# VARIABILITY OF SOILS ALONG A TOPOSEQUENCE IN DELTA STATE UNIVERSITY, ASABA CAMPUS, NIGERIA.

**Ojobor, S. A.**
Department of Agronomy, Delta State University, Asaba Campus
smartojobor@gmail.com08065938821

**Abstract**
The study was conducted on soils along a toposequence in Delta State University, Asaba Campus to investigate the influence of topography on soil physical and chemical properties. Reconnaissance survey was conducted to find out toposequence characteristics and one of the hills with a length of 302m was chosen and it was delineated into three strata namely: hill crest, middle crest and valley bottom with distance of 151m apart. Three profile pits were dug to a depth of 105cm andsoil samples were taken at seven levels (0-15, 16-30, 31-45, 46-60, 61-75, 76-90 and 91-105cm). The soil samples were air dried and sieved with 2mm mesh.Soil texture, bulk density, pH, N, P, K, Ca, Mg, Na and ECEC were measured. Data obtained were analyzed using mean and coefficient of variation.Sand fraction decreased from hill crest tovalley bottom and clay content increased from hill crest to valley bottom while bulk density increased with soil depth.Soil chemical properties were highly variable, soil acidic increases with depth though,the hill and middle crest were more acidic than valley bottom. Organic carbon, total nitrogen,available phosphorus and ECECwere low and decreases with depth except at valley bottom that was high.The valley bottom had more nutrient than hill and middle crest. An understanding of the degree of soil variability along toposequence will enhance nutrient management plan for sustainable cropproduction.

**Keywords:** Toposequence, Soil variability, Asaba, Soil properties, Nutrient elements.

**Introduction**

Soilin Delta State University, Asaba Campus is formed on toposequence, the slope configuration may greatly influenced its moisture and nutrientdistribution. The movement of watermay exert a strong effect on the transfer and storage of nutrient elements, heat and air within the soil profile (Joss, 2000). A toposequence is succession of soils formed from the crest to the valley bottom that contains a range of soil profile that is representatives of the soil (Akinso, 2006). Properties of soil (physical, chemical, biological and mineralogical characteristics) formed along the slope are usually different, hence the agricultural use and management may likely differs. The differences along the toposequence are results of erosion, leaching and depletion of its chemical compounds etc. These processesledto morphological changes associated with soil colour and horizonation due to changes in hydrology related to topographic position.

Relationship betweenslope formed and soil propertiesare not easily predictable and also, variations within the toposequence are controlled by interaction of soil forming factors (parent material, living organisms, climate, relief and time) (Sinowski and Auerswald, 1999). In addition, Anikwe and Obi (1999) stressed that the amount of soil heat and moisture depends on the slope gradient. Thus, soil on hilly slope will differ from those of the lower crest.The percolating water will move literally across the profile instead of dominant flow andthe surface soil are subjected to erosion. Therefore,for the sustainable use of soils oncontinuous crop production in this present condition,it is essential forproper examinationbe made on the soil toposequence, this information will enhance its agricultural potential. It isimperative to examine the soil variability for good soil management and conservation (Tabi and Ogunkunle, 2007). Different agricultural management practices needs to be adopted within each slope class to caution the impact of the changes.Improper or wrong management practices can exact negative effect on the soil.

Soil variability has been observed to caused crop growth and yield variation (Brouwer *et al.*, 1993) and significantly influenced soil management and crop production (Fasina, 2003). The soil variation over the landscape is well known to both soil scientist and other land users.Also,its adverse effects on land use have been documented worldwide (McBratney *et al.*, 2000 and Fasina, 2003).Stoop (1987) observed high degree of variability in crop stands and low productivity, and noted that yield tend to decreased from fertile valley bottom to infertile uplands. In spike of these soil variability, recommendations of management practices are often made without due consideration of the topography that influenced it (especially fertilizer application) (Oluwatosin *et al.*, 2001), this brings about sharp variations in crop yield. In line with this, Moorman *etal.* (1981) noted that an understanding of the basic soil properties is essential for developing management practices that will maintain the productive potential of the soil. Therefore, this study evaluated the physical and chemical properties of the soil along a toposequence in Delta State University, Asaba Campus.

**Materials and Methods**

The experiment was conducted in Delta State University, Asaba Campus. The site is situated in the rainforest zone, with longitude $6^0$ $14^1$E and latitude $6^0$ $14^1$N. Asaba has a bi-modal rainfall pattern with break in August. The rainy season runs between mid March to mid November while the dry season runs from late November to the end of March with annual rainfall between 1500 to 1800mmand annual temperature ranged from 25°C to 37°. The relative humidity is usually high in the month of June to September with average figure of 75.8% (Nigeria Meteorological Agency, Asaba (2015)).

The soils of the area are general deep, loose, porous and sandy to clay loam. They leached due to high intensity of rainfall associated with the environment. The topography is undulating with slope gradient of about 2 to 5% with four major hills. The vegetation of the area is typically rainforest with trees, sedges and weeds of various species. Land use characteristic includes arable crops (yam, cassava, maize, vegetables) and permanent crops (oil palm and rubber plantation).

Reconnaissance survey was conducted on 10th May, 2013 round the study area. The aim of the visit was to find out land form with toposequence characteristics. One of the hills was chosen for the studyand it was delineated into three strata namely: hill crest, middle crest and valley bottom. The toposequence has a distance of 302m with a length of 151m between the crest and middle crest, and also 151m between the middle crest and the valley bottom. Three representative soil profiles were dug to a depth of 105cm.Soil samples were taken at seven levels (0-15, 16-30, 31-45, 46-60, 61-75, 76-90 and 91-105cm). Seven composite soil samples were taken from each profile, given a total of twenty one (21) soil samples. The soil samples were air dried at room temperature and sieved with 2mm mesh. Soil parameters measured were: soil texture, bulk density, pH, N, P, K, Ca, Mg, Na and ECEC. The soil pH was on a ratio of 1:2 soil/water suspensions (IITA, 1979). Organic carbon was determined using the Walkley Black Method. Exchangeable bases (K, Ca. Mg and Na) were extracted by ammonium acetate extraction, Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) while K and Na were read using Flame Photometer. The available P was extracted with Bray-1 extracting solution and further reading was carried out Colormetrically. Total N was determined by the Kjeldhal distillation method. The data obtained were statistically analyzed using mean and coefficient of variation.

**Results and Discussion**

**Physical properties of the study area**

The particle size distribution is shown on Table 1, sand fractions were dominant, most especially at the top soils with over 70%sand and it decreases with depth.At the hill crest, sand fraction varied from 92.2% to 83.2 with a mean of 89.1% and coefficient of variation (CV) of 4.7%.At the middle crest, it rangesbetween 93.7 and 71.7% with mean of 82.6% and CV of 12.4%, while the sand fraction varied from 89.2 to 77.2% at the valley bottom with mean of 82.0% and CV of 6.2%. The silt fraction do not decreased with depth at the hill crest butit does at both the middle crest and valley bottom. The mean values were 1.5, 1.8 and 1.8% while CVwere 42.3, 44.8 and 79.1% for hill crest, middle crest and valley bottom respectively. Clay fraction increases with depth,the mean values were 9.4, 15.7 and16.2% while CV were 47.1, 35.8 and 39.5% for hill crest, middle crest and valley bottom respectively. Bulk density also increased with depth in the entire crest. The mean were 1.18, 1.41 and 1.51% while CVwere9.0, 15.0 and 15.0% for hill crest, middle crest and valley bottom respectively.The sub-soils were sandy loam, loamy sand and sandy clay loam respectively.

The clay distribution between the crest and the lower slope appears to have resulted from lateral clay translocation (Idoga *et al*., 2007). Clay material at the crest could be removed in suspension and deposited at the lower slope by surface wash.The coefficient of variation for sand fraction indicates that the whole area seems to be homogenous. The slight variability of soil texture could be attributed to the slope which is a major factor of soil formation (Fasina *et al*., 2007). Ogunkunle (1993) identified the possible causes of this as micro-relief, soil erosion and deposition, he further attributed decreased of sand and increased of clay content with depth as illuviation of clay down the sub-soil horizon. The bulk density tend toincrease with depth, the lower bulk density found at the surface soil and higher value at the sub-soil could be attributed to decreasing organic matter of the study area with depth (Brandy, 1996 and Malgwi *et al*., 2000).

**Chemical properties of the study area**

Table 2 shows the soil chemical properties, it was acidic and increases with depth. At the hill, the soil pH ranges from 5.6 to 4.5 with mean of 4.9 and coefficient of variation (CV) of 10.0%. At the middle crest, soil pH ranges from 5.5 to 4.5 with mean of 4.9 and CV of 10.0% while at the valley bottom,it ranges between 6.5 and 5.1 with mean of 5.8 and CV of 12.3%. Soil organic carbon was generally low and it ranges from 1.02 – 0.32% with mean of 0.65% and CV of 49.2% at the hill crest. The middle crest and valley bottom had meanof 0.59 and 0.90, and CV of 49.2 and 66.7% respectively.

Nitrogen was low, at the hill crest, the mean was 0.049 with CV of 56.3%. The middle crest had mean of 0.049% and CV of 56.3% while the valley bottom nitrogen content ranges from 0.121 to 0.035% with mean of 0.061% and CV of 50.8%. The available phosphorus decreases down the soil profile. Itvaried from 8.05 to 2.64mg/kg with mean of 3.78mg/kg and CV of 31.5mg/kg at the hill. The middle crest had mean available phosphorus of 3.78mg/kg and CV of 31.5%, while at the valley bottom,the mean was 9.8mg/kg and CV of 25.5%. The ECEC was also low and decreases with depth. It ranges from 3.25 to 1.80cmol/kg with mean of 2.43cmol/kg and CV of 35.8% at the hill crest.At the middle crest, it ranges from4.25 to 1.16cmol/kg with mean of 2.43cmol/kg and CV of 35.8% while at the valley bottom, theECEC ranges from 13.66 to 2.54cmol/kg with mean of 5.48cmol/kg and CV of 57.4%.

The high variability of soil chemical properties could be due to variation imposed by management practices (bush burning and cultivation) (Zebarth *et al*., 2002). Leaching of basic cations from the soil surface couple with effects of parent materials could led to the low pH. According to Lekwa and Whiteside (1986), Akamigbo and Asadu (1990) and Asadu (1990), soil pH is accounted for by the effects of parent materials, loss of basic cations through leaching and soil erosion, and dominance of sesquioxides in the exchanged complex site.There was higher organic matter at the top soil than the subsoil, this could be due to high microbial activities at the top soil. Also, organic materials are not easily moved down the soil profile unlike the nutrient minerals.Effects of climate and topography couple with inadequate nitrogen fertilizers application could be attributed to low nitrogen observed. This findings correlate with the work of Mbagwu and Obi (1995) who stated that leaching of nitrogen, less fallow period and non-application of nitrogen fertilizers led to low soilnitrogen. The low available phosphorus could be attributed to low soil pH which tend to fixed available phosphorus in the soil (Benka-coker and Ekundayo, 1995). Theeffects of erosion and leaching could also be attributed to low available phosphorus (Ojobor *et al.*, 2013). Exchangeable bases of the areas could be affected by leaching of basic cations by action of rain. Though, it has been reported that soils formed on basement complex rock are generally high in exchangeable bases especially K (FMANR, 2012), but this was not the case due to effects of climate that leached the basic cations and plant uptake of the nutrient without replacement through fertilizer application..

**Variation of soil properties**

The coefficient of variation (CV) values determined for the 14 soil physical and chemical properties area showed in Table 1 and 2 below. According to Wilding and Dress (1978), four of the soil properties (silt, clay, bulk density and Na) were less variable (CV<15%), three properties (pH, P and ECEC) were moderately variable (CV=15-35%), while seven properties (sand, OC, N, K, Ca, Mg and H) were highly variable (CV>35%) at the hill crest.

At the middle crest, five soil properties (sand, silt, bulk density, pH and Na) were less variable (CV<15%),two properties (p and ECEC) were moderately variable (CV=15-35%). Also, seven soil properties (silt, OC, N, K, Ca, Mg and H) were highly variable (CV>35%). Then at the valley bottom, three soil properties (silt, clay and pH) were less variable (CV<15%), two properties (P and Na) were moderately variable (CV=15-35%) and nine soil properties (silt, clay, OC, N, K, Ca, Mg, H and ECEC) were highly variable (CV>35%).

**Conclusion**

The study evaluated the physical and chemical properties of soil along a toposequence. The result showed that some of the soil properties were less and moderately variable, but higher percentage were highly variable at the hill crest.An understanding of the degree of soil variability along the toposequence of an area is highly essential for sustainable land use management for crop production.

**Table 1: Physical properties of the soil along the toposequence**

| Location/ Depth (cm) | Sand | Silt | Clay | Textural Class | Bulk Density ($g/cm^3$) |
|---|---|---|---|---|---|
| | -------------------%-------------- | | | | |
| **Hill Crest** | | | | | |
| 0 – 15 | 92.2 | 2.5 | 5.3 | sand | 1.05 |
| 16 – 30 | 91.2 | 2.0 | 6.8 | sand | 1.09 |
| 31 – 45 | 89.6 | 1.6 | 8.8 | sand | 1.12 |
| 46 – 60 | 89.7 | 1.0 | 9.3 | sand | 1.20 |
| 61 – 75 | 89.7 | 1.0 | 9.3 | sand | 1.29 |
| 76 – 90 | 83.7 | 3.0 | 13.3 | loamy sand | 1.29 |
| 91 – 105 | 83.2 | 2.5 | 14.3 | loamy sand | 1.35 |
| **Mean%** | **89.1** | **1.5** | **9.4** | | **1.18** |
| **C.V%** | **4.7** | **42.3** | **47.1** | | **9.0** |
| **Middle Crest** | | | | | |
| 0 – 15 | 93.7 | 3.0 | 3.3 | sand | 1.00 |
| 16 – 30 | 93.2 | 2.5 | 4.3 | sand | 1.30 |
| 31 – 45 | 90.2 | 2.0 | 7.8 | sand | 1.39 |
| 46 – 60 | 84.7 | 1.5 | 13.8 | loamy sand | 1.46 |
| 61 – 75 | 73.0 | 1.2 | 25.8 | sandy clay loam | 1.52 |
| 76 – 90 | 71.7 | 1.0 | 27.3 | sandy clay loam | 1.62 |
| 91 – 105 | 71.7 | 1.0 | 27.3 | sandy clay loam | 1.62 |
| **Mean%** | **82.6** | **1.8** | **15.7** | | **1.41** |
| **C.V%** | **12.4** | **44.8** | **35.8** | | **15.00** |

**Continuation of Table 1. Physical properties of the soil along the toposequence**

| Location/ Depth (cm) | Sand | Silt | Clay | Textural Class | Bulk Density ($g/cm^3$) |
|---|---|---|---|---|---|
| | -------------------%-------------- | | | | |
| **Valley Bottom** | | | | | |
| 0 – 15 | 89.2 | 4.5 | 6.3 | sand | 1.05 |
| 16 – 30 | 88.3 | 2.4 | 9.3 | sand | 1.28 |
| 31 – 45 | 84.2 | 2.0 | 13.8 | loamy sand | 1.46 |
| 46 – 60 | 78.7 | 1.5 | 19.8 | sandy loam | 1.55 |
| 61 – 75 | 78.7 | 1.0 | 20.3 | sandy loam | 1.59 |
| 76 – 90 | 78.2 | 0.5 | 21.3 | sandy clay loam | 1.67 |
| 91 – 105 | 77.2 | 0.5 | 22.3 | sandy clay loam | 1.85 |
| **Mean** | **82.0** | **1.8** | **16.2** | | **1.51** |
| **C.V%** | **6.2** | **79.1** | **39.5** | | **15.00** |

**Table 2: Chemical properties of the soil along the toposequence**

| Location/ | pH | O.C | N | P | K | Ca | Mg | Na | H | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | ($H_2O$) | ------%------ | | $mgkg^{-1}$ | -------------------$cmolkg^{-1}$-------------------- | | | | | |
| **Hill Crest** | | | | | | | | | | |
| 0 – 15 | 5.6 | 1.02 | 0.087 | 8.05 | 0.11 | 1.68 | 0.88 | 0.18 | 0.40 | 3.25 |
| 16 – 30 | 5.1 | 0.77 | 0.053 | 7.28 | 0.09 | 0.96 | 0.64 | 0.17 | 0.50 | 2.36 |
| 31 – 45 | 4.8 | 0.62 | 0.049 | 6.84 | 0.07 | 0.88 | 0.56 | 0.16 | 0.60 | 2.27 |
| 46 – 60 | 4.8 | 0.56 | 0.044 | 4.72 | 0.06 | 0.72 | 0.48 | 0.14 | 0.60 | 2.00 |
| 61 – 75 | 4.7 | 0.42 | 0.031 | 4.59 | 0.05 | 0.72 | 0.40 | 0.13 | 0.50 | 1.80 |
| 76 – 90 | 4.5 | 0.39 | 0.081 | 3.57 | 0.04 | 0.64 | 0.32 | 0.12 | 0.70 | 1.82 |
| 91 – 105 | 4.5 | 0.32 | 0.028 | 2.64 | 0.02 | 0.56 | 0.24 | 0.12 | 1.00 | 1.94 |
| **Mean** | **4.9** | **0.65** | **0.049** | **3.78** | **0.06** | **1.13** | **0.05** | **0.15** | **0.29** | **2.43** |
| **C.V(%)** | **10.0** | **49.2** | **56.3** | **31.5** | **45.0** | **70.8** | **68.0** | **15.3** | **84.0** | **35.8** |

**Continuation of Table 2. Chemical properties of the soil along the toposequence**

| Location/ Depth (cm) | pH ($H_2O$) | O.C | N | P | K | Ca | Mg | Na | H | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ------%------ | | mgkg$^{-1}$ | -------------------cmolkg$^{-1}$-------------------- | | | | | |
| **Middle Crest** | | | | | | | | | | |
| 0 – 15 | 5.5 | 1.26 | 0.104 | 6.37 | 0.14 | 2.76 | 0.96 | 0.19 | 0.20 | 4.25 |
| 16 – 30 | 5.3 | 0.85 | 0.066 | 3.88 | 0.10 | 1.54 | 0.72 | 0.17 | 0.30 | 2.83 |
| 31 – 45 | 5.0 | 0.69 | 0.044 | 3.65 | 0.08 | 0.98 | 0.64 | 0.14 | 0.20 | 2.04 |
| 46 – 60 | 4.7 | 0.55 | 0.038 | 3.34 | 0.06 | 0.80 | 0.48 | 0.14 | 0.30 | 1.79 |
| 61 – 75 | 4.6 | 0.46 | 0.035 | 3.36 | 0.05 | 0.72 | 0.32 | 0.14 | 0.80 | 2.04 |
| 76 – 90 | 4.6 | 0.41 | 0.031 | 2.96 | 0.04 | 0.64 | 0.24 | 0.13 | 1.10 | 1.16 |
| 91 – 105 | 4.5 | 0.32 | 0.025 | 2.89 | 0.02 | 0.48 | 0.16 | 0.13 | 1.10 | 1.90 |
| **Mean** | **4.9** | **0.59** | **0.049** | **3.78** | **0.06** | **1.13** | **0.50** | **0.15** | **0.29** | **2.43** |
| **C.V(%)** | **10.0** | **49.2** | **56.3** | **31.5** | **45.0** | **70.8** | **68.0** | **15.3** | **84.0** | **35.8** |

| Location/ Depth (cm) | pH ($H_2O$) | O.C | N | P | K | Ca | Mg | Na | H | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ------%------ | | mgkg$^{-1}$ | -------------------cmolkg$^{-1}$-------------------- | | | | | |
| **Valley Bottom** | | | | | | | | | | |
| 0 – 15 | 6.5 | 2.14 | 0.121 | 25.7 | 0.49 | 8.60 | 4.16 | 0.21 | 0.20 | 13.66 |
| 16 – 30 | 6.4 | 1.09 | 0.075 | 18.7 | 0.17 | 4.48 | 2.08 | 0.18 | 0.20 | 7.11 |
| 31 – 45 | 5.7 | 0.96 | 0.069 | 9.5 | 0.10 | 3.52 | 0.96 | 0.16 | 0.20 | 4.94 |
| 46 – 60 | 5.6 | 0.64 | 0.047 | 4.9 | 0.09 | 2.48 | 0.64 | 0.16 | 0.50 | 3.87 |
| 61 – 75 | 5.6 | 0.53 | 0.041 | 4.7 | 0.09 | 1.76 | 0.56 | 0.14 | 0.80 | 3.35 |
| 76 – 90 | 5.4 | 0.47 | 0.038 | 3.5 | 0.08 | 1.28 | 0.48 | 0.13 | 1.90 | 2.87 |
| 91 – 105 | 5.1 | 0.44 | 0.035 | 1.6 | 0.05 | 0.96 | 0.40 | 0.13 | 1.00 | 2.54 |
| **Mean** | **5.8** | **0.90** | **0.061** | **9.8** | **0.15** | **3.30** | **1.33** | **0.16** | **0.59** | **5.48** |
| **C.V(%)** | **12.3** | **66.7** | **50.8** | **25.5** | **106.7** | **62.5** | **103.8** | **18.1** | **69.5** | **57.4** |

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