NAU Journal of Civil Engineering (NAUJCVE) May/June 2026

Nnamdi Azikiwe University Journal of Civil Engineering (NAUJCVE)

Volume-5, Issue-3, pp-79-84
www.naujcve.com
Research Paper Open Access

Geo-Spatial Evaluation of Soil Nitrogen Holding Capacity On A Farmland In Bosso, Niger State, Nigeria

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ABSTRACT *: The main objective of this study was to map the spatial pattern of soil nitrogen retention capacity on the farm in Bosso, Niger State, Nigeria. It provides the sustainable land management practices in the face of global climatic change and increasing problems of food security. Total number of 100 composite samples were collected from the grid units of the farm and nitrogen retention capacity of these soil samples were measured in the laboratory. Spatial variation was predicted using Kriging geo-statistical approach with ArcGIS 10.5 version software as an interpolation tool in order to map the spatial distribution of soil nitrogen of the study area. The soil nitrogen varied between 0.00% to 0.07% in certain samples which lie between 0.07% to 0.13% and others between 0.13% to 0.32%. all in cmol/kg. It was shown that values in few isolated locations were high between 0.07% to 0.13%. Other locations were 1-4 cmol/kg, 14 cmol/kg, 15 cmol/kg, 17 cmol/kg, 20 cmol/kg and 21 cmol/kg, close to locations with the very low nitrogen. It is recommended to apply nitrogen fertilizers in the farm soil in order to increase the nitrogen availability for plants, so that crops can grow, develop and produce more yield. Also, the study recommended the cultivation of nitrogen fixing leguminous crops in the study area for optimum yield.*

KEYWORDS: *Evaluation, Farmland, Geo-Spatial, Nitrogen, Soil*

Date of Submission: 03-06-2026 Date of acceptance: 28-06-2026

I. INTRODUCTION

Understanding variations in soil nutrients across space has great implications for advancing sustainable agricultural practices, particularly in a region like Nigeria, where food security and ecological stability are important issues. Soil nitrogen is one of the most important macronutrients which has significant effects on crop yield and soil condition (Duraisamy et al., 2017). Factors such as soil type, land use, and climatic condition affect the distribution of soil nutrients within agricultural landscapes (Liu et al., 2021). As such, it is important to conduct an evaluation on the distribution of soil nitrogen in order to propose appropriate fertilization strategies. In particular, it is important for countries such as Nigeria to conduct this kind of analysis in order to maximize use of inputs and improve crop yield.

The utilization of geo-spatial technologies like GIS and geostatistical methods for evaluation and mapping of soil parameters have changed the ways these attributes are being studied. Using methods such as Kriging, researchers are able to produce a high level of detail for soil attribute maps and to discover hidden heterogeneity (Sowmiya et al., 2024; Sahabiev et al., 2018). In the case of Nigeria which has predominantly small-scale farmers, the ability to spatially predict soil properties can be utilized to implement site-specific land management approaches to increase both productivity and sustainability (Bedru & Motunrayo, 2022). The study seeks to make use of geo-spatial tools to analyse the spatial patterns

of soil nitrogen holding capacity within the farmlands at Bosso, Niger State.

The information derived from this study goes beyond a spatial representation; it offers information that could be used to tailor an appropriate amount of fertilizer to apply to specific regions, reduce environmental impact from overuse and misuse of inputs, and sustain the land (Elrys et al., 2023). A better understanding of spatial nitrogen can help the farmer or land manager make decisions such as what crop to grow and what crop rotation pattern to adopt, including the addition of legumes for natural accumulation of nitrogen to the soil (Chiriac et al., 2025), It is crucial to support agriculture sustainability in agro-ecological regions such as Nigeria.

The impacts of climate change also exacerbate soil variability and nutrient cycling problems. Variations in soil nitrogen content are likely to be made more severe by changes in climate patterns (Arif et al., 2025). Therefore, the analysis of the distribution of nitrogen is critical to developing a suitable system for the nation's farmlands that can respond to the challenges of global climate change and produce more food for the growing populace (Escandón-Panchana, 2025). By identifying areas with low nitrogen retention capacity, the intervention can be directed towards such areas thereby ensuring crop performance, and sustainability of resources (De Caires et al., 2025).

II. MATERIALS AND METHODS

Niger Resources Farm Limited (NRFL) is the owner of the farm which is located at km 32, Sabon Daga, off the Minna-Bida Road, Bosso local government area, Niger state Nigeria (Fig. 1). The farm is located at the longitudinal range of 6019’30” to 6022’24” East and latitude 9023’22” to 9027’14” respectively. It is positioned East of Federal University of Technology, north of Maizube Farm and southwest of Katcha local government area.

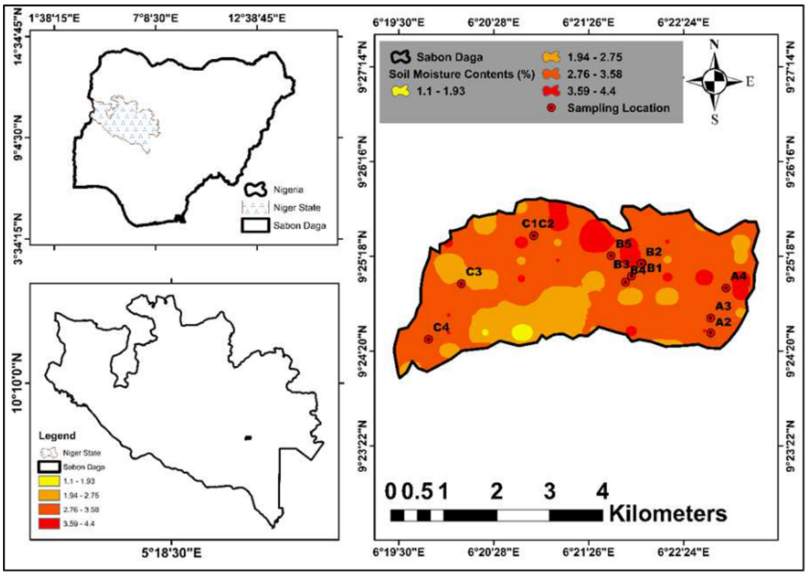

Fig. 1: Map of Nigeria Showing Niger State and Sabo Daga

At 100m radius of each assigned position, soil samples were obtained using a 25cm soil auger vertically pushed in the soil, drilled and rotated to extract the soil sample. In each grid, a total of 100 composite samples were collected at 100m radius, in each composite there were 4 samples as centered on the grid (Fig. 2). Collected composite samples were immediately placed in a sterile polythene (so as not to include potency reaction of polythene with elements in the soil), labeled and transported to the laboratory for analysis, where each of the samples collected was prepared for testing to know the moisture content.

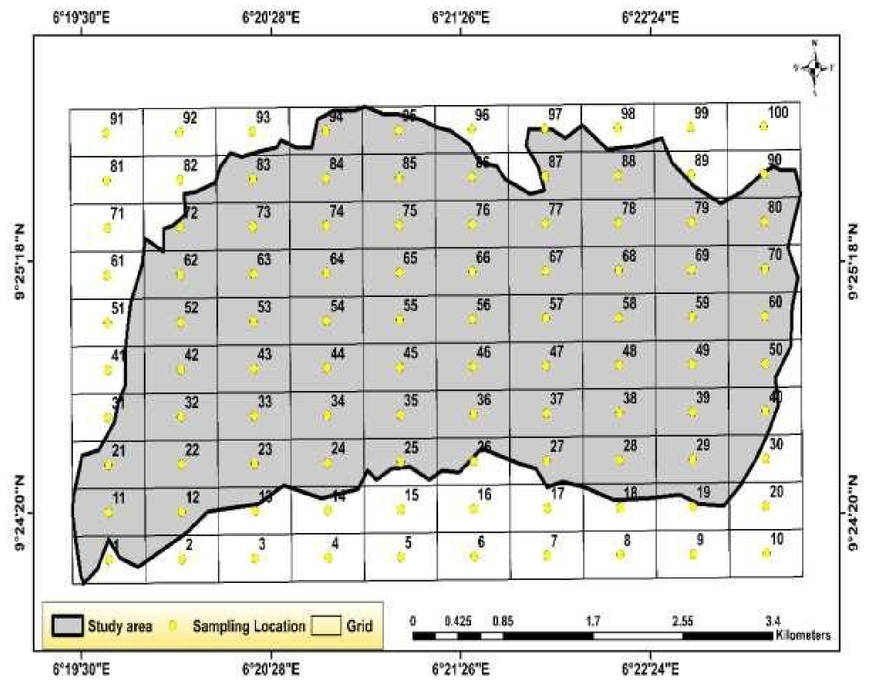

Fig.2: Soil Sample Locations

Total Nitrogen in the soil samples was analyzed using 0.2g soil and weighed into 100ml kjedahl digestion flask. Selenium catalyst tablet and 4ml concentrated H2SO4 was added into the

digestion flask and put on a digester until the solution turned clear and let to cool down to slightly warm. Then 10ml distilled water was added and the sample solution filtered through a Whatman No. 1 filter paper into a 100ml volumetric flask. The flask was later rinsed with distilled water and the filtrate made up to mark. The concentration of Nitrogen in filtrate was measured using colorimetric technique. Thus, 5ml filtrate was pipetted into a 25ml volumetric flask. 2.5ml alkaline phenol, 1ml sodium potassium tartrate and 2.5ml sodium hypochlorite, were properly mixed and marked with distilled water and read calorimetrically at 630nm.

However, 1000ppm N-standards was prepared by dissolving 4.7g of ammonium sulphate in a 1L volumetric flask with distilled water. 100ppm N standards was prepared from the 1000ppm N stock solution, from which 5, 10, 15, 20, 25ppm N standards were prepared. To each of the standards, 4ml of H2SO4 and 0.95g of anhydrous sodium sulphate was added and the standards were given the same treatment as that of the sample above, before being made up to 100ml. A blank solution, not containing any nitrogen, but with the same amount of acid and anhydrous sodium sulphate was also prepared and the presence of nitrogen was inferred determined as in equation 1.

$$N\,(ppm) = \frac{IR \times SR \times CV \times \text{extractvolume} \times 10 - 6 \times 100 \times CF}{\text{Weight or sample x Aliquot taken}} \quad ....(1)$$

Where:

IR = Instrument reading

SR = Reciprocal of slope obtained from plot of standards CV=Colour volume

CF = Correction factor

The soil sample, dried in air was again grounded to get a particle size passing 2 mm sieve. The sieved soil sample of 1 (one) gram was weighted into the digestion flask. 10 ml of concentrated HSO was poured into the digestion flask which was holding the soil sample. A tablet of selenium catalyst was dropped in the digestion flask containing soil sample and concentrated sulfuric acid. The digestion flask containing soil sample and concentrated sulfuric acid was then heated using digestion block slowly to 350C. The digestion flask was then removed from heating when the solution turned clear showing that all organic matter has been digested. The digested solution was allowed to cool and then poured into the distillation apparatus. Excess of NaOH solution was added to the digested solution until it became alkaline. The solution was then distilled in order to evolve the ammonia to receive flask which contained known volume of boric acid solution. The distillation was allowed till all the ammonia had been distilled over. The solution containing the distilled ammonia in boric acid was titrated against 0.1N sulfuric(H_2SO_4) acid by using methyl red indicator for its end point. The volume of the acid required in titration was then recorded. Total nitrogen in soil was then calculated using equation 2.

$$\text{Total nitrogen}\left(\frac{\text{mg}}{\text{kg}}\right) = \frac{(V_1 - V_0)\times N\,14\times 1000}{W}$$

……..(2)

Where:

V1 = Volume of acid used for the sample (ml)

V0 = Volume of acid used for the blank (ml)

N = Normality of the acid

W = Weight of the soil sample (grams)

14 = Atomic weight of nitrogen

Geo-spatiial distribution of soil moisture parameters of study area was acquired using geo- stastistics as a quantitative measure for spatial variability estimation. Kriging interpolation tool in ArcGIS 10.5 was used as it provides a linear unbiased optimal interpolater and predictor over a region due to its best interpolation capability. The physiochemical parameters of soil were then converted into geo-spatiial analysis database in the form of access .dbf extension which were responsible for the input, output and back-end processing data.

Having applied the developed Kriging interpolation, a coordinate (northing and easting) was given to each soil sample site and each soil moisture value obtained was encoded by a letter z (z 1, z 2, z 3----z n) where z indicates the value of the physiochemical parameters of the soil samples analyzed from each site. The validation of the developed Kriging interpolation system was conducted using the RMSE (Mean Square Error) and Root Mean Square Error according to the definition by (Nicholas et al. 2023). It is presented in equation 3 and 4:

$$MSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[Z(z_i) - z'(x_i)\right]^2}$$

…….(3)

$$MSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[Z_1(z_i) - Z_2'(x_i)\right]^2}$$

…….(4)

III. RESULTS AND DISCUSSION

The soil N content distribution of the study area is given in Fig. 3. The soil N content of the study area was in the range of 0.00-0.07%, 0.07-0.13% and 0.13-0.32% in one sample compost soil. The distribution of soil N showed that most part of the farm contained low N content and only a few dispersed plots contained high N content. There was certain area around the low soil N content, in which N contents ranged from 0.07 to 0.13%. This area included grids 1-4,14,15,17, 20 and 21, respectively.

Nitrogen in soil can be taken by plants in the forms of losses via leaching and volatilization. It is gained by inputs via fixation by soil microorganisms and from leguminous nodules. In soil, nitrogen level represents availability of nutrients to plants and nutrient cycling in the area of study. The available nitrogen in soil indicated by results from the current study was between 0.00-0.32%. This Nitrogen level is considered low to moderate with greatest availability of nutrients for plant uptake.

Soil nitrogen processes are fundamental component for plant development and ecosystem function in similar study performed by. Nitrogen overuse and excessive fertilizer application deteriorates soil property, as well as results in considerable emissions of N2O and NH3 as greenhouse gases and air pollutant respectively. Thus, it is very important first to understand clearly about soil nitrogen transformation in order to develop effective countermeasures for these impacts. In similar study (Xu et al., 2024), shows that values of soil organic carbon (SOC) ranged from 2.95- 21.50 gkg-1, total nitrogen (TN) ranged from 0.27-2.44 mg·kg−1 and available nitrogen ranged from 18.20-170.45 mgkg-1, were low for most values fell within deficient levels. The finding showed remarkable spatial variations of soil nitrogen contents, especially where agriculture practice was intensive. The study revealed that Paddy field and HF belt provided high concentration values for SOC and TN compared with orchards and dryland. This implies that there is usually uneven distribution of Nitrogen in the soil based on soil quality, fertilizer application and introduction of nitrogen fixing crops.

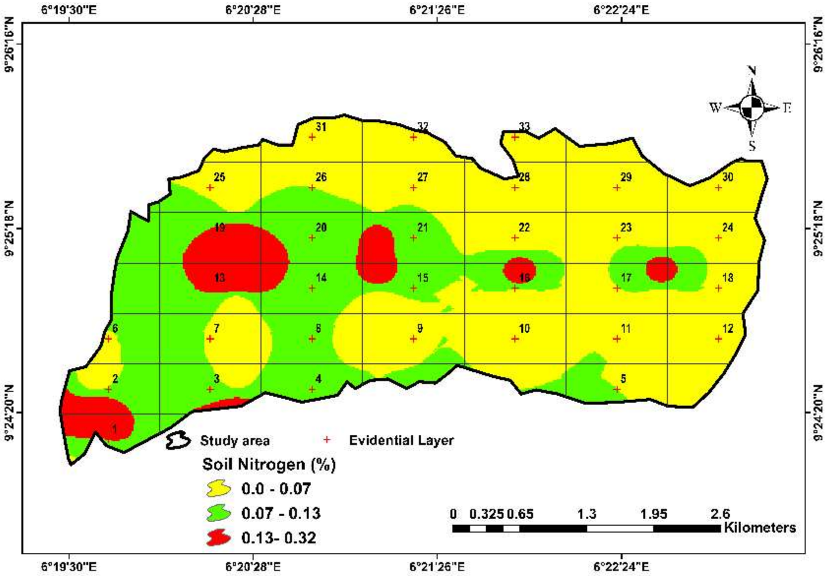

Fig.3: Soil Nitrogen Contents Distribution in the Study Area

IV. CONCLUSION AND RECOMMENDATION

The findings reveals that the soil nitrogen in general in the study area is low to medium with majority of the plots having nitrogen contents that limit optimum productivity and crop yield. The distribution across the plots reveals that there is a substantial part of the land with limited nitrogen content that is attributed to limited soil organic matter. The input of soil nitrogen and soil organic matter shows the value of maintaining healthy soil and crop productivity. The existing condition of low soil nitrogen implies that crop productivity will be minimal in some of the low nitrogen areas. It is recommended that the productivity of crops will improve by addition of nitrogen through fertilizer application. Secondly, cultivation of leguminous crops such as groundnut, soya bean and other rhizomes is capable of adding atmospheric nitrogen into the soil. Thus, the high nitrogen containing plots showing positive correlation with soil organic matter, are to be used for production of other nitrogen deficient plants.

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