

Assessment and Classification of Soil Fertility in Nekede, Imo State, Using the Fertility Capability Classification (FCC) System

Ogechi Mercy Okorocho¹, Okuwa Joel Agwu² Andrew Wenibo³, Adaobi Uchenna Onyecher⁴, Okorie Kelechi Blessing⁵

^{1,2,3}Department of Agricultural Technology Federal Polytechnic Nekede Owerri Imo State, Nigeria

⁴Department of Soil Science and Technology Federal University of Technology Owerri, Nigeria

⁵Department of Soil Science, University of Agriculture and Environmental Sciences Umuagwo, Imo State, Nigeria

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ABSTRACT

The declining productivity of agricultural soils in Nekede, Imo State, necessitates a functional assessment of their fertility status for sustainable crop production. This study evaluated and classified the fertility capability of soils in the Nekede area using the Fertility Capability Classification (FCC) system. Soil samples were collected from five distinct locations at two depths (0–20 cm and 20–40 cm) using a stratified systematic sampling design. Samples were analyzed for key physical and chemical properties following standard laboratory procedures. Results indicated that soils are predominantly sandy loam with high sand content (>75%) across both depths. Chemically, soils were strongly acidic, with mean topsoil pH of 5.1 and subsoil pH of 4.9. Low inherent fertility was observed, characterized by low organic carbon (1.2% in topsoil), deficient available phosphorus (9.5 mg/kg), low exchangeable potassium (0.15 cmol/kg), and a very low cation exchange capacity (<6.1 cmol/kg). Analysis of variance (ANOVA) revealed statistically significant differences ($p < 0.05$) between topsoil and subsoil for all major properties, including increased clay content with depth. Based on these properties, soils were classified under the FCC system as SBe⁺-ac-nk, indicating sandy topsoil with low CEC, a subsoil with higher clay content, aluminum toxicity, and deficiencies in nitrogen and potassium. Recommendations include the application of organic manure to ameliorate acidity, integrated use of organic and inorganic fertilizers to improve nutrient levels and retention, and adoption of conservation practices like mulching. This research provides a foundation for sustainable soil fertility management in the region.

Keywords: Classification, Fertility Capability, Toxicity, Sustainable, Conservation

INTRODUCTION

Soil fertility refers to the soil's capacity to provide essential nutrients in sufficient amounts and proper balance for plant growth (John & Heiniger, 2020). Several factors affect soil fertility, including texture, pH, organic matter content, and nutrient availability. Nutrient deficiencies can lead to reduced plant growth, and extreme deficiencies can cause stunting or plant death (Singh et al., 2015). Soil fertility is fundamental to agricultural productivity, as it determines the soil's ability to provide necessary nutrients for plant growth (Tang, 2020; Brady & Weil, 2017; Havlin et al., 2014). Fertile soils are essential for sustainable agriculture, providing a habitat for roots and facilitating nutrient absorption.

In regions like Nekede, Imo State, where soil fertility degradation is prevalent, assessing soil fertility status is critical for informing agricultural management practices (Ukaegbu et al., 2024; Lal, 2015). Fertility degradation in tropical regions is often associated with high rainfall, acidic parent materials, and low organic matter content, which promote nutrient leaching and aluminum toxicity (Sanchez, 2019; Brady & Weil, 2017).

The Fertility Capability Classification (FCC) system, introduced by Buol et al. (1975), assesses soil fertility based on measurable physical and chemical characteristics, categorizing soils according to constraints related to texture, acidity, nutrient availability, and other growth-limiting factors (Sanchez et al., 2003; Srinivasa et al.,

2022; Obalum et al., 2017). The FCC system evaluates both topsoil and subsoil properties and consists of three categorical levels: Type (topsoil texture), Substrata Type (subsoil texture), and 15 modifiers, including acidity, aluminum toxicity, low CEC, nutrient deficiencies, and other constraints.

Nekede soils face challenges including fertility degradation, soil erosion, and nutrient depletion, resulting in reduced crop yields and environmental degradation. This study aimed to assess and classify the fertility capability of soils in Nekede to guide management strategies and sustainable agricultural productivity.

MATERIALS AND METHODS

Study Area

The study was conducted in Nekede, Imo State, located in the coastal plain sands region of southeastern Nigeria. The area experiences a tropical monsoon climate, with annual rainfall of 2,412 mm and mean temperatures of 25.9°C (NIMET, 2022; Lal, 2015). Nekede is a peri-urban settlement near Owerri, at the confluence of the Nworie and Otamiri Rivers (Fidelis Okorie et al., 2020; Ukaegbu et al., 2024). Rainfall occurs primarily in two wet seasons (Ezemonye & Emeribe, 2016).

Parent materials are primarily marine-origin coastal plain sands with nearly level to gently undulating plains. Soil textures range from sandy loam to sandy clay loam with low fertility, high acidity, and low CEC (Obi & Ebo, 2015). Land use predominantly involves arable farming with crops such as cassava, yam, maize, and melon (Ukaegbu et al., 2024).

Field Study

Soil samples were taken from five distinct locations at two depths: 0-20 cm (topsoil) and 20-40 cm (subsoil) following standard soil survey procedures (USDA, 2017). Composite samples were obtained from multiple point within each location using a soil auger. Samples were air-dried, crushed, sieved with 2mm sieve, and prepared for laboratory analysis (Figure I) The field study ensured representation across varying soil types and land uses to capture fertility variability. The samples were analyzed for physical properties, including texture, bulk density, and particle size, and chemical properties, such as pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, cation exchange capacity (CEC), and micronutrients using standard methods.

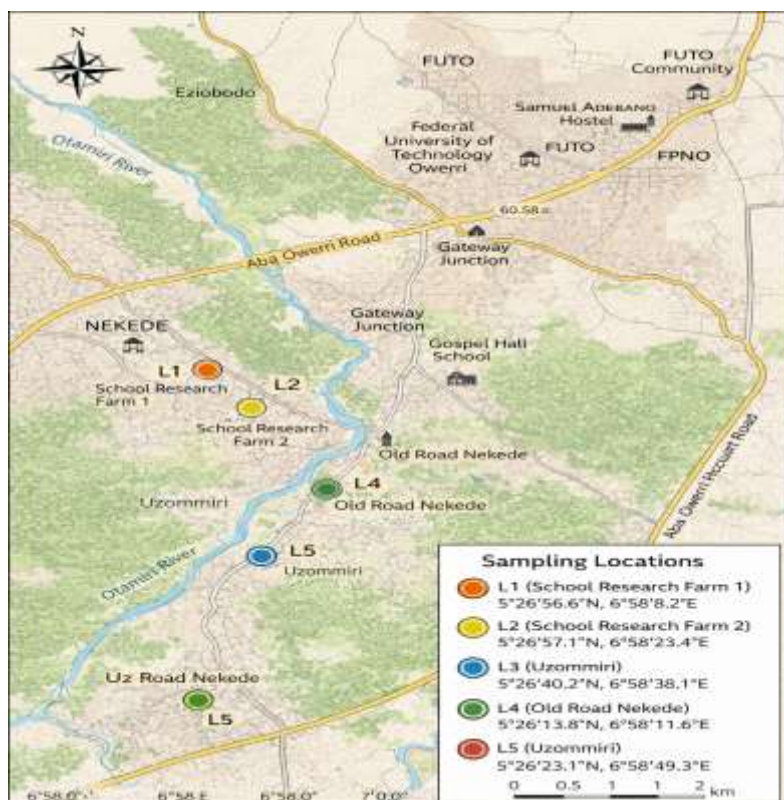


Figure 1 Location Map of the Study area

Laboratory Analysis

Each sample was analyzed for key physical and chemical properties following standard procedures:

Physical properties: Particle size distribution was determined using the hydrometer method (Gee & Bauder, 2017), and bulk density was measured using the core method.

Chemical properties

pH and EC: Soil pH was measured in a 1:1 soil-water suspension using a calibrated glass electrode; electrical conductivity was determined using a conductivity meter (McLean, 2020).

Organic Carbon: The Walkley-Black wet oxidation method was used, with correction factors applied to estimate total organic carbon (Walkley & Black, 2021).

Total Nitrogen: The Kjeldahl method was employed, involving digestion, distillation, and titration (Brenner & Mulvaney, 2017).

Available Phosphorus: The Bray-1 method was used due to the acidic nature of the soils (Bray & Kurtz, 2019).

Exchangeable Bases: Ammonium acetate extraction at pH 7 was used to determine exchangeable K, Ca, Mg, and Na (Richards, 2016).

Exchangeable Acidity: 1 M KCl extraction followed by titration was used to quantify Al^{3+} and H^+ .

Cation Exchange Capacity (CEC): Effective CEC was calculated as the sum of exchangeable bases and exchangeable acidity; base saturation was computed accordingly.

Micronutrients: DTPA extraction was used to determine available Fe, Zn, Cu, and Mn (Sultanpur & Schwab, 2019).

All measurements were performed in duplicate with quality control samples included. Results were recorded in standard units and validated using a certified reference soil.

Data Analysis

Descriptive statistics (mean, standard deviation, coefficient of variation) were computed for all soil parameters. The coefficient of variation was used to assess variability across sampling points (Ukaegbu *et al.*, 2024). Inferential statistics such as ANOVA were employed to detect significant differences in soil properties between depths or locations. Where significant, post-hoc tests like Tukey's HSD were conducted.

Multivariate techniques, including Pearson correlation and principal component analysis, were used to explore relationships between soil variables and identify major soil fertility drivers.

RESULTS AND DISCUSSION

Table 1: Chemical and physical properties of soil in the study area for top soil (0-20cm)

Sample ID	pH	OC (%)	TN (%)	P (mg/kg)	K (cmol/kg)	CEC (cmol/kg)	Sand (%)	Silt (%)	Clay (%)	Textural Class
L1	5.3	1.50	0.09	12.1	0.18	6.20	80.0	9.0	11.0	Sandy Loam
L2	4.9	1.00	0.07	8.5	0.12	5.10	82.0	8.0	10.0	Sandy Loam
L3	5.2	1.40	0.10	10.2	0.17	6.50	75.0	11.0	14.0	Sandy Loam
L4	4.8	0.90	0.06	7.1	0.11	4.90	84.0	7	9.0	Sandy

										Loam
L5	5.3	1.20	0.08	9.6	0.17	6.30	76.0	10	14.0	Sandy Loam
Mean	5.10	1.24	0.08	9.50	0.15	5.80	79.4	9.0	11.6	Sandy Loam

OC = Organic Carbon, TN = Total Nitrogen, P = Available Phosphorous, K = Exchangeable Potassium, CEC = Cation Exchange Capacity, pH = Acidity, L1 = School Research Farm L2 = School Research Farm, L3 = Uzommiri, L4 = Old Road Nekede, L5 = Uzommiri

Table 2 Chemical and physical properties of soil in the study area for subsoil (20-40cm)

Sample ID	pH	OC (%)	TN (%)	P (mg/kg)	K (cmol/kg)	CEC (cmol/kg)	Sand (%)	Silt (%)	Clay (%)	Textural Class
L1	5.1	1.00	0.06	8.2	0.13	6.50	78.0	8.0	14.0	Sandy Loam
L2	4.7	0.70	0.04	5.1	0.08	5.30	80.0	7.0	13.0	Sandy Loam
L3	4.9	0.90	0.05	6.8	0.12	7.10	72.0	10.0	18.0	Sandy Loam
L4	4.6	0.60	0.03	4.5	0.06	5.00	82.0	6.0	12.0	Sandy Loam
L5	5.0	0.80	0.05	6.4	0.11	6.60	73.0	9.0	18.0	Sandy Loam
Mean	4.88	0.80	0.05	6.20	0.10	6.10	77.0	8.0	15.0	Sandy Loam

OC = Organic Carbon, TN = Total Nitrogen, P = Available phosphorous, K = Exchangeable Potassium, CEC = Cation Exchange Capacity, pH = Acidity, L1 = School research farm L2 =School research farm, L3 = Uzommiri, L4 =Old road Nekede, L5 = Uzommiri

The soils in the Nekede area were found to be predominantly sandy loam, with a high sand content (>75%). The topsoil had a mean pH of 5.1, while the subsoil was more acidic with a pH of 4.9. Organic carbon content in the topsoil was low, averaging 1.2%, and the subsoil had even lower organic carbon levels. Both topsoil and subsoil exhibited deficiencies in available phosphorus and exchangeable potassium, with CEC values below 6.1 cmol/kg, indicating poor nutrient retention capacity these findings align with the study conducted by (Mbagwu & Anikwe, 2018; Ukaegbu et al., 2024) on Soil properties and productivity of southeastern Nigeria soils.

The strongly acidic nature of the soils (mean pH 5.1 in topsoil and 4.9 in subsoil) is consistent with soils of humid tropical environments where heavy rainfall enhances leaching of basic cations and accumulation of exchangeable aluminum (Brady & Weil, 2017; Sanchez, 2019). Low organic carbon and total nitrogen values observed in both depths further indicate poor inherent fertility and limited biological activity, which negatively affect soil structure and nutrient cycling (Lal, 2015).

The low available phosphorus and exchangeable potassium recorded in the soils reflect the combined effects of phosphorus fixation under acidic conditions and potassium leaching in sandy soils (Havlin et al., 2014; Obalum et al., 2017). The very low CEC values (<6.1 cmol/kg) indicate poor nutrient holding capacity, a common limitation of sandy tropical soils (Brady & Weil, 2017).

Statistical Analysis of Key Soil Properties between Depths

Soil Property	Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
pH	Between Depths	0.112	1	0.112	5.32*	0.039



	Within Depths	0.168	8	0.021		
Organic Carbon (%)	Between Depths	0.400	1	0.400	16.00*	0.004
	Within Depths	0.200	8	0.025		
Total Nitrogen (%)	Between Depths	0.00225	1	0.00225	18.00*	0.003
	Within Depths	0.00100	8	0.000125		
Available P (mg/kg)	Between Depths	27.23	1	27.23	15.21*	0.005
	Within Depths	14.32	8	1.79		
Clay Content (%)	Between Depths	28.90	1	28.90	10.72*	0.011
	Within Depths	21.56	8	2.70		

Note: * indicates a statistically significant difference at $p < 0.05$.

The analysis of variance (ANOVA) showed statistically significant differences ($p < 0.05$) between the topsoil and subsoil for all key properties, including pH, organic carbon, total nitrogen, available phosphorus, and clay content. The increased clay content in the subsoil was particularly noteworthy, indicating a textural shift with depth. Furthermore, Pearson's correlation analysis revealed a strong positive significant correlation between Organic Carbon and CEC ($r = 0.81, p < 0.01$). This confirms that the constraints are interlinked and that managing one (e.g., acidity and organic matter) can positively influence others.

FCC Class: SBe+ac-nk: Sandy topsoil (S), Subsoil with higher Clay (Be+), acidic (ac), nitrogen and potassium deficiencies (nk),.

Dose Values are per hectare.

Methods indicate recommended application strategy

sample	Depth In (cm)	pH	Organic Carbon %	Total Nitrogen %	Available p (mg/kg)	Potassium (cmol/kg)	CEC (cmol /kg)	Textural Class	FCC Class	Limitation	Recommendation /Amendment	Dose	Method
L1	0-20	5.3	1.5	0.9	12.1	0.18	6.2	Sandy Loam	SBe-ac-nk	Acidic, low O.M, Low CEC	Organic Manure	5-10 tons/ha	Incorporation / Broadcasting
L2	0-20	4.9	1	0.07	8.5	0.12	5.1	Sandy Loam	SBe-ac-nk	Acidic, N/K Deficiency	NPK fertilizer and Compost Manure	60 kg N/ha, 40 kg P ₂ O ₅ /ha, 40 kg K ₂ O/ha	Broadcast and Mix
L3	0-20	5.2	1.4	0.1	10.2	0.17	6.5	Sandy Loam	SBe-ac-nk	Low Fertility, Sandy	Mulching/cover crop	3-5tons/ha	Surface Application
L4	0-20	4.8	0.9	0.06	7.1	0.11	4.9	Sandy Loam	SBe-ac-nk	Aluminum Toxicity,	Green Manure and Organic Matter	3tons/ha and 5tons/ha	Incorporate into soil
L5	0-20	5.3	1.2	0.08	9.6	0.17	6.3	Sandy Loam	SBe-ac-nk	Low CEC, N/K Deficiency	Integrated Fertilizer and Compost	60 kg N/ha, 40 kg P ₂ O ₅ /ha, 40 kg K ₂ O/ha and Compost	Broadcast/ Incorporate
L1	20-40	5.1	1	0.06	8.2	0.13	6.5	Sandy Loam	SBe-ac-nk	Subsoil Acidity, N/k low	Organic Manure	5-10tons/ha	Incorporation
L2	20-40	4.7	0.7	0.04	5.1	0.08	5.3	Sandy Loam	SBe-ac-nk	Nutrient Leaching	NPK and Compost	60 kg N/ha, 40 kg P ₂ O ₅ /ha, 40 kg K ₂ O/ha and Compost	Broadcast/ Incorporate
L3	20-40	4.9	0.9	0.05	6.8	0.12	7.1	Sandy Loam	SBe-ac-nk	Low Fertility, Clay Increase	Mulching/Cover crop	3-5ton/ha	Surface Application



L4	20-40	4.6	0.6	0.03	4.5	0.06	5	Sandy Loam	SBe-ac-nk	Aluminum Toxicity	Green Manure and Organic Manure	3tons/ha+5tons/ha	Incorporation into the Soil
L5	20-40	5	0.8	0.05	6.4	0.11	6.6	Sandy Loam	SBe-ac-nk	Low CEC, N/K Deficiency	Integrated Fertilizer and Compost	60 kg N/ha, 40 kg P ₂ O ₅ /ha, 40 kg K ₂ O/ha and Compost	Broadcast/ Incorporate

Fertility Capability Classification (FCC)

Using the FCC system, the soils of Nekede were classified as SBe⁺-ac-nk. This classification indicates a sandy topsoil with low CEC, a subsoil with higher clay content, and significant acidity, leading to aluminum toxicity. The deficiencies in nitrogen and potassium further limit the soils' fertility, making them unsuitable for optimal crop production without intervention this was in line with the study of Sanchez et al., 2003; Srinivasa et al., 2022) on Fertility Capability Classification (FCC) for sustainable land management.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The soils in the Nekede area was assessed and classified of its fertility capability, the soils were found to be severely degraded, with significant fertility constraints. The soils were characterized by a sandy texture, strong acidity, low nutrient retention capacity, and multiple nutrient deficiencies. The FCC classification of SBe⁺-ac-nk highlights these constraints and provides a framework for soil management.

Recommendations

The classification highlights constraints that limit crop production. Targeted interventions are necessary to restore fertility and enhance sustainability. I recommend the following;

Soil Acidity Amelioration through the application of organic manure at 5–10 tons/ha to raise pH and reduce aluminum toxicity.

Nutrient Management by Integrating the application of NPK fertilizer and organic amendments to address nitrogen and potassium deficiencies. For example, 60 kg N/ha, 40 kg P₂O₅/ha, 40 kg K₂O/ha combined with compost or green manure.

Soil Conservation Practices through the adoption of mulching, cover cropping, and conservation tillage to enhance soil structure and organic matter retention

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