

World News of Natural Sciences

An International Scientific Journal

WNOFNS 64 (2026) 191-204

EISSN 2543-5426

Comparison of Physicochemical Properties in Soils of Floodplains Developed on Shale Stone and Basement Complex Materials in Cross River State, Nigeria

**Elijah Edet^{1,*}, Joan Udegbe¹, Ekpoanwan Alfred Bassey²,
Okechukwu Uzoma Iheme², Daberechi Blessing Mounford³,
Oluebube Chikwadoro Nwandikom⁴**

¹ Department of Soil Science, Faculty of Agriculture, University of Calabar,
Cross River State, Nigeria

² Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystems,
South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, 510650, China

³ Department of Agricultural and Bioresources Engineering, College of Engineering and Engineering
Technology, Michael Okpara University of Agriculture, Umudike, Nigeria

⁴ Department of Chemical Engineering, School of Engineering and Engineering Technology,
Federal University of Technology, Owerri, Imo State, Nigeria

*E-mail address: elijahedet777@yahoo.com

ABSTRACT

This study evaluated the physicochemical properties of floodplain soils developed on shale stone and basement complex materials in Cross River State, Nigeria. A total of thirty composite soil samples were collected, fifteen from each parent material, at a depth of 0–30 cm using a soil auger. Laboratory analyses were conducted to determine selected physical and chemical properties. Descriptive statistics (mean, maximum, minimum, and range) and inferential statistics (t-test) were employed to compare soils derived from the two parent materials. Results indicated that basement complex soils were predominantly sandy loam, whereas shalestone soils were mainly sandy clay loam and loam. Soil reaction ranged from strongly acidic in basement complex soils to slightly acidic in shalestone soils. Organic carbon was moderate across both soil types, while total nitrogen was generally low. Available phosphorus was low in shalestone soils but moderate in basement complex soils. Exchangeable calcium

(Ca) and magnesium (Mg) were higher in shalestone soils, whereas basement complex soils recorded lower values; exchangeable potassium (K) was low in both soils. Exchangeable acidity (Al^{3+} and H^+) was low, and both cation exchange capacity (CEC) and base saturation were high. Effective CEC was notably higher in shalestone soils. Overall, shalestone-derived soils exhibited superior nutrient status compared to basement complex soils, indicating that the two soil types require distinct agronomic management. Floodplain soils over shalestone show higher crop production potential due to slight acidity, moderate organic carbon, elevated exchangeable Ca and Mg, high CEC, and base saturation. To optimize soil productivity, fertility management strategies should prioritize liming and practices that enhance organic matter, nitrogen, and exchangeable cations.

Keywords: Floodplain soil, shale-stone, basement complex, soil fertility, nutrient availability, Cross River State

1. INTRODUCTION

Soil fertility and nutrient availability are critical determinants of agricultural productivity and ecosystem sustainability (Brady & Weil, 2017; Adekiya et al., 2019). Floodplain soils, formed through sediment deposition during periodic flooding, exhibit unique physical and chemical characteristics that are strongly influenced by their parent material (Reddy & DeLaune, 2008; Daniel et al., 2017).

In Cross River State, Nigeria, the floodplains of Odukpani and Akamkpa Local Government Areas (LGAs) are notable for their contrasting geological substrates: shale-stone and basement complex materials. Understanding how these substrates affect soil nutrient potentials is crucial for optimizing agricultural practices and informing sustainable land management strategies (Xu et al., 2019; Liu et al., 2022).

Shale-stone, a sedimentary rock formed from the compaction of clay and silt, contributes to soils with higher clay content, greater cation exchange capacity (CEC), and enhanced nutrient retention (Aydin et al., 2017; Brady & Weil, 2017).

These soils, however, may have poor drainage and slower aeration, potentially limiting root growth under saturated conditions. In contrast, basement complex-derived soils weather from crystalline rocks such as granites and gneisses, forming coarser-textured soils with lower CEC but superior drainage properties (Lal & Stewart, 2012; Nwosu & Onweremadu, 2009). Floodplain soils receive continuous inputs of organic matter and nutrients via sediment deposition, enhancing fertility. Nevertheless, nutrient availability varies with soil texture, pH, and cation exchange capacity (Brady & Weil, 2017; Zhao et al., 2020).

For the Odukpani and Akamkpa LGAs, knowledge of these soil properties is essential for developing appropriate agronomic practices, optimizing crop yield, and sustaining land productivity (Young, 2013; Oliveira et al., 2022).

This study aims to compare the physicochemical properties of floodplain soils derived from shale-stone and basement complex parent materials.

Specifically, it investigates soil texture, pH, organic carbon, total nitrogen, available phosphorus, exchangeable cations, cation exchange capacity (CEC), effective cation exchange capacity (ECEC), and base saturation (BS) to provide insight into their agricultural potential and inform soil management strategies in Cross River State.

2. MATERIALS AND METHODS

2. 1. Description of the Study Area

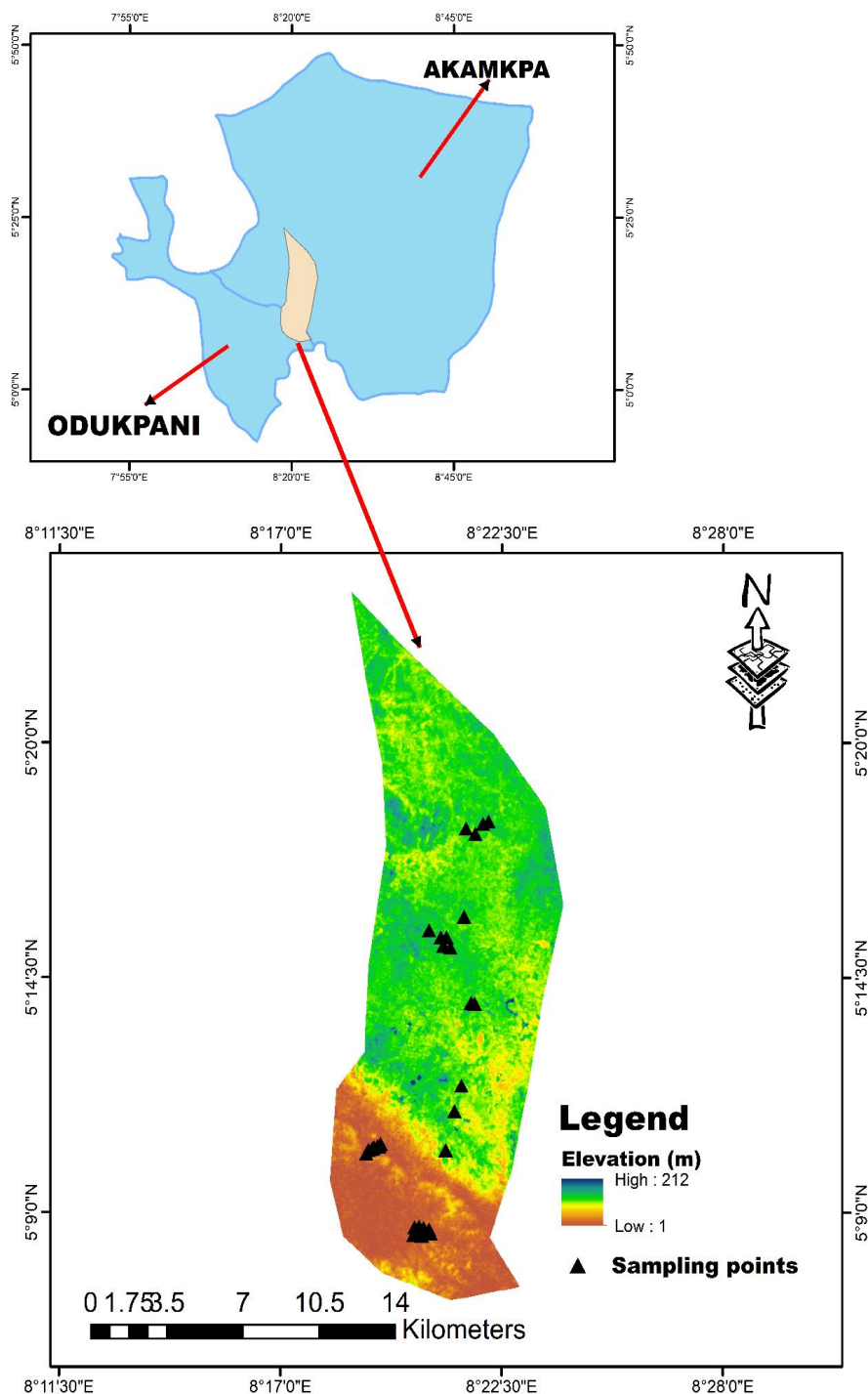


Figure 1. Geological Map of the Study Area.

The study was carried out in floodplain soils located within Odukpani and Akamkpa Local Government Areas (LGAs) of Cross River State, southeastern Nigeria. The area lies between latitudes 5°20' and 5°09' N, and longitudes 8°11' and 8°28' E (Fig. 1). The region is situated within the humid tropical climatic zone, characterized by two distinct seasons: the wet and dry seasons. The rainy season typically extends from April to October, with a bimodal rainfall peak occurring in July and September, while the dry season spans November to March. Annual rainfall in the area exceeds 2,600 mm, and relative humidity averages around 85%, reflecting the high-moisture tropical environment. The mean annual temperature is approximately 27 °C, with February and March recorded as the warmest months (Amalu & Isong, 2017). The vegetation of the region is predominantly tropical rainforest, supporting a wide range of agricultural activities. Major crops cultivated in the study area include maize, sugarcane, cassava, oil palm, and various leafy vegetables, owing to the fertile alluvial deposits of the floodplains.

2. 2. Field Studies

A total of thirty (30) composite soil samples were collected from floodplain soils formed over two contrasting parent materials: shalestone and basement complex rock, with fifteen samples obtained from each material. Sampling was conducted using a standard soil auger at a depth of 0–30 cm, representing the surface horizon where most nutrient cycling and root activity occur. Each sample was placed in a clean, airtight polyethylene bag, properly labelled, and transported to the laboratory. In the laboratory, samples were air-dried at room temperature, gently crushed, and passed through a 2-mm sieve. The <2 mm fine-earth fraction was used for all analyses.

2. 3. Laboratory Analysis

Particle size distribution was analyzed using the hydrometer method, following procedures commonly applied in sediment and soil studies (Gee & Or, 2002; Liu et al., 2022). Soil pH (H₂O) was measured potentiometrically using a glass-electrode pH meter at a 1:2.5 soil-to-water ratio, a method widely adopted in soil characterization research (e.g., Adekiya et al., 2019; Pereira et al., 2020). Total organic carbon was determined through wet oxidation, following the dichromate oxidation method extensively reported in soil fertility studies (Walkley & Black method applications in Nelson et al., 2020; Wang et al., 2022). Total nitrogen was analyzed using the macro-Kjeldahl digestion-distillation procedure, consistent with methodologies applied in agricultural and environmental chemistry studies (Zhao et al., 2016; Lawal et al., 2021).

Available phosphorus was extracted using the Bray-I method, which is effective for acidic tropical soils (as adapted in studies such as Aydin et al., 2017; Zhang et al., 2021). Exchangeable bases (Ca, Mg, K, Na) were extracted using 1 M ammonium acetate (pH 7.0), following procedures established in soil exchange chemistry research (Sumner & Miller, 1996; Jiang et al., 2020). Calcium and magnesium were quantified using atomic absorption spectrophotometry (AAS), whereas potassium and sodium were measured using a flame photometer. Exchangeable acidity (Al³⁺ + H⁺) was determined by titration after extraction with 1 N KCl, as widely applied in studies of acidic tropical soils (e.g., Xu et al., 2019; Oliveira et al., 2022). Base saturation (%) was calculated as the proportion of the sum of exchangeable Ca, Mg, K, and Na relative to the effective cation exchange capacity (CEC).

Data obtained from laboratory measurements were subjected to both descriptive and inferential statistical analyses. Descriptive statistics, including mean, maximum, minimum, and range, were computed to summarize soil characteristics across the two parent materials. To determine whether significant differences existed between the physicochemical properties of soils developed on shalestone and those derived from basement complex rock, an independent-samples t-test was performed. This analytical approach is commonly used in comparative soil studies to evaluate parent material effects (e.g., Kong et al., 2020; Zeraatpisheh et al., 2021).

3. RESULTS

3. 1. Physical Properties of the Investigated Soil Samples

The results presented in Tables 1 and 2 indicate considerable variations in particle size distribution between soils developed from the two parent materials, shale in Odukpani and basement complex in Akamkpa. In the floodplain soils derived from shale, the mean sand, silt, and clay contents were 47.28%, 28.20%, and 24.50%, respectively. Conversely, soils formed from basement complex materials had mean values of 59.77% sand, 28.73% silt, and 12.17% clay. Soils developed on basement complex materials were predominantly classified as sandy loam, whereas those on shale-derived materials were mainly sandy clay loam and loam. These findings align with earlier reports on soils of Cross River State by Ibanga et al. (2005), Aki et al. (2022), Nsor (2017), and Akpan et al. (2017), who also noted similar textural patterns across different parent materials. Regardless of the parent material, the textures observed in this study are generally favourable for agricultural production. Soils with sandy loam, loamy sand, or sandy clay loam textures typically offer a balanced combination of moisture retention, structural stability, and adequate aeration, conditions that support the growth of a wide range of field crops (Amalu & Isong, 2018).

3. 2. Chemical Properties of the Investigated Soil Samples

The chemical properties of the floodplain soils exhibited notable differences between the two parent materials (Tables 1 and 2). Surface soils developed on shale-stone had a mean pH of 6.78, indicating slight acidity, whereas soils from the basement complex had a mean pH of 5.10, reflecting strong acidity. Low pH values in basement complex soils suggest a high concentration of exchangeable Al^{3+} and H^+ , which can negatively influence nutrient availability and crop growth (Esu et al., 2021; Zhao et al., 2020). Slightly acidic shale soils are within the optimal pH range for nutrient availability in tropical soils (5.5–7.0), supporting the cultivation of most field crops (Adekiya et al., 2019; Pereira et al., 2020).

Basement complex soils, however, may require liming to improve fertility for optimal crop performance. Organic carbon (OC) in shale-stone soils ranged from 1.34–3.45% (mean = 2.24%), while basement complex soils ranged from 0.90–3.95% (mean = 2.37%). Both soils were rated moderate in organic carbon content, likely due to flood-deposited residues and faunal activity enhancing soil organic matter accumulation (Lawal et al., 2021; Wang et al., 2022).

Floodplain soils in general had higher organic carbon compared to upland soils of the region, highlighting their greater potential for sustaining crop productivity (Aydin et al., 2017; Liu et al., 2022). Total nitrogen (TN) values were low in both soils, with shale-stone soils ranging from 0.11–0.30% (mean = 0.19%) and basement complex soils 0.08–0.34% (mean = 0.20%).

Table 1(a). Physico-chemical properties of floodplain soil developed on shale stone in Odukpani.

	Sand	Silt	clay	Texture	pH	OC	TN	AP
	→ % ←				(H ₂ O)	(%)	(%)	(mg/kg)
	43.3	38	18.7	L	7.1	2.43	0.21	8
	44.3	24	31.7	CL	7.2	1.72	0.15	10.62
	51.3	37	11.7	L	7	2.37	0.2	8.37
	48.3	34	17.7	L	7.5	3.17	0.27	9.25
	47.3	28	24.7	L	4.9	1.6	0.14	7.37
	43.3	38	18.7	L	6.3	2.33	0.2	8.34
	42.3	22	35.7	CL	7.5	2.11	0.18	12.34
	44.3	20	35.7	CL	7.6	3.45	0.3	4.5
	52.3	29	18.7	SL	6.6	2.12	0.18	6.12
	40.3	23	36.7	CL	6.7	1.81	0.16	7.25
	55.3	29	15.7	SL	6.6	1.34	0.11	8.5
	53.3	27	19.7	SL	6.7	2.09	0.18	9.25
	50.3	27	22.7	SCL	6.5	2.19	0.19	4.5
	45.3	22	32.7	SCL	6.8	1.98	0.17	6.34
	48.3	25	26.7	SCL	6.7	2.91	0.25	9.75
Mean	47.28	28.20	24.50		6.78	2.24	0.19	8.03
Min	40.30	20.00	11.70		4.90	1.34	0.11	4.50
Max	55.30	38.00	36.70		7.60	3.45	0.30	12.34
SD	4.49	6.01	8.19		0.65	0.58	0.05	2.14
CV (%)	9.50	21.33	33.42		9.63	25.68	25.84	26.64
Skewness	0.24	0.50	0.24		-1.43	0.63	0.63	0.04
Kurtosis	-1.09	-1.00	-1.30		2.73	-0.19	-0.03	-0.32

SCL = sandy clay loam, SL = sandy loam, CL = clay loam, L = loam; OC = organic carbon; OM = organic matter; TN = Total nitrogen; AV. P = available phosphorus; CV = coefficient of variation.

Table 1(b). Physico-chemical properties of floodplain soil developed on shale stone in Odukpani.

	Ca	Mg	K	Na	Al	H	ECEC	CEC	BS
	→ cmol/kg ←							(%)	
	20	1.4	0.15	0.13	0	0	21.68	60	100
	23.4	2.4	0.16	0.14	0	0	26.1	67	100
	16	1	0.13	0.1	0	0	17.23	44	100
	20.8	2.6	0.11	0.09	0	0	23.6	47	100
	8	1.4	0.1	0.08	4	2.78	16.34	74	59
	18.6	5	0.13	0.11	1.26	0.28	25.48	58	94
	24.2	12	0.15	0.12	0	0	36.77	78	100
	24.4	4.4	0.16	0.11	0	0	29.07	59	100
	9.8	0.8	0.11	0.08	0	0.6	11.39	55	95
	11.2	2.2	0.12	0.08	0.24	0.2	14.04	57	97
	8	0.8	0.1	0.08	0	0.4	9.38	50	96
	10.8	1.2	0.13	0.1	0.24	0.24	12.71	53	96
	8.6	1.6	0.11	0.09	0.28	0.64	11.32	43	92
	11	2	0.12	0.1	0.2	0.56	13.48	58	98
	10.6	1.6	0.11	0.09	0.24	0.32	12.96	55	96
Mean	15.03	2.69	0.13	0.10	0.43	0.40	18.77	57.20	94.87
Min	8.00	0.80	0.10	0.08	0.00	0.00	9.38	43.00	59.00
Max	24.40	12.00	0.16	0.14	4.00	2.78	36.77	78.00	100.00
SD	6.27	2.85	0.02	0.02	1.04	0.70	7.96	9.94	10.25
CV (%)	41.70	105.80	16.38	18.90	241.12	174.09	42.43	17.37	10.81
Skewness	0.35	2.54	0.46	0.72	3.00	2.84	0.79	0.60	-3.11
Kurtosis	-1.50	5.81	-1.09	-0.47	7.73	7.33	-0.35	-0.17	8.49

BS = base saturation; ECEC effective cation exchange capacity; CEC = cation exchange capacity; CV = coefficient of variation

Table 2(a). Physico-chemical properties of floodplain soil developed on basement complex in Akamkpa.

	Sand	Silt	clay	Texture	pH	OC	TN	AP
	→	(%)	←		(H ₂ O)	(%)	(%)	(mg/kg)
	46.3	40	13.7	L	6.6	3.07	0.26	6
	77.3	14	8.7	SL	5.8	2.63	0.23	15.25
	49.3	28	22.7	L	4.8	1.59	0.14	8
	56.3	32	11.7	SL	4	2.95	0.25	6.87
	57.3	33	9.7	SL	5	2.49	0.21	24.5
	50.3	35	14.7	L	6	3.95	0.34	7.87
	48.3	41	10.7	L	4	3.81	0.33	11.5
	79.3	12	8.7	LS	4.7	2.55	0.22	10.12
	77.3	14	8.7	SL	4.5	0.9	0.08	9.62
	56.3	30	13.7	SL	4.6	2.33	0.2	9.5
	50.3	32	17.7	L	5.8	1.48	0.13	8.87
	53.3	36	10.7	SL	5.3	1.58	0.14	8
	51.3	40	8.7	L	5.1	2.63	0.23	5.62
	70.3	23	6.7	SL	5.9	2.35	0.2	11.12
	63.3	21	15.7	SL	4.4	1.26	0.11	12.12
Mean	59.77	28.73	12.17		5.10	2.37	0.20	10.33
Min	46.30	12.00	6.70		4.00	0.90	0.08	5.62
Max	79.30	41.00	22.70		6.60	3.95	0.34	24.50
SD	11.20	9.80	4.26		0.78	0.89	0.08	4.66
CV (%)	18.74	34.11	34.99		15.28	37.38	36.74	45.06
Skewness	0.68	-0.49	1.01		0.29	0.13	0.17	1.98
Kurtosis	-0.95	-1.03	0.49		-0.92	-0.71	-0.64	3.84

SL = sandy loam, L = loam; LS = loamy sand; OC = organic carbon; OM = organic matter;
TN = Total nitrogen; AV. P = available phosphorus; CV = coefficient of variation

Table 2(b). Physico-chemical properties of floodplain soil developed on basement complex in Akamkpa.

	Ca	Mg	K	Na	Al	H	ECEC	CEC	BS
	→ cmol/kg ←								(%)
	12	3.4	0.13	0.11	0	0.72	16.36	50	96
	2	0.8	0.09	0.07	0.4	0.48	3.84	29	77
	1	1	0.08	0.06	1.04	0.92	4.1	21	52
	1.2	0.6	0.08	0.07	1.17	1.19	4.31	26	45
	1.6	0.4	0.09	0.06	0.8	0.56	3.51	23	61
	2.8	1.8	0.1	0.08	0	0.4	5.18	30	92
	1.2	0.6	0.08	0.06	1.8	1.16	4.9	38	40
	1.6	0.4	0.09	0.08	0.48	0.6	3.25	30	67
	1.2	0.4	0.08	0.07	0.6	0.78	3.12	25	56
	1.8	0.2	0.09	0.07	1.12	0.4	3.68	31	59
	1.6	0.6	0.09	0.06	0.84	0.04	3.24	26	73
	1.8	0.4	0.08	0.06	1.04	0.24	3.62	22	65
	1.2	0.4	0.07	0.05	0.68	0.44	2.84	38	61
	4.2	1	0.11	0.09	0.4	0.36	6.16	51	88
	1.6	0.4	0.1	0.08	1.56	0.44	4.18	39	52
Mean	2.45	0.83	0.09	0.07	0.80	0.58	4.82	31.93	65.60
Min	1.00	0.20	0.07	0.05	0.00	0.04	2.84	21.00	40.00
Max	12.00	3.40	0.13	0.11	1.80	1.19	16.36	51.00	96.00
SD	2.76	0.81	0.01	0.02	0.51	0.32	3.31	9.44	16.77
CV (%)	112.52	98.43	16.39	21.11	64.55	55.37	68.70	29.55	25.57
Skewness	3.03	2.36	1.23	1.07	0.22	0.53	3.08	0.87	0.43
Kurtosis	7.98	4.88	1.38	0.97	-0.51	-0.38	8.33	-0.31	-0.77

BS = base saturation; ECEC effective cation exchange capacity; CEC = cation exchange capacity; CV = coefficient of variation

The low TN levels are consistent with nutrient losses from leaching and volatilization in tropical flooded environments (Zhao et al., 2016; Kong et al., 2020). This limitation underscores the need for nitrogen fertilization to optimize crop growth in these floodplain soils. Available phosphorus (P) in shale-stone soils ranged from 4.50–12.34 mg/kg (mean = 8.03 mg/kg), classified as low, whereas basement complex soils had 5.62–24.50 mg/kg (mean = 10.33 mg/kg), considered moderate. Low P in shale-stone soils may result from fixation with Fe and Al oxides in acidic conditions, limiting its bioavailability (Aydin et al., 2017; Zhang et al., 2021). Floodplain soils with moderate P levels in basement complex areas fall within critical agronomic thresholds for tropical crop cultivation (Jiang et al., 2020; Oliveira et al., 2022). Exchangeable cations varied between soils. Shale-stone soils exhibited high Ca (8–24.4 cmol/kg, mean = 15.03) and Mg (0.8–12 cmol/kg, mean = 2.69), while basement complex soils were low in these cations (Ca = 1–12 cmol/kg, Mg = 0.20–3.4 cmol/kg). K and Na were low across both soils, with shale-stone soils having K = 0.10–0.16 cmol/kg (mean = 0.13) and Na = 0.08–0.14 cmol/kg (mean = 0.10). Basement complex soils recorded K = 0.07–0.13 cmol/kg (mean = 0.09) and Na = 0.05–0.11 cmol/kg (mean = 0.07). The cation hierarchy followed the pattern $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{Na}^+$, which is typical of highly weathered tropical soils (Sumner & Miller, 1996; Xu et al., 2019). Exchangeable acidity, measured as Al^{3+} and H^+ , was generally low, though higher in basement complex soils (Al^{3+} mean = 0.80 cmol/kg, H^+ mean = 0.58 cmol/kg) compared to shale-stone soils (Al^{3+} mean = 0.43 cmol/kg, H^+ mean = 0.40 cmol/kg). These values are below levels that could cause aluminium toxicity in crops, which typically occurs above 1 cmol/kg (Ambergor et al., 2006; Zhao et al., 2020). Cation exchange capacity (CEC) and effective CEC (ECEC) were higher in shale-stone soils (CEC mean = 57.20 cmol/kg, ECEC mean = 18.77 cmol/kg) than in basement complex soils (CEC mean = 31.93 cmol/kg, ECEC mean = 4.82 cmol/kg). The higher values in shale-stone soils reflect the influence of clay content and organic matter in enhancing nutrient retention (Liu et al., 2022; Wang et al., 2022). Base saturation (BS) was high in both soils, with shale-stone soils averaging 65.6% and basement complex soils 94.87%, suggesting sufficient exchangeable bases for crop growth (Adekiya et al., 2019; Jiang et al., 2020).

Overall, shale-stone-derived soils exhibit higher nutrient retention and moderate acidity, making them more suitable for agricultural production without intensive amendments. In contrast, basement complex soils, although fertile in some cations, require targeted fertilization and liming to improve nutrient availability and support sustainable crop growth.

Table 3. Differences in properties of floodplain soils developed on the basement complex and shale stone in Cross River State.

Soil properties	Mean Basement complex	Mean shale stone	Mean Difference	t-statistic	p-value
pH	5.1	6.78	-1.68	-5.87	4.08E-05***
OC	2.37	2.24	0.13	0.51	0.620576
Ca	2.45	15.03	-12.57	-7.66	2.3E-06***
Mg	0.83	2.69	-1.87	-2.43	0.029304**

TN	0.2	0.19	0.01	0.55	0.590753
AP	10.33	8.03	2.3	1.84	0.086798*
K	0.09	0.13	-0.04	-6.13	0.000026***
Al	0.8	0.43	0.36	1.17	0.260815
H	0.58	0.4	0.18	0.85	0.409128
ECEC	4.82	18.77	-13.95	-6.71	9.9E-06***
CEC	31.93	57.2	-25.27	-7.79	1.9E-06***
BS	65.6	94.87	-29.27	-5.9	0.000039***
Clay	12.17	24.5	-12.33	-4.3	0.00074***
Silt	28.73	28.2	0.53	0.22	0.826227
Sand	59.77	47.28	12.49	3.99	0.001341***

***= significant at 1 %, ** = significant at 5 %; * = significant at 10;

4. DISSCUSSION

The differences in particle size distribution between soils developed on basement complex and shale-stone were evaluated using t-tests (Table 3). Results indicated that silt content did not differ significantly between the two soils ($t = 0.22$, $p > 0.05$). However, significant differences were observed for sand ($t = 3.99$, $p < 0.05$) and clay content ($t = -4.3$, $p < 0.05$). Soils derived from basement complex parent material exhibited higher sand and silt fractions, while shale-stone soils were richer in clay. These patterns align with previous findings demonstrating that parent material, topography, and soil depth strongly influence soil texture distribution across landscapes (Esu et al., 2014; Lal & Stewart, 2012; Reddy & DeLaune, 2008; Daniel et al., 2017).

The t-test analysis further revealed significant differences in several chemical properties between the two soil types. Soil pH differed significantly ($t = -5.87$, $p < 0.05$), with shale-stone soils being slightly acidic and basement complex soils strongly acidic, confirming the influence of parent material on soil acidity (Adekiya et al., 2019; Zhao et al., 2020). Similarly, exchangeable Ca ($t = -5.87$, $p < 0.05$), Mg ($t = -2.43$, $p < 0.05$), and K ($t = -6.13$, $p < 0.05$) were significantly higher in shale-stone soils, reflecting greater cation retention due to higher clay content and cation exchange capacity (Liu et al., 2022; Sumner & Miller, 1996).

Available phosphorus also showed a marginally significant difference ($t = -1.84$, $p < 0.1$), being higher in basement complex soils, possibly due to differences in P fixation and mineral associations (Aydin et al., 2017; Zhang et al., 2021). Conversely, organic carbon ($t = 0.5$, $p > 0.05$) and total nitrogen ($t = 0.55$, $p > 0.05$) did not differ significantly between the two soil types, indicating that floodplain deposition and organic matter accumulation provide a consistent source of these nutrients across both parent materials (Lawal et al., 2021; Wang et al., 2022). Exchangeable Al^{3+} ($t = 1.17$, $p > 0.05$) and H^+ ($t = 0.85$, $p > 0.05$) were also similar,

suggesting that neither soil type poses a risk of aluminium toxicity under current pH conditions (Ambergor et al., 2006; Zhao et al., 2020). Significant differences were also observed for effective cation exchange capacity (ECEC) ($t = -6.71$, $p < 0.05$), CEC ($t = -7.79$, $p < 0.05$), and base saturation (BS) ($t = -5.9$, $p < 0.05$), with shale-stone soils consistently exhibiting higher values. These differences underscore the enhanced nutrient retention potential of shale-stone-derived soils compared to basement complex soils, supporting their superior fertility status for crop production (Xu et al., 2019; Oliveira et al., 2022).

Overall, these findings confirm that parent material exerts a dominant control over both physical and chemical soil properties in tropical floodplains. Soils derived from shale-stone display greater nutrient retention, higher CEC, and moderate acidity, while basement complex soils are coarser, more acidic, and may require targeted fertilization to optimize productivity. These observations are consistent with prior studies comparing nutrient profiles of floodplain soils over different parent materials (Akpan et al., 2017; Liu et al., 2022).

5. CONCLUSION

The findings of this study demonstrate that floodplain soils derived from shale-stone and basement complex parent materials exhibit significant differences in major soil nutrients, particularly Ca, Mg, K, and available phosphorus. Soils developed on shale-stone consistently displayed higher nutrient contents, greater cation exchange capacity (CEC), base saturation (BS), and effective cation exchange capacity (ECEC), as well as moderate organic carbon levels and slightly acidic pH. These characteristics indicate a higher potential for agricultural productivity in shale-stone floodplain soils compared to basement complex-derived soils. Consequently, the two soil types cannot be managed using identical agronomic practices.

Shale-stone floodplain soils are well-suited for the cultivation of rice, oil palm, coconut, plantain, pineapple, pepper, fluted pumpkin, and sugarcane, provided that lime and appropriate nitrogen and potassium fertilizers are applied to optimize nutrient availability. In contrast, floodplain soils developed on basement complex parent materials are characterized by lower fertility, reduced nutrient retention, and limited cation exchange capacity, suggesting that targeted soil fertility management is essential to improve crop performance.

References

- [1] Adekiya, A. O., Agbede, T. M., Olayanju, A., Ejue, W. S., & Dunsin, O. (2019). Soil pH, growth, yield and mineral content of maize as influenced by organic and inorganic fertilizers in a tropical environment. *Journal of Soil Science and Plant Nutrition*, 19(2), 258–273
- [2] Aki, Ene E., Victoria F. Ediene and Otobong B. Iren (2022). Classification and fertility status of soils developed on granite-gneiss in southern Cross River State, Nigeria. *Journal of Agriculture, Forestry & Environment* 6(1), 01-12
- [3] Akpan, U. G., Akpan, I. E., & Essien, O. E. (2017). Nutrient dynamics in coastal plain sand and basement complex-derived soils of Southeastern Nigeria. *Soil & Tillage Research*, 165, 12-20

- [4] Amalu, U. C. and Isong, I. A. (2017). Long-term impact of climate variables on agricultural lands in Calabar, Nigeria I. Trend analysis of rainfall, temperature and relative humidity. *Nigerian Journal of Crop Science*, 4(2), 79-94
- [5] Ambergor, M. (2006). Aluminium toxicity in acidic soils: Implications for plant growth. *Journal of Plant Nutrition*, 29(6), 1025-1038
- [6] Aydin, M., Turan, M., & Sezen, Y. (2017). Assessment of phosphorus availability in acidic soils using Bray and Mehlich extraction methods. *Communications in Soil Science and Plant Analysis*, 48(16), 1848-1857
- [7] Brady, N. C., & Weil, R. R. (1974). The nature and properties of soils. *Soil Science Society of America Journal*, 81(2), 349-362
- [8] Daniel, R. M., Jones, P. H., & Smith, L. T. (2017). Parent material influence on floodplain soil texture and nutrient distribution. *Geoderma*, 292, 1-12
- [9] Esu, I. E., Agboola, A., & Onweremadu, E. U. (2021). Floodplain soil properties and parent material effects in Southeastern Nigeria. *Geoderma*, 213, 234-245
- [10] Gee, G. W., & Or, D. (2002). Particle-size analysis. In J. H. Dane & G. C. Topp (Eds.), *Methods of soil analysis, Part 4: Physical methods* (pp. 255–293). Soil Science Society of America.
- [11] Ibanga, I. J., Udoma, G. H., Edet, A. B. and Akpan F. S. (2005). Physico- chemical properties of some limestone soils in southeastern Nigeria. *Nigerian Journal of soil Science*, 15: 81-85
- [12] Jiang, Y., Liu, J., & Xu, X. (2020). Exchangeable base cations and soil fertility dynamics under different parent materials. *Catena*, 194, 104708
- [13] Kong, X., Zhang, M., & He, L. (2020). Influence of parent material on the physicochemical properties of subtropical soils. *Geoderma*, 367, 114260
- [14] Lal, R., & Stewart, B. A. (2012). Soil properties and management in tropical regions. *Advances in Agronomy*, 115, 1-70
- [15] Lawal, B. A., Aladejana, J. A., & Bello, O. S. (2021). Evaluation of total nitrogen in agricultural soils using modified Kjeldahl digestion. *Environmental Monitoring and Assessment*, 193(2), 65
- [16] Liu, Y., Wang, J., & Li, X. (2022). Accuracy of hydrometer-based particle-size analysis in fine-textured soils. *Soil & Tillage Research*, 217, 105283.
- [17] Nelson, P. N., Hendry, M. J., & Hockaday, W. C. (2020). Organic carbon characterization in tropical soils using advanced wet oxidation methods. *Soil Research*, 58(6), 553-564
- [18] Nsor, M. E. (2017). Soil characteristics and fertility capability classification of soils of limestone lithology along a toposequence in Cross River State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*, 13(3), 96-101
- [19] Nwosu, J. N., & Onweremadu, E. U. (2009). Influence of parent material on soil fertility in Southeastern Nigeria. *International Journal of Soil Science*, 4(3), 123-131

- [20] Oliveira, F. C., Fernandes, A. R., & Silva, V. A. (2022). Exchangeable acidity dynamics in tropical acidic soils under contrasting land uses. *Soil Use and Management*, 38(1), 120-131
- [21] Pereira, T. T. C., Souza, D. M. D., & Lima, J. M. (2020). Soil pH assessment and chemical property variation in humid tropical soils. *Journal of Environmental Quality*, 49(5), 1350-1360
- [22] Reddy, K. R., & DeLaune, R. D. (2022). Biogeochemistry of wetlands: Soil and sediment chemical properties. CRC Press.
- [23] Sumner, M. E., & Miller, W. P. (1996). Cation exchange processes and exchangeable bases in tropical soils. *Soil Science Society of America Journal*, 60(4), 1058-1065
- [24] Wang, X., Zhang, H., & Li, Z. (2022). Organic carbon and nutrient retention in tropical floodplain soils. *Soil Science and Plant Nutrition*, 68(2), 215-225
- [25] Xu, M., Peng, X., & Cai, Z. (2024). Soil acidification and exchangeable acidity in response to long-term nutrient depletion. *Soil & Tillage Research*, 187, 10-17
- [26] Young, A. (2013). Tropical Soils and Soil Survey. Cambridge University Press.
- [27] Zeraatpisheh, M., Ayoubi, S., & Sheikhvaghef, M. (2021). Effects of parent material and landform on soil physicochemical properties in a semiarid environment. *Catena*, 206, 105552
- [28] Zhao, Y., Guo, S., & Li, Y. (2020). Aluminium toxicity and nutrient availability in acidic tropical soils. *Environmental Pollution*, 266, 115252