# EPIPEDAL NITROGEN MAPPING OF SOILS OF A FARMLAND IN A HUMID TROPICAL ENVIRONMENT

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**Abstract**
Nitrogen content of epipedons of soils of a humid tropical environment at Okemuen in Uhunmwonde Local Government Area (LGA) of Edo State, Nigeria was investigated and mapped. Soil samples were collected using soil auger at different locations of the farmland guided by topography and vegetation. Soil samples were collected at 0-15 cm and 15-30 cm but only epipedons were considered for nitrogen analysis. Routine laboratory methods were used in analyzing the collected soil samples after necessary sample preparations for some soil characteristics. Geostatistical tools were employed in the mapping of values of data. Results showed variability in the distribution of nitrogen in the epipedal horizons of the farmland. Total nitrogen was moderate ranging from 0.16 to 0.17 g/kg, requiring more input of total nitrogen in the farmland. Six mapping units were identified and nitrogen augmentations should vary according to inherent status of nitrogen in the various soil units.
Keywords: Epipedon, Farmland, Mapping, Tropical soils, Variability

**Introduction**

Nitrogen can occur in soils in varying forms including organic compounds, nitrates, nitrite anions and ammonium ions. Supply of nitrogen is greatly influenced by microbial activities. Nitrate forms tend to be higher after dry long spells and early rains in the tropical soils (Landon, 1991).Nitrogen is one of the primary macronutrients in soils that can improve yields in the humid tropics. Nitrogen is a component of proteins and enzymes and indeed part of all living cells. Stark and Richards, (2008) reported that the element is found in organic compounds in plants as amino acids, nucleic acids, enzyme and chlorophyll. It is involved in synthesis and transfer of energy and promotes luxuriant growth and production of seeds and fruits. Nitrogen can only be utilized by crops when changed to simple inorganic forms by microbial decomposition by a pedogenic process referred to as mineralization though some plants such as rice use nitrogen in form of ammonium cation. Nitrogen plays a major role in activities of microorganisms and changes in its dynamics in the soilsphere is closely linked to alterations in microbial activities involved in nitrogen cycling (Dilfusa,2012) But, nitrogen in form of nitrates are readily soluble and easily lost in soils due to soil erosion, leaching, volatilization, denitrification especially under waterlogged conditions and by crop removals without replacement. Of these sources of nitrogen loss, the chemical nature of nitrogen makes very mobile especially under humid climatic conditions. Onweremadu *et al* .(2024) stated that leaching contributes a significant proportion in translocating nitrogen beyond the reach of most arable crops especially shallow-rooted types in the humid tropics..The situation could affect nutrient balances and ratios as Malvi (2011), reported that there is a pre-determined ratio of nutrients required by plants depending on its life cycle, environment and genotypic characteristics to attain a crop's maximum genetic potential. Optimum performance is enhanced with nutrient balance (Jarvan, 2004). Scholars have worked on specific nutrients with Essel *et al*. (2021) stressing need for balanced phosphorus to sulphur ratio and Sait (2015) reporting iron –Manganese ratio. However, this depends on soil type as Ca: Mg ratios recommended for sandy soils is 3: 1 and in clayey soils adequate calcium –magnesium ratio is 7:1 (Philips, 2021; Osemwota *et al*., 2007). Values ranging from greater than 10 g/kg, 5- 10 g/kg, 2-5 g/kg, 1 -2 g/kg and less than 1.0 g/kg have been rated as very high, high, medium, low and very low, respectively (Landon, 1991).Consequent upon these, crops manifest varying deficiencies symptoms including yellowing of older leaves of arable and tree crops when there is depletion nitrogen in soils. These losses are highly pronounced in epipedons (surficial soil horizons) where most crops particularly the shallow-rooting varieties intercept nutrients for proper growth and development. Oftentimes, some technologies have been employed in enhancing deficiencies in tropical soils including the use of forage legumes, grain legumes and green manures. Popular technologies in West Africa are the application of *Arachis hypogeal* (Groundnut), *Glycine max* (Soybeam), *Cajanus cajan* (Pigean pea) and *Vigna unguiculata* (Cowpea). Ogoke (1999) and Amusan *et al*. (2011) observed significant contributions of legume-based fertilization to nitrogen status to West African soils. Yet, growth and yield of most crops have witnessed declined nitrogen in tropical soils, making it expedient to investigate total nitrogen status of these tropical soils including soils of an agrarian community of Okemuen in Uhunmwonde Local Government Area (LGA) of Edo State, Nigeria. Obasi (2010) mapped selected soils on a toposequence in Amasiri, Ebonyi State, Nigeria and reported vertical and spatial variability in nitrogen in investigated soils. Obidike-Ugwu, *et al.* (2022) applied Semivariogram model in the investigation of spatial variability of soil properties in tropical forest soils. Again, Onyechere *et al*.(2023) reported variability of selected soil properties using geostatistical approach as Wilding et al. (1994) ranked these variations in soil properties using conventional statistical tools.

The major objective of this investigation was to assess the nitrogen content of epipedons (surface horizons of soils of a farmland at Okemuen in Edo State of Nigeria. Specifically, the study mapped the soil nitrogen data in this farmland for the purpose of sustainable crop production.

## Materials and Methods

### Study Area

#### Location

The study was conducted at a farmland in Okemuen in Uhunmwonde Local Government Area (LGA) of Edo State, Nigeria, located between Latitudes $6^0$ $30^l$ and $6^0$ $50^l$ N; and Longitudes $6^0$ $00^l$ and $7^0$ $30^l$ E. Okemuen is about 40 kilometres to Ambrose Alli University, Ekpoma in Edo State, Nigeria.

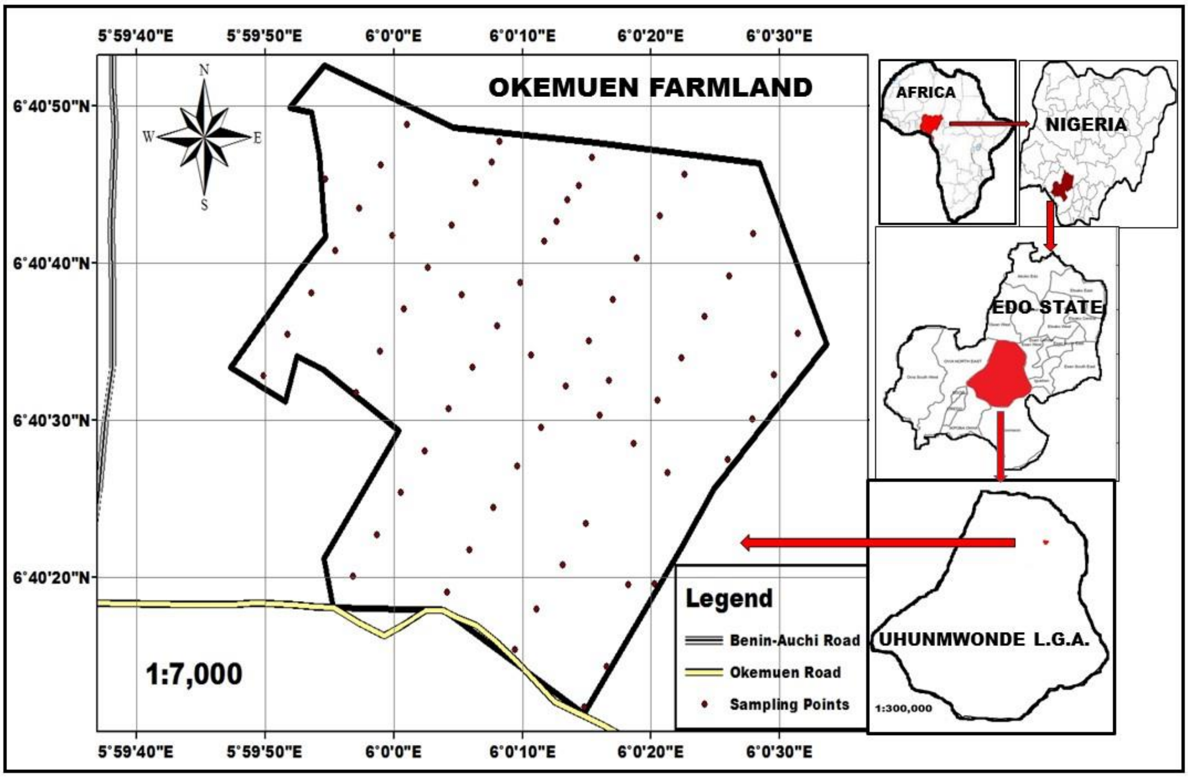


**Fig.1: Location Map**

#### Geology and Geomorphology

The lithologic materials consist of a mixture of Shale and sand deposits. The geomorphology of the area consists of inland valleys, plains, river slopes and hills.

#### Climate

Okemuen lies within the humid tropics with annual rainfall of about 1800mm and annual temperature range of 29 to $31^0$C.The area has a bimodal rainfall pattern with peaks during July and September every year. However, there has been recent changes in climatic characteristics referred to as climate change. Relative humidity is generally high during wet seasons and reduces during last dry months of the year. The Southwest and Northeast Trade winds govern the rainfall and dryness characteristics of the area. Dry season tends to be sunny and dry with harmmattan winds blowing across the area. Evapo-transpiration is high, leading to wilting of most plants except some deep-rooted ones.

#### . Vegetation

The vegetation is a typical rainforest belt with multiple plant species. Plants are arranged in storeys with sun-loving plants towering above sun-hating plants. It is a mixed vegetation comprising trees, shrubs, herbaceous species, climbers and saprophytes. Built-up vegetations of varying economic crop types exist in the area. The vegetation has of recent witnessed pronounced deforestation as the area supplies fuelwood to towns proximal to it including Benin City, Ekpoma and the Local .Government Headquarters at Ehoor.

#### Hydrology

The hydrology of the area is governed by local rivers and their tributaries. Volumes of the river increases during rainy season due to in-flow of runoff water after rains, sometimes causing overflows at the banks. However, ground water harvesting is common in the area as dwellers sink wells to tap the underground water resources.

**Socioeconomy**

Smallscale agriculture is a major socioeconomic activity. Farmers exist in farming communities where they reside with farming as major occupation. Dominant crops include cassava, yam, maize, cocoa, plantain, banana, pineapple, oil palms, rubber and a host of others. These crops are cultivated in a mixed cropping system to avoid crop failure. Bush fallowing is used for soil fertility regeneration although fallow length has been shortened due to less farmland. Land clearing is by slash-and-burn method. Other socioeconomic activities are sand mining, processing for oil palm products, cassava processing, lumbering, fishing, hunting and marketing of farm products. Local markets abound and road-side trading is common.

**Materials**

These include auger, munsell colour chart, core samplers, handheld global positioning system (GPS) receiver, roller tapes, recording materials, existing maps (Local Government Area, survey plan and topomap of the farmland), geospatial softwares and writing materials

**Brief description of sampling site**

Sampling sites were all located on the farmland. The farmland is characterized by a mixture of vegetation types including existing patches of secondary forest, cocoa plantation, pineapple plantation, pockets of plantain and banana crops, old cassava stands, grasses and a variety of wild plants. Pathways form entry to the farm. There are evidences of interill, rill and rainsplash erosion. Inland valleys exist. There is abundance of leaf litter and other plant debris although these crop residues vary with plant type. Soils are subjected overland flow.

**Field Studies/Activities**

Initial field activity was on reconnaissance to the site to select sampling points. Selection of sampling points were guided by topography, changes in vegetation and some soil macromorphological indices. Soil sampling from sites was done with the help of auger at 0- 15 cm depth. Sampling sites were georeferenced using Handheld Global Positioning System (GPS) receiver (Garmin Ltd, Kansas USA). Munsell Colour Chart was used to obtain and record information on soil colour and this was done *in situ* (Munsell Colour Company, 1994).Macro-morphological properties were observed *in situ* and recorded using appropriate field tools. These auger soil samples assisted in ascertaining Nitrogen fertility status of soils based on selected soil attributes and compared with existing national and international standards and scientific reports of various researchers. Core soil samples were collected for bulk density and other physical parameters.

**Laboratory Studies**

Soil samples were air-dried and sieved using 2-mm sieve and analyzed using standard procedures. Particle size distribution was determined using Hydrometer method (Gee and Or, 2002).Bulk density was assessed by core procedure(Grossman and Reinsch, 2002). Moisture content (Waterholding Capacity) was measured gravimetrically (Obi, 1990). Soil pH was determined electrometrically indistilled water in a soil-water ratio of 1:2.5 (Hendershot *et al*., 1993).Organic carbon was estimated by dichromate wet-oxidation according to the procedure of Nelson and Sommers (1996). Total nitrogen was determined by Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982). Available phosphorus was measured by Bray 11 method (Olsen and Sommers, 1982). Exchangeable acidity was extracted using normal potassium chloride solution and determined by titration method. Exchangeable bases were extracted using ammonium acetate. Exchangeable potassium and sodium were determined by flame photometer while Exchangeable calcium and magnesium were estimated by atomic absorption spectrometer. Cation exchange capacity was determined by ammonium acetate method (Thomas, 1982). Base saturation was obtained by calculation, using the relationship existing between total exchangeable bases and cation exchange capacity (IITA, 1982).

**Spatial Analysis and Mapping**

Generated target soil properties and soil-related environmental co-variates (FAO,1983;Sys, 1989; Ogunkunle,1993; Eze, 2014) for soil nitrogen mapping (Sanchez *et al*.,2003: Sanchez *et al*.,2009).Values of total nitrogen were subjected to geostatistical tools for the generation of maps at a large scale of 1:7000, after passing through transformation process (Wu *et al*,2006). In this, the geostatistical Wizard of the Geostatistical analyst extension of Arc GIS Version 10.2 was used to perform all geostatistical analysis. The ordinary kriging (OK) interpolation method was used for prediction of unmeasured sites (Foody, 2004). Semi-variogram was used to examine spatial distribution structure of soil nitrogen based on regionalized variable theory and intrinsic hypothesis(Karl and Maurer, 2010). Appropriate models applicable to semi-variogram were employed. The best-fit with the lowest value of residual sum of squares was selected for soil nitrogen. Cross-validation technique was used for evaluating the performance of Ordinary Kriging.

**Results and Discussion**

Soil textural class ranges from sand to loamy sand ,although dominated by loamy sand. The implication of this is nitrogen being very soluble and mobile could be easily leached towards the endopedons (sub-surface horizons).

Table 1: Particle Size Distribution

| S/N | Sample Code | Depth (cm) | % Sand | % Silt | % Clay | Textural Class |
|---|---|---|---|---|---|---|
| 1 | Ok 01 | 0-15 | 87.8 | 0.8 | 11.4 | Loamy Sand |
| 2 | Ok 01 | 15-30 | 82.8 | 3.8 | 13.4 | Loamy Sand |
| 3 | Ok 02 | 0-15 | 89.8 | 1.8 | 8.4 | Sand |
| 4 | Ok 02 | 15-30 | 88.8 | 1.8 | 9.4 | Loamy Sand |
| 5 | Ok 03 | 0-15 | 85.4 | 5 | 9.6 | Loamy Sand |
| 6 | Ok 03 | 15-30 | 85.4 | 5 | 9.6 | Loamy Sand |
| 7 | Ok 04 | 0-15 | 87.4 | 5 | 7.6 | Loamy Sand |
| 8 | Ok 04 | 15-30 | 85.4 | 4 | 10.6 | Loamy Sand |
| 9 | Ok 05 | 0-15 | 89.4 | 4 | 6.6 | Sand |
| 10 | Ok 05 | 15-30 | 86.4 | 5 | 8.6 | Loamy Sand |
| 11 | Ok 06 | 0-15 | 86.4 | 5 | 8.6 | Loamy Sand |

**SOIL CHEMICAL PROPERTIES**

In soil fertility indices, soil pH varied from 4.22 to 6. 31, a range rated extremely acidic to slightly acidic (FDALR,1985:SPDC,2003).Organic carbon ranged from 0.31 g/kg (very low) to 2.57 g/kg (Very high). (FDALR,1985:SPDC,2003).However, this distribution has currently kept the soils stable, but, with conventional tillage , this carbon content may deplete, calling for caution on the management of soil organic carbon in the farm, an element whose ratio with nitrogen determines rate of decomposition and immobilization by microorganisms. In this case, nitrate fertilizers mixed or blended with organic manure sources are recommended. Available phosphorus which is a primary macronutrient varied from 1.75 to 5,26 mg/kg which is rated low(FDALR,1985:SPDC,2003). Generally, secondary macronutrients: exchangeable calcium and magnesium were low to moderate in these soils. .

Another important macronutrient exchangeable potassium was very low (less than 0.2 cmol/kg) using FDALR (1985). This nutrient is very important for crops especially tuber crops as it is responsible for trans-locating the photosynthate to the tubers. Cation exchange capacity ranges from 8.03 to 14.48 cmol/kg, and rated low to moderate (FDALR,1985). But, base saturation was high to very high,, ranging from 75.77 % to 91.58 %, implying that if nutrients are made available in the soil system, crop roots can easily have access to them by interception, mass flow and diffusion. Total nitrogen ranged from 0.015% (low)(min.) to 0.017 %(low)(max.) in surface soils(FDLAR,1985;FPDD,1989;FMANR,1990).This result could affect nitrogen status in relation to other nutrient elements in the epipedon, resulting to imbalances in requirements of nitrogen for most plants especially crops

Table 2: Soil chemical properties

| Pedon | Depth (cm) | pH | OC | OM | TN | C:N | Ava P (mg/kg) | $Ca^{2+}$ cmol/kg | $Mg^{2+}$ cmol/kg | $K^{+}$ cmol/kg | $Na^{+}$ cmol/kg | $H^{+}$ cmol/kg | $Al^{3+}$ cmol/kg | TEA cmol/kg | CEC cmol/kg | %BS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ok 01 | 0-15 | 4.72 | 0.94 | 1.61 | 0.017 | 55.71 | 3.51 | 6.5 | 5.7 | 0.04 | 0.15 | 1.72 | 0.05 | 1.77 | 12.39 | 87.51 |
| Ok 01 | 15-30 | 5.40 | 0.62 | 1.08 | 0.017 | 37.14 | 5.26 | 8.1 | 2.9 | 0.04 | 0.13 | 1.41 | 0.04 | 1.45 | 11.17 | 88.52 |
| Ok 02 | 0-15 | 6.10 | 0.98 | 1.68 | 0.017 | 59.02 | 5.26 | 5.3 | 7.5 | 0.15 | 0.62 | 1.51 | 0.03 | 1.54 | 13.57 | 89.78 |
| Ok 02 | 15-30 | 5.94 | 0.31 | 0.54 | 0.017 | 18.89 | 1.75 | 3.7 | 8.1 | 0.07 | 0.65 | 1.20 | 0.02 | 1.22 | 12.52 | 91.09 |
| Ok 03 | 0-15 | 5.91 | 1.25 | 2.15 | 0.018 | 71.31 | 1.75 | 3.5 | 10.3 | 0.10 | 0.58 | 1.46 | 0.02 | 1.48 | 14.48 | 90.73 |
| Ok 03 | 15-30 | 5.64 | 0.86 | 1.48 | 0.017 | 49.42 | 1.75 | 4.5 | 6.1 | 0.05 | 0.6 | 1.20 | 0.02 | 1.22 | 11.25 | 90.25 |
| Ok 04 | 0-15 | 5.56 | 1.48 | 2.55 | 0.018 | 81.43 | 3.51 | 4.5 | 5.9 | 0.06 | 0.61 | 1.43 | 0.02 | 1.45 | 11.07 | 88.43 |
| Ok 04 | 15-30 | 5.51 | 0.82 | 1.41 | 0.017 | 48.75 | 3.51 | 4.5 | 4.9 | 0.06 | 0.64 | 1.19 | 0.02 | 1.21 | 10.1 | 89.32 |
| Ok 05 | 0-15 | 6.17 | 1.48 | 2.55 | 0.017 | 86.77 | 3.51 | 3.7 | 6.5 | 0.05 | 0.61 | 1.64 | 0.05 | 1.69 | 10.86 | 86.55 |
| Ok 05 | 15-30 | 5.84 | 0.51 | 0.87 | 0.017 | 29.68 | 3.51 | 3.9 | 4.7 | 0.11 | 0.11 | 1.27 | 0.03 | 1.30 | 9.35 | 87.83 |
| Ok 06 | 0-15 | 6.31 | 1.95 | 3.36 | 0.017 | 116.07 | 3.51 | 4.3 | 8.1 | 0.09 | 0.09 | 1.01 | 0.04 | 1.05 | 13.34 | 92.72 |
| Ok 06 | 15-30 | 6.00 | 0.51 | 0.87 | 0.017 | 30.18 | 3.51 | 3.3 | 9.7 | 0.07 | 0.07 | 1.19 | 0.02 | 1.21 | 13.73 | 91.91 |
| Ok 07 | 0-15 | 6.00 | 0.51 | 0.87 | 0.017 | 29.21 | 3.51 | 2.7 | 8.1 | 0.14 | 0.14 | 1.02 | 0.04 | 1.06 | 11.57 | 91.58 |
| Ok 07 | 15-30 | 5.47. | 0.74 | 1.28 | 0.017 | 42.68 | 1.75 | 2.7 | 4.7 | 0.06 | 0.06 | 1.15 | 0.05 | 1.20 | 8.03 | 87.00 |
| Ok 08 | 0-15 | 4.66 | 2.34 | 4.03 | 0.017 | 137.00 | 1.75 | 3.9 | 5.7 | 0.08 | 0.08 | 1.68 | 0.02 | 1.70 | 10.18 | 85.66 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ok 08 | 15-30 | 4.50 | 1.48 | 2.55 | 0.017 | 86.77 | 1.75 | 3.3 | 4.5 | 0.08 | 0.08 | 1.70 | 0.02 | 1.72 | 8.37 | 82.95 |
| Ok 09 | 0-15 | 4.25 | 1.52 | 2.62 | 0.017 | 88.33 | 1.75 | 5.5 | 4.1 | 0.01 | 0.1 | 1.21 | 0.03 | 1.24 | 10.34 | 89.29 |
| Ok 09 | 15-30 | 4.22 | 1.13 | 1.95 | 0.017 | 66.22 | 1.75 | 2.3 | 5.3 | 0.06 | 0.06 | 2.27 | 0.06 | 2.33 | 8.38 | 78.26 |
| Ok 10 | 0-15 | 4.88 | 1.09 | 1.88 | 0.017 | 65.00 | 1.75 | 3.5 | 5.3 | 0.08 | 0.08 | 1.99 | 0.03 | 2.02 | 9.49 | 82.48 |
| Ok 10 | 15-30 | 4.68 | 0.59 | 1.01 | 0.017 | 34.82 | 1.75 | 3.5 | 6.3 | 0.06 | 0.06 | 2.47 | 0.02 | 2.49 | 10.44 | 80.75 |
| Ok 11 | 0-15 | 5.75 | 1.33 | 2.29 | 0.016 | 81.65 | 1.75 | 5.1 | 3.9 | 0.07 | 0.07 | 2.36 | 0.04 | 2.40 | 9.64 | 80.07 |
| Ok 11 | 15-30 | 5.24 | 2.57 | 4.44 | 0.016 | 158.50 | 1.75 | 3.1 | 5.1 | 0.07 | 0.07 | 2.79 | 0.05 | 2.84 | 8.88 | 75.77 |

Key: OK = Okemuen, pH= Pondus Hydrogenium,OC = Organic Carbon, OM = Organic Matter, TN = Total Nitrogen, C:N = Carbon Nitrogen Ratio, Ava P = Available Phosphorus, $Ca^{2+}$, Exchangeable Calcium, $Mg^{2+}$ Exchangeable Magnesium, $K^{+}$ = Exchangeable Potassium, $Na^{+}$ = Exchangeable Sodium, $H^{+}$ = Exchangeable Hydrogen, $Al^{3+}$ = Exchangeable Aluminium, TEA = Total Exchangeable Acidity, CEC = Cation Exchange Capacity, BS = Base Saturation.

**Spatial Distribution of Total Nitrogen**

Geospatial analysis of values of total nitrogen on the farmland are shown in Fig. 2, indicating higher concentration of the primary essential nutrient in the northwestern part of the land. Values of total nitrogen gradually declined towards the northeastern part of the farmland and were found to be least towards the southernmost portions of the land. For the purpose of agronomy, nitrogen loving -crops such as vegetable crops are recommended. Nitrogen units on soils of the farmland were as follows: 0.0158- 0.016 g/kg, 0.016-0.0161 g/kg, 0 .0161 -0.0163 g/kg, 0.0163.0. 0165 g/kg, 0.0165 – 0.0167 g/kg and 0.0167 -0.0168 g/kg. This is in line with Obasi, (2010), who reported variability of soil nutrients including nitrogen in soils of Amasiri in Ebonyi State, Nigeria.

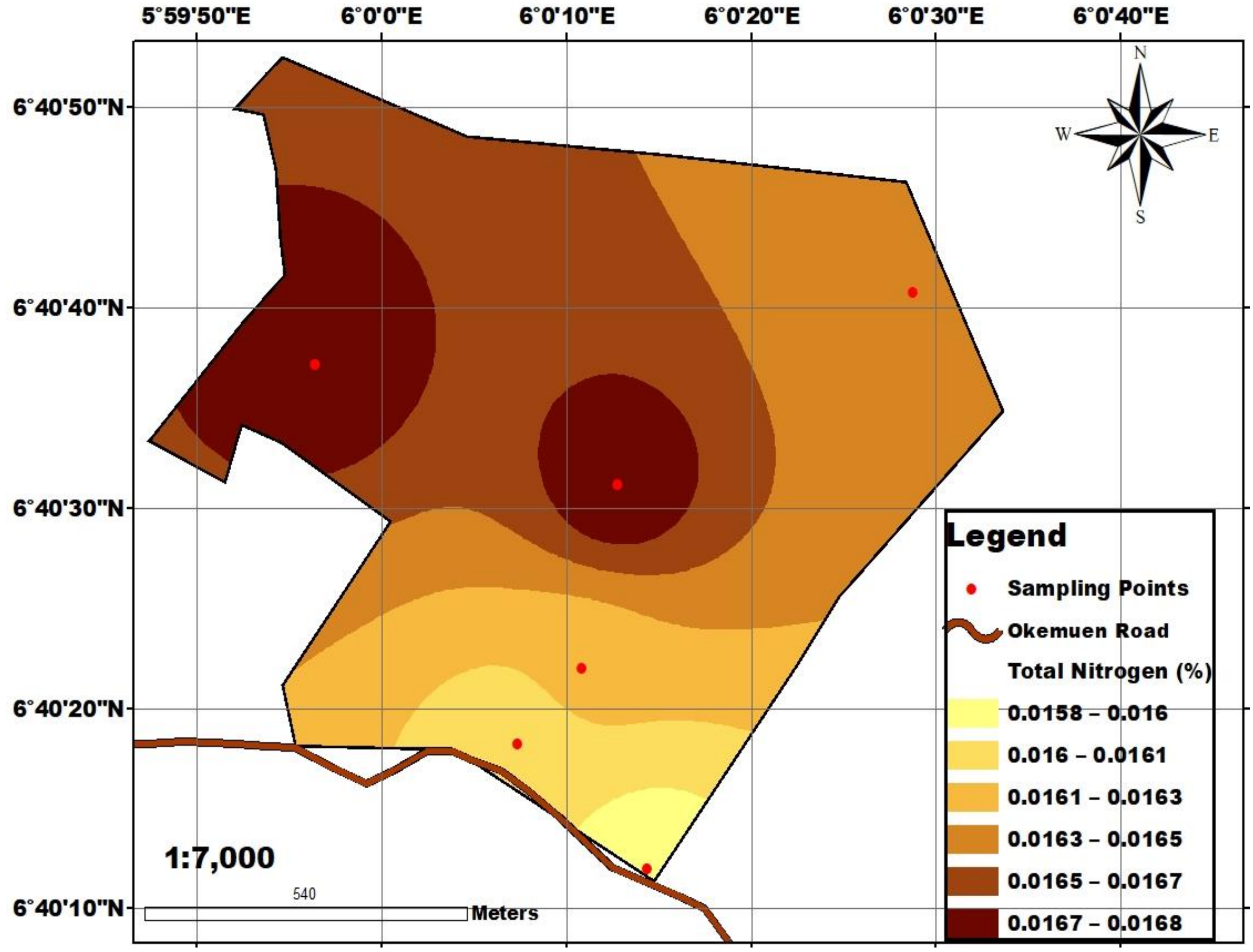


**Fig.2.Percent total nitrogen content at 0-15 cm depth**

**Conclusion**

The study investigated soil nitrogen distribution in the epipedons of soils of a farmland Okemuen in Uhunmwonde Area of Edo State ,Nigeria and obtained values were mapped using geostatistical tools.

Results showed variability in the distribution of nitrogen in the epipedal horizons of the farmland. Total nitrogen was moderate ranging from 0.16 to 0.17 g/kg. Six mapping units were identified and nitrogen ranges were 0.0158- 0.016 g/kg, 0.016-0.0161 g/kg, 0 .0161 -0.0163 g/kg, 0.0163.0. 0165 g/kg, 0.0165 – 0.0167 g/kg and 0.0167 -0.0168 g/kg..

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