

ORIGINAL RESEARCH ARTICLE

Impact Of Floods on Soil Properties and Nutrient Levels in Ringim and Auyo, Jigawa State, Nigeria

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ABSTRACT

This study analysed the impact of floods on soil physical and chemical properties in Ringim and Auyo Local Government Areas (LGAs) of Jigawa State, Nigeria. Composite soil samples (n = 8 sites, each from 8–15 subsamples at 0–30 cm depth) were collected in August 2022 (pre-flood) and November 2022 (post-flood). Laboratory analyses followed standard protocols (Walkley–Black for organic carbon, Kjeldahl for total nitrogen, Bray-I for phosphorus, flame photometry for potassium, hydrometer method for texture). Results showed that soil pH increased by 0.72 units (95% CI: 0.31–1.12; p = 0.003), while organic carbon declined by 38% (p = 0.075). Nitrogen decreased significantly (–0.10%; p = 0.041), phosphorus declined moderately (–1.13 mg/kg; p = 0.304), and potassium increased slightly but not significantly. Principal Component Analysis (PCA) confirmed strong co-variation among organic carbon and nitrogen losses. These changes indicate reduced soil fertility and may threaten agricultural productivity in flood-prone communities of Jigawa State.

INTRODUCTION

Flooding is among the most catastrophic natural hazards, with major impacts on agriculture, soil fertility, and ecosystem resilience (WHO, 2024). Soils, as the foundation of crop production, are highly sensitive to physical and chemical alterations caused by floods, including erosion, nutrient loss, and changes in pH and organic matter. While flood-borne sediments may occasionally replenish soils with nutrients, prolonged waterlogging often depletes them of nitrogen, organic carbon, and structural stability (Echendu, 2020; Umar & Grey, 2023).

As a consequence of floods, the entry of nutrient-rich sediments, which are plentiful in vital components such as nitrogen, phosphorus, and organic matter, may result in an increase in soil fertility. This may be the case since these sediments contain a lot of these elements. These types of deposits, which are typically found in floodplains, enhance soil productivity and support plant growth. They are typically found in floodplains. Particularly in dry and semi-arid locations, floods have the potential to remove excess salts from the soil, which can enhance the soil's structure and reduce its salinity (Idris, 2020; Alani et al., 2023). Floods also have the ability to remove an excessive amount of salts from the soil.

While flooding is a major driver of the observed soil changes, post-flood management such as tillage, fertiliser

application, residue burning, and cropping cycles may also alter soil physical and chemical properties (Alam, 2014; Gupta et al., 2024; Sánchez-Rodríguez et al., 2017).

Our observations should therefore be interpreted as associations rather than definitive causation, unless supported by hydrological or sediment chemistry data (Bonotto, 2022; Schwab et al., 2022). Increases in soil pH may temporarily improve nutrient availability, but reductions in organic matter and nitrogen threaten long-term soil fertility and resilience (Saco et al., 2021).

These findings underscore the vulnerability of Jigawa's agricultural soils to recurrent floods and highlight the importance of adopting conservation practices to reduce erosion and sustain productivity (Srivastava et al., 2023; Rogger et al., 2017).

There is a substantial level of concern over the impact that floods have on the soil's characteristics and the quantity of nutrients it contains in Jigawa State, Nigeria. This is because agriculture is the major source of income for a huge number of communities in this state. According to Gambo et al. (2024), the Ringim and Auyo Local Government Areas (LGAs), which are considered significant agricultural zones within the state, are at risk of frequent flooding. The population faces substantial hurdles in preserving their livelihoods and ensuring access

ARTICLE HISTORY

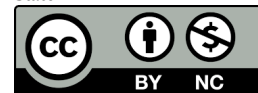
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KEYWORDS

Soil fertility, Flooding, Nutrient dynamics, Agricultural resilience, Jigawa State



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to food due to the floods, which have a detrimental impact on the fertility of the land and affect agricultural yields. Understanding how floods influence nutrient levels and soil quality in these areas is essential for creating sustainable land management practices and mitigating the adverse effects of flooding on agriculture. This information is necessary in order to develop approaches that can be used to manage land in a sustainable manner.

Despite this, no published studies have provided paired pre- and post-flood soil chemistry data for these areas. This study fills that gap by systematically comparing soil properties before and after flood events, thereby contributing to evidence-based soil and water management strategies in flood-prone environments.

MATERIALS AND METHODS

Study Area

Selected communities in Jigawa State, Nigeria's Ringim and Auyo Local Government Areas (LGAs), which are situated in the Sudano-Sahelian ecological zone of Northern Nigeria, were the sites of this study. With a population of 192,024 according to the 2006 census, Ringim occupies an area of 1,057 km² and is located at coordinates 12° 9' 4" N and 9° 9' 45" E. It shares borders with Gabasawa LGA of Kano State to the west, Babura LGA to the north, and Taura LGA to the east. Auyo LGA, which has 132,001 residents according to the 2006 census, is located along the Hadejia River in the

northeastern region of Jigawa State. It occupies 536 km². It is bordered to the north by Hadejia, Kiri Kasama, and Malam Madori LGAs, east by Bauchi State, west by Kaugama and Miga LGAs, and south by Kafin Hausa LGA. Less than 10% of people in both LGAs reside in cities, making them primarily rural areas. About 85% of the workforce is employed in agriculture, which is the primary economic activity. Rice, millet, cowpea, peanut, and sesame are among the main crops farmed in the area. Limestone and kaolin also support the region's economy. The Sudan Savannah's climate is typical, with a dry season from October to April and a wet season from May to September. Temperatures range from highs of 40°C during the hot season to lows of 11°C during the Harmattan period. Due to the geography of these local government areas (LGAs) and their proximity to the Hadejia River, they are suitable for both rainfed and irrigated agricultural approaches. Conversely, the region is prone to flooding, particularly in recent years, as evidenced by the devastating flood disasters that occurred in 2021 and 2022. This is especially true in recent years. The last several years have shown this to be particularly true. The floods have resulted in significant soil erosion, loss of nitrogen, and degradation, posing substantial challenges to the long-term viability of the food supply and the efficiency of agricultural production. These issues are a direct result of the floods. It is essential to be aware of the implications of catastrophic floods in order to ensure that agricultural livelihoods are protected and that Jigawa State can sustain its food security throughout the state.

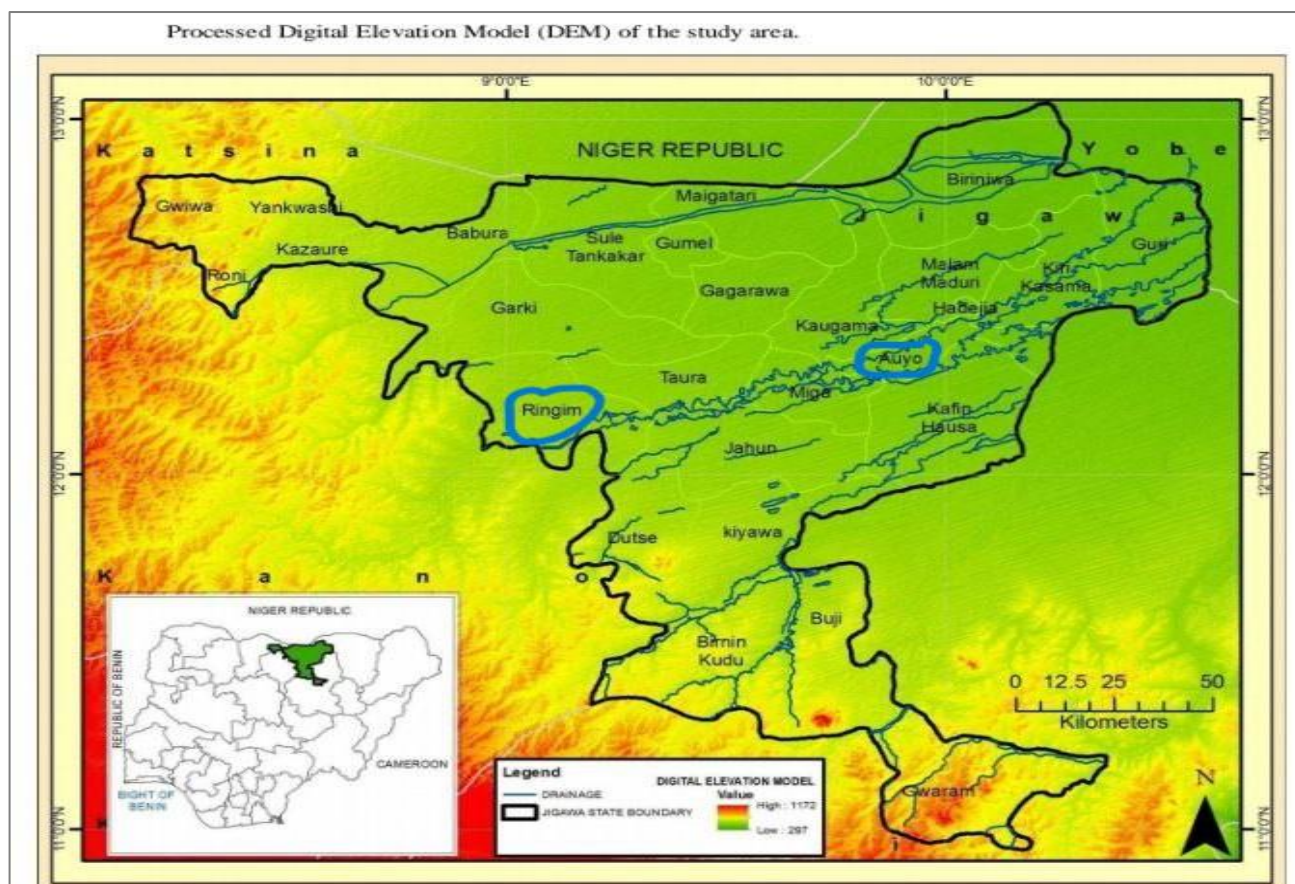


Figure 1: Map of Jigawa State Showing the Study Area

Soil Sampling

Soil samples were collected from eight farms: Dingare, Zangon Karara, Sintilmawa, Gujaba, Tsagan (Ringim), Furwa, Makerayi, Kataye, Zabarau (Auyo). At each farm, 8–15 subsamples were taken with a soil auger at a depth of 0–30 cm, spaced ~100 m apart, and composited. Pre-flood samples were collected in August 2023, and post-flood samples were collected in November 2023. All sites were GPS-referenced and revisited for paired comparisons. Samples were air-dried, sieved (<2 mm), and stored in labelled polyethylene bags.

Laboratory Analysis

Soil samples were analysed at the Soil Science and Microbiology Laboratories, Bayero University, Kano, following internationally recognised protocols. Samples were air-dried at room temperature, gently crushed, and passed through a 2-mm sieve. The prepared soils were stored in clean, labelled polyethylene bags under ambient laboratory conditions prior to analysis.

The following parameters were assessed:

- i. **pH:** Measured in a 1:2.5 soil-to-water suspension using a calibrated digital pH meter (Hanna HI2211). Precision: ±0.01 (ISO 10390, 2005).

- ii. **Organic Carbon (OC):** Determined by the Walkley–Black wet oxidation method (Walkley & Black, 1934). Titration performed against a standard ferrous ammonium sulfate solution. LOD: 0.01%.
- iii. **Total Nitrogen (N):** Measured by the Kjeldahl digestion–distillation method (AOAC, 1990). Digestion with concentrated H₂SO₄ and a catalyst, followed by steam distillation. LOD: 0.01%.
- iv. **Available Phosphorus (P):** Extracted using the Bray-I method (Bray & Kurtz, 1945). Absorbance of the blue colour measured with UV–Vis spectrophotometer (Shimadzu UV-1800). Detection limit: 0.1 mg/kg.
- v. **Exchangeable Potassium (K):** Extracted with neutral ammonium acetate and determined using a flame photometer (Jenway PFP7). Detection limit: 0.01 cmolc/kg.
- vi. **Particle Size Distribution:** Determined by the hydrometer method (Gee & Bauder, 1986).

Each analysis was conducted in duplicate. Quality assurance and control included blanks, duplicates, and certified reference soils. Instruments were calibrated daily, and replicate analyses were accepted within a relative deviation of ±5 %.

Table 1. Analytical Methods Used for Soil Analyses

Parameter	Method	Reference/Standard	Instrument/Model	Detection Limit	Units
pH (H ₂ O)	Soil:water 1:2.5	ISO 10390	Digital pH meter	±0.01	–
Organic Carbon	Walkley–Black	Walkley & Black	Titration	0.01%	%
Nitrogen	Kjeldahl digestion	AOAC 984.13	Distillation set	0.01%	%
Phosphorus	Bray-I extraction	Bray & Kurtz	Spectrophotometer	0.1 mg/kg	mg/kg
Potassium	Flame photometry	AOAC 975.03	Jenway PFP7	0.01 cmolc/kg	cmolc/kg
Particle size	Hydrometer method	Gee & Bauder	Hydrometer	±1%	% sand/silt/clay

Statistical Analysis

Data were analysed using SPSS v25. Paired t-tests compared pre- and post-flood soils. Shapiro–Wilk tests were used to assess normality; Wilcoxon signed-rank tests were employed when the assumptions were not met. Effect sizes (Cohen’s d) and 95% CIs were calculated. Holm–Bonferroni corrections controlled for multiple testing. Principal Component Analysis (PCA) summarises multivariate changes.

Specifically, statistical graphs (scatterplots, boxplots) and the PCA biplot were produced using R (v4.2.2) with ggplot2, cowplot, and factoextra packages; descriptive statistics were generated in SPSS v25; and formatting/polishing was done in Microsoft Excel 2019.

RESULTS AND DISCUSSION

Soil Properties Before and After Flooding

Flooding significantly altered soil properties (Table 2). Soil pH increased (mean difference = +0.72; p = 0.003).

Organic carbon decreased (-38%; $p = 0.075$), nitrogen declined significantly (-0.10%; $p = 0.041$), while phosphorus and potassium showed moderate, non-significant changes. Texture fractions (sand, silt, clay) remained stable.

Table 2. Summary of Soil Properties Before and After Flooding (n=8 sites)

Variable	Pre-flood (Mean ± SD)	Post-flood (Mean ± SD)	Difference (Post-Pre) Wilcoxon	95% CI	Test (t/)	p (adj)
pH	5.56 ± 0.73	6.28 ± 0.71	+0.72	0.31–1.12	t(7)=4.32	0.003*
OC (%)	0.56 ± 0.32	0.35 ± 0.13	-0.21	-0.43–0.01	t(7)=2.09	0.075
P (mg/kg)	7.17 ± 4.60	6.04 ± 2.94	-1.13	-3.67–1.41	t(7)=1.11	0.304
N (%)	0.22 ± 0.09	0.12 ± 0.04	-0.10	-0.19–0.01	t(7)=2.45	0.041*
K (cmolc/kg)	0.44 ± 0.23	0.61 ± 0.48	+0.17	-0.13–0.47	t(7)=1.02	0.340
Sand (%)	67.8 ± 15.0	68.4 ± 10.8	+0.6	-4.5–5.8	t(7)=0.23	0.823
Silt (%)	18.1 ± 11.6	18.1 ± 10.3	0.0	-5.2–5.2	t(7)=0.00	1.000
Clay (%)	14.1 ± 7.3	13.5 ± 3.0	-0.6	-5.1–3.8	t(7)=0.28	0.791

*Significant at $p < 0.05$ (Holm-adjusted); OC: Organic Carbon; P: Phosphorus; N: Nitrogen; K: Potassium

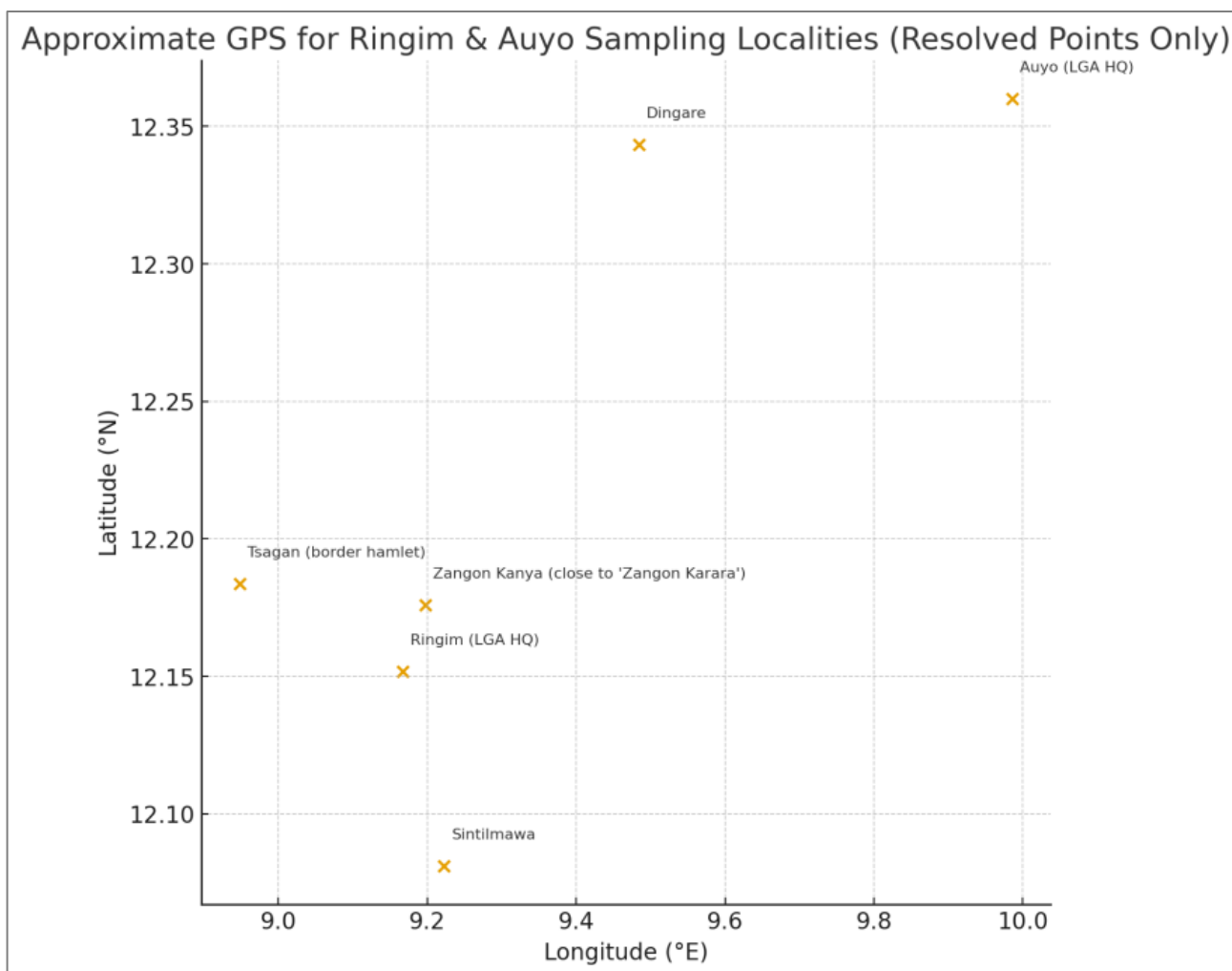


Figure 2. Map of sampling sites in Ringim and Auyo LGAs with flood extent (2022).

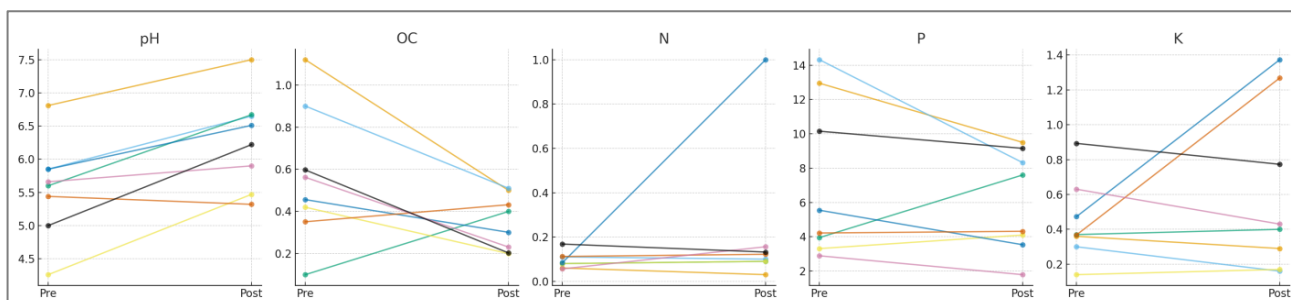


Figure 3. Paired scatterplots of soil pH, OC, N, P, K pre- vs post-flood (n=8 sites).

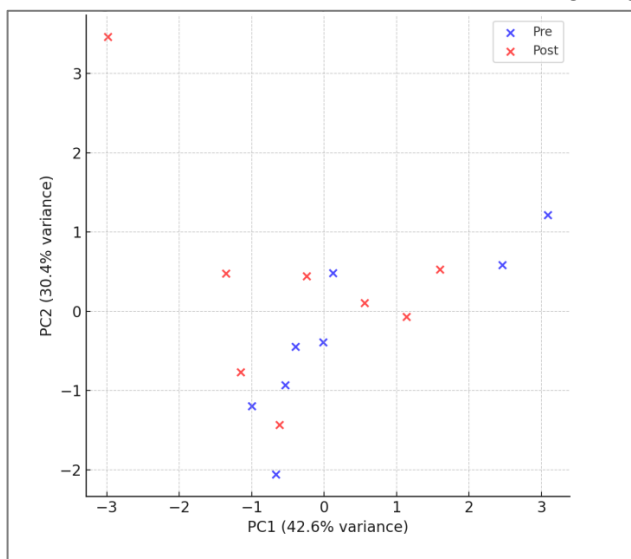


Figure 4. PCA biplot of soil variables showing clustering of pre- and post-flood samples.

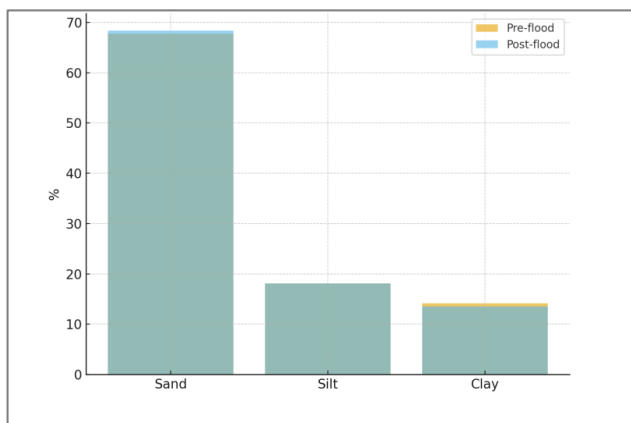


Figure 5. Average particle size distribution (sand, silt, clay) before and after flood

Flooding significantly impacted soil chemistry, particularly in terms of pH and nitrogen levels. The mean pH increased from 5.56 to 6.28, indicating the deposition of alkaline sediments and/or the leaching of acidic components (Idris, 2020). Such changes are consistent with previous studies of floodplains (Bedadi et al., 2023).

Organic carbon declined by ~38% across sites, although this difference was not statistically significant at $p < 0.05$. This reduction is consistent with erosion of topsoil, microbial mineralisation under waterlogged conditions, and physical removal of residues (Anabaraonye et al., 2021; Musa et al., 2024). Nitrogen declined significantly ($p = 0.041$), reflecting its susceptibility to leaching, denitrification, and volatilisation during inundation (Ubechu et al., 2022). Phosphorus declined moderately, likely due to surface runoff and adsorption to sediments (Odoh & Nwokeabia, 2024). Potassium remained relatively stable, in line with its stronger binding to soil exchange sites (Ibrahim & Tasi’u, 2020). Texture (sand, silt, clay) did not change significantly, suggesting limited sediment redistribution. Porosity declined slightly,

indicating possible compaction and fine sediment deposition (Maleki & Eslamian, 2024).

Comparable paired pre- and post-flood studies report both nutrient depletion and enrichment, depending on the sediment type, flood duration, and land use. For instance, Hafeez et al. (2019) observed variable nutrient changes following flooding in Pakistan, while Bedadi et al. (2023) and Ubechu et al. (2022) documented declines in organic matter and nitrogen in Ethiopian and Nigerian floodplains. Such differences can be attributed to variations in sediment chemistry, hydrological residence time, and post-flood land management practices. These factors are consistent with our observations in Ringim and Auyo, where alkaline sediment inputs and post-flood tillage likely contributed to the rise in pH and decline in soil organic matter.

However, while floods are the most obvious driver of these changes, post-flood tillage, fertiliser application, residue burning, and cropping cycles may also influence soil properties. The observed changes should therefore be interpreted as associations rather than definitive causation, unless supported by hydrological or sediment chemistry data. Increased soil pH may temporarily enhance nutrient availability, but declines in organic matter and nitrogen threaten long-term fertility and resilience. These findings highlight the vulnerability of Jigawa’s agricultural soils to recurring floods and underscore the importance of implementing conservation practices.

RECOMMENDATIONS

Adopting integrated soil management strategies is essential. Conservation tillage and cover crops can reduce erosion and add ~40–60 kg N/ha annually. Application of compost at 10 t/ha can restore ~0.3% of the organic carbon and 20–30 kg of nitrogen per hectare. Structural interventions (levees, drainage canals, check dams) can reduce waterlogging and erosion. Extension services should prioritise feasible and cost-effective practices, such as organic amendments and conservation tillage. Long-term monitoring, including sediment analysis and repeated sampling, is needed to track recovery trajectories.

CONCLUSION

This study provides the first paired pre- and post-flood soil chemistry assessment in Ringim and Auyo LGAs of Jigawa State. Flooding was associated with significant increases in pH and declines in organic carbon and nitrogen, highlighting the vulnerability of agricultural soils to recurrent flood events. These findings provide evidence for targeted soil conservation and flood management interventions to safeguard agricultural productivity.

Compliance Statements

- **Ethical Approval:** Not applicable (no human or animal subjects).
- **Permits:** Soil sampling was conducted with consent of local landowners.

- **Data Availability:** Raw data and GPS coordinates are available on request from the corresponding author.
- **Conflict of Interest:** None declared.
- **Funding:** No external funding was received.

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