# Comparative Assessment of Soil Properties derived from basalt and Sandstones Parent Materials in the Rainforest Zone of Cross River State

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## ABSTRACT

The soils developed from sandstone and basalt parent materials in the rainforest zone around Ikom Local Government Area contribute to agriculture specifically cocoa production but seem different in soil properties. This study was carried out to compare the properties of soils derived from sandstone and basalt parent materials in the study area. Two toposequences were identified, one in each of the parent material location. Three profile pits were dug in the crest, middle slope and valley bottom positions of each of the two studied toposequences. T-test analysis results showed that there was significant difference between the mean values of sand, silt and bulk density, and differed ($p \leq 0.05$) between the sandstone and basaltic soils. However, the chemical properties of the two soils were statistically similar, except for total nitrogen and exchangeable $Al^{3+}$ as well as cation exchange capacity and base saturation which were significantly different. The soils can be managed by the application of organic and inorganic fertilizers; return of crop residues, liming and planting of acid tolerant crops in the soils.

**Keywords:** toposequence, sandstone, basalt, parent materials

## INTRODUCTION

Parent materials from which soils are developed is a key factor that determines the kinds and contents of secondary minerals of soils, and influences soil texture and chemical properties. It exerts an influence resulting to changes in soil properties (Nsor and Ibanga, 2007). Soils developed from basalt are prone to leaching and plinthization due to the preponderance of free iron and aluminum oxides released during weathering. Plinthite is initially formed below the soil surface and remains soft and exposed to the surface which hardens to iron pan resulting in decline in its suitability for Agriculture (Esu, 2010; Ofem and Esu, 2015).

Basalt is an extrusive igneous rock with less than 20% quartz and less than 10% feldspathoid minerals with about 65% of feldspatic minerals occurring as plagioclase (Eshett, 1987). Its weathering is rapid because of the oxidation of Fe bearing minerals to rust-like compounds (Akpan-Idiok *et al.* (2016). The rust-like colouration impacts on the overlying soil in accordance with the findings of Ekwueme (2004) and Ibanga (2006) that the underlying geology of a place determines soil type. Sandstones are clastic and are formed from cemented grains of pre-existing rocks (Esu, 2010). Sandstone is medium grained and composed of quartz and occurs in the major ecological zones of Nigeria (Ogunwale and Ashaye, 1975). The chemical constitution of sandstone is the same as that of sand; the rock is thus composed essentially of quartz. The weathering of sandstone parent material results in fractured materials with the individual grains remaining unaffected, thus giving the soil surface a granular appearance (Redmond, 2009). Sandstone soils are known to be porous due to the dominance of sand-sized particles and influenced by the leaching of basic cations (Ofem *et al.* 2020).

Soils developed from sandstone are usually shallow to deep, well-drained, dark grayish brown, loamy sand in textures, slightly acidic, low base saturation and cation exchange capacity (Ofem *et al.* 2021). Soils derived from basalt in the Ikom area have been described as strongly acid in reaction, moderate in organic carbon (15.9-19.1 g/kg), available phosphorus (6.12-13.5 mg/kg) and total nitrogen (1.3-1.5 g/kg), but with moderately low exchangeable calcium, magnesium, potassium and sodium (Akpan-Idiok *et al.* 2016).

The productivity of basaltic and sandstone soils appears to have declined drastically following intensified land use with poor management. This situation calls for soil fertility investigations that will improve the fertility condition of the soils and manage the soils for future use.

The Ikom rainforest zone of Cross River State is an important agricultural zone with the soils supporting diverse tree crops such as banana, avocado, cocoa, oil palm etc. The area has a major tropical rainforest in Cross River State and has a beehive of economic activities due to its role as a border community with the Republic of Cameroun. This has led to the interest of many investors in agriculture and facilitated our interest on the soils overlying sandstone and basalt which are dominant lithologies in the area. The continuous use and declining productivity of these soils necessitated the present study with a view of making recommendations that will enhance their utilization

The current study was conceived with the objective of characterizing the soils with respect to their physical and chemical properties and comparing the properties of the soils derived from these contrasting parent materials

## Materials and Methods

### Location of the Study Area

The study was carried out in Ikom Local Government Area in Central Cross River State. Ikom lies between latitude 6°05' and 6°083' N, and longitude 8037' and 8°617' E of the equator with a mean elevation of 19.73m above sea level. Ikom LGA with an area coverage of 1861.926 square kilometers is bounded in the North by Ogoja, Northeast by Boki, East by Etung and in the south by Obubra Local Government Areas (Fig. 1).

**Climatic of the Area:** The study area is characterized by two climatic seasons; the rainy and the dry seasons. Rainfall amount ranges from 2000 to 3500 mm/annum (Bisong, 1994), with a bimodal graph pattern and a short break during August called August break, while temperature ranges from 27 to 28 °C with a relative humidity of 70-80% (Bulk Trade, 1989). The soil moisture regime is udic with an isohyperthermic temperature regime (Akpan-Idiok *et al.*, 2016).

**Vegetation and Land Use**

Ikom lies within the rainforest zone of Cross River State. The vegetation is affected by climate, topography and associated human activities such as quarrying, deforestation and subsequent cultivation. Common plant species in the area include guinea grass (*Panicum maximum*), teak (*Tectoni grandis*), Oil palm (*Elaeis guinensis*), Gmelina (*Gmelina arbore*) and Pear (*Dacryadis edulis*). Though excavation of basalt and laterite is a common practice in the area, cocoa (*Theobroma cacoa*), plantain/banana (*Musa spp*), Maize (*Zea Mays*), Yam (*Dioscoria spp*), Cassava (*Manihot spp*) and vegetables are commonly grown.

**Geology/Geomorphology**

The area is underlain by basalt (basaltic lava), sandstones and igneous rocks characterized by large and medium grain size and weathered debris (saprolite). The study area is characterized by gently sloping landscape of 0-8% gradient without a shoulder but with the crest gradually sloping towards the streams.

**Field Studies**

Soil profiles were dug at the crest, middle slope and valley bottom positions along each of the two studied toposequences. This resulted in six soil profiles (Plates 1-6). The soil profiles were described according to the guidelines of FAO (2006). Thereafter, soil samples were collected from the morphogenetic horizons into well labeled sample bags and taken to the laboratory for analysis. Soil samples meant for bulk density were collected with the aid of core cylinders. The samples were transported to the laboratory, oven-dried at 105 $^{o}$C until constant weight was obtained.

**Laboratory analyses**

The soil samples were air-dried, the peds were crushed, made to pass through 2 mm aperture sieve and used for laboratory analyses. Particle size distribution was obtained by Bouyoucos hydrometer method, soil pH ($H_2O$) was determined using a soil: water ratio of 1:2.5 with a glass electrode pH meter. Organic carbon content was obtained using the procedures of Walkley–Black modified acid–dichromate procedure, while total nitrogen was determined by the Macro - Kjeldahl digestion method and available P was carried out by Bray P1. Basic cations in the soils' exchange complex were extracted with 1 *N* ammonium acetate at neutral pH. Ca and Mg in the exchange complex were ascertained by the Versenate EDTA titration method, while K and Na were obtained by subjecting the soil extract to a flame photometer. Soil cation exchange capacity (CEC) was obtained by extraction using 1 *N* $NH_4OAc$ at pH = 7.0. Base saturation was calculated by dividing the sum of exchangeable basic cations by the cation exchange capacity by ammonium saturation and multiplied by 100 %. All laboratory analyses were carried out by the procedures in Soil Survey Staff (2014). Bulk density was obtained by dividing the oven dry weight of soil by the volume of soil in cylinder and results expressed in $Mg/m^3$.

**Statistical Analysis**

The laboratory data were analyzed for Mean, Correlation and Duncan's Multiple Range Test using GenStat software.

**Results and discussion**

**Physical properties of sandstone and basaltic Soils**

Physical properties of the studied soils are presented in Table 1. Sand content ranged from 29.2 to 61.2% for sandstone and 21.2 to 55.2% for basalt derived soils with significantly higher values occurring in the soils over sandstone at $p \le 0.05$ (Table 1). Silt content ranged from 18 to 28% for sandstone and 24 to 54 % for basalt derived soils with values in soils over basalt significantly higher than those over sandstone at $p \le 0.05$. Ranges of 16.8 - 50.8 and 14.8 - 46.8 % were obtained for clay in the soils over sandstone and basalt, respectively with no significant difference occurring in clay between the soils at $p \le 0.05$. Basaltic soils have been described as lateritic, deep with heavy clay in the subsoil and little horizon differentiation (Corbett, 2006), while Ofem *et al.* (2020) reported sand content that exceeds 65 % for the sandstone soils of Bekwarra.

Soil bulk density was less than 1.8 $Mg/m^3$ for both soils without a significant difference in values between the two soils at $p \le 0.05$, while particle density was less than 2.80 $Mg/m^3$ for the studied soils. The bulk density values are favourable for plants roots proliferation and indicate the absence of root restricting layers. Such values indicate good air and water movement in the soils. Furthermore, total porosity values of 22 - 51 for sandstone and 16 – 65 % for basalt indicate adequate soil air and water movement which is likely to encourage oxidation processes over reduction in the soils. The T-test result shows that there is no significant difference in total porosity between the two soils at 5 % level of confidence.

**Chemical properties of sandstone and basaltic derived soils**

Chemical properties of the soils are presented in Table 2. Soil pH had a range of 5.1 - 5.8 for the studied soils with t-test result that indicates no significant difference in pH between sandstone and basalt derived soils at 5 % level of confidence (Table 2). However, soil pH in soils derived from basalt exceeded those over sandstone by less than 1 pH unit. The little lithological influence could be attributed to the similarity in environmental factors. For instance, both soils are found under the same climate. The range in pH for both soils indicates that the soils are strongly to moderately acid on the scale of Holland *et al.* (1989) and have relative similarity in the ionic content of the soil solution. Contrary to the current study, soil pH of 4.0 - 5.0 was reported by Akpan-Idiok *et al.* (2016) for the soils developed from basalt; the pH was attributed to the presence of significant amounts of exchangeable $Al^{3+}$ and $H^+$ that could affect plant growth. Soil organic carbon and total N were less than 0.98 and 0.14 %, respectively and qualify the two studied soils in the low category of the rating scale of Holland *et al.* (1989). Such low values may have resulted from the continuous cultivation of the soils in an attempt to meetup with the growing demands of food crops in the economic booming zone of Ikom. Though no significant difference occurred in organic carbon content of the soils over sandstone and basaltic at $p>0.05$, there appeared to exist a comparatively higher set of organic carbon values for soils over basalt than those over sandstone. According to Akpan-Idiok *et al.* (2016), total N of basaltic soils range from 0.13 to 0.15 %.

Available phosphorus ranges of 5.00 - 12.87 for sandstone and 4.4 - 31.0 mg/kg for basaltic soils indicate moderate and high values, respectively in the studied soils on the scale of Holland *et al.* (1989). However, available P was not significantly different between the sandstone and basalt-derived soils at 5% level of confidence. Basaltic soils are fertile but deficient in phosphorus (Teitzel and Bruce, 1972), while Kparmwang et al. (1992) described the soils as having a favourable agricultural potential. Akpan-Idiok et al. (2016) and Akpan-Idiok et al., (2004) obtained a range of 5.6 - 13.5 mg/kg for available P in the basaltic soils of Ikom.

Exchangeable $Ca^{2+}$ for soils over sandstone and basalt had ranges of 4.0 - 5.2 and 3.40 - 6.40 cmol/kg, respectively, while $Mg^{2+}$ was 0.2 - 0.6 for soils over sandstone and 1.0 - 2.4 cmol/kg for soils over basalt. Exchangeable $K^{+}$ and $Na^{+}$ were less than 0.12 cmol/kg in the entire studied soils. Exchangeable $Ca^{2+}$ and $Mg^{2+}$ were rated moderate on the scale of Holland *et al.* (1989), while $K^{+}$ and $Na^{+}$ were low on the scale of Holland *et al.* (1989). Such low values may have been due to the effects of leaching in the high rainfall zone of Ikom. T-test results show no significant difference in all the exchangeable bases between soils derived from sandstone and basalt. Means of 4.6, 1.2, 0.10 and 0.075 cmol/kg were obtained by Akpan-Idiok *et al.* (2016) for exchangeable Ca, Mg, K and Na, respectively in Ikom area, while Esu (1988) reported higher values of $Ca^{2+}$ in similar soils in Northern Nigeria.

Cation exchange capacity in the soils derived from sandstone had a range of 9.0-20.0 cmol/kg, while those over basalt had a range of 18.0-39.0 cmol/kg. Values in the sandstone-derived soils are moderate, while those in the basaltic soils are moderate to high on the scale of Holland *et al.* (1989). The Bt horizons of both soils had the highest cation exchange capacity (CEC) values. This may indicate that clay content was relatively responsible for the soils' CEC in the Bt horizons. The cation exchange capacity of the soils derived from basalt was significantly higher than that of the soils derived from sandstone. This may have been due to the dominance of the basaltic soils with silt and relatively higher clay content compared to the sandstone-derived soils as silt particles could also contribute to the adsorption of ions.

Base saturation values of the soils were in the ranges of 26.3 – 58.0 and 16.6 – 26.3 % for the soils derived from sandstone and basalt, respectively resulting in low to moderate values on the scale of Holland *et al.* (1989). This suggests that the concentration of exchangeable bases in the soil solution is low and will affect the adsorption and desorption of the cations on the soils exchange complex. Base saturation was significantly higher in the soils derived from sandstone than those from basalt. Higher base saturation values in the soil solution imply availability of exchangeable bases in the soil exchange complex.

The Exchangeable $H^+$ was 0.76 - 1.96 for sandstone and 1.00 - 3.80 cmol/kg for basalt-derived soils. T-test results indicate no significant difference between the two soils for exchangeable $H^+$ whereas exchangeable $Al^{3+}$ was significantly higher than exchangeable $H^+$. However, ranges of 0.52 - 2.88 and 0.00 - 0.80 cmol/kg of exchangeable $Al^{3+}$ for soils over sandstone and basalt, respectively indicates a more influence of exchangeable $H^+$ (Higher value) on the soils with a significant difference in $Al^{3+}$ between the sandstone and basalt derived soils at $p>0.05$ %. Ofem et al. (2020) reported that values of exchangeable $Al^{3+}$ were less than 2.1 cmol/kg in the sandstone soils of Bekwarra.

**Summary and conclusion**

The comparative assessment of physico-chemical properties of basaltic and sandstone-derived soils in Ikom Local Government Area of Cross River State, Nigeria was carried out with a view to suggesting appropriate management strategies for the soils. Six profile pits were dug in the Crest, Middle slope and Valley bottom positions along two distinct toposequences; one on sandstone and the other on basalt. The t-test analysis results of the soil physical properties showed that there was no significant ($p>0.05$) difference between the mean particle density and total porosity of the soils. However, mean values of sand, silt and bulk density differed ($p\leq0.01$) between the sandstone and basaltic soils. The chemical properties of these soils were statistically ($p>0.05$) similar. However, significantly higher values of total nitrogen were obtained in the basalt-derived soils, whereas exchangeable $Al^{3+}$ was significantly higher in the sandstone-derived soils.

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**Table 1: T-test for the physical properties of sandstone (S) and basaltic (B) soils**

| Soil horizon | Sand | | Silt | | Clay | | BD | | PD | | Total Porosity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | B | S | B | S | B | S | B | S | B | S | B |
| | % | | | | | | Mg/m$^3$ | | | | % | |
| Soil on the crest | | | | | | | | | | | | |
| Ap | 57.2 | 45.2 | 22 | 40 | 20.8 | 14.8 | 1.48 | 0.91 | 2.75 | 2.45 | 46 | 63 |
| Bt1 | 41.2 | 33.2 | 22 | 38 | 36.8 | 28.8 | 1.70 | 1.06 | 2.20 | 2.35 | 22 | 55 |
| Bt2 | 29.2 | 37.2 | 20 | 38 | 50.8 | 24.8 | 1.61 | 1.03 | 2.66 | 2.98 | 40 | 65 |
| Crt | 39.2 | 23.2 | 20 | 54 | 40.8 | 22.8 | 1.56 | 1.23 | 2.21 | 1.97 | 30 | 38 |
| Soil on the middle slope | | | | | | | | | | | | |
| Ap | 59.2 | 37.2 | 24 | 40 | 16.8 | 22.8 | 1.49 | 1.14 | 2.70 | 2.26 | 44 | 50 |
| Bt1 | 49.2 | 21.2 | 20 | 42 | 30.8 | 36.8 | 1.62 | 1.17 | 2.24 | 2.31 | 27 | 49 |
| Bt2 | 49.2 | 13.2 | 18 | 40 | 32.8 | 46.8 | 1.73 | 1.38 | 2.36 | 2.36 | 26 | 42 |
| Crt | 63.2 | 21.2 | 20 | 36 | 16.8 | 42.8 | 1.62 | 1.39 | 2.27 | 2.19 | 28 | 37 |
| Soil on the valley bottom | | | | | | | | | | | | |
| Ap | 53.2 | 55.2 | 28 | 24 | 18.8 | 20.8 | 1.10 | 1.18 | 2.25 | 1.41 | 51 | 16 |
| Bt | 61.2 | 31.2 | 20 | 30 | 18.8 | 38.8 | 1.20 | 1.47 | 2.40 | 2.69 | 50 | 45 |
| t (Observed value) | -3.487 | | 6.401 | | 0.318 | | -3.661 | | -0.721 | | 1.693 | |
| \|t\| (Critical value) | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | |
| p-value (Two-tailed) | **0.003** | | **<0.0001** | | 0.754 | | **0.002** | | 0.480 | | 0.108 | |
| | ** | | *** | | *ns* | | ** | | *ns* | | *ns* | |

S= Sandstone soils, B= basaltic soils, ns = not significant at 5% confidence level. BD = bulk density

**Table 2: T-test of the chemical properties of sandstone and basaltic soils**

| Soil horizon | pH | | OC | | TN | | Avail. P | | Ca | | Mg | | K | | Na | | Al | | H | | CEC | | BS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % | | | | mg/kg | | | | | | | | cmol/kg | | | | | | | | % | |
| **Soil on the crest** | | | | | | | | | | | | | | | | | | | | | | | | |
| | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B |
| Ap | 5.6 | 5.8 | 0.80 | 2.43 | 0.07 | 0.21 | 9.00 | 6.4 | 4.8 | 6.4 | 0.4 | 1.0 | 0.10 | 0.12 | 0.08 | 0.10 | 1.12 | 0.68 | 0.96 | 2.36 | 10 | 39 | 53.8 | 19.5 |
| Bt1 | 5.5 | 5.9 | 0.50 | 0.98 | 0.04 | 0.08 | 12.87 | 4.9 | 4.6 | 4.8 | 0.4 | 2.4 | 0.09 | 0.11 | 0.07 | 0.09 | 1.28 | 0.20 | 1.52 | 1.60 | 12 | 36 | 43.0 | 20.6 |
| Bt2 | 5.4 | 6.0 | 0.46 | 0.56 | 0.03 | 0.04 | 5.00 | 7.1 | 5.0 | 4.2 | 0.6 | 0.8 | 0.10 | 0.10 | 0.08 | 0.09 | 1.88 | 0.00 | 2.44 | 0.96 | 20 | 24 | 28.9 | 21.6 |
| Crt | 5.1 | 6.1 | 0.30 | 0.40 | 0.02 | 0.03 | 5.75 | 31.0 | 4.2 | 3.8 | 0.4 | 0.4 | 0.08 | 0.09 | 0.06 | 0.07 | 2.84 | 0.12 | 1.88 | 1.48 | 18 | 23 | 26.3 | 18.9 |
| **Soil on the middle slope** | | | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 5.4 | 5.7 | 0.80 | 1.58 | 0.07 | 0.14 | 9.37 | 15.6 | 4.0 | 4.8 | 0.6 | 0.8 | 0.09 | 0.10 | 0.07 | 0.08 | 0.80 | 0.48 | 1.12 | 1.32 | 15 | 30 | 31.7 | 19.2 |
| Bt1 | 5.3 | 4.8 | 0.34 | 0.50 | 0.02 | 0.04 | 6.00 | 5.0 | 5.0 | 3.6 | 0.4 | 0.4 | 0.07 | 0.09 | 0.06 | 0.07 | 2.20 | 1.24 | 1.32 | 3.80 | 12 | 25 | 46.1 | 16.6 |
| Bt2 | 5.3 | 5.1 | 0.30 | 1.65 | 0.02 | 0.14 | 5.87 | 6.8 | 5.0 | 3.4 | 0.2 | 0.2 | 0.10 | 0.08 | 0.08 | 0.07 | 2.88 | 1.40 | 0.76 | 1.40 | 19 | 20 | 32.1 | 18.8 |
| Crt | 5.4 | 5.2 | 0.22 | 0.20 | 0.01 | 0.10 | 5.12 | 4.4 | 5.0 | 3.6 | 0.2 | 0.4 | 0.10 | 0.09 | 0.07 | 0.08 | 1.84 | 2.08 | 1.56 | 1.08 | 15 | 18 | 35.8 | 23.2 |
| **Soil on the valley bottom** | | | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 5.4 | 5.7 | 1.18 | 1.42 | 0.10 | 0.12 | 9.87 | 11.4 | 5.2 | 4.4 | 0.4 | 0.8 | 0.11 | 0.10 | 0.09 | 0.07 | 0.56 | 1.20 | 1.96 | 1.00 | 10 | 21 | 58.0 | 25.6 |
| Bt | 5.4 | 5.5 | 0.24 | 0.32 | 0.01 | 0.02 | 9.87 | 5.9 | 4.4 | 4.0 | 0.6 | 0.6 | 0.09 | 0.08 | 0.07 | 0.07 | 0.52 | 0.80 | 1.40 | 2.04 | 9 | 18 | 57.3 | 26.3 |
| t (Observed) | 1.425 | | 1.934 | | 2.440 | | 0.719 | | 1.365 | | 1.782 | | 0.553 | | 1.306 | | -2.227 | | 0.672 | | 4.314 | | -5.155 | |
| \|t\| (Critical) | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | | 2.101 | |
| p-value | 0.171 | | 0.069 | | **0.025** | | 0.482 | | 0.189 | | 0.092 | | 0.587 | | 0.208 | | **0.039** | | 0.510 | | **0.0004** | | **<0.0001** | |
| | *ns* | | *ns* | | * | | *Ns* | | *ns* | | *ns* | | *ns* | | *ns* | | * | | *ns* | | ** | | *** | |

BS= Base saturation, S= Sandstone soils, B= basaltic soils, ns = not significant at 5% confidence level. BD = bulk density

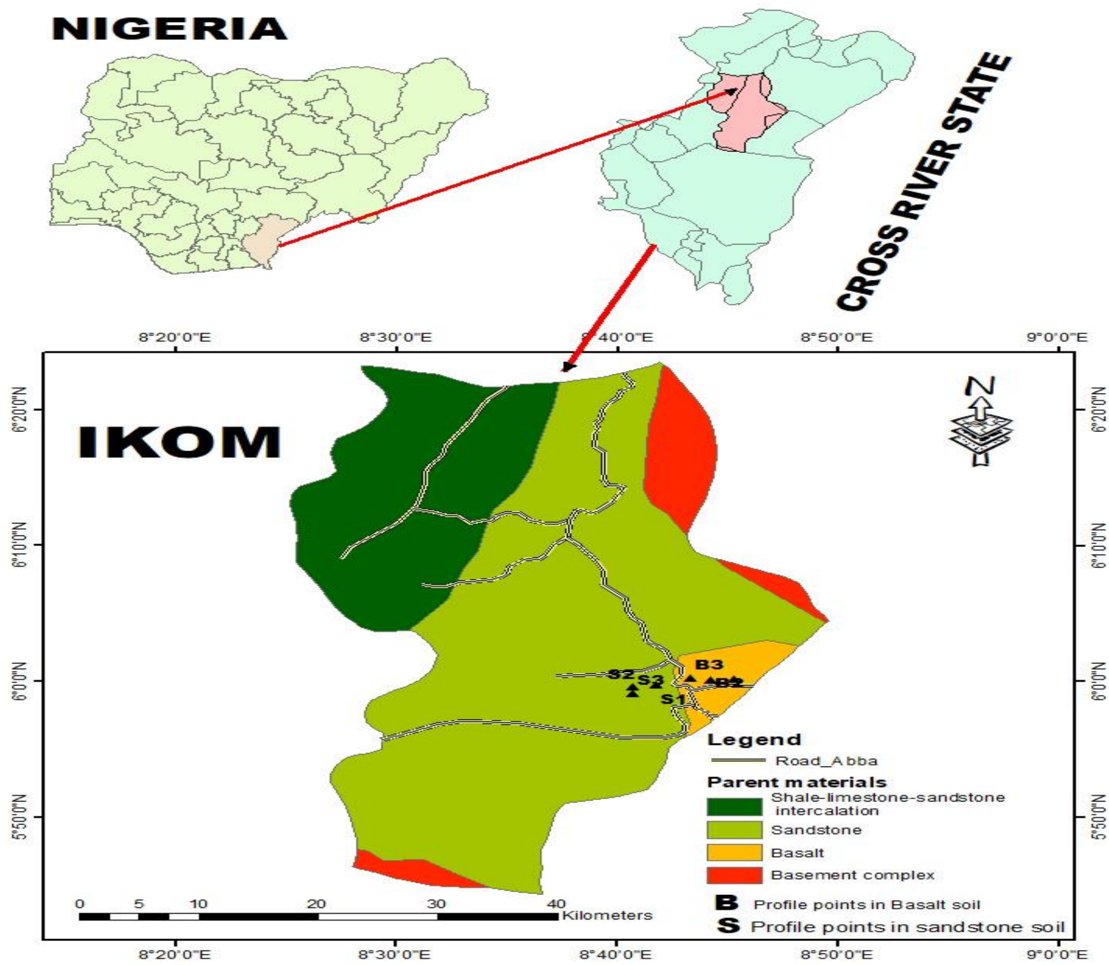


Figure 1: Map showing the study area (adapted from Ekwueme (2004)

Plate 1: Basalt profile pit 2

Plate 2: Sandstone profile pit 2