



Geospatial Assessment of Soil Physicochemical Properties in Kaita Local Government Area of Katsina State-Northern Nigeria



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ABSTRACT

This study investigated the spatial distribution and variations of soil physicochemical properties in Kaita Local Government Area, Katsina State-Northern Nigeria. Soil samples were collected, air-dried, sieved to two (2) mm, and analyzed for pH, particle size distribution, total nitrogen, available phosphorus, organic carbon, and exchangeable potassium using standard laboratory techniques. Soil pH was measured potentiometrically in soil suspensions, particle size distribution was determined by hydrometer analysis following dispersion, and nutrient contents were quantified via Macro-Kjeldahl digestion, spectrophotometry, and flame photometry. Descriptive statistical parameters and spatial interpolation using Inverse Distance Weighted (IDW) techniques with ArcGIS 10.8 were used enabled the visualization of soil physicochemical property distributions, with convergence indicated by a texture correlation coefficient (R^2) of 0.53. The results revealed that a predominance of sandy soils (80–88%), moderate clay (6–12%) and silt contents (2–9%), and mildly acidic to neutral pH (6.4–7.3) respectively. While organic carbon levels were low (0.02–0.24%), phosphorus moderately distributed (14–35 ppm), and nitrogen markedly deficient in 97.5% of samples in the study area. The heterogeneity of physiochemical properties of the soil suggests that there is need for spatially targeted soil management practices. Recommendations include integrated soil management through organic amendments, fertilization, acidity correction, and conservation practices is significant for improving soil fertility and productivity; regular monitoring and geospatial tools are important for managing variability and ensuring sustainable agriculture in the study area.

Keywords:

Soil properties;
Spatial Variability;
Soil fertility;
Nutrient deficiency;
Geospatial analysis

INTRODUCTION

Soil is a fundamental resource that supports human sustenance, and its quality is largely influenced by management practices. Sustainable agricultural production requires an understanding of the spatial variability of soil physicochemical properties, particularly in arid and semi-arid regions where soils are inherently constrained (Denton *et al.*, 2017; Biswas & Zhang, 2018; Almasi *et al.*, 2023). Variations in soil characteristics significantly affect crop productivity, land suitability, and environmental sustainability. Therefore, assessing soil variability is significant for soil surveys, land evaluation, and effective environmental management practices (Denton *et al.*, 2017; Forkuor *et al.*, 2017).

Traditional approaches in analyzing soil physicochemical properties rely on soley descriptive and inferential statistics to characterize distributions and relationships among different variables.

While informative, these methods often lack spatial context, limiting their ability to capture heterogeneity across landscapes (Denton *et al.*, 2017). In contrast, geospatial approaches is used for integrating field observations with GIS, remote sensing, and geostatistical tools like ordinary kriging and inverse distance weighting (IDW) which provide more accurate mapping of soil variability (Forkuor *et al.*, 2017; Almasi *et al.*, 2023). Spatial interpolation techniques estimate soil physicochemical properties at unsampled locations based on known data points, with closer observations exerting greater influence on predicted values (Almasi *et al.*, 2023). These methods, combined with continuous monitoring, are very vital for detecting changes, identifying degradation hotspots, and supporting sustainable land management. Advances in remote sensing and geographical information systems have further improved efficiency, accuracy, and speed in soil spatial analysis (Forkuor *et al.*, 2017; Costa *et al.*, 2018).

Soil fertility, which determines a soil’s potential to support plant growth, depends on physical, chemical, and biological factors, including organic matter, nutrient availability, soil reaction, and soil structure (Biswas & Zhang, 2018). Limitations in any of these factors can reduce productivity, emphasizing the importance of evaluating and mapping spatial variability for sustainable agriculture development (Denton *et al.*, 2017; Almasi *et al.*, 2023).

Digital Soil Mapping (DSM) offers a robust approach for generating spatially explicit soil information by integrating field data with environmental covariates such as terrain attributes and satellite imagery (Costa *et al.*, 2018; Almasi *et al.*, 2023). Digital Soil Mapping (DSM) produces high-resolution raster maps, enabling visualization of soil distribution patterns and prediction uncertainties. Advanced statistical and machine learning algorithms within DSM further enhance prediction accuracy across diverse soil-landscape conditions (Costa *et al.*, 2018). Furthermore, irrigation is a major driver influencing soil physicochemical properties, particularly in arid and semi-arid environments. While it aid supports agricultural productivity, improper irrigation practices can lead to degradation, including salinization and nutrient imbalance (Almasi *et al.*, 2023). Considerable existing research has largely focused on wastewater irrigation, with limited attention to natural surface water sources such as rivers and reservoirs. This knowledge gap is notable in northern Nigeria study area inclusive where irrigation underscore local food production.

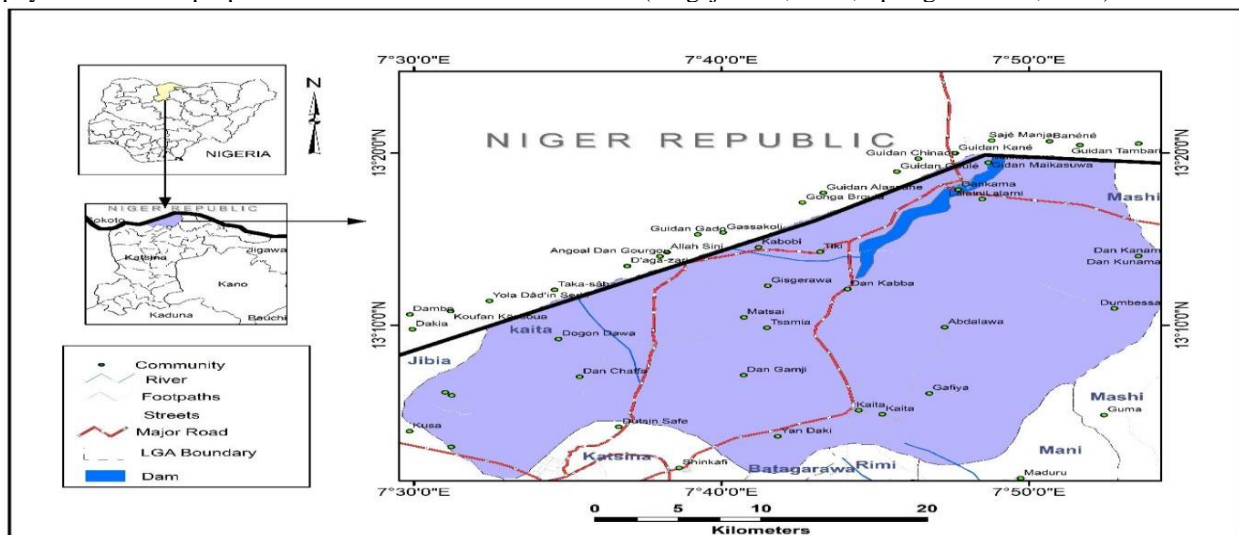
Kaita Local Government Area in Katsina State-Northern part of Nigeria represents such a region, where agriculture is vital to the economy but information on irrigation effects on soil is limited. This study, therefore, aims to assess and map the spatial variability of soil physicochemical properties in Kaita Local Government

Area of Katsina State-Northern Nigeria identify factors influencing variability, and provide data to support sustainable soil management. Specifically, the objectives are to: (i) collect and analyze soil samples across the study area; (ii) map spatial distribution of soil properties; and (iii) determine causes of spatial variability.

MATERIALS AND METHODS

Description of the Study Area

Kaita Local Government Area is located in northern part of Katsina State, Northern Nigeria, approximately between latitudes 12°54'N and 13°10'N and longitude 7°03'4"E, sharing borders with Niger Republic to the North and neighbouring LGAs as Mashi to the East, Katsina local government Area to the South and Jibia to the West respectively. Katsina LGA covers about 1,037 km² and had a population of 169,748 as of 2006 census (NPC, 2006). The terrain consists of gently undulating plains with elevations ranging from 473 to 534 meters above sea level, shallow valleys, and sandy soils typical of the Sahelian savannah, which are prone to degradation under poor management (Magaji, et al., 2025). The region experiences a hot, semi-arid climate (BSh), with a short wet season from May to September and a long dry season dominated by harmattan winds. Annual rainfall is low and highly seasonal, averaging around 516 mm of rainfall, while temperatures range from 35°C to 42°C (NomadSeason, 2025; Springer Nature, 2026). The Gada River and other seasonal streams form the main drainage network, flowing northwest into Niger Republic. Agricultural activities are primarily rain-fed, with some supplemental irrigation, and the combination of semi-arid climate, sandy soils, and nutrient limitations presents challenges for sustainable soil and crop management (Magaji et al., 2025; Springer Nature, 2026).



Source: Google-Earth Map

Figure 1: Map of the Study Area.

Research Design

This study employed a field-based soil sampling and laboratory analysis approach to assess key physical and chemical properties of soils in the study area. The main method involved collecting soil samples from selected locations and analyzing them in the laboratory to determine parameters such as soil texture, organic carbon, pH, and major nutrients. The procedure combined systematic field sampling with standardized laboratory protocols to ensure accurate and representative characterization of soil variability across the study area.

Soil sampling and laboratory testing

Soil samples were collected using a purposive random sampling approach during the dry season, ensuring that recently fertilized plots were avoided and samples were taken between crop rows to represent the area accurately (Zonneveld, 1989; Poeplau et al., 2018; Mascher et al., 2019). Care was taken to minimize spatial redundancy by maintaining a minimum distance between sampling points. Locations were recorded using a Garmin GPS receiver, and samples were collected using a soil auger, hand trowel, and stored in polythene bags for laboratory analysis.

In the laboratory, samples were oven-dried at 45°C for 24 hours, ground, and passed through a 2-mm sieve. Particle size distribution (sand, silt, and clay) was determined using the pipette method (Gee & Bauder, 1986), and soil texture classes were classified based on the USDA soil texture triangle using the soiltexture R package (Moeys, 2016). Soil organic carbon (SOC) was measured using the wet oxidation method (Walkley & Black, 1934).

Laboratory Analysis Procedures

The soil sample collected using Augar were stored in bag and air-dried and passed through a 2mm sieve for the laboratory analysis. The sieved samples were used to make a comparative analysis of the physical and chemical properties of soil among the samples. Laboratory analyses were performed to quantify key soil physicochemical properties, including soil pH, organic carbon (OC), total nitrogen (TN), available phosphorus (AP), exchangeable potassium (K), and particle size distribution (PSD). Soil pH was measured using standard potentiometric methods, while OC was determined via the wet oxidation method (Walkley & Black, 1934). Total nitrogen, available phosphorus, and exchangeable potassium were analyzed following established laboratory protocols, and particle size distribution was determined using the pipette method (Gee & Bauder, 1986). All procedures adhered to internationally recognized methods to ensure accuracy and reproducibility (FAO, 2019; Moeys, 2016).

1. Determination of Soil (pH)

In the laboratory determination of soil pH, the apparatus, reagents as well as the procedures used are; 4 beakers of

50 moles labelled A, B, C & D as containers for soil samples, pH meter, weighing scale and plain sheet and time piece. Distilled water, calcium chloride and potassium chloride. Weight 20g of air dry soil in to the 50ml beaker, 20ml of distilled water was added and allows it to stand for 30mins. Solution of CaCl₂, KCl were added, stir for 2 minutes occasionally and electrodes of the pH meters were inserted into the partly settled suspension and measured with pH, but the suspension were not stirred during measurement.

2. Determination of Particle Size Distribution (PSD)

Plastic bottle of 1000cm³ labelled as A, B, C and D containers of soil sample, mechanical shaker, hydro meter, time piece, weighing scale and plain sheet. Distilled water, Calgon solution and 4 soil samples labelled A - D. 50gram of soil samples weighed and put into plastic bottles, 100ml of carbon solutions was added and shared with mechanical shaver for 15 minutes, water added to make 95 mole and hydrometer inserted after shaking, first reading was taken after shaking in 100 seconds (hydrometer reading) and allowed to stay for 2 hours undisturbed and second hydrometer reading was taken. This was repeated 12 times.

3. Determination of Total Nitrogen (TN)

Macro-Kjeldahl digestion – distilled apparatus, Macro-Kjeldahl flask 500ml and 750ml, burette, Bunsen burner, pipette (atomic), weighing scale and time piece. Distilled water, soil sample labelled A-D, mercury tablet, K₂SO₄ solution, H₂SO₄ solution and H₃BO₃ indicator solution. This procedure quantifies total nitrogen via digestion, distillation, and titration. It converts organic N to NH₄⁺ using H₂SO₄ catalysis. Weigh 10 g soil (sieved <0.5 mm) into 500 ml macro-Kjeldahl flasks (A-D). Add 20 ml distilled water, swirl, and stand 30 min for equilibration. Add 1 g K₂SO₄-HgO (catalyst prevents N loss as NH₃) and 10 g K₂SO₄ (raises boiling point). Pipette 30 ml conc. H₂SO₄ (safety: use fume hood, anti-bump granules optional). Digest at low heat (~360°C) until clear (1-2 hr), ensuring reflux to neck. Cool, dilute with 100 ml water. Transfer to 750 ml flask, retaining sand (wash 4×50 ml water to avoid distillation bumping). Add 50 ml 4% H₃BO₃ + mixed indicator (bromocresol green/methyl red) to 500 ml Erlenmeyer under condenser (tip 4 cm above liquid). Add 150 ml 40% NaOH (10N), distill 150 ml at <30°C condenser temp. Regulate to prevent frothing/suck-back. Titrate distillate with 0.01N H₂SO₄ (25 ml burette, 0.1 ml grad.). At end point, the colour changes from green to pink (pH ~4.65).

4. Determination of Available Phosphorus (AP)

Centrifuge, mechanical shaker, electro photometer, burette, test tube, pipette, weighing scale and time piece. Ammonium fluoride (NH₄F) distilled water, ammonium molybdate solution (NH₄)₅ MO₇O₂₄.4H₂O, SnCl₂.H₂O

solution, H₂SO₄. 4gram of soil samples sieved to 2.0mm pass into 15ml centrifuge tube and 7ml of extracting solution added. The mixture was shake for 1min using mechanical shaker and centrifuge to suspension at 2.0rpm for 15minutes. Pipette was used to transfer 2ml of the clear supernatant into 20ml test tube. 5ml of distilled water and 2ml of ammonium molybdate solution added. The content mixed properly and 1ml of SnCl₂.2H₂O solution added. After 5mins percentage of transmittance measured on the spectrophotometer at 660nm wave length. Standard curved prepared within the range of ppm, and available phosphorus calculated.

5. Determination of Organic Carbon (OC)

A 500mls conical flask labelled A, B, and C as containers of soil sample, burette, test tube, time piece, weighing scale, ordinary plain sheet. Potassium dichromate solution (K₂Cr₂O₇), 1g of 4soil samples labelled A, B, and C, concentrated sulphuric acid (H₂SO₄), distilled water, diphenyl-amine indicator, concentrated orthophosphoric acid (H₃PO₄), ammonium ferrous sulphate solution. Weigh 1g of each soil sample in to 500mls conical flask, 5ml of potassium dichromate solution was added in to each flask, 10mls of concentrated H₂SO₄ was added to each conical flask, solution allow standing for 30 minutes to 1 hour, 100mls of water added, 3-4 drops of diphenyl-amine (indicator) added, 0.5ml of ammonium ferrous sulphate solution titrated with the solutions and turn to greenish end point, organic carbon (%) calculated by using formula.

(Black titration-sample titration) x 0.0013x1.33x 0.5 x 100/weight of sample

6. Determination of Exchangeable Base (K)

A Centrifuge, 100ml volumetric flask, mechanical shaker, atomic absorption spectrophotometer, flame photometer, time piece. A citric acid, glacial and NH₄OAC solution, ammonium acetate solution NH₄OAC solution, distilled water. 5g of sample of A-C 30ml of in NH₄OAC was added and shaker on a mechanical shaker for 2 hours, centrifuge (2.000rpm for 5---10 minutes), carefully decanted the clear supermatant in to 100ml volumetric flask, another 30ml of NH₄OAC solution was added and shacked for 30minutes, centrifuge and transfer the supermatant in to the some volumetric flask, stem c repeated and transfer the supermatant in to

the same volume of flask, make up to mix with the NH₄OAC solution, Na and K are determined by reading flame photometer.

Spatial analysis of Soil Properties

All vector dataset were converted to raster format based on their geospatial reference (coordinates), this is to allow for geospatial analysis. Henceforth, the dataset was subjected to spatial interpolation. Inverse distance weighted (IDW) technique was used to analyse the spatial distribution of the soil properties across the study area.

Statistical Analysis

Descriptive statistics was applied together with Coefficient of variation analysis, Skewness and Kurtosis for some inference. Coefficient of variation (CV) was calculated for each property under different land uses as in Eq. 3.

$$CV = \frac{100 \times S}{\bar{x}} \quad (1)$$

S: standard deviation

\bar{x} : sample mean

The variability was further classified after Wilding and Drees (1978) as follows:

- i. CV of < 15%: least variable
- ii. CV of 15–35%: Moderately variable
- iii. CV of > 35%: highly variable

RESULTS AND DISCUSSION

Table 1 revealed that descriptive statistical results of soil analysis. The analysis of the collected data for soil physical properties (Sand, Silt, Clay and pH) as well as Total Nitrogen, Organic Carbon, Phosphorous and Potassium was achieved using descriptive statistics. The spatial distribution of each soil parameter was evaluated using spatial analysis tools in ArcGIS 10.8 software and the thematic layers of each of the soil properties were generated using Inverse Distance Weighted (IDW) technique. Statistically, the result indicates that the observations of soil properties (soil pH, porosity, bulk density) showed normal distribution, whereas, the soil texture and SOM distribution indicate positively skewed distribution.

Table 1: Soil Physicochemical Properties in the study area

Soil Properties	Mean	St. Dev.	Min	Max	Skew	Kurt	CV	Remark
Clay	9.38	1.77	6	12	-0.76	1.47	18.87	MV
Silt	5.63	2.33	2	9	-0.03	-0.78	41.38	HV
Sand	85.00	3.07	80	88	-0.51	-1.17	3.61	LV
pH	6.89	0.29	6.4	7.3	-0.21	-0.17	4.21	LV
OC	0.10	0.08	0.02	0.24	0.41	-1.23	80	HV
TN	0.49	0.39	0.09	1.02	0.26	-1.87	79.59	HV

AP	21.88	6.75	14	35	1.12	1.00	30.85	MV
EK	0.25	0.04	0.16	0.3	-0.94	1.72	16	MV

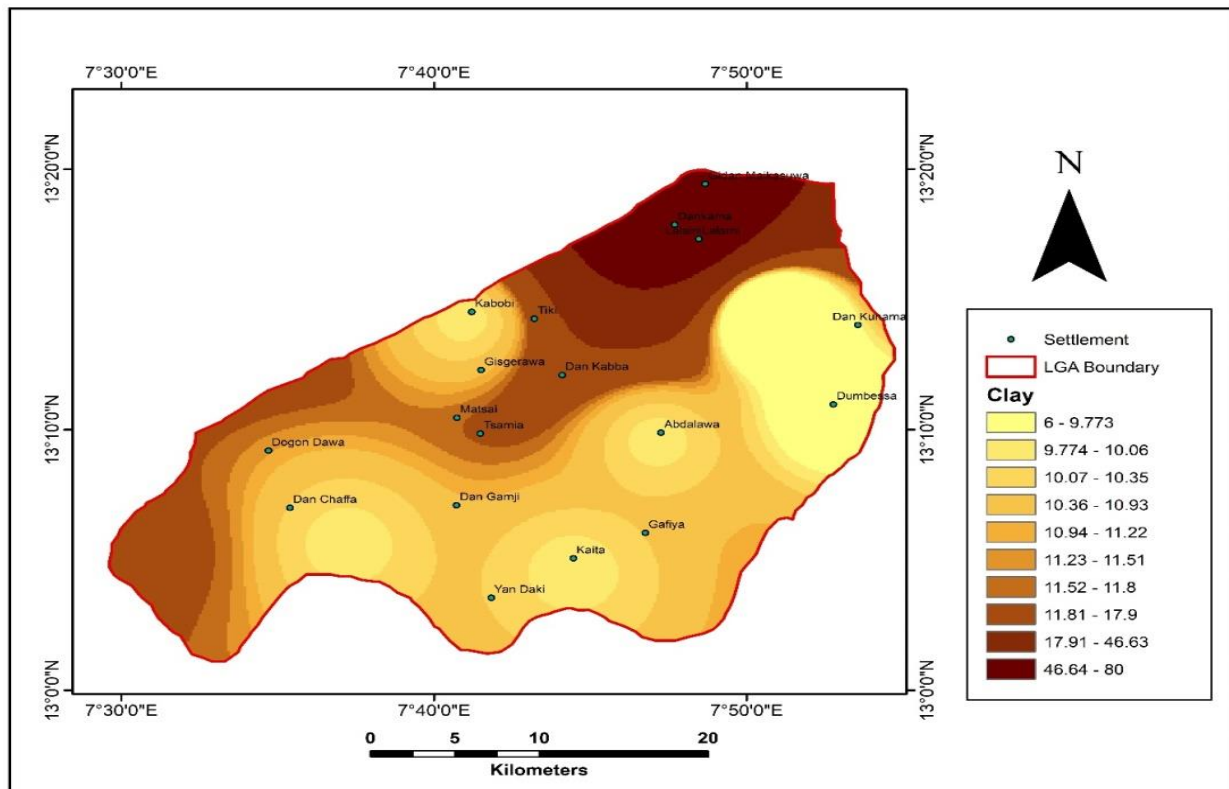
Source: Field Survey (2025)

NB: MV=Moderate variability; HV=High variability; LV=Low variability

The spatial interpolation of soil texture was conducted, with the correlation coefficient, $R^2 = 0.53$. Figures 1 to 3 reveals the spatial distribution of the soil texture classes with about 26%, 71% and 2% of the total area classified as high, moderate and low texture soil respectively. The soil in the study area generally, is more or less textually Sandy loam while less than 10% was Clay soil. This indicates a generally sandy soil across the study area. The implication of this was that soils needed fertility amendment of Nitrogen, Potassium and Phosphorous among others.

Clay content vary between 12.0% and 6.0% with a mean value of 9.38% (Table 1) across the whole sampling points with standard deviation of 1.77 % and skewness

and Kurtosis of -0.76% and 1.47% respectively, indicates a relatively peaked distribution, reflecting a controlled but non-uniform spatial pattern (Webster & Oliver, 2007). It could be observed that the difference between the mean values is significant. Further evidence of this could be observed from the interpolated surface of the study area (Figure 2). It could further be concluded that clay moderately variable across the study area. This implies that clay was not found all over the study area. This is true because clay was usually found in selected places. Therefore, the soil in the study was predominantly sandy, with low clay content and limited water- and nutrient-holding capacity. This agrees with previous studies which noted that sandy soils are typically low in fertility and highly susceptible to nutrient leaching (Lal, 2015; Brady & Weil, 2016).

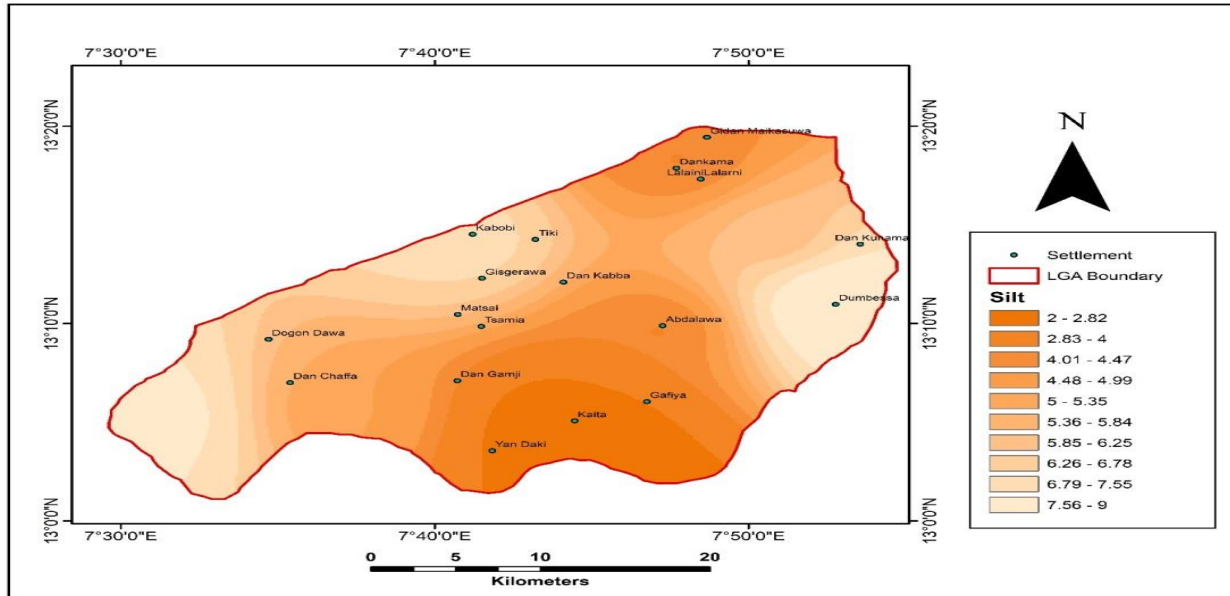


Source: Field Survey (2025)

Figure 2: Spatial Distribution of Clayey soil across the Study area

Silt values vary between 2.0% and 9.0% with mean value of 5.63% and a standard deviation of 2.33% and skewness of -0.03% and kurtosis of -0.78% (Table 1). This result indicates a significant value across the sampling points. It could be observed from the interpolated surface, the silt in soils of the area was predominant in the central, eastern

and south-western parts of the study area. This could probably associated with some drainages that pass through the area (Figure 3). Silt was also found to be highly variable implying that it was found in some restricted places usually along flooded areas.

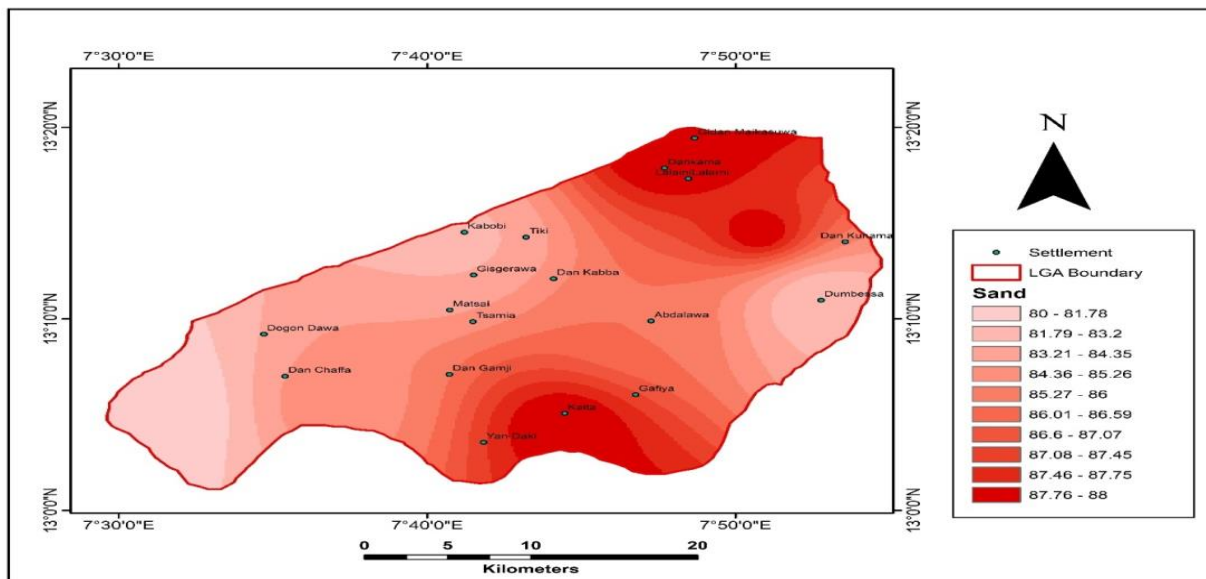


Source: Field Survey (2025)

Figure 3: Spatial Distribution of Silty soil across the study area

The sand values vary between 80.0% and 88.0% with mean value of 85.0% a standard deviation of 3.07%, skewness of -0.51% and a kurtosis of -1.17%. The deviation in the mean values of the 3.07% across all sampling points implied that there was no significant difference in sand content of the soil in the study area. This could further be buttressed by the interpolated map of the study area which depicted high sand content in the extreme northern parts of the study area. It was discovered that sand was least variable and implication was that greater parts of the study was generally sandy in

nature. Spatial interpolation revealed that higher silt concentrations are predominantly distributed in the central, eastern, and south-western parts of the study area. This pattern aligns with earlier findings that silt fractions often accumulate in relatively lower landscape positions due to erosion deposition processes and surface runoff redistribution (Lal, 2015). However, spatial concentration may influence soil moisture retention and nutrient dynamics in these zones, given that silt particles contribute moderately to water-holding capacity compared to sand-dominated areas (Brady & Weil, 2016)

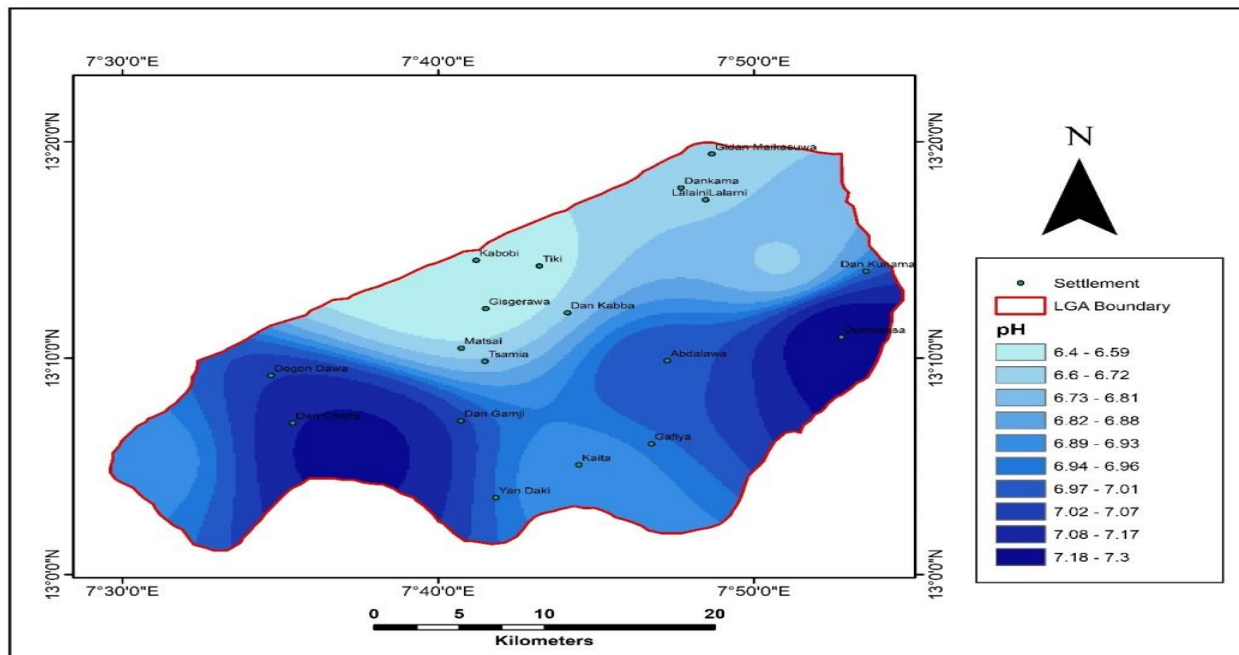


Source: Field Survey (2025)

Figure 4: Spatial Distribution of Sandy soil across the Study area

Soil pH measures the acidity and alkalinity in given soils and usually ranges from 0 to 14, with 7 being neutral, values below 7 are acidic and above 7 are alkaline. The optimal pH for most plant growth ranges between 5.5 and 7.0. The soil pH result ranges between 6.4 to 7.3 across the sampling points in the study area with 6.89 as mean and 0.29, -0.21 and -0.17 as standard deviation skewness and kurtosis respectively. This could be interpreted that there was no significant difference in the value of soil pH across the study area. Similar studies suggesting that no significant spatial difference in soil pH (Wilding, 1985; Webster & Oliver, 2007). The result obtained shows that a larger portion of the soil in the area has a pH value of less than 6, indicating that the soil is moderately acidic. However, 20% of the soil in the study area has pH value greater than 6, implies that the area is more or less neutral in nature. Spatially, the distribution of the soil pH in the study area shows that less alkaline soils are found more

in the central part of the study area (Figure 5). It was further discovered that pH displayed least variability across the study area. The implication of this was that the soil was general acidic in nature. In general, soil pH exhibited the least variability among the measured properties, consistent with findings that pH often shows low spatial variation compared to other soil chemical properties due to its buffering capacity (Lal, 2015). The implication is that the soils are generally slightly acidic to neutral, which is favorable for nutrient availability, although slight acidity in some zones may influence the availability of essential nutrients such as phosphorus and micronutrients (Brady & Weil, 2016). Similarly, previous findings showed that proximity to gas flaring sites reduces soil pH and organic carbon, indicating soil acidification and organic matter loss (Mohammed et al., 2025).

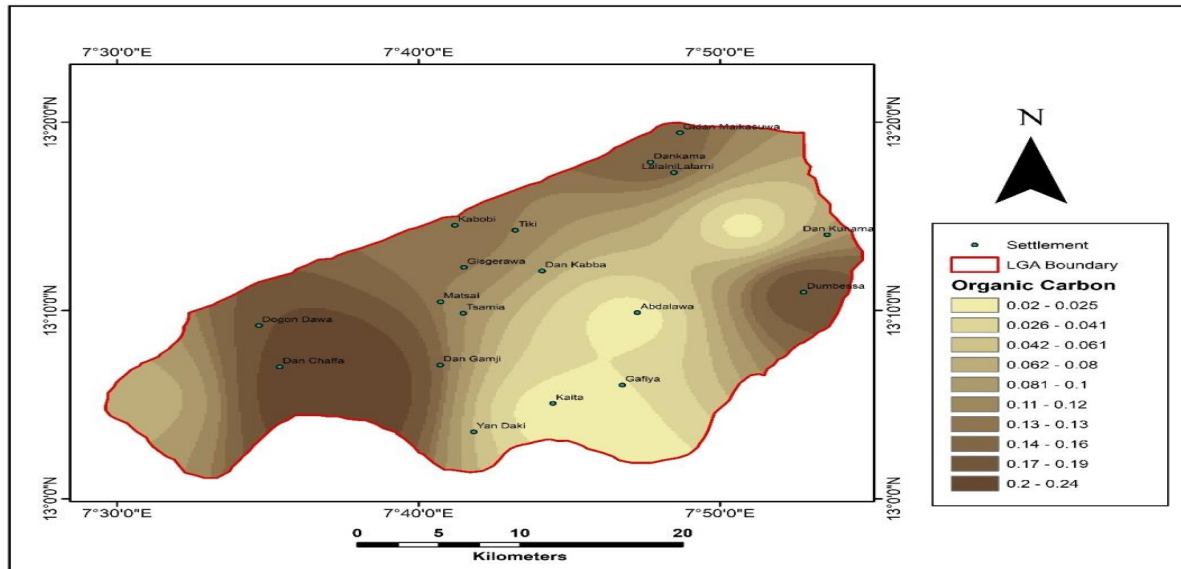


Source: Field Survey (2025)

Figure 5: Distribution of Soil pH across the study area

Organic Carbon values vary between 0.02% and 0.24 % with mean value of 0.10%, a standard deviation of 0.08%, Skewness of 0.41% and a Kurtosis of -1.23%. The deviation in the mean values of the 0.08 across the study area implies that there was no significant difference in Organic Carbon content of the soil in the study area. Figure 6 presents the interpolated map of the study area displaying low concentration around the central portions of the study area. Higher OC was found in the western and eastern parts of the study area. This results is consistent with earlier findings that organic carbon distribution is strongly influenced by land use, vegetation cover, and organic matter inputs, which tend to vary

spatially (Lal, 2015). OC content in soil was characterized by high variability across the study area. The implication of this was that OC was very low in soils across the study area. Therefore, the OC content is very low across the study area, reflecting poor organic matter status of the soils. This agrees with previous findings that sandy soils in semi-arid environments typically contain low organic carbon due to rapid decomposition and limited biomass input (Brady & Weil, 2016; Lal, 2015). The implication is that soil fertility may be constrained, necessitating the incorporation of organic amendments such as manure, compost, or crop residues to improve soil structure, nutrient availability, and overall productivity.

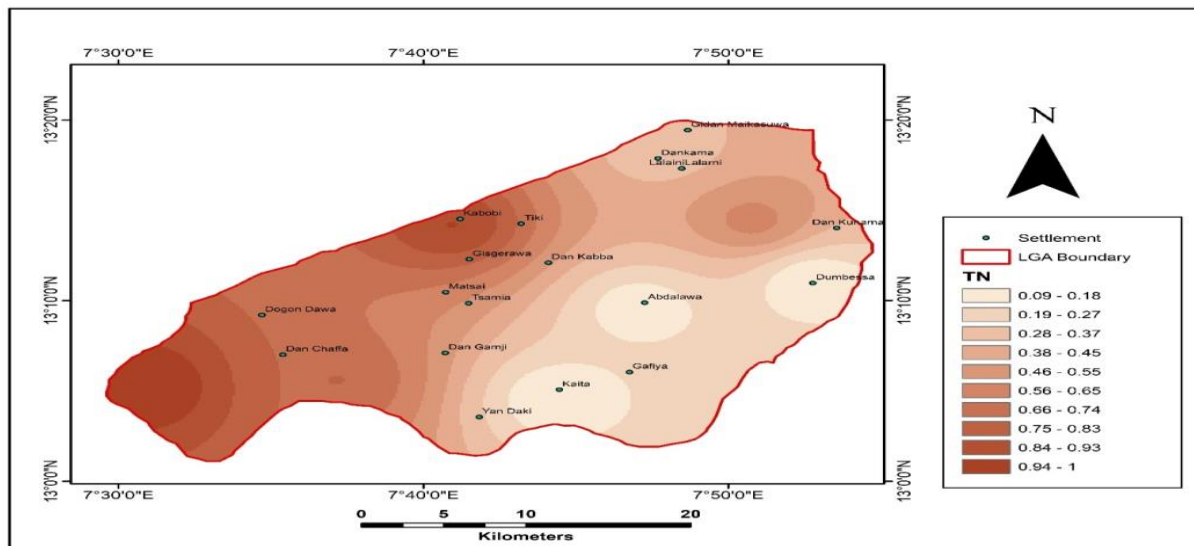


Source: Field Survey (2025)

Figure 6: Spatial Distribution of Organic Carbon in soil across the study area

Total Nitrogen values vary between 0.09% and 1.02% with mean value of 0.49%, a standard deviation of 0.39%, Skewness of 0.26% and a Kurtosis of -1.87%. The deviation in the mean values of the 0.39% across the study area implies that there was no significant difference in Total Nitrogen content of the soil in the study area. Figure 6 presents the interpolated map of the study area displaying low concentration around the central and eastern portions of the study area. Higher TN was found in the western and eastern parts of the study area (Figure 6). Spatially, Total Nitrogen was characterized by high variability implying that the property was very low in the

soil across the study area. Therefore, total N were characterized by high variability and generally low levels across the study area. This align with similar findings that sandy soils in semi-arid regions are typically deficient in nitrogen due to low organic matter content and high leaching losses (Brady & Weil, 2016; Lal, 2015). The implication is that nitrogen is a limiting nutrient in the study area, and its improvement through integrated soil fertility management practices such as the application of organic amendments and nitrogen-based fertilizers is significant for sustainable crop production.

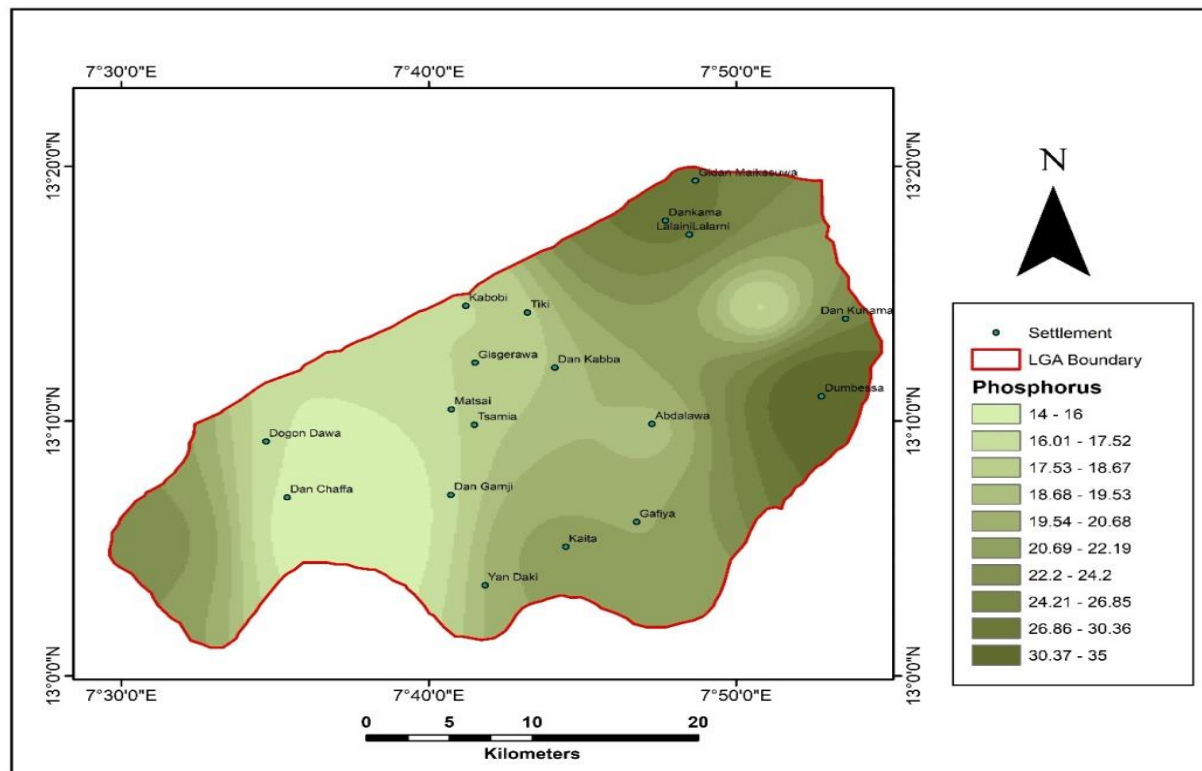


Source: Field Survey (2025)

Figure 7: Spatial Distribution of Total Nitrogen in soil across the study area

Phosphorous in soils in the study area (Table 1) range between 14ppm and 35ppm with a mean of 21.88ppm and a standard deviation of 6.75ppm with 1.12ppm, 1.00 and 30.85ppm as Skewness, Kurtosis and Coefficient of variability respectively. Available phosphorous content in soil was found to be moderate across the study area. It could be observed from figure 8 that AP was predominant in eastern parts of the study area. This spatial pattern may be influenced by variations in soil management practices, organic matter inputs, and parent material (Lal, 2015).

Generally, the moderate levels of available phosphorus are consistent with findings in semi-arid soils, where phosphorus availability is often constrained by fixation processes and soil pH conditions (Brady & Weil, 2016). The implication is that while phosphorus may not be critically deficient across the entire area, site-specific management practices, including targeted fertilizer application, may be required to optimize crop productivity.

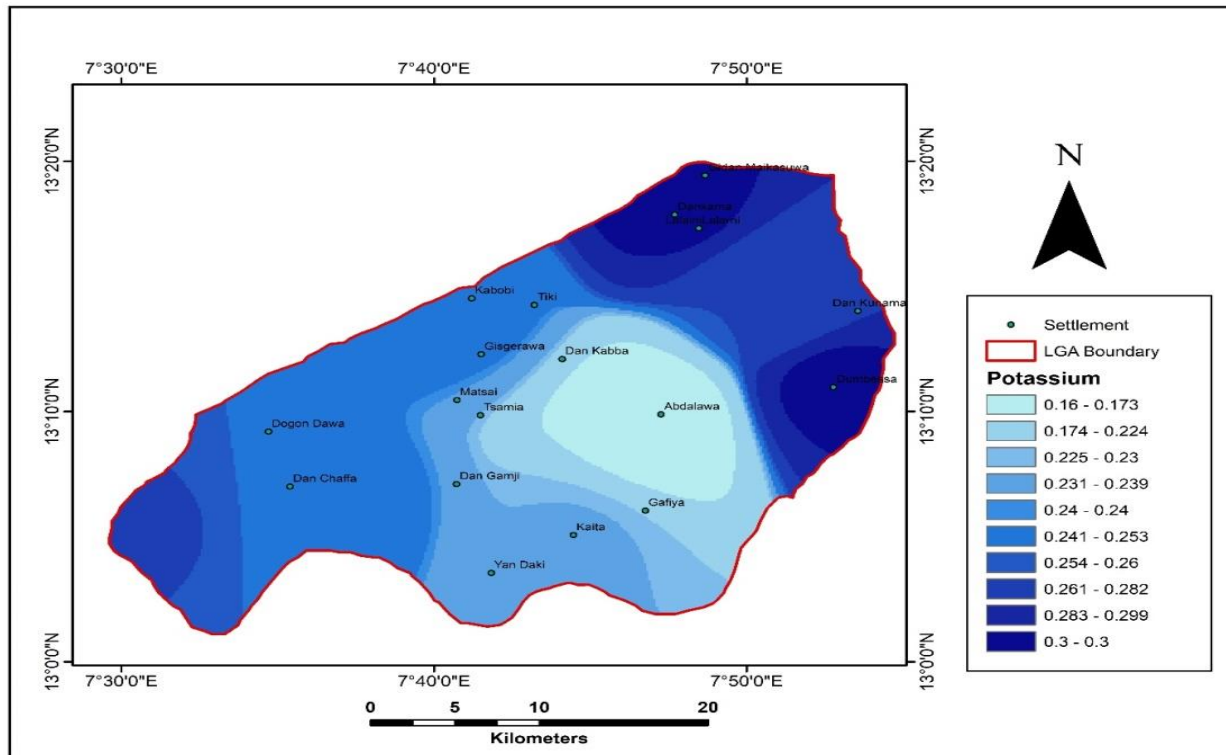


Source: Field Survey (2025)

Figure 8: Spatial Distribution of Phosphorous in soil across the study area

Potassium values vary between 0.16 mg/kg and 0.3 mg/kg with mean value of 0.25 mg/kg, a standard deviation of 0.04 mg/kg, skewness of -0.94 mg/kg and a kurtosis of -1.23 mg/kg. The deviation in the mean values of the 0.08 mg/kg across the study area implies that there was no significant difference in Potassium content of the soil in the study area. Figure 9 presents the interpolated map of the study area displaying moderate concentration across the study area. Higher Potassium content in soil was found in the south western and north eastern parts of the study area. This pattern suggests some localized enrichment, possibly influenced by soil parent material, fertilizer application, or organic matter distribution (Lal, 2015). Potassium content in soil was characterized by

moderate variability across the study area. The implication of this was that Exchangeable Potassium was uniformly distributed in soils across the study area. In general, exchangeable potassium is characterized by moderate variability and a fairly uniform distribution across the study area. This finding is consistent with previous studies indicating that potassium often exhibits less spatial variability compared to more dynamic nutrients like nitrogen (Brady & Weil, 2016). The implication is that potassium is not severely limiting in most parts of the study area; however, site-specific management may still be required to address localized variations and ensure optimal crop productivity.



Source: Field Survey (2025)

Figure 9: Spatial Distribution of Potassium in soil across the study area

CONCLUSION

This study mapped soil variability in Kaita LGA, Katsina State, using GIS-based IDW interpolation. Soils are predominantly sandy loam with low variability in texture and pH, but high variability in silt, organic carbon, and total nitrogen, while clay, available phosphorus, and exchangeable potassium showed moderate variability. Fertility hotspots were observed in western and eastern zones, whereas central areas exhibited nutrient deficits associated with drainage and irrigation limitations. In general, low organic matter and nutrient levels constrain sustainable crop production, highlighting ongoing soil degradation in northern Nigeria particularly in Northern part of Katsina State.

Recommendations

Based on the soil analysis, the study recommended that;

- i. Apply organic amendments (compost, manure) and site-specific NPK fertilizers to improve nutrient availability.
- ii. Use leguminous cover crops to enhance nitrogen levels and sustain soil fertility.
- iii. Correct soil acidity in localized areas using gypsum or elemental sulfur.
- iv. Implement conservation practices such as mulching, no-till, and contour farming to reduce erosion and improve moisture retention.

- v. Conduct regular soil monitoring with geospatial tools to track variability and guide precision agriculture.
- vi. Integrate remote sensing and machine learning in future research to support climate-resilient soil management.

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