

INVESTIGATING THE RELATIONSHIP BETWEEN SOIL PHYSIO-CHEMICAL PROPERTIES AND POTASSIUM FORMS IN SOUTHEASTERN NIGERIA

ABSTRACT

This study was conducted to explore the intricate relationship between soil physio-chemical properties and potassium (K) forms in tropical soil ~~ofs from~~ southeastern Nigeria. ~~Soils of the-~~ region ~~are~~ characterized by diverse geological parent materials, including coastal plain sand, alluvium, shale, sandstone, and basement complex. A systematic sampling approach was employed, involving soil collection at three depths (0–20 cm, 20–40 cm, and 40–60 cm) across 45 sites, based on detailed geological maps. Laboratory analyses ~~of collected samples were carried out for-~~ measured soil pH, texture, organic carbon, cation exchange capacity (CEC), and ~~various-~~ potassium fractions: (-total, water-soluble, exchangeable, non-exchangeable, and mineral K); using standardized protocols. Key findings indicated that soil pH predominantly ranged from 4.37 to 5.47, with basement complex soils exhibiting the highest acidity (pH 4.5–4.7), and sandstone-derived soils showing relatively higher pH (5.3–5.4). Textural analysis revealed high sand content (>81%) in sandstone and coastal plain sands, influencing drainage and nutrient retention. Organic carbon and CEC varied significantly among parent materials, with volcanic soils (sandstone and alluvium) displaying higher organic matter and potassium availability. Correlation analyses showed significant positive relationships ($p < 0.05$) between soil pH, organic carbon, CEC, and potassium forms, especially water-soluble and exchangeable K. Notably, soils derived from sandstone and alluvium parent materials had higher potassium concentrations, suggesting better nutrient availability, whereas acidic, low-CEC soils like shale and basement complex exhibited lower potassium mobility and fixation. These results underscore the critical influence of soil physio-chemical attributes particularly pH, organic matter, and texture on potassium dynamics, which directly impact soil fertility and crop productivity. The findings highlight the need for tailored nutrient management strategies that consider geological and soil property variability to optimize potassium use efficiency and sustain soil health in southeastern Nigeria's diverse agro-ecological zones.

Keywords: Soil Physio-Chemical Properties, Potassium Forms, Soil Fertility, Parent Material, Soil pH, Nutrient Dynamics and Tropical Soils.

1.0 INTRODUCTION

Soil physio-chemical properties are fundamental determinants of soil fertility and influence the availability and dynamics of essential nutrients, including potassium (K). Potassium is a vital macronutrient involved in various physiological processes in plants, such as enzyme activation, osmotic regulation, and photosynthesis (Marschner, 2012). Its bioavailability is largely governed by soil mineralogy, texture, pH, cation exchange capacity (CEC), and organic matter content,

which collectively influence the forms and mobility of potassium within the soil matrix (Sparks, 2003).

In tropical regions such as southeastern Nigeria, the diverse geological substrates give rise to soils with varying physio-chemical characteristics, which can significantly affect potassium retention, fixation, and release (Akinlosotu *et al.*, 2018). Example, soils derived from volcanic parent materials tend to have higher clay content and mineralogical diversity, impacting potassium dynamics differently compared to sandy or lateritic soils (Ojo *et al.*, 2020). Understanding the relationship between soil physio-chemical properties and potassium forms is crucial for developing targeted nutrient management strategies that optimize crop productivity and sustain soil health.

Despite the recognized importance of these factors, limited research has been conducted to delineate the specific interactions and correlations between soil properties and potassium forms in soils of southeastern Nigeria. Most studies have either focused on individual soil properties or nutrient levels without integrating the comprehensive relationship between soil physio-chemical attributes and potassium dynamics (Obalum *et al.*, 2019). Therefore, this study aims to investigate the interrelationship between key soil physio-chemical properties such as pH, CEC, organic carbon, and texture and the various forms of potassium in soils from different parent material within southeastern Nigeria. The findings are expected to contribute valuable insights for soil fertility assessment and management in tropical soils with diverse geological backgrounds.

2.0 Materials and Methods

2.1 Study Area

The study was conducted in southeastern Nigeria, which spans latitudes 4°47'35"N to 7°7'44"N and longitudes 7°54'26"E to 8°27'10"E (Anejionu *et al.*, 2013). Covering approximately 29,095 square kilometers, representing about 3.19% of Nigeria's landmass, the region possesses a humid tropical climate characterized by high temperatures, humidity, and bimodal rainfall patterns. Mean minimum and maximum temperatures range from 21°C to 30°C along the coast and 29°C to 33°C inland (Chukwu, 2007). The climate features high humidity, often exceeding 90% in the mornings, decreasing to 60–80% in the afternoons (Igwe, 2012; Ezemonye and Emeribe, 2012). Rainfall is heavy, ranging from 1500 mm to over 2500 mm annually (Chukwu *et al.*, 2009). The region experiences two distinct seasons: dry (November–April) and rainy (April–October), with a brief dry spell called the “August break” (Ufot *et al.*, 2016).

The soils here are predominantly sandy and low in organic matter, with high susceptibility to erosion and land degradation. They are derived mainly from shale, sandstone, and alluvial parent materials, and are classified as Ultisols, specifically the typic Hapludult (Federal Department of Agriculture and Land Resources (FDALR), 1985; Nwaogu and Ebeniro, 2009). The area features three vegetation zones: mangroves, freshwater swamp forests, and rainforests, with distinct ecological characteristics (Onweremadu *et al.*, 2007). Agriculture is a primary socio-economic activity, with crops such as oil palm, rice, groundnut, cocoa, and rubber, and food crops including yam, cassava, cocoyam, and vegetables. Livestock such as poultry are also prominent.

2.2 Soil Sampling

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Soil samples were collected based on a geological reference map, from five contrasting parent materials: Coastal plain sand, Alluvium, Shale, Sandstone, and Basement complex. Sampling was performed at three depths (0–20 cm, 20–40 cm, 40–60 cm) using soil augers, with three replications per site. The locations, coordinates, land use, and parent material types are detailed in Table 1. A hand-held GPS was used for geolocation (Pansu and Guatheyrus, 2006).

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Table1. Soil Parent Materials and Sample Locations

Parent Material	Location	LGA	State	Latitude	Longitude	Land use
Coastal plain sand	Umudike	Ikwuano	Abia	5.47573	7.55244	Fallow
Coastal plain sand	Umuchima	Isiala Ngwa North	Abia	5.34801	7.34521	Cassava
Coastal plain sand	Umuamachi	Aba North	Abia	5.11422	7.30507	Fallow
Coastal plain sand	Umulogho	Obowo	Imo	5.55285	7.38484	Fallow
Coastal plain sand	Obokwe	Ngor-okpala	Imo	5.52541	6.95813	Cassava and fluted pumpkin
Coastal plain sand	Ubomori	Owerri West	Imo	5.29324	7.08316	Maize, okro and oil palm
Sandstone	Univ.Rd Nsukka	Nsukka	Enugu	6.85333	7.39361	Cassava, plaintain and pear
Sandstone	Amankwo	Udi	Enugu	6.47516	7.25502	Cassava
Sandstone	Ndiagu	Eze agu	Enugu	6.30524	7.21511	Fallow
Shale	Ngbo	Ohaukwu	Ebonyi	6.46722	7.99417	Fallow
Shale	Osebi	Izzi	Ebonyi	6.45305	8.33226	Cassava
Shale	Nwafo Ogu	Abakaliki	Ebonyi	6.19116	8.15923	Fallow
Alluvium	Nzam	Anambra West	Anambra	6.45639	6.72472	Fallow
Alluvium	Onono	Anambra East	Anambra	6.21731	6.78621	Yam, pear, and plantain
Alluvium	Umunankwo	Ogbaru	Anambra	5.93416	6.72904	Cassava and oilpalm
Basement Complex	Awii	Akampa	Cross-River	5.30361	8.36455	Cassava
Basement Complex	Ibine	Ikom	Cross-River	6.20702	8.65921	Cocoyam and pumpkin
Basement Complex	Abinti Abangork	Obubra	Cross-River	5.94102	8.25218	Fallow

2.3 Experimental Design

The study followed a 5×3 factorial design within a Randomized Complete Block Design (RCBD). The factors included parent material type (Coastal plain sand, Alluvium, Shale, Sandstone, Basement complex) and sampling depths (0–20 cm, 20–40 cm, 40–60 cm), with three replicates for each combination, resulting in 45 observation units.

2.4 Sample Preparation

Collected soil samples were air-dried, crushed, and sieved through a 2 mm mesh. The prepared samples were stored appropriately for laboratory analysis of physical and chemical properties and forms of potassium following standard protocols.

2.5 Determination of Physio-chemical Characteristics of Soil

Soil pH (H₂O) was measured in a 1:2.5 soil-to-water suspension using a calibrated pH meter. The soil texture was determined through standard particle size analysis, following the

hydrometer method, to quantify sand, silt, and clay fractions. The textural class was classified according to the USDA soil textural triangle.

Chemical properties were analyzed using standard laboratory procedures. Available phosphorus (P) was determined via the Bray P2 method and expressed in Mg/kg. Total nitrogen (N) was measured using the Kjeldahl method, and organic carbon (OC) was analyzed using Walkley-Black wet digestion method. Organic matter (OM) was calculated using the relationship between soils as a percentage of OC and OM. Exchangeable cations (Ca, Mg, K, Na) were extracted with ammonium acetate and quantified via atomic absorption spectrophotometry. Exchangeable acidity was determined using titration with calcium carbonate. The cation exchange capacity (CEC) was calculated as the sum of exchangeable cations, and base saturation (BS) was derived from CEC and exchangeable bases.

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2.6 Laboratory Analysis of Potassium Forms

Total Potassium (K): Determined via HF-H₂SO₄ digestion (Jackson, 1958; 1964). One gram of soil was digested in a crucible with HF and HClO₄, heated until dryness, cooled, re-digested, transferred to a volumetric flask, and filtered. Potassium concentration was measured using a flame photometer.

Water-soluble Potassium: Extracted by shaking 2.5 g of soil with 50 ml distilled water for 1 hour (Thomas, 1996). The extract was analyzed for K concentration using a flame photometer.

Exchangeable Potassium: 2.5 g of soil was shaken with 1 M NH₄OAc solution (50 ml) for 30 minutes (Thomas, 1996), then allowed to settle. The supernatant was filtered, and 5 ml was analyzed for K content with a flame photometer.

Non-exchangeable or Fixed Potassium: 2.5g of soil sample was weighed and transferred into a test tube. Hot 1M HNO₃ was transferred into the test tube and shaken for 30mins (Pratt, 1965) and allowed to cool and K concentration determined by a flame photometer.

Available Potassium:

This form of K was obtained by summation of solution K and exchangeable K.

Mineral or Structural Potassium: Mineral K was determined by subtracting total K from HNO₃ extractable.

3.0 Results and Discussion

3.1 Soil Physio-Chemical Properties across Different Parent Materials and Depths

The study reveals that soil pH of across different parent materials and depths predominantly falls within the acidic range, with values ranging from 4.37 to 5.47. Across all depths, soil pH values predominantly ranged from slightly acidic to neutral, with the basement complex soils

consistently exhibiting the lowest pH (around 4.5 to 4.7), indicative of higher acidity. In contrast, sandstone-derived soils maintained relatively higher pH values, averaging around 5.3 to 5.4, suggesting less acidity. The alluvial soils showed a moderate pH (5.3 to 5.47), slightly higher than basement complex and sandstone soils, possibly due to the influence of recent sediments. Texture analysis revealed that parent material significantly influences sand, silt, and clay fractions. For instance, sandstone and coastal plain sands (Imo) are characterized by high sand content (>81%), especially at shallow depths, tapering slightly with depth, which implies good drainage but potentially limited nutrient retention. Conversely, alluvium displayed higher silt contents across depths while coastal plain sand (Abia) and shale derived soils displayed highest clay fraction especially at greater depths (-20-40 and 40-60 cm depth respectively), indicating more fine textured soils with higher water retention and cation exchange capacity (CEC). These textural differences support variations in nutrient dynamics, including potassium retention.

Organic carbon (O.C) content generally decreased with increasing depth, consistent with typical organic matter distribution in soils. Notably, the basement complex soil at 0-20 cm had higher organic carbon (2.15%), correlating with their richer organic matter, likely due to deposition from surface runoff. In contrast, shale soils had lower organic carbon levels (0.29%), which may be attributed to lower organic matter input or faster decomposition rates under their texture and acidity.

Total nitrogen was higher (0.35%) in shale at 0-20 cm depth, decreasing at deeper layers at 40-60cm depth (0.05%). The low nitrogen content across the study area reflects typical conditions for tropical soils, often requiring addition of nitrogen fertilizers to meet crop demands corroborating earlier studies like those of Oladipo *et al.* (2017), which highlighted poor nutrient holding capacity and vulnerability to leaching.

Shale soils exhibited the lowest organic carbon at 40-60 cm (0.29%), aligning with their finer texture and lower biological activity. The higher organic matter in surface horizons of basement complex suggests recent organic inputs or better organic matter accumulation, which may influence nutrient availability, including potassium. The elevated cation exchange in these soils underscores their potential for nutrient retention, especially for cations like Ca, Mg, and K.

Available phosphorus (Av. P) was relatively low across all parent material, with the mean value (24.32 mg/kg), with highest value of 36.70 (mg/kg) observed in basement complex aligning with their higher organic matter content. The consistent low levels of phosphorus suggest potential limitations for crop productivity, necessitating fertilizer application or organic amendments.

Table 2: Physico-chemical properties of the studied soils

	pH (H ₂ O)	Sand (%)	Silt (%)	Clay (%)	Av.P (mMg ¹)	T.N Kg ¹ (%)	O.C (%)	Ex. Cations (cmol kg ⁻¹)				TEA (cmol kg ⁻¹)
								Ca	Mg	K	Na	
0-20cm												
Alluvium	5.30	43.73	36.67	19.60	26.87	0.12	1.35	7.20	4.00	0.13	0.13	0.75
Basement complex	4.67	68.20	18.67	13.13	32.33	0.15	2.15	4.53	2.67	0.15	0.12	0.88
Coastal plain sand (Abia)	4.93	61.73	8.67	29.60	24.90	0.10	1.07	2.00	1.07	0.20	0.15	2.61
Coastal plain sand (Imo)	5.20	81.73	4.00	14.27	29.13	0.11	1.32	3.87	1.87	0.15	0.10	1.04
Sandstone	5.34	85.07	4.53	10.40	21.53	0.09	1.50	7.33	4.27	0.15	0.13	0.67
Shale	5.17	69.67	19.20	11.13	17.70	0.35	0.52	3.33	1.73	0.11	0.11	0.72
20-40cm depth												
Alluvium	5.47	35.07	42.00	22.93	21.53	0.07	0.98	8.53	4.00	0.11	0.11	0.93
Basement complex	4.61	68.20	12.00	19.80	36.70	0.13	1.37	2.93	1.73	0.13	0.13	1.49
Coastal Plain sand (ABIA)	5.00	61.07	8.67	30.27	25.87	0.08	1.20	2.40	1.07	0.19	0.12	2.40
Coastal plain sand (IMO)	5.29	79.07	4.00	16.93	25.10	0.17	1.10	3.07	1.47	0.14	0.09	0.80
Sandstone	5.40	81.07	6.13	12.80	20.13	0.07	1.08	6.00	2.67	0.15	0.13	0.59
Shale	4.63	57.67	18.53	23.80	16.07	0.06	0.43	3.60	2.00	0.12	0.11	1.81
40-60cm depth												
Alluvium	5.40	34.40	38.00	27.60	23.53	0.07	0.69	8.13	4.27	0.12	0.12	1.36
Basement complex	4.50	66.87	10.00	23.13	25.03	0.08	0.87	3.33	1.33	0.12	0.12	1.81
Coastal Plain sand (ABIA)	4.83	64.40	8.00	27.60	27.37	0.10	1.24	2.40	0.93	0.20	0.13	2.35
Coastal plain sand (IMO)	5.18	75.07	2.67	22.27	26.43	0.09	1.02	3.20	1.47	0.13	0.10	0.85
Sandstone	5.13	73.07	6.80	20.13	21.70	0.06	0.59	5.73	3.07	0.13	0.11	0.67
Shale	4.37	52.33	16.53	31.13	15.77	0.05	0.29	3.73	1.73	0.10	0.09	3.76
Mean	5.02	64.36	14.73	20.92	24.32	0.11	1.04	4.52	2.30	0.14	0.12	1.42
LSD (0.05) PM	0.45	9.28	6.08	7.15	7.94	NS	0.47	2.27	1.33	0.01	0.02	0.47
LSD(0.05) DE	NS	NS	NS	5.06	NS	NS	0.33	NS	NS	0.01	NS	0.33
LSD (0.05) PM X DE	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.81

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3.2 Potassium Forms and Distribution

The distribution of potassium (K) across different soil types and depths reveals distinct patterns, influenced by mineralogy and organic matter (Table 2). As shown in Table 2, Total potassium

content in the soil's ranges from 0.302 to 0.901 cmol kg^{-1} , with an average mean of 0.605 cmol kg^{-1} across all samples. The highest total K was observed in the basement complex soils at 0.901 cmol kg^{-1} , especially at the surface (0-20cm depth), indicative of the mineral-rich parent material characteristic of this geological setting. This mineral K pool is crucial for long-term fertility, as supported by Oladipo *et al.* (2017). Conversely, the lowest total K was found in the shale soils (0.302 cmol kg^{-1}) at 0-20 cm depth. These variations underscore the influence of parent material, with mineral rich basement complex soils harboring higher total K reserves, whereas shale tend to have lower total K levels.

Water-soluble (Solution) potassium, representing the immediately available form for plant uptake, ranged from 0.155 to 1.003 cmol kg^{-1} . The highest value was recorded in the coastal plain sand (Imo) at 1.003 cmol kg^{-1} at the 20-40 cm depth indicating rapid K availability but also potential leaching losses. Shale ~~exhibit~~exhibits comparatively lower soluble K, with the lowest at 0.155 cmol kg^{-1} . The relatively narrow range suggests that while soluble K is influenced by parent material, it is also modulated by soil texture and moisture conditions. Water-soluble K constitutes a major fraction of available K in sandy soils, aligning with findings by Oladipo and Akinrinde (2014), who noted that sandy terrains tend to have higher soluble K due to minimal fixation.

Exchangeable K, which is readily available for plant uptake and held on soil cation exchange sites. The study revealed that exchangeable K concentrations vary from 0.100 cmol kg^{-1} in shale to 0.203 cmol kg^{-1} coastal plain sand across the soil types and depths. The coastal plain sand (Abia) had highest value of exchangeable K (up to 0.203 cmol kg^{-1}) at both 0-20 and 40-60 cm depth, emphasizing the influence of parent material on exchangeability.

Non-exchangeable K, (HCl and HNO_3 Extracted) especially as extracted by HCl, constitutes a significant reserve in many soils. The study indicated that the values range from approximately 0.118 to 8.645 cmol kg^{-1} . The highest non-exchangeable K, particularly in the HCl extract, was observed in the coastal plain sand (Imo) at 8.645 cmol kg^{-1} (0-20 cm depth). This form of K is primarily mineral-bound and slowly released, serving as a long-term K reserve. On the other hand, non-exchangeable K (HNO_3 extractible) recorded the highest value at 40-60 cm depth with alluvium soil (0.303) and the least value in sandstone (0.111 cmol kg^{-1}). The higher non-exchangeable K in mineral-rich parent materials emphasizes their potential as K reservoirs for

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future plant uptake. Non-exchangeable (HCl extractable) K fractions tend to decrease with depth, indicating that surface soils generally have higher bioavailable K pools.

The Available potassium reflects K readily available for plant uptake. Coastal plain sand (Imo) again shows elevated available K (up to 1.146 cmol kg⁻¹). Shale ~~havehas~~ lower available K, with the lowest at 0.272 cmol kg⁻¹, emphasizing their limited immediate nutrient supply. This pattern reflects the influence of parent material and soil texture, with coarse-textured soil offering higher available K.

The mineral or structural K, representing potassium locked within mineral lattices, which becomes available to plants only upon mineral weathering over time. The highest mean concentration was observed in basement complex soil (0.636 cmol kg⁻¹ at 0-20cm), aligning with the mineral rich composition typical of basement complex parent material. Conversely, shale soils exhibited the lowest value of mineral K (0.171 cmolkg⁻¹), reflecting their relatively lower mineral content. This aligns that soils rich in mineral K may contribute to sustained potassium supply over time, but weathering rates dictate immediate availability.

3.3 Influence of Parent Material and Depth

The distribution of potassium forms in soils of the study area varies significantly with parent material and depth. The variation in K forms across different parent materials is evident. Soils derived from basement complex parent material consistently display higher total and mineral K contents, reflecting their mineral richness and geological history. While soils from coastal plain sands had the highest values of ~~water-soluble~~water-soluble K, available, exchangeable and non-exchangeable forms of K. Depth-wise, the 0-20 cm layer generally contains higher K concentrations across all soil types, attributable to surface accumulation of organic matter and mineral weathering products. As depth increases, K levels decrease, especially in sandy soils, indicating limited downward translocation and leaching of K.

These findings align with literature emphasizing the importance of parent material in determining soil potassium dynamics. Foth (1990), highlighted that mineral K availability depends largely on mineral composition and weathering rates, which are inherently linked to parent material. Similarly, (Menzies, 2004) stressed that soils derived from shale or sedimentary parent materials tend to have lower exchangeable K but higher non-exchangeable pools that become available over time. In contrast (Rengel,1999), argue that management practices such as fertilization and organic matter addition can significantly modify potassium availability,

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sometimes over showing parent material effects underscoring the need for site specific soil management based on detailed K fractionation data.

Table 3 Forms and Distribution of Potassium in the Soils (cmol/kg)

Depth (cm)	Total K	Water Soluble/Solution K	Exchangeable-K	Non-Exchangeable-K (HCl)	Non-Exch k (HNO ₃)	Available K	Mineral/Structural K
Alluvium							
0-20	0.760	0.230	0.129	0.303	0.166	0.359	0.594
20-40	0.737	0.226	0.113	0.292	0.133	0.339	0.604
40-60	0.629	0.187	0.116	0.244	0.303	0.303	0.507
Basement complex							
0-20	0.901	0.346	0.152	0.355	0.265	0.498	0.636
20-40	0.665	0.206	0.132	0.258	0.170	0.339	0.495
40-60	0.562	0.184	0.122	0.220	0.156	0.306	0.406
Coastal plain sand (Abia)							
0-20	0.652	0.253	0.203	0.259	0.173	0.456	0.479
20-40	0.529	0.279	0.195	0.211	0.166	0.474	0.363
40-60	0.506	0.220	0.203	0.195	0.171	0.423	0.335
Coastal plain sand (Imo)							
0-20	0.550	0.520	0.145	8.645	0.179	0.665	0.371
20-40	0.579	1.003	0.143	0.226	0.171	1.146	0.408
40-60	0.660	0.695	0.133	0.234	0.173	0.828	0.487
Sandstone							
0-20	0.710	0.506	0.152	0.283	0.185	0.659	0.525
20-40	0.701	0.667	0.150	0.249	0.166	0.817	0.535
40-60	0.679	0.725	0.126	0.268	0.168	0.851	0.511
Shale							
0-20	0.302	0.216	0.114	0.118	0.131	0.330	0.171
20-40	0.313	0.155	0.121	0.123	0.111	0.276	0.202
40-60	0.460	0.172	0.100	0.183	0.113	0.272	0.347
Mean	0.605	0.377	0.142	0.704	0.162	0.519	0.443
LSD PM	0.189	0.223	0.014	NS	0.030	0.226	0.171
LSD	NS	NS	0.010	NS	0.021	NS	NS
Depth							
LSD	PM	NS	NS	NS	NS	NS	NS
X	DE						

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3.4 Correlation Coefficient between the Potassium Forms and Some Physical and Chemical Properties of the Soils

Correlation analysis between various forms of potassium (K) and soil physio-chemical properties reveals important insights into soil fertility dynamics and nutrient availability. These

significant correlations imply meaningful relationships that influence soil behavior and crop productivity. The strong positive correlation between Total K and organic carbon ($r=0.730^{**}$) suggests that soils with higher organic carbon content tend to have higher total potassium as organic matter enhances soil structure, cation exchange capacity, and nutrient retention (Sanchez, 1976). Organic inputs can also contribute to the mineralization of potassium from organic matter and mineral weathering, thus increasing total K pools. This relationship underscores the importance of organic matter management to sustain potassium reserves. ~~Also~~ Also, total K had a positive link with Av. P and total exchangeable bases ($r = 0.426^{**}$ and $r = 0.553^{**}$ respectively). The significant positive relationship between water Soluble K and sand ($r=0.364^{**}$), total exchangeable acidity ($r=0.346^{*}$) and a negative correlation with silt ($r = -0.396^{**}$) suggests that soils with higher silt content tend to have greater water-soluble potassium, likely due to increased surface area and retention capacity of finer particles. Silt-rich soils may facilitate better K retention and availability, corroborating findings by Brady and Weil (2002). Exchangeable potassium exhibits a negative correlation with silt content ($r = -0.362^{**}$) and a positive correlation with organic carbon ($r=0.392^{**}$) which indicates that organic matter enhances the pool of exchangeable potassium and also contributes to soil CEC and can chelate cations, facilitating potassium retention and exchangeability (Sparks, 2003). There was strong positive correlation between Non-exchangeable potassium (HCl) and organic carbon, Av.P, TEB ($r = 0.714^{**}$, $r = 0.469^{**}$ and $r = 0.524^{**}$) and Non-exchangeable K (HNO_3 Extractible) with sand, organic carbon, Av.P ($r = 0.327^{*}$, $r = 0.818^{**}$, $r=0.498^{**}$) respectively. This aligns that non-exchangeable K becomes available over time through weathering or organic matter decomposition (Sparks, 2003), facilitating the release of non-exchangeable K through microbial mineralization and chelation processes (Hillel, 2004). Available K showed positive correlations with sand ($r=0.378^{**}$) and a negative correlation with silt and organic carbon ($r= -0.428^{**}$, $r= -0.318^{*}$). Mineral K showed a positive correlation with organic carbon, Av.P and TEB ($r=0.647^{**}$, $r=0.373^{**}$, and $r=0.591^{**}$) emphasizes the role of organic matter in maintaining and mineralizing K pools, corroborating studies that highlight organic matter as a key driver in nutrient cycling and mineralization processes from organic and mineral sources, thus increasing mineral K availability (Huang *et al.*, 2018).

Table 4. Correlation Coefficient between the Potassium Forms and Some Physical and Chemical Properties of the Soils

*Correlation is significant at the 0.05 level (1-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

The significant positive and negative correlations between potassium forms and soil properties underscore the complex interactions governing K availability. Managing organic matter, soil pH, and texture can optimize potassium nutrition, thereby enhancing soil fertility and crop productivity.

3.5 Conclusion

The findings of this study underscore the significant influence of soil physio-chemical properties and parent material types on the forms and availability of potassium in southeastern Nigeria soils. The predominantly acidic pH across various parent materials, coupled with distinct textural differences, highlights the complex interactions affecting potassium dynamics. Soils derived from sandstone and coastal sands exhibit high sand content and lower nutrient retention potential, while alluvial and shale soils demonstrate relatively higher fertility indicators, such as organic carbon and cation exchange capacity, which are conducive to potassium retention and availability.

Given these variations, targeted soil management practices are essential to optimize potassium use efficiency and sustain soil fertility. Specifically, areas with sandy and acidic soils, such as those derived from coastal sands and sandstone, may benefit from liming to raise soil pH and organic matter amendments to enhance nutrient retention. Conversely, soils with higher CEC and

K Forms	pH	Clay	Sand	Silt	Org.C	TN	Av.P	TEB	TEA
Total K	0.235	0.072	-0.153	0.146	0.730**	0.001	0.426**	0.553**	-0.212
WS-K	0.224	-0.099	0.364**	-0.396**	0.170	0.012	0.119	0.076	0.346*
Exch-K	-0.031	0.180	0.187	-0.362**	0.392**	-0.009	0.260	-0.245	0.227
Non-Exch-K (HCl)	0.187	0.114	-0.190	0.164	0.714**	0.017	0.469**	0.524**	-0.178
Non-Exch-K (HN0₃)	0.036	-0.218	0.327*	-0.267	0.818**	0.110	0.498**	0.159	-0.197
Available K	0.217	-0.079	0.378**	-0.428**	0.208	0.011	0.144	0.050	-0.318*
Mineral K	0.258	0.129	-0.245	0.224	0.647**	-0.023	0.373**	0.591**	-0.197

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organic matter, like alluvial and shale soils, require careful monitoring to prevent deficiencies and maintain productivity.

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