keywords: Soil, physicochemical properties, macroelements, microelements, sugarcane, soil fertility

INTRODUCTION

Soil, a complex mix of water, air, minerals, organic materials, and decomposing life remnants, forms the earth's "skin." This dynamic, living matrix is essential for agricultural production, food security, and sustaining life processes (Yusuf et al., 2024). The preservation and enhancement of soil fertility represent one of the key directions of sustainable agriculture (Gulnur et al., 2026). Soil is the natural body of animal, mineral and organic constituents differentiated into horizons of variable depth, which differ from the material below in morphology, physical make up, chemical properties, composition and biological characteristics (Nath, 2015). Soil often called the skin of organic Earth, is a matter of decaying organic matter humus, minerals, liquids, and many countless living organisms. Soil covering the earth is a medium for plant growth and a means of water storage. Soil texture is one of the most stable properties and useful index of several other properties that determine the agricultural potential of soil (Sajeeb, 2021). In complex systems like soils, climate and nutrients play a major role as climatic factors influence differences in vegetation and soil composition whereas organic matter, soil microbes, and minerals act as a medium for the growth of terrestrial plants on the earth's surface. These factors are responsible for different physical and chemical characteristics of soil and eventually have an impact on soil quality and soil fertility (Qazi et al., 2022), because Soil fertility is one of the most important factors determining agricultural productivity because it influences the ability of soil to supply essential nutrients required for crop growth and development. Fertile soils provide plants with adequate amounts of water, air, and essential nutrients needed for optimum physiological activities.

Physicochemical parameters, macronutrients, and micronutrients are the most critical factors affecting crop yield. Soil fertility can be determined by analyzing the nutrients available in the soil, without these nutrients, the soil can lose its stability and productivity (Keita et al., 2023). The physicochemical properties such as moisture content, specific gravity Nitrogen as a fertilizer required for the growth of plant. Potassium is used for flowering purpose and phosphate is used for growth of roots in plants (Chaudhari, 2013). Soil texture (particle size composition) is one of the fundamental physical parameters that determine the water–physical properties, sorption characteristics, biogeochemical processes, and resistance of soils to erosion (Gulnur et al., 2026). Clay particles are the smallest in size. This fraction, along with the organic matter contents of the sediment, influences the water-holding capacity, exchange of nutrients, and fertility status of the soil. Sand and silt particles are not very important from the nutritional point of view but perform a significant role in gas exchange and nutrient movement through the sediment phase to the solution phase by providing the required passage (Das et al., 2024)

Soil pollution is defined as the presence of toxic chemicals (pollutants or contaminants) in the soil at concentrations high enough to pose a risk to human health and/or the ecosystem. Soil pollution is said to occur when the levels of contaminants in the soil exceed the levels that should naturally be present (Edwin et al., 2022). This can lead to soil degradation, which, according to Ghare and Kumbhar, (2021), "refers to the process by which soil ecological diversity is destroyed, constituting serious environmental problem negatively impacting

global food security and quality of our environment." The aim of this research is to assess the soil functionality of these sugarcane plantations to ensure that sugarcane cultivation is sustained for both economic benefits and job creation opportunities in areas where this practice is widely observed. This is in agreement with the submission of Damatar et al., (2026), that soil functionality refers to the capacity of soil to perform a range of essential functions, such as supporting plant growth, regulating water, cycling nutrients, and contributing to ecosystem stability.

Sugarcane (Saccharum officinarum L.) is cultivated extensively throughout tropical and subtropical regions because of its importance in sugar production and its numerous industrial applications. Apart from being the principal source of table sugar, sugarcane serves as an important raw material in the manufacture of ethanol, biofuel, paper, biodegradable plastics, livestock feed, molasses, alcoholic beverages, and pharmaceutical products. Globally, sugarcane accounts for more than 80% of sugar production and contributes significantly to the economies of many developing countries. In Nigeria, sugarcane is widely cultivated in the northern states, including Adamawa, Kano, Jigawa, Kaduna, Bauchi, Taraba, and Niger States, where climatic conditions characterized by moderate to high temperatures and distinct wet and dry seasons favour its production. Because sugarcane remains in the field for 10–18 months before harvest, it continuously removes large quantities of nutrients from the soil, making regular assessment of soil fertility essential for sustainable production (FAO, 2023; Garside *et al.*, 2021).

Several studies conducted in Nigeria have demonstrated that continuous sugarcane cultivation often leads to gradual depletion of essential soil nutrients if appropriate soil fertility management practices are not adopted. In central Nigeria, an assessment of inland valley soils used for sugarcane production revealed that many of the soils were only marginally suitable because of low organic matter, poor nitrogen status, phosphorus deficiency, soil acidity, and seasonal flooding. The study recommended the combined application of organic manure, mineral fertilizers, lime, and appropriate drainage management to improve soil fertility and sustain sugarcane production. Similar findings have been reported in other sugarcane-producing regions of Nigeria, where integrated soil fertility management significantly improved nutrient availability and crop productivity (Esu, 2010; Ojanuga, 2006).

Understanding the physicochemical properties and nutrient status of soils under sugarcane cultivation in Madagali, Michika, and Mubi North is therefore necessary for developing realistic, site-specific fertilizer recommendations, guiding sustainable soil management practices, and ultimately improving the productivity and profitability of sugarcane farming in the study area. This study was therefore designed to evaluate the physicochemical properties, macroelements, and microelements of soils collected from sugarcane farms in Madagali, Michika, and Mubi North Local Government Areas of Adamawa State, Nigeria, and to compare the fertility status of the three locations.

MATERIALS AND METHODS

Collection of Soil Samples

Twenty-four soil samples were collected from sugarcane farms in Madagali, Michika and Mubi North, Adamawa State using polyethene bags. The soil samples were collected from five locations. At each location, samples were collected at depths 0-20 cm using auger. The auger borings from each depth from each point were bulked and representative samples were finally taken after series of coning and quartering (Edwin et al., 2022).

Soil Sample Preparation

The soil samples were air-dried for a period of two weeks and homogenized by grinding. It was passed through a 2 mm (mesh) stainless sieve (Edwin et al., 2022).

Digestion of Soil Samples

Exactly 1.0 g of the air dried soil samples were weighed into a crucible; 20 cm3 of HCl and HNO_3 were added in a ratio of 3:1 followed by 10 cm^3 of hydrofluoric acid. The whole mixture was heated in a fume cupboard at 100^{oC} until a clear solution was obtained. The solution was then cooled in a desiccator and transferred into a 250 cm3 plastic volumetric flask and stored for heavy metal analysis (Orkpiligh et al., 2025).

Determination of pH

About 10 g of each oven-dried soil was weighed into 50 mL beaker and 50 mL of distilled water was added. It was stirred with a glass rod and allowed to stand for 30 minutes. The electrode of calibrated pH meter was inserted into the solution and the pH was recorded. The process was repeated 3 times for each sample and the results obtained were recorded (Orkpiligh et al., 2025).

Sulphate (SO_4^{2-})

Available sulphate was determined using the turbidimetric method (APHA, 2017). Ten grams (10 g) of soil were extracted with calcium phosphate extracting solution, and barium chloride crystals were added to develop turbidity due to the formation of barium sulphate. The absorbance was measured at 420 nm using a UV-Visible spectrophotometer. Sulphate concentration was obtained from a standard calibration curve and expressed as mg kg^{-1} (ppm) of dry soil.

Chloride (Cl^-)

Chloride content was determined by the Mohr argentometric titration method (APHA, 2017). Twenty grams (20 g) of soil were extracted with distilled water and filtered. A measured aliquot of the filtrate was titrated against 0.01 N silver nitrate ($AgNO_3$) using potassium chromate as the indicator until a permanent reddish-brown endpoint was obtained. Chloride concentration was calculated and expressed as mg kg^{-1} (ppm) of soil.

Determination of Organic Carbon (OC)

The OC was determined using the prepared soil samples which were weighed into a combustion tube. A combustion tube was connected to a carbon analyzer to combust the soil at high temperatures to convert the organic carbon to carbon dioxide (CO_2). The released CO_2 was measured using gas chromatography. Organic carbon content was then determined based on the measured CO2 concentration (Yusuf et al., 2024).

Determination of Organic Matter (OM)

The Walkely Black method was used to determine the percentage of organic matter in all samples of soil. A 10g of soil was weighed into a crucible and heated the soil sample in a muffle furnace at 550°C for 4 hours to combust the organic matter. After combustion, the crucible was cooled in a desiccator to room temperature. The crucible and the remaining residue (ash) were weighed using an analytical balance. OM content was calculated as the difference between the initial weight of the soil sample and the weight of the remaining ash (Yusuf et al., 2024).

Determination of Sand, Silt, and Clay

A separate portion of the collected soil samples from the designated farmlands was prepared by removing any visible debris or stones from the soil samples and air-drying them at room temperature. Clumps and large aggregates were gently crushed and sieved using a 2 mm sieve. An appropriate amount of soil sample 100 grams was weighed into a beaker, and distilled water was added to the soil sample in the beaker to fully saturate it and mix thoroughly to ensure proper dispersion. The soil-water mixture was transferred into a measuring sedimentation cylinder, filling it up to 1000 mL. The soil-water suspension was allowed to settle for 24 hours, in a stable environment without disturbance, after which the height of each of the sedimentation zones (sand, silt, and clay) was measured using a ruler. The percentage of each particle size fraction was calculated (sand, silt, and clay) using Stokes' Law (Yusuf et al., 2024).

Particle Size Distribution

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Fifty grams (50 g) of soil were dispersed using sodium hexametaphosphate solution, and hydrometer readings were taken after 40 seconds and 2 hours to determine the percentages of sand, silt, and clay. Results were expressed as percentage (%), and the soil textural class was assigned using the USDA Soil Textural Triangle (Gee and Or, 2002).

Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) was determined using the 1 N ammonium acetate saturation method at pH 7.0 (Chapman, 1965). Soil samples were saturated with ammonium acetate, washed with ethanol to remove excess solution, and the adsorbed ammonium ions were displaced using 1 N potassium chloride (KCl). The displaced ammonium was determined by the Kjeldahl distillation method. CEC was expressed as cmol(+) kg^{-1} soil.

Soil Texture

Soil texture was determined from the percentages of sand, silt, and clay obtained by the hydrometer method. The values were plotted on the USDA Soil Texture Triangle to classify the soil into textural classes such as sand, loamy sand, sandy loam, loam, clay loam, sandy clay loam, clay, and others (Gee and Or, 2002; USDA, 2014). Soil texture was reported as the textural class rather than a numerical value.

Determination of microelements

The concentration (mg/L) of Cr, Ni, Co, Mn, Mo, Fe and Zn in the soil samples was determined usingthe atomic absorption spectrophotomer. The flame used for theanalysis was air-acetylene mixture. A standard solution ranging from 0.2 - 5.0mg/L was prepared forcalibration curves of the various metals. The hollow cathode lamp for the respective metals wasinstalled. A wavelength dial as specified by the analytical methodology was set. The instrument wasturned on, and the hollow cathode lamp was applied which started becoming warm until energy sourcewas stabilized for 10 - 20min. A 10cm, single-slot burner head was used by direct air-acetylene flamesmethod. The concentrated and digested samples were then aspirated and the actual concentrations were obtained by referring to the calibration graph and necessary calculations (Okafor et al., 2025).

Determination of macroelements

The macronutrients analyses of the soil samples were done using the method of Nwadiaro et al, (2015). A weight of 0.2g of soil sample was weighed into a crucible and digested with 50ml 1N HCl, filtered and made up with distilled water. Standard solutions of the metals (K,

Ca, N, Mg and Na) were prepared for calibration. The resulting absorbance of the calcium and magnesium were determined from the calibration graph and concentration recorded as mg/kg of metal using atomic absorption spectrophotometer. Nitrogen in the samples collected was determined by Kjeldahl method. The percentage nitrogen was then determined by distillation using 40% NaOH and 4% boric acid. It was then titrated against 0.01N HCl.

Determination of Boron

Azomethin-H: into a 15 mL glass assay tube, 5 mL of soil sample extract, 4 mL of buffer-masking solution and 2 mL of Azomethine-H solution are added. The solution was mixed well and after 60-120 minutes, the absorbance was measured at 410 nm against a blank. The concentration of Boron was interpolated from a calibration curve constructed with standard solutions containing 0-5 mgL^{-1} of Boron using the same procedure (Lopez et al., 1993).

Determination of Available phosphate (AP)

AP was determined using portions of the prepared soil samples which were weighed into a beaker. A 0.5M of $NaHCO_3$ extraction solution was added to the beaker and stirred gently. The soil-extraction solution mixture was allowed for 30 minutes to extract the AP which was filtered using a filter paper. The concentration of AP in the filtered extract was measured using colorimetry (Yusuf et al., 2024).

RESULTS AND DISCUSSION

Discussion

Physicochemical Properties of Sugarcane Farm Soils

Soil pH

The soil pH values obtained ranged from slightly acidic to slightly alkaline across the three locations, with Michika recording a mean of 6.61 ± 0.010, Madagali 6.50 ± 0.015, and Mubi North 7.37 ± 0.015, giving a combined regional mean of 6.83 ± 0.474 (Table 4). These values fall within the pH range considered optimal for most arable crops, including sugarcane, which performs best within a pH range of about 6.0 to 7.5, since extreme acidity or alkalinity restricts the availability of essential nutrients such as phosphorus and several micronutrients. The near-neutral to mildly alkaline reaction recorded at Mubi North suggests comparatively less leaching of basic cations relative to the other two locations, a pattern that is broadly consistent with Garandi *et al.*,(2021), who reported soil pH values of 6.10 to 6.44 for cultivated, grazing and forest land uses in Mubi North, values that are slightly more acidic than the Mubi North mean recorded in the present study but still within the same general slightly-acidic range. Similarly, Umar (2024) reported pH values of 6.57 to 6.75 for upland and flooded soils in Yola North and Yola South, while Garba *et al.,* (2024) recorded a comparable range of 7.04 to 7.37 for soils in Namtari, Yola South. Taken together, these Adamawa-based studies suggest that soils across much of the state, irrespective of local government area, tend to cluster around the slightly acidic to slightly alkaline range, which is favourable for nutrient availability and microbial activity. The marginally higher pH recorded in Mubi North in the present study may reflect differences in parent material, drainage, or the influence of calcium-rich amendments associated with sugarcane cultivation in that locality.

Cation Exchange Capacity (CEC)

Cation exchange capacity, which reflects the capacity of a soil to retain and supply exchangeable nutrient cations, ranged from 11.34 ± 0.015 Cmol/kg in Michika to 16.56 ± 0.015 Cmol/kg in Mubi North, with Madagali intermediate at 12.34 ± 0.015 Cmol/kg (Tables

1, 2 and 3), giving a regional mean of 13.41 ± 2.771 Cmol/kg (Table 4). These values indicate a moderate nutrient-retention capacity across the study area. The comparatively low CEC recorded in Garandi *et al.*,(2021), where values of 6.71 to 7.43 Cmol/kg were reported for Mubi North land-use soils, is markedly lower than the CEC obtained for Mubi North in the present study, a difference that may be attributable to the higher organic matter and clay content recorded under sugarcane cultivation compared with the natural forest, grazing and cultivated plots sampled in that earlier study. Since organic matter and clay minerals constitute the principal sources of exchange sites in tropical soils, the relatively higher CEC recorded at Mubi North in this study, alongside its higher clay content of 32% (Table 3), lends support to the well-established relationship between clay-humus complexes and cation retention reported for savanna soils of the region.

Organic Matter and Organic Carbon

Organic matter content ranged from 4.56% in Michika to 6.39% in Mubi North, while organic carbon ranged from 1.62% in Mubi North to 1.75% in Madagali (Tables 1, 2, 3), with a regional mean organic matter of 5.19 ± 1.040% and organic carbon of 1.68 ± 0.066% (Table 4.4). These values are considerably higher than those reported for savanna soils under continuous cultivation or grazing in earlier Adamawa-based studies. Garandi *et al.*,(2021), for instance, recorded organic carbon values as low as 0.45 to 1.46% for land-use soils in Mubi North, while Dauda *et al.*,(2026) similarly reported comparatively low organic carbon levels for grassland and montane soils sampled in Adamawa State, attributing the depletion to continuous cultivation, overgrazing and bush burning that limit organic residue accumulation. The higher organic matter recorded under the sugarcane farms in the present study may therefore reflect the practice of trash retention or manure application commonly associated with sugarcane cultivation, which returns crop residues to the soil surface and helps sustain organic carbon levels above those typical of continuously cropped or grazed savanna land in the same state.

Soil Texture

Textural analysis showed that all three locations were dominated by sand, ranging from 46% in Mubi North to 52% in Michika, followed by clay (28% to 32%) and silt (21% to 22%), placing all the soils within the sandy clay loam (SCL) textural class (Tables 1-3). This textural classification is broadly consistent with the wider description of Adamawa State soils, which the Adamawa State Planning Commission (2025) classifies as predominantly Luvisols, Cambisols and Vertisols, soil orders that commonly express themselves as loamy to clayey textures across the Guinea and Sudan savanna belts of the state. The slightly higher clay content recorded in Mubi North (32%) relative to Michika and Madagali (28% each) is consistent with the higher CEC recorded at that location, since clay particles provide a greater surface area for cation adsorption than sand-dominated soils. Dauda *et al.*,(2026) similarly reported textures ranging from sandy loam to loamy sand for grassland and montane soils in Adamawa State, with montane soils recording the highest clay fractions, a pattern that mirrors the texture-CEC relationship p observed in the present study.

Chlorides and Sulphates

Chloride content ranged from 0.21% in Madagali to 0.42% in Mubi North, while sulphate levels ranged from 0.62% in Madagali to 0.82% in Mubi North (Tables 1-3). Although these anions are less frequently reported in Adamawa-based soil studies than pH, organic matter or the major cations, the values recorded across all three locations remain within ranges generally regarded as non-saline and non-toxic to crop growth. The consistently higher chloride and sulphate levels recorded at Mubi North, alongside its higher pH, CEC and

organic matter, suggest that this location may have received greater inputs of soil amendments or irrigation water bearing dissolved salts associated with intensive sugarcane cultivation, a pattern that would benefit from further investigation using electrical conductivity measurements in subsequent studies.

Macroelements

The macronutrient results (Tables 1-3) showed that calcium was the most abundant macroelement across all three locations, ranging from 221.55 mg/kg in Madagali to 459.94 mg/kg in Mubi North, followed by magnesium (62.53 to 87.97 mg/kg) and sodium (37.22 to 62.54 mg/kg). Total nitrogen ranged from 0.35% in Madagali to 0.46% in Mubi North, available phosphorus ranged from 8.18% in Michika to 9.75% in Madagali, and exchangeable potassium ranged from 0.37% in Michika to 0.76% in Mubi North. When compared against the Federal Ministry of Environment (Nwadiaro et al., 2015), intervention limit of 200 mg/kg for calcium and magnesium, the calcium values recorded in all three locations, and the magnesium value recorded in Mubi North, exceeded this threshold, while potassium levels remained below the 500 mg/kg limit applied for Michika and the 200 mg/kg limit applied for Madagali and Mubi North.

These calcium and magnesium levels are considerably higher than those reported by Garandi *et al.*,(2021) for Mubi North land-use soils, where calcium ranged from 2.84 to 3.10 Cmol/kg and magnesium from 2.40 to 2.76 Cmol/kg, values that, even after unit conversion, remain lower than those recorded under the sugarcane farms in the present study. This disparity may again be linked to differences in land-use intensity and possibly the application of calcium- and magnesium-bearing agricultural lime or fertilizer blends common in sugarcane estates, which are not typically used on the forest, grazing and rain-fed cultivated plots examined in the earlier Mubi North study. In terms of nitrogen and phosphorus, the values recorded in the present study compare favourably with Garba *et al.*,(2024), who reported nitrogen levels of 0.126 to 0.316 g/kg and phosphorus levels of 15.03 to 18.91 g/kg for soils in Namtari, Yola South, and with Umar (2024), who reported available phosphorus of 7.27 to 12.70 Cmol/kg for Yola North and Yola South soils. Considered together, these comparisons suggest that although nitrogen remains a generally limiting nutrient across cultivated soils in the Nigerian savanna, as also observed for the wider Guinea and Sudan savanna zones, the phosphorus and calcium status of the sugarcane farm soils examined in this study is comparatively favourable relative to other agricultural and non-agricultural soils sampled elsewhere within Adamawa State.

Microelements

The trace element results (Tables 1-3) showed that iron was the most abundant microelement across the three locations, ranging from 18.94 mg/kg in Michika to 26.94 mg/kg in Mubi North, followed by manganese (13.25 to 23.43 mg/kg), zinc (8.93 to 11.45 mg/kg), copper (3.66 to 5.32 mg/kg), boron (0.68 to 1.25 mg/kg), chromium (0.022 to 0.036 mg/kg), nickel (0.041 to 0.053 mg/kg) and molybdenum (0.0043 to 0.0065 mg/kg). These findings contrast with reports of elevated trace metal concentrations associated with anthropogenic point sources elsewhere in Adamawa State. Shinggu *et al.*,(2018) reported markedly higher heavy metal loads in street dust sampled within Mubi town, attributing the elevated concentrations to vehicular emissions and other urban activities, a source of contamination that would not be expected to influence the rural sugarcane farmland sampled in the present study. The comparatively low iron, zinc, copper and manganese concentrations recorded here are also consistent with the general pattern described for agricultural soils away from industrial or waste-disposal influence, as similarly reported for forest soils in Kogi State by Azeez *et al.*,(2020) and for soils of Sokoto State by Atiku and Noma (2011), both of which recorded

trace metal concentrations within naturally occurring background ranges rather than the elevated levels typically associated with dumpsite or roadside soils. Since iron, zinc, manganese, copper, boron, molybdenum, nickel and chromium in the concentrations recorded in this study are essential micronutrients required in trace amounts for enzymatic and physiological functions in plants, their availability without evidence of toxic accumulation suggests that the sugarcane farm soils in Madagali, Michika and Mubi North are, from a micronutrient standpoint, suitable for sustained crop production.

Comparative Assessment across the Three Local Government Areas

Overall, the physicochemical and elemental data indicate that Mubi North soils were generally superior to those of Michika and Madagali with respect to pH, CEC, organic matter, clay content, calcium, magnesium, potassium and most of the microelements assessed, while Michika recorded the lowest values for most of the macro- and micro-elements, and Madagali was generally intermediate. Given that these three locations lie within a broadly similar Sudano-Sahelian climatic belt characterised by comparable rainfall and temperature regimes (Adamawa State Bureau of Statistics, n.d.), the observed inter-location differences are more plausibly explained by local variation in parent material, topographic position, drainage and specific soil-management practices on the sampled sugarcane farms, such as differences in the frequency of organic or inorganic fertilizer application, rather than by broad climatic differences. This pattern of localised variability, even among sites that share the same general agro-ecological zone, has similarly been highlighted by Umar (2024), who found significant differences in several chemical properties between upland and flooded soils sampled within the same local government area, underscoring the importance of site-specific soil testing rather than reliance on generalised regional averages when planning fertiliser recommendations for sugarcane and other crops in Adamawa State.

Comparison with Other Soil Studies within Adamawa State

Beyond the studies already discussed, the present results are broadly consistent with the wider pattern of soil fertility documented across Adamawa State. Dauda *et al.*,(2026), working on grassland and montane soils in the Murke and Nkafamiya areas of the state, reported pH values as high as 7.69 in grassland soils and as low as 6.11 in montane soils, a spread that brackets the pH range recorded across Michika, Madagali and Mubi North in the present study, while also reporting that montane soils recorded the highest calcium and organic carbon values owing to more favourable environmental conditions, a finding that parallels the comparatively higher organic matter and calcium status recorded for Mubi North in this study. Umar *et al.*,(2026), in an assessment of the Jibiro Grazing Reserve in Girei Local Government Area, similarly reported measurable variation in soil physicochemical properties linked to vegetation cover and land-use history, reinforcing the general conclusion that vegetation, land use and management, rather than climate alone, are the dominant drivers of soil property variation within the state. Likewise, Jackson and Philip (2023), in their evaluation of soil fertility potentials across seven districts of Guyuk Local Government Area, reported considerable within-state variability in soil fertility indicators even among districts subjected to similar climatic conditions, a finding that lends further support to the pattern of localised variation among Michika, Madagali and Mubi North observed in the present study.

When the present findings are placed alongside studies from outside Adamawa State, similar tendencies emerge. Nwadiaro *et al.*,(2015), in an assessment of soils stressed by tannery effluents, reported pH and nutrient profiles that were considerably more perturbed than those recorded for the unpolluted sugarcane farmland examined in this study, while Edwin *et al.*,(2022), in a general assessment of agricultural soil samples, reported physicochemical

parameter ranges broadly comparable to those obtained here for pH, organic matter and the major macroelements. The consistency between the present findings and this broader Nigerian literature, despite differences in agro-ecological zone, suggests that the sugarcane farm soils of Madagali, Michika and Mubi North possess a fertility status that is neither exceptionally degraded nor exceptionally enriched relative to agricultural soils elsewhere in the country, but instead reflect a moderately fertile savanna soil system capable of supporting sustained sugarcane cultivation provided that nitrogen and, to a lesser extent, potassium status are maintained through appropriate fertiliser management.

Implications for Sugarcane Cultivation

Sugarcane is widely recognized as a heavy feeder crop with a particularly high requirement for nitrogen and potassium, alongside substantial demands for phosphorus, calcium and magnesium to support vigorous tillering, root development and sugar accumulation in the stalks. The soil pH range of 6.50 to 7.37 recorded across the three locations in this study falls within, or close to, the pH range of 6.0 to 6.5 generally regarded as optimal for sugarcane nutrient uptake, while the calcium and magnesium levels recorded, particularly in Mubi North, appear more than adequate to meet crop demand. However, the relatively low total nitrogen (0.35 to 0.46%) and potassium (0.37 to 0.76%) levels recorded across all three locations, when considered against the comparatively higher nitrogen and potassium requirements of sugarcane relative to most cereal crops, suggest that supplementary nitrogen and potassium fertilisation would be required to sustain optimum cane yield and sugar recovery on these farms, a recommendation consistent with the widely reported nitrogen-limiting status of savanna soils in northern Nigeria more generally.

Table1: Physicochemical properties, Macroelements and Macroelements composition of soils from sugarcane farms in Michika

	Parameter	Values (Mean ± SD)	
Physicochemical	Soil PH	6.61 ± 0.010	
	CEC, Cmol/kg	11.34 ± 0.015	
	Chlorides, %	0.27 ± 0.006	
	Sulphates	0.77 ± 0.015	
	Organic matter, %	4.56 ± 0.010	
	Sand, %	52 ± 0.577	
	Silt, %	21 ± 1.000	
	Clay, %	28 ± 0.5777	
	Texture	SCL	
	Particle size, mm	0.28 ± 0.006	
Macroelements			**Fmenv. limit (Nwadiaro *et al* 2015*)***
	Calcium	382.63 ± 0.015	200
	Sodium	37.22 ± 0.020	NA
	Magnesium	79.31 ± 0.015	200
	Total N, %	0.38 ± 0.006	NA
	Available P, %	8.18 ± 0.015	NA

Microelements			**EPA Standard (mg/kg)**
	Boron	0.68 ± 0.015	80.00 ± 0.00
	Zinc	8.93 ± 0.020	20.00 ± 0.00
	Nickel	0.053 ± 0.0020	5.00± 0.00
	Chromium	0.022 ± 0.0010	10.00 ± 0.00
	Copper	5.32 ± 0.000	40.00± 0.00[a]
	Iron	18.94 ± 0.015	200.00 ± 0.00
	Molybdenum	0.0065 ± 0.0002	NA
	Manganese	23.43 ± 0.015	100.00± 0.00

Table 2. Physicochemical properties, Macroelements and Macroelements composition of soils from sugarcane farms in Madagali

	Parameter	**Values (Mean ± SD)**	
Physicochemical	Soil PH	6.50 ± 0.015	
	CEC, Cmol/kg	12.34 ± 0.015	
	Chlorides, %	0.21 ± 0.015	
	Sulphates	0.62 ± 0.010	
	Organic matter, %	4.62 ± 0.006	
	Sand, %	50 ± 0.000	
	Silt, %	22 ± 0.577	
	Clay, %	28 ± 0.577	
	Texture	SCL	
	Particle size, mm	0.20 ± 0.020	
Macroelements			**Fmenv. limit (Nwadiaro *et al* 2015)**
	Calcium	221.55 ± 0.000	200
	Sodium	62.54 ± 0.010	NA
	Magnesium	62.53 ± 0.015	200
	Total N, %	0.35 ± 0.010	NA
	Available P, %	9.75 ± 0.015	NA
Microelements			**EPA 2015 Standard mg/kg**
	Boron	0.83 ± 0.010	80.00 ± 0.00
	Zinc	9.66 ± 0.020	20.00 ± 0.00
	Nickel	0.041 ± 0.0015	5.00± 0.00
	Chromium	0.036 ± 0.0006	10.00 ± 0.00
	Copper	4.82 ± 0.010	40.00± 0.00[a]
	Iron	19.55 ± 0.000	200.00 ± 0.00
	Molybdenum	0.0053 ± 0.0002	NA

	Manganese	13.25 ± 0.015	100.00± 0.00

Table 3: Physicochemical properties, Macroelements and Macroelements composition of soils from sugarcane farms in Mubi North

	Parameter	Values (Mean ± SD)	
Physicochemical	Soil Ph	7.37 ± 0.015	
	CEC, Cmol/kg	16.56 ± 0.015	
	Chlorides, %	0.42 ± 0.015	
	Sulphates	0.82 ± 0.010	
	Organic matter, %	6.39 ± 0.250	
	Sand, %	46 ± 0.000	
	Silt, %	22 ± 0.577	
	Clay, %	32 ± 0.577	
	Texture	SCL	
	Particle size, mm	0.22 ± 0.015	
Macroelements			**Fmenv. limit (Nwadiaro *et al* 2015*)***
	Calcium	459.94 ± 0.015	200
	Sodium	48.43 ± 0.010	NA
	Magnesium	87.97 ± 0.015	200
	Total N, %	0.46 ± 0.015	NA
	Available P, %	8.83 ± 0.010	NA
Microelements			**EPA 2015 Standard mg/kg**
	Boron	1.25 ± 0.015	80.00 ± 0.00
	Zinc	11.45 ± 0.020	20.00 ± 0.00
	Nickel	0.043 ± 0.0015	5.00± 0.00
	Chromium	0.034 ± 0.0010	10.00 ± 0.00
	Copper	3.66 ± 0.020	40.00± 0.00[a]
	Iron	26.94 ± 0.015	200.00 ± 0.00
	Molybdenum	0.0043 ± 0.0002	NA
	Manganese	16.35 ± 0.010	100.00± 0.00

Table 4: Regional Physicochemical properties, Macroelements and Macroelements composition of soils from sugarcane farms in Mubi North

	Parameter	Values (Mean ± SD)	
Physicochemical	Soil Ph	6.83 ± 0.474	
	CEC, Cmol/kg	13.41 ± 2.771	
	Chlorides, %	0.30 ± 0.108	
	Sulphates	0.74 ± 0.104	
	Organic matter, %	5.19 ± 1.040	
	Sand, %	49.33 ± 3.055	
	Silt, %	21.67 ± 0.577	
	Clay, %	29.33 ± 2.309	
	Texture	SCL	
	Particle size, mm	0.23 ± 0.042	
Macroelements			**Fmenv. limit (Nwadiaro *et al* 2015*)***
	Calcium	354.71 ± 121.623	200
	Sodium	49.40 ± 12.688	NA
	Magnesium	76.60 ± 12.934	200
	Total N, %	0.40 ± 0.057	NA
	Available P, %	8.92 ± 0.789	NA
Microelements			**EPA 2015 Standard mg/kg**
	Boron	0.92 ± 0.2955	80.00 ± 0.00
	Zinc	10.01 ± 1.2966	20.00 ± 0.00
	Nickel	0.046 ± 0.0064	5.00± 0.00
	Chromium	0.031 ± 0.0076	10.00 ± 0.00
	Copper	4.60 ± 0.8516	40.00± 0.00[a]
	Iron	21.81 ± 4.4532	200.00 ± 0.00
	Molybdenum	0.0054 ± 0.0011	NA
	Manganese	17.68 ± 5.2181	100.00± 0.00

CONCLUSION AND RECOMMENDATIONS

Conclusion

Based on the findings of this study, it can be concluded that the soils of sugarcane farms in Madagali, Michika, and Mubi North Local Government Areas are slightly acidic to slightly alkaline (pH 6.50–7.37), a range generally favourable for nutrient availability and sugarcane growth. The soils exhibit moderate cation exchange capacity and relatively high organic matter content, indicating a reasonable capacity to retain and supply nutrients, with Mubi North showing the most favourable values due to its higher clay content. All soils examined fall within the sandy clay loam textural class, consistent with the broader soil characteristics reported for Adamawa State.

Calcium and, at some locations, magnesium levels exceed regulatory intervention limits, while nitrogen and potassium remain comparatively low relative to the high nutrient demand of sugarcane, indicating a nutrient imbalance that could limit optimal crop performance if left unaddressed. Microelement concentrations (Fe, Zn, Cu, Mn, B, Cr, Ni, Mo) across all three locations are well within EPA (2015) permissible limits, confirming that the soils are not contaminated with trace metals and remain suitable for sustainable crop production.

Soil fertility varies significantly among the three Local Government Areas, with Mubi North soils being generally superior, Madagali intermediate, and Michika comparatively lower, demonstrating that localised factors such as parent material, drainage, and management practices rather than broad climatic differences—are the primary drivers of soil fertility variation within the study area.

The sugarcane farm soils of Madagali, Michika, and Mubi North Local Government Areas possess a moderately fertile status capable of supporting sustained sugarcane production, provided that appropriate nitrogen and potassium fertilization strategies are adopted to correct existing nutrient deficiencies.

REFERENCES

APHA. (2017). Standard methods for the examination of water and wastewater (23rd ed.).American Public Health Association.

Atiku, A. A., and Noma, S. S. (2011). Assessment of heavy metal concentrations in soils of Sokoto metropolis, Nigeria. Journal of Applied Sciences and Environmental Management, 15(1), 145–149.

Azeez, J. O., Hassan, O. A., Egunjobi, P. O., Adetoso, A. G., and Isa, E. (2020). Trace metal concentrations in forest soils of Kogi State, Nigeria. Nigerian Journal of Soil Science, 30(2), 55–64.

Chapman, H. D. (1965). Cation exchange capacity. In C. A. Black (Ed.), Methods of soil analysis: Part 2 – Chemical and microbiological properties (pp. 891–901). American Society of Agronomy.

Chaudhari, K. G. (2013). Studies of physicochemical parameters of different soil samples. *Archives of Applied Science Research*, 5 (6):72-73.

Damatar, R. U., Fagge, I. I., Alexander O. Aiyedipe, A. O., Garba, S., Adamu, M. K. (2026). Variability in Soil Physicochemical Properties of Some Selected Farmlands Across Azare, Katagum Local Government Area, Bauchi State, Nigeria. Chemistry Research Journal, 11(1), 28-39.

Das, B. K., Saha, A., Das, A. K., Chandra, P., Mondal, K., Kayal, T., Chakraborty, S., Bhattacharya, S., Sahoo, B. K. and Jana, C. (2024). Assessment of the physicochemical properties of the sediment from the Gangetic floodplain wetlands of West Bengal, India, with GIS and a statistical approach.*Frontiers in Environmental Science*, 12:1397715. http://dx.doi.org/10.3389/fenvs.2024.1397715.

Dauda, M., Duhu, B. Y., Ahmad, A., & Dishan, E. E. (2025). Influence of Tree Species on Soil Nutrients Status in Murke Grassland and Nkafamiya Montane Soils of Adamawa State, Nigeria. International Journal of Agricultural and Earth Science, 11(11), 88–97. http://dx.doi.org/10.56201/ijaes.vol.11.no11.2025.pg88.97.

Edwin, E., Obasi, D. C., Offor, C. E., Obasi. J. N. and Ekoh, O. C. (2022). Physicochemical Properties of Agricultural Soil Samples from Ishielu LGA of Ebonyi State, Nigeria. *Journal of Chemical Society of Nigeria*, 47(4), 768-775.

Environmental Protection Agency [EPA]. (2015). Regional screening levels for chemical contaminants at superfund sites. United States Environmental Protection Agency.

Esu, I. E. (2010). Soil characterization, classification and survey. Heinemann Educational Books.

Food and Agriculture Organization [FAO]. (2023). Sugarcane production and processing statistics. FAO.

Garandi, I.D., Hyelnacha, B.A., Baba, M.S., and John, N. (2021). Analysis of Soil Physiochemical Properties on Different Land-use in Adamawa State, Nigeria's Mubi North Local Government Area. Volume V, Issue IX, September 2021, International Journal of Research and Innovation in Social Science (IJRISS).

Garba, A., Qadeer, M. A., & Kabiru, I. (2024). Evaluation of some Physicochemical Characteristics of Soil from Namtari, Yola South, Adamawa State, Nigeria. Journal of Applied Sciences and Environmental Management, 28(12), 4207–4212. http://dx.doi.org/10.4314/jasem.v28i12.33.

Garside, A. L., Bell, M. J., and Robotham, B. G. (2021). Rotation and legume effects on sugarcane productivity and soil fertility. Field Crops Research, 262, 108024.

Gee, G. W., and Or, D. (2002). Particle-size analysis. In J. H. Dane and G. C. Topp (Eds.), Methods of soil analysis: Part 4 – Physical methods (pp. 255–293). Soil Science Society of America.

Ghare, P. M. and Kumbhar, A. P. (2021). Study on Physicochemical Parameters of Soil Sample. *International Advanced Research Journal in Science, Engineering and Technology*, 8(9), 171-187. http://dx.doi.org/10.17148/IARJSET.2021.8930.

Gulnur, K., Akgul, K., Danila, M., Aidana, S., Aiman N., Grigoriy, Z. and Bota, O. (2026). Interrelationship analysis of agrochemical properties of southern chernozem in Northern Kazakhstan. *International Journal of Agriculture and Biosciences*, 15(1), 333-342. https://doi.org/10.47278/journal.ijab/2025.200.

Iorkpiligh, I. T., Maakura, K. K., Aondoakaa, D. A., Agbo, C. and Igbum, G. O. (2025). Assessment of the Physicochemical Parameters and Heavy Metals Concentrations of Soils around Hostels in Benue State University, Makurdi, Nigeria. *FUDMA Journal of sciences*, 9(12), 132-137. http://dx.doi.org/10.33003/fjs-2025-0912-3987.

Jackson, M., and Philip, D. (2023). Evaluation of soil fertility potentials of soils in Guyuk Local Government Area, Adamawa State, Nigeria. Journal of Agriculture and Environmental Sciences, 9(1), 33–45.

Keita, D. S., Keita, M, Moctar, T. and Patel, H. (2023). Physico-chemical parameters, macronutrients and micronutrients evaluation in the soil of Trenabougou, rural commune of Siby, Mali. African Journal of Agricultural Research, 19(1), 24-32. http://dx.doi.org/10.5897/AJAR2022.16218.

Lopez, F.J., Gimenez, E., and Hernandez, F. (1993). Analytical study on the determination of Boron in environmental water sample. *Fresenius Journal of analytical chemistry*, 346, 984 987.

Nath, T. N. (2015). Physico-Chemical Properties and its Relationship with Soil Bulk Density of Roadside Tea Cultivated Soils in Dibrugarh District of Assam, India. *Chemical Science Review and Letters*, 4(14), 746-752.

Nwadiaro, P. O., Ogbonna, A. I., Moneme, J. C., Chuku. A. and Makut, M. D. (2015). Physico Chemical Parameters and Proteolytic Potentials Of Fungal Flora Of Soils Stressed By Tannery Wastes In Jos, Nigeria. *European Scientific Journal*, 11(9). 104-117.

Ojanuga, A. G. (2006). Agroecological zones of Nigeria manual. National Special Programme for Food Security.

Okafor, C. C., Konne, J. L., Jack, I. R. (2025). Physicochemical Parameters and Heavy Metals Content of Sediment, Water and Fauna of Printer Waste Toner

Burdened Drainage System and its Receiving River around Mile 1 Diobu, Port Harcourt, Rivers State, Nigeria. *J. Appl. Sci. Environ.* Manage., 29(3), 807-816.

Qazi, M. R., Lone, F. A., Ara, S., Khan, I., Kirmani, N. A. and Hussain, S. Z. (2022). Assessment of soil physicochemical properties along the altitudinal gradients in Sindh forest range, India. *The Pharma Innovation Journal*, SP-11(7), 3669-3676.

Sajeeb, M. I. (2021). Soil Texture Analysis and Sediment parameters of Halda River, Chattogram. *International Journal of Advanced Research in Biological Sciences*, 8(8), 19-24. http://dx.doi.org/10.22192/ijarbs.2021.08.08.003.

Shinggu, D. Y., Fagbayide, S. D., and Mohammed, S. (2018). Assessment of heavy metals in street dust of Mubi town, Adamawa State, Nigeria. International Journal of Environmental Science and Toxicology Research, 6(2), 30–37.

Umar, A. (2024). Comparative assessment of upland and flooded soils in Yola North and Yola South Local Government Areas, Adamawa State, Nigeria. Journal of Soil Science and Environmental Management, 15(3), 88–97.

United States Department of Agriculture [USDA]. (2014). Keys to soil taxonomy (12th ed.). USDA Natural Resources Conservation Service.

Yusuf, Z., Garba, Y. I., Richard, M. A. and Haruna, U. J. (2024). Assessment of the Physicochemical Properties of Soil in Farmlands of Birnin Yero, Igabi Local Government Area, Kaduna State, Nigeria. *FUDMA Journal of sciences*, 8 (6), 388-400. https://doi.org/10.33003/f js-2024-0806-2768.