

COMPARATIVE ASSESSMENT OF PRIMARY NUTRIENT ELEMENTS IN SOILS OF CONTRASTING PARENT MATERIALS IN SOUTH-EAST NIGERIA

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ABSTRACT

The study investigated primary nutrient elements in soils of contrasting parent materials in south-east Nigeria. Two sites were selected; Okigwe in Imo state (Shale) and Michael Okpara University of Agriculture, Umudike in Abia state (Coastal plain sands parent material)- CPS. The objective of this research was to know if there was any variation in the primary nutrient elements such as nitrogen, phosphorus and potassium in soils derived from the contrasting parent materials in the soils of these areas. Physical and chemical properties of the soil in each parent material were collected at the depth of 0-20cm and 20-40cm. Results showed that coastal plain sand-derived soils were more sandy, contained lower quantity of organic matter and low exchangeable bases compared to shale. Base saturation (92.28%) and effective cation exchange capacity (9.24cmol/kg) were significantly ($P<0.05$) higher in shale at soil depth of 0-20cm than soil derived from coastal plain sands. Exchangeable acidity (H^+ & Al^{3+}) (1.81 & 0.75cmol/kg) and organic carbon (1.37%) were found to be higher in shale parent material than in coastal plain sand-derived soils. Significantly higher ($P<0.05$) proportion of potassium (0.382cmol/kg) were recorded at soil depth of 0-20cm in soils derived from shale than in coastal plain sand-derived soils. Significantly higher ($P<0.05$) available phosphorus (19.1mg/kg) was recorded in soils derived from shale at 0-20cm of depth compared to coastal plain sands parent material (16.88mg/kg) at the same depth. The highest quantity of total nitrogen (0.137%) was recorded at soil depth of 0-20cm was recorded in coastal plain sands parent material. Soils primary nutrient elements (nitrogen, potassium and phosphorus) significantly ($p<0.05$) varied due to parent materials. The results of this study revealed that parent material had great influence on soil properties. The soils of the Shale and Coastal Plain Sands parent materials are physically and chemically different in most of their properties, and soil depth also had great impact in the levels of the soil nutrients as well as the particle size distribution of the soils. Therefore, different management practices need to be adopted for sustainable crop production on the soils from both sources.

Key words: Primary nutrient elements; soil; parent material; shale; coastal plain sands

INTRODUCTION

Soil properties are determined by its parent material and by the interactions between the parent material and the hydrosphere, atmosphere, and biosphere (Hugget, 2023). Nutrient elements in soils are generally dependent on the lithology of soil parent material, geochemical and pedological processes responsible for the formation of soils (Hardy and Cornu, 2006). Variations in soils could be attributed to the nature of parent material as it influences soil characteristics (Ibanga, 2006). Parent material also constitutes and influences the primary source of plant nutrients (Giesler *et al.*, 2005).

Primary nutrient elements (N:P:K) are those yield limiting nutrient elements required by crops in large amounts (Alfaro *et al.*, 2003; Zhang *et al.*, 2011). Nitrogen is considered the most important growth-limiting factor in non-legumes (Zebareth *et al.*, 2009). The relative importance of phosphorus (P) and nitrogen (N)

in limiting plant productivity can vary across ecosystems due to differences in a range of factors such as, N deposition, parent material, the nutrient element forms, soil age, pH, and concentrations of soluble aluminum (Al), iron (Fe) and calcium (Ca) (Weintraub, 2011). Potassium (K) plays a very significant role in crop growth due to its functions as an activator of numerous enzymatic reactions and in electrochemical process (Krauss and Johnson, 2002). The ability of a soil to supply potassium to a crop depends on its forms and distribution as influenced by soil physico-chemical properties. Potassium occurs in different forms in the soils such as water soluble, exchangeable, non-exchangeable and in mineral form (Idigboret *et al.*, 2009). However, the concentration of these varying forms of potassium and other macro nutrient elements depends relatively on parent material and other related soil factors. Therefore, the major objective of the present study is to

evaluate the effects of Parent materials on the contents of primary nutrient elements (N.P.K) relative to soil-depth in Southeast Nigeria.

OBJECTIVE OF THE STUDY

To investigate any variation in the content of the primary nutrient elements (nitrogen, phosphorus and potassium) in soils of contrasting parent materials which were Coastal plain sands (CPS) and Shale.

MATERIALS AND METHODS

Description of the Study Areas

The research was conducted in two different locations in south-east Nigeria. These areas include: Umudike in Ikwuano LGA, which is one of the major food producing areas in Abia State and presently where Michael Okpara University of Agriculture is located. It is geographically situated about latitude 5° 29' North and longitude 7° 33'E. The extent is about 31,000 ha and Okigwe which is the third largest city after Owerri and Orlu in Imo state. It is located in Okigwe Local Government Area of Imo state, Nigeria. Okigwe is geographically situated between Latitude 5 49' 45 North and Longitude 7 21' 2 East and lies between the port Harcourt Enugu-Maidugiri rail line and was the primary host site of the old Imo state University (now Abia state University). Being the nearest city to the biggest cattle market in Nigeria located at the Umunneochi area of Abia state this city has grown into a major cattle transit town for the south-eastern region of Nigeria. Okigwe has a population of 132,237 (2005 census) and remains one of the breadbaskets of Nigeria with terrace cultivation practiced on its hilly farmlands.

Climates of the study areas

They have humid tropical climate with distinct wet season (April to October) and dry season (November to March). Annual rainfall in the area ranges from 170mm to 3000mm with peaks in July and September average temperature range between 27°C and 35°C.

Soils of the study area

The soils in Okigwe and Umudike in Ikwuano are underlain by parent materials comprising of Shale and Coastal plain sands respectively.

Relief and Geology

Ikwuano has undulating plains while Okigwe is made up of highlands. Over 80 percent of Eastern Nigerian is of sedimentary geological deposits made up of shale, coastal

plain sands, false bedded sandstones and alluvium.

Land Use of the study areas

The major land use of these areas is agriculture; cultivation of arable crops which include cassava (*Manihot*spp) yam (*Dioscorea*spp), Maize (*Zea mays*) Cocoyam (*Colocasia*esculentus) Also palm trees, melon and garden vegetables which include fluted pumpkin (*Telfaria*occidentalis)

Vegetations of the study areas

Following engagements has continued to be a principal management practice to restore soil productivity in these areas.

The vegetation of these areas is tropical rain forest consisting mainly of trees, shrubs and grasses.

Site Selection

Two sites underlain by two different parent materials (shale and coastal plain sands) were selected for this study.

Soil Sampling

Auger samples were collected inside fallow at least 50m away from roads and foot paths. A total of five (5) composite soil samples were collected (per parent material), covering a land area of about 1,000 m². Ten samples were collected per parent material, giving a total of 20 samples for the two parent materials, using a soil auger at the soil depth of 0-20cm and 20-40cm. Materials used in collecting soil samples included cutlass for site clearing, soil auger, soil sampling bags, masking tape for tagging and identification of samples, card board paper for spreading the samples as well as writing materials among other things.

sample preparation

Before taking it to the lab for analysis, the soil samples (auger samples) were air-dried at room temperature. After air-drying, the soil was crushed with wooden roll and sieved with a 2mm sieve.

Laboratory Analysis

Routine analysis was carried out for soils in the two Parent Materials (shale and CPS). Primary nutrient (nitrogen, phosphorus potassium) analyses were also carried out.

Soil Physical Property Determination

Particle size analysis was determined by the hydrometer method (Gee and Or, 2002).

Soil Chemical Analyses

Soil pH 1:2.5 water suspension was measured with pH-meter (Thomas, 1996).

Exchangeable Base cations (Ca, Mg, Na and K)

Exchangeable base cations were extracted with IN ammonium acetate. Potassium (K) and Sodium (Na) were determined by flame photometry, while calcium (Ca) and Magnesium (Mg) were determined by EDTA titration (Thomas, 1996).

Total exchangeable bases (TEB) =Summation of the base cations.

Available phosphorus

Available phosphorus in the soil was extracted by bray 2 method of Olsen and Sommers (1982)

Organic Carbon

Organic carbon was determined by the chronic acid wet oxidation method (Walkley and Black, 1934) as modified by Juo (1979). Organic carbon was oxidized by potassium dichromate in the presence of concentrated H₂SO₄ and then titrated with ferrous ammonium sulphate.

Total Nitrogen

Total nitrogen was determined by the micro kjeldahl method of Bremmer (1965) as described by Udo and Ogunwale (1978).

STATISTICAL ANALYSIS

Data generated from the soil analysis were subjected to analysis of variance using Randomized Complete Block Design (RCBD); the soil depths were two (0-20 cm and 20-40 cm), and the two parent materials (Shale and CPS) were the blocking factor. Significant means were separated using Least Significant Difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Effects of the parent materials and soil depth on the physical properties of soil in the study area

Particles size distribution of soils studied are as shown in Table 1. The table shows that sand content dominated silt and clay content down the depth in CPS than in Shale parent material. The high sand contents of the soils could be attributed to unconsolidated sand deposits formed over coastal plain sands parent material as reported by Lekwa, (2002). However, the dominant sand content was found to decrease with an increase in depth for soils derived from both parent materials.

Silt decreased in content with an increase in soil depth in shale parent material and increased in content with increase in depth in coastal plain sands parent material while clay content also increased with an increase in soil depth in shale and coastal plain sands. The high clay, content value observed in shale and coastal plain sand at soil depth of 20 – 40cm could be as a result of increase in clay translocation from the surface subsurface horizons or removal of clay from the surface by run-off (Oguike and Mbagwu, 2009)

The table shows that the texture of soil was observed to be sandy clay loam in shale and coastal plain sands at 20 – 40cm. The soil texture in coastal plain sands at depth of 0-20cm was sandy loam.

Soils derived from coastal plain sands (CPS) contained significantly higher ($p < 0.05$) proportion of sand compared to Shale. Generally, soil depth significantly affected the sand, silt and clay contents of the soils studied. This is in line with the work of Olubanjoet *al.* (2017).

Table 1: Effects of Parent Material and Soil Depth on Particle Size Distribution of Soil in the Study Area

Parent material	Depth (cm)	Sand g/kg	Silt g/kg	Clay g/kg	Texture
Shale	0-20	522	262	216	Sandy clay loam
Shale	20-40	487	215	298	Sandy clay loam
Coastal plain sands	0-20	660	149	191	Sandy loam
Coastal plain sands	20-40	617	157	226	Sandy clay loam
LSD (0.05) parent material		1.83	1.07	1.73	
LSD (0.05) Depth		1.83	1.07	1.73	
LSD (0.05) parent material x depth		NS	1.52	2.45	

Effects of Parent Material and Soil Depth on Chemical Properties of Soil in the Study Areas

The effects of parent material and soil depth on soil chemical properties of soil in the study areas are as shown in Table 2. The soil

pH ranged from 4.60 – 6.45, which indicates strong to slight acidity (Chudeet *al.*, 2005) in coastal plain sands parent material as well as

in shale. The low pH values of these soils could be due to the low leaching of basic cations due to their coarse texture. This finding corroborates the work of Ekerette (2001) on some coastal plain sand soils of western Nigeria. The pH of newly formed soils is determined by the mineral in the parent material. The organic carbon contents of the soils studied ranged from 0.90% to 1.37% which is an indication of low to moderate concentration (Chudeet *al.*, 2012) in the Shale and CPS parent materials. In both, organic carbon/organic matter decreased with increase in depth. This observation is in line with the findings of Chikezieet *al.* (2010) on characteristics of two benchmark soils of contrasting parent materials in Abia state, southeastern Nigeria, who reported that the high temperature and relative humidity conditions of the environment favour rapid decomposition and mineralization of soil organic matter. Hence the low to moderate values obtained.

Amongst the exchangeable cations evaluated in the two parent materials, calcium was higher in the Shale parent material (6.45 and 3.70cmol/kg at 0-20 and 20-40 cm depths respectively) than in the CPS (4.90cmol/kg and 3.30cmol/kg at the two depths respectively); exchangeable magnesium followed the same pattern (1.45 and 0.85 cmol/kg at 0-20 and 20-40 cm depths respectively) as well as the sodium. The decrease in values of the nutrients with soil depth is not unusual; Chikezieet *al.* (2010) observed the same trend in some soils of southeastern Nigeria. Calcium and magnesium were found to be greater in value in shale than in coastal plain sands parental material, but sodium was higher in the CPS (0.25 and 0.185 cmol/kg at 0-20 and 20-40 cm Shale parent material than in the CPS.

depths) than in Shale parent material (0.236 and 0.17 cmol/kg at the 0-20 and 20-40 cm depths respectively).

In both shale and coastal plain sands parent materials, the soil exchangeable acidity (EA) was found to increase with increase in soil depth. Generally, CPS had higher values of EA (1.33 and 1.81 cmol/kg at 0-20 and 20-40 cm depths respectively) and Exchangeable aluminium (0.53 and 0.75 cmol/kg at 0-20 and 20-40 cm depths respectively) when compared with the Shale parent material that had EA (0.71 and 1.43 cmol/kg at 0-20 and 20-40 cm depths respectively). This could be as a result of leaching reported by Havlinet *al.*(2005). Higher values of EA recorded in CPS may be the cause of high acidity observed in the soil.

Effective Cation Exchange Capacity (ECEC) in all the soils studied ranged between 5.85 and 9.24 cmol/kg in both parent materials. The highest ECEC value was recorded in Shale at the depth of 0-20cm (9.24 cmol/kg) and 20-40 cm (6.43 cmol/kg). The values were significantly higher than what was obtained in CPS at both depths (7.61 and 5.81 cmol/kg respectively). Onweremaduet *al.* (2011) also obtained low ECEC in soil derived from coastal plain sands in south east Nigeria and attributed it to the nature of the parent material which may be dominated by low activity clay such as Kaolinite (Afuet *al.*, 2022). There was also a significant ($p < 0.005$) variation in ECEC across soil depths.

Base saturation decreased in value with an increase in soil depth in soils derived from shale parent material and coastal plain sands. Base saturation was significantly higher ($p < 0.05$) in

Table 2: Effect of Parent Material and Soil Depth on Chemical Properties in the Soils of the Study Area

Parent material	Depth (cm)	pH value H ₂ O	pH KCl	Organic Carbon %	Organic Matter %	Ca ²⁺ Cmol/kg	Mg ²⁺ Cmol/kg	Na ⁺ Cmol/kg	Exchange Acidity Cmol/kg	Al ³⁺ Cmol/kg	ECEC Cmol/kg	BS %
Shale	0-20	6.45	5.85	1.37	2.36	6.45	1.45	0.24	0.71	0.30	9.24	92.28
Shale	20-40	5.65	5.10	0.90	1.55	3.70	0.85	0.17	1.43	0.47	6.43	77.74
Coastal plain sands	0-20	5.75	5.15	1.03	1.77	4.90	0.85	0.25	1.33	0.53	7.61	82.67
Coastal plain sands	20-40	5.15	4.60	0.75	1.30	3.10	0.55	0.19	1.81	0.75	5.85	69.08
LSD (0.05) parent material		0.15	0.27	0.05	0.07	0.07	0.15	0.004	0.57	0.03	0.11	0.77
LSD (0.05) Depth		0.15	0.27	0.05	0.07	0.07	0.15	0.004	0.57	0.03	0.11	0.77
LSD (0.05) parent material x depth		0.22	0.38	0.06	0.10	0.11	0.22	NS	0.08	0.05	0.15	1.10

Effects of Parent Material and Soil Depth on Primary Elements in the Shale and Coastal Plain Sands parent materials. The effects of parent materials and soil depth on the primary nutrient elements in the Shale and CPS parent materials are as shown in Table 3.

Total Nitrogen

Total nitrogen (TN) varied with an increase in soil depth in soils derived from the different parent materials. TN values of these soils were found to be slightly higher in coastal plain sands at 0-20cm soil depth. However, they were generally low in both parent materials (Landon, 1991). The low nitrogen may be due to volatilization, high temperature, crop removal and also could be due to the low organic carbon content of the soils.

Available phosphorus (AV.P)

Available phosphorus value in soil derived from the two parent materials ranged from 12.96 to 19.1mg/kg, which was moderate for soils of the study area (Chudeet *al.*, 2012) and considered to be above the critical limit of

10mg/kg given by Esu (1999). Shale parent material had values significantly ($p < 0.05$) higher than the CPS. *Afu et al.* (2020) made a similar observation as they obtained higher P in Shale than in Sandstone.

Potassium (K)

The results of potassium in the two parent materials significantly varied ($p < 0.005$). Potassium value decreased with an increase in soil depth in both parent materials. Shale had significantly higher values than the CPS parent material. This variation in the total amount of potassium realized from different parent materials could be attributed to the soil environment and nature of K-bearing minerals in the Shale (Hosseinpour and Kalbasi, 2002).

Table 3: Effect of Parent Material and Soil Depth on Primary Mineral Elements in Soils of the Study Area

Parent material	Depth (cm)	Total Nitrogen %	Available P mg/kg	Potassium Cmol/kg
Shale	0-20	0.127	19.10	0.382
Shale	20-40	0.077	14.26	0.274
Coastal plain sands	0-20	0.137	16.88	0.300
Coastal plain sands	20-40	0.087	12.96	0.200
LSD (0.05) parent material		0.002	0.26	0.007
LSD (0.05) Depth		0.002	0.26	0.007
LSD (0.05) parent material x depth		NS	0.37	0.010

CONCLUSION

The results of this study revealed that parent material had great influence on soil properties. The soils of the Shale and Coastal Plain Sands parent materials are physically and chemically different in most of their properties, and soil depth also had great impact in the levels of the soil nutrients as well as the particle size distribution of the soils. A critical look at the result shows that soil from the Shale parent material is relatively more fertile than that from the coastal plain sands. Therefore, different management practices need to be adopted for sustainable crop production on the soils from both sources; liming is required to ameliorate the strong acidity obtained in the CPS parent material, while practices that increase soil total nitrogen and soil organic matter should also be carried out on both soils.

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