

## RESEARCH ARTICLE

# EVALUATION OF SOIL ORGANIC MATTER AND CATION EXCHANGE CAPACITY IN RELATION TO DISTANCE FROM DAM IN DUTSINMA FLOODPLAIN SOILS KATSINA STATE NIGERIA

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## ARTICLE DETAILS

## Article History:

Received 4 June 2025  
Revised 9 July 2025  
Accepted 10 August 2025  
Available online 10 September 2025

## ABSTRACT

Dams significantly alter the hydrological and sedimentary dynamics of surrounding landscapes, influencing soil formation, nutrient distribution, and agricultural potential. Understanding the spatial variation in soil properties relative to dam proximity is essential for sustainable land management. This study investigates the impact of proximity to a dam on various soil physicochemical properties. Notably Soil organic matter and CEC. Soil samples were collected from three distinct zones—onshore, midshore, and offshore—and analyzed for texture, organic carbon, cation exchange capacity, nutrient content, pH, electrical conductivity, and exchangeable acidity. The findings reveal spatial variations in soil composition and fertility, with midshore zones exhibiting optimal conditions for agricultural productivity. The results showed that the soils were slightly acidic, with a mean pH of 5.947, and had low electrical conductivity, indicating low soil salinity. The soil texture was predominantly sandy, with high sand content (82%) and low clay content (7.53%). The mean organic carbon and organic matter contents were moderate, ranging from 1.549% to 2.671%. The effective cation exchange capacity (ECEC) was moderate, with a mean value of 11.560 cmol/kg. The study also found that distance from the dam influenced soil properties, particularly soil texture, exchangeable acidity, and cation exchange capacity.

## KEYWORDS

Organic Matter, Cation Exchange Capacity, Floodplain, Dutsinma

## 1. INTRODUCTION

Soil health is a cornerstone of sustainable agriculture and environmental stability, directly impacting crop productivity, water management, and ecosystem services. Two critical indicators of soil health are Soil Organic Matter (SOM) and Cation Exchange Capacity (CEC). SOM, composed of decomposed plant and animal residues, cells, and tissues of soil organisms, plays a vital role in soil structure, nutrient retention, water-holding capacity, and nutrient supply to plants. Higher SOM levels typically enhance soil fertility, reduce erosion, and improve water infiltration, particularly in dynamic floodplain ecosystems (Sanchez, 2019).

CEC, a measure of a soil's ability to retain and exchange positively charged ions like calcium, magnesium, and potassium, is largely influenced by SOM levels and soil texture. Soils with higher CEC can hold and supply more nutrients to plants, making them more fertile and resilient against nutrient loss (Sposito, 2008). Understanding the trends of SOM and CEC together provides valuable insights into soil fertility and management strategies for agricultural productivity.

Soil organic matter (SOM) and cation exchange capacity (CEC) are crucial components of floodplain soils, influencing the mobility and retention of metals and organic compounds. The relationship between SOM and CEC is complex, with organic matter contributing significantly to CEC due to its abundant negatively charged functional groups. However, this relationship is modulated by soil mineralogy, redox conditions, and the presence of iron and manganese oxides (Du Laing et al., 2009; Ferreira et al., 2021; Noma and Sani 2008).

Dams are critical infrastructures that regulate water flow, sediment transport, and nutrient cycling in terrestrial ecosystems. Their presence alters the physical and chemical characteristics of adjacent soils, influencing land use potential and agricultural productivity. Understanding how soil properties vary with distance from a dam is essential for sustainable land management and environmental conservation.

Distance from water bodies plays a significant role in shaping SOM and CEC, with soils proximal to water bodies tending to have higher SOM and CEC due to periodic flooding and sediment deposition. This relationship is spatially heterogeneous and influenced by factors like avulsion stage, vegetation succession, and soil texture. Studies have shown that effective CEC and base saturation decrease significantly with increasing distance from water bodies, reflecting the diminishing influence of hydrological connectivity and sediment transport (Abdulkadir et al., 2025; Louzada et al., 2024; Zhang et al., 2024; Clark et al., 2019).

The complex interplay of hydrological, sedimentological, biological, and chemical factors influencing SOM and CEC highlights the need for an integrated understanding of these spatial gradients and their mechanistic bases. Managing soil fertility in riparian and upland zones requires consideration of these factors, as well as the potential for anthropogenic interventions like biochar amendments to modify SOM and CEC dynamics.

Dutsinma floodplain soils, characterized by seasonal inundation and intensive agricultural use, offer a unique opportunity for studying SOM and CEC trends (Abdulkadir et al., 2025). By examining these trends, researchers can develop targeted strategies to optimize agricultural practices, manage nutrient resources, and predict soil fertility responses

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to environmental changes.

Floodplains are subjected to repeated flooding and human intervention, which can have varying effects on soil quality. While periodic floods can replenish soils with fresh sediment and nutrients, they can also accelerate nutrient leaching, reduce SOM levels, and degrade soil structure. Over time, these processes may significantly impact SOM and CEC in floodplain soils, affecting crop yields and the sustainability of agricultural practices.

The distance from water bodies is a critical factor influencing the spatial distribution and dynamics of SOM and CEC in floodplain soils. However, the relationship between distance from water bodies and SOM and CEC is complex and modulated by various hydrological, sedimentological, and biogeochemical processes. Despite its importance, the effect of distance from water bodies on SOM and CEC in Dutsinma floodplain soils remains poorly understood, particularly in the context of sustainable agriculture and ecosystem management.

This study aims to investigate the effect of distance from water bodies on SOM and CEC in floodplain soils, with a focus on understanding the underlying mechanisms and processes that govern this relationship. By examining the spatial patterns and dynamics of SOM and CEC in relation to distance from water bodies, this study seeks to provide valuable insights into the management of floodplain soils for sustainable agriculture and ecosystem services.

## 2. MATERIALS AND METHOD

### 2.1 Study Area and Site Selection

**Study Area:** The study was conducted in the Dutsin-ma floodplain, a region known for its periodic flooding and agricultural land use. This area is characterized by diverse soil types influenced by sediment deposition from seasonal flooding. **Site Selection and Soil sampling:** This study employed a systematic approach to select representative sampling sites across the floodplain. Composite soil samples were collected from three distinct zones, varying in distance from the dam: onshore (closest to the dam), midshore (intermediate distance), and offshore (farthest from the dam). A total of 60 soil samples were collected, with 20 samples from each

zone, at a depth of 0-30 cm using a soil auger. At each site, multiple soil cores were extracted and combined to create composite samples, ensuring representation of site-wide conditions. The collected samples were then air-dried, crushed, and sieved to pass through a 2 mm mesh, separating fine earth from larger particles. Finally, the samples were labeled and stored in moisture-free conditions for further analysis in the laboratory.

### 2.1 Laboratory Analysis

**Particle Size Analysis** The Bouyoucos hydrometer method (Bouyoucos, 1962) was used to conduct particle size analysis, with distilled water and calgon solution (sodium hexametaphosphate) serving as dispersing agents. The analysis provided percentage compositions of sand, silt, and clay, allowing for the classification of soil textures using the USDA soil textural triangle. Soil pH in water and in 0.01M CaCl<sub>2</sub> was determined using Glass electrode pH meter (ITA, 1982). The EC was determined from saturation extract of the soil samples using an electrical conductivity meter. Organic carbon {Acid dichromate wet oxidation method (Nelson and Sommers, 1996). The exchangeable bases, Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, and Mg<sup>2+</sup>, were extracted in 1MNH<sub>4</sub>Cl and analyzed by atomic emission spectroscopy (for Ca<sup>2+</sup> and Mg<sup>2+</sup>) and flame absorption atomic spectroscopy (for Na<sup>+</sup> and K<sup>+</sup>) (Pratt, 1965). The Cation exchange capacity (CEC) was obtained by summation of the exchangeable bases and acidity

## 3. DATA ANALYSIS

The data was analyzed using SPSS Version 26.0 to obtain descriptive statistics such as Mean, Median, Range, Maximum, Minimum, Variance, Skewness, Kurtosis and Coefficient of variation while correlation analysis was done to understand the relationships among the measured soil properties.

## 4. RESULTS AND DISCUSSION

Table 1: shows the descriptive statistics of Soil properties of Dutsin-ma Flood plain soils. The statistics of soil properties in Dutsin-ma floodplain soils reveal interesting trends:

**Table 1: Descriptive Statistics Of Soil Properties**

Soil parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
pH	5.6	6.5	5.947	0.2560	0.066	0.398	.262
EC	0.03	0.29	0.094	0.064	0.004	2.111	5.831
SAND	68	88	82.00	4.957	24.571	-1.592	3.855
SILT	4	28	9.80	5.401	29.171	2.977	10.610
CLAY	4	12	7.53	2.356	5.552	0.197	-.728
OC (%)	1.276	1.915	1.549	0.195	0.038	0.362	-.909
OM(%)	2.201	3.301	2.671	0.336	0.114	0.362	-.909
Ca (Cmol/kg)	1.090	4.711	3.070	0.980	.962	-.498	.109
Mg (Cmol/kg)	3.450	11.146	6.061	2.056	4.231	1.079	1.307
K (cmol/kg)	0.136	1.146	0.428	0.245	0.061	2.046	4.977
Na (cmol/kg)	0.618	3.403	1.366	0.805	0.649	1.914	2.917
EA	0.333	0.833	0.633	0.201	0.040	-.405	-1.431
ECEC	6.569	18.127	11.560	3.360	11.296	0.436	-.472

OC= Organic Carbon, OM= Organic Matter, Ea= Excheangeable Acidity, ECEC= Effective Cation Exchange Capacity

### 4.1. Soil pH

Soil pH plays a crucial role in determining nutrient availability and crop productivity and influences soil microbial activity, which is essential for decomposing organic matter, fixing nitrogen, and solubilizing minerals (Shehu et al., 2015; Fierer and Jackson, 2006). The mean pH of the soil of the study area is (5.9) and range between (5.6-6.5) and this suggests minimal variation in soil acidity. Similar results were reported who both reported low variability of soil pH in soils of the savannah region of Nigeria (Aliyu et al., 2025; Fatima et al., 2022; Adak et al., 2019). This results indicates slightly acidic soil condition and is consistent with the findings of, who reported acidic pH levels in Nigerian floodplain soils (Smith et al., 2020).

### 4.2 Electrical Conductivity (EC)

Soil Electrical Conductivity (EC) is a crucial parameter in determining soil

salinity, which can significantly impact crop productivity and soil health. The study soil EC values can be classified into different categories, with values below 4 dS/m generally considered non-saline (Richards, 1954; Zaman et al., 2018). The mean EC (0.094 dS/m) indicates low soil salinity, This shows that EC was within the normal range and soils were free from saline problems, as the EC of these soils was far below 4.0 dS m<sup>-1</sup>. consistent with the findings, who reported low EC values in soils with low salt concentrations of (Aliyu et al., 2025). The positive skewness (2.111) and high kurtosis (5.831) suggest a few high EC values, potentially indicating localized salinity issues. The low EC Values indicates low salinity problem and most plants can be able to thrive and favorable for satisfactory plant growth. This result was similar to that of (Cui et al., 2025; (Fatima et al., 2022).

### 4.3 Soil Texture

The high mean sand content (82%) and low mean clay content (7.53%)

suggest a sandy soil texture. consistent, who reported similar soil textures in Nigerian floodplains (Williams et al., 2018). The results are in agreement with the findings of who both reported that the dominance of sand contents in Northern Nigerian soils is as a result of sorting of materials by clay eluviation (Shehu et al., 2015; Malgwi et al., 2000; Voncir et al., 2008). The negative skewness (-1.592) and high kurtosis (3.855) for sand content indicate a peaked distribution with a long tail towards lower sand contents. A study found that sandy soils have poor water retention due to their large particle size and pore space (Smith et al., 2020). Similarly, Research by reported that high sand content in soils can lead to increased infiltration rates and reduced water availability for plants (Johnson et al., 2019).

#### 4.4 Organic Carbon (OC) and Organic Matter (OM)

The mean OC (1.549%) and OM (2.671%) contents indicate moderate levels of organic matter, consistent with who reported similar OC and OM levels in soils with moderate fertility (Davis et al., 2020). The narrow ranges for OC (1.276-1.915%) and OM (2.201-3.301%) suggest minimal variation in soil fertility. This moderate level of organic matter in the study area may be attributed to Increased organic matter deposition and mineralization as Floodwaters often carry nutrient-rich sediments that deposit on the floodplain, enriching the soil with organic matter (Abdulkadir, 2025). Another reason for the higher organic matter content is the soil texture, pH, and cation exchange capacity (CEC) in Dutsinma floodplain soils may influence organic matter levels. as, soils with higher sand content may experience faster organic matter decomposition due to better aeration. The Luvisol soil type found in similar floodplain areas can exhibit moderate to high levels of organic matter due to their formation

processes and nutrient-rich sediments. (Abdulkadir 2025).

#### 4.6 Exchangeable Cations

The mean values for exchangeable cations (Ca, Mg, K, Na) indicate a dominance of Mg, followed by Ca, consistent with who reported similar cation exchange patterns in Nigerian soils (Adeyemo et al., 2017). The positive skewness for Mg (1.079), K (2.046), and Na (1.914) suggests a few high values, potentially indicating localized nutrient hotspots.

#### 4.7 Effective Cation Exchange Capacity (ECEC)

The Effective Cation Exchange Capacity (ECEC) is a vital soil property affecting nutrient availability and retention, with an average value of (11.560 cmol/kg) indicating a moderate capacity to retain cations. This falls within the moderate range of 5-15 Cmol/kg, suggesting careful nutrient management is necessary to optimize crop productivity (Hazelton and Murphy, 2007). The mean ECEC (11.560 cmol/kg) indicates moderate cation exchange capacity, consistent with Olowookere et al. (2019), who reported similar ECEC values in soils with moderate fertility. A moderate ECEC suggests that the soil has a moderate ability to retain nutrients, making them available to plants. This can impact soil fertility and plant growth. Research has also reported that ECEC values in this range can support a wide range of crops, including cereals and legumes. (Johnson et al., 2019). The result obtained is in line with studies who obtained ECEC values between 5-15 cmol/kg (Smith et al., 2019). Similarly obtained similar results in the same area (Abdulkadir et al., 2025).

**Table 2:** Influence Of Distance From The Dam On Some Selected Soil Properties

SOIL PROPERTIES	ONSHORE	MIDSHORE	OFFSHORE	SED	TREND WITH DISTANCE
SAND	85.60a	81.20ab	79.20b	2.154	Decreases offshore
SILT	7.4	8.8	3.52	3.52	Increases offshore
CLAY	7.0	8.0	7.6	1.78	Slight Variation
OM	1.59	1.56	1.59	0.1248	Stable
K	0.351	0.488	0.45	0.173	Highest Midshore
Mg	6.181	6.529	5.476	1.607	Decreases offshore
Na	0.896	1.657	1.548	0.489	Increases offshore
Ca	2.806	3.486	2.921	0.725	Peaks Midshore
ECEC	11.0	12.8	10.9	255	Peaks midshore
PH	5.92	6.04	5.88	0.183	Slightly acidic
EC	0.054	0.144	0.086	2.038	Highest midshore
EA	0.8a	0.633ab	0.467b	0.096	Decreases Midshore

OM= Organic Matter, ECEC= Effective Cation Exchange Capacity, EC= Electrical Conductivity, EA= Exchangeable Acidity

The table 2 presents the impact of distance from the dam on various soil properties.

#### 4.8 Influence of distance on Soil textural properties

For Soil Textural classes, Sand content decreases with distance from the dam, with onshore soils having the highest sand content (85.60%) and offshore soils having the lowest (79.20%). Silt content increases with distance from the dam, with offshore soils having the highest silt content (13.2%). Sand content decreases with increasing distance from the dam, while silt content increases. This pattern suggests sediment sorting due to water movement, where coarser particles settle near the dam and finer particles are transported further away. This observation aligns with who reported similar sediment redistribution in dam-influenced landscapes (Morrison, 2019; Abdulkadir et al., 2025).

#### 4.9 Influence of distance on soil organic matter

Soil Fertility parameters such as Organic carbon (OC) content remains relatively consistent across distances, ranging from 1.56 to 1.59%. Organic carbon levels remain relatively stable across zones, indicating uniform organic matter input. However, ECEC peaks midshore, suggesting enhanced nutrient retention due to optimal moisture and sediment deposition. The researchers supports this, noting that midshore zones often benefit from periodic flooding and nutrient accumulation (Jibrin et al., 2008 ;Noma and Sani, 2008).

#### 4.10 Soil Acidity and Salinity

Soil pH remains relatively consistent across distances, ranging from 5.88 to 6.04. Electrical conductivity (EC) values are generally low, with onshore soils having the lowest EC (0.054 dS/m). Exchangeable acidity (EA) decreases with distance from the dam, with onshore soils having the highest EA (0.800 cmol/kg) and offshore soils having the lowest (0.467 cmol/kg). EC is highest midshore, indicating greater salt concentration, possibly from water seepage. EA decreases offshore, suggesting reduced acid-forming ions. These findings mirror those of who observed similar patterns in dam-influenced soils (Nwankwo et al., 2015; Abdulkadir et al., 2022).

#### 4.11 Influence of distance on soil exchangeable bases Cation (Nutrients K, Mg, Na, Ca) and ECEC

Effective cation exchange capacity (ECEC) varies slightly, with midshore soils having the highest ECEC (12.8 cmol/kg). Exchangeable potassium (K), magnesium (Mg), and calcium (Ca) contents vary across distances, with midshore soils generally having higher values. Midshore zones exhibit higher concentrations of K, Mg, Na, and Ca, reflecting nutrient enrichment. Offshore zones show reduced Mg and Ca levels, which may impact soil fertility. The study emphasized the role of hydrological gradients in nutrient distribution, corroborating these findings (Ogunwale et al., 2002).

The changes in soil properties with distance from the dam can be

attributed to several factors such as Sedimentation and Deposition as the dam's presence can alter the natural flow of water, leading to sedimentation and deposition of finer particles (silt and clay) further away from the dam. This can result in a decrease in sand content and an increase in silt content with distance from the dam.

Another reason is the Water Flow and Energy as The energy of water flowing from the dam decreases with distance, leading to a decrease in the transport capacity of coarser particles (sand). Finer particles (silt and clay) are deposited further away from the dam due to reduced water energy (Sao et al., 2023; Havlin et al., 2012)

Nutrient and Sediment Transport is the other factor as The dam can trap sediments and nutrients, leading to a decrease in nutrient availability downstream. However, the midshore area may receive a mix of nutrient-rich sediments from both the dam and surrounding landscape (He et al. 2023; Sani et al 2023). Soil formation processes, such as weathering and erosion, can vary with distance from the dam, influencing soil properties like texture and fertility (Brady et al. 2019). Changes in water table depth, groundwater flow, and surface water flow can influence soil properties, such as exchangeable acidity and cation exchange capacity, with distance from the dam (Hillel et al., 2020).

## 5. CONCLUSION

The findings suggest that distance from the dam influences soil properties, particularly soil texture, exchangeable acidity, and cation exchange capacity. These changes may impact soil fertility and plant growth in the area. Distance from the dam significantly influences soil texture, nutrient availability, and chemical properties. Midshore zones exhibit the most favorable conditions for agriculture, with higher nutrient levels and cation exchange capacity. These findings underscore the importance of spatial soil assessment in dam-affected regions for informed land use planning.

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