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Variability of Selected Soil Properties of a River Slope in Amaigbo, Southeastern Nigeria

Ndukwu, B.N., Onweremadu E.U., Nkwopara U.N., Ahukaemere C.M.
Ihem E.E. and Agim L.C.
Department of Soil Science and Technology,
Federal University of Technology
P.M.B 1526 Owerri, Nigeria

Abstract:

The study investigated variability of selected soil properties of a riverslope in Amaigbo, Southeastern Nigeria. A transect was used to align soil pedons dug on three physiographic positions, namely upper slope, midslope and footslope. Soil samples were collected from horizons based on soil profile differentiation. Data collected were subjected to statistical analysis using coefficient of variation (CV) and correlation. Results showed that soil properties differed in their degree of variation among the physiographic units. Sand content had low variation in the upper slope (CV = 2.66 %), high variation in midslope (CV = 109.39 %) and moderate variation in the footslope (CV = 20.11 %). Clay content, and pH varied highly in footslope (CV = 60.00 % and 87.12 %) while in upper slope and midslope pH had low variation. High CVs were recorded in both total N and % base saturation in the three (3) physiographic units. The pH had positive significant relationship with organic matter (OM) in all the physiographic units ($r = 0.96, 0.78, 0.99, P < 0.05$) for upper slope, midslope and footslope, respectively. Positive significant relationship existed between pH and available P ($r = 0.98, 0.95$ $P < 0.05$) both in midslope and footslope. Organic matter had positive significant relationship with available P in footslope ($r = 0.94, P < 0.05$). A more intensive soil sampling from landscape of the River slope with the inclusion of more parameters will provide a better and reliable representation of the variability of soil properties even at a regional scale.

Keywords: Physiographic unit, Topography, Variability, Tropical soil.

1.0 Introduction

Soils exhibit tremendous variability in their biological, chemical and physical properties. According to Lark & Wheeler (2000), variation in soil properties has long been known and has been the subject of much research.

Pedologists have identified fundamental soil forming processes that influence soil properties: parent material, topography, climate, time and organisms (Soil Survey Staff, 2006). Parent material from which soils develop is a key factor that in many cases determine the kind and contents of secondary minerals of soils, therefore determines its texture and chemical properties (IUSS working Group WRB, 2006). However, living organisms such as vegetation also have an important role in a number of processes involved in soil formation including organic matter accumulation, profile mixing and biogeochemical nutrient cycling (Nsalambi *et al.,* 2010). Hunter *et al*, (1982) and Yost *et al.,* (1982) reported that soil forming factors affect different properties differently at different depths. Variability of soil pH for example, increases with depth (Ogunkunle & Ataga, 1985). Ogunkunle (1993), working on Alfisols of Southwestern Nigeria, observed that soil pH was the least variable (low variability) property, irrespective of depth. The variability of soil properties like organic matter, available phosphorus, total nitrogen and Cation Exchange Capacity, increases with depth. Properties such as soil pH and porosity are among the least variable, while those pertaining to water or solute transport are among the most variable. Organic matter and percentage (%) clay range from moderate to high variability. While available phosporus and potassium were observed to be highly variable (Beven *et al.,* 1993; Wollenhaupt *et al*., 1997).

Studies on the variability of soil properties have overtime been related to many factors as land use (Langley-Turnbaugh & Keirstead, 2005; Eden *et al.,* 1991; Amusan *et al.,* 2001), slope disposition (Dowling *et al.,* 1986; Huang *et al.,* 2001) Small changes in topography affects the transport and storage of water across and within the soil profile, wetlands (Bruland & Richardson, 2005), and field crops (Cox *et al.,* 1998). Wetland soils are quite variable in nature but are always high in clay activity, unlike tropical upland soils which are dominated by low-activity clay (Kyuma, 1985). Birkeland (1999) reported marked variabilities in soil properties due to slope aspect. Topography affects absorbance of solar energy such that south-facing slopes in the Northern hemisphere are more perpendicular to the sunrise and are warmer hence soils on such slopes have lower organic matter content (Esu, 2005). This is possible due to temperature which increases rate of decomposition and consequent loss of soil carbon (*Eshett et al.,* 1989). Landscape position creates differences in soil formation and consequently difference in soil properties along a hillslope (Brubaker *et al.,* 1993). This influences runoff, drainage and temperature and soil erosion.

Amaigbo has been known to be one of the communities in Nwangele, in Imo State with large population. Due to the population increase, and short fallows periods, farmers tend to cultivate fragile lands including steep slopes which have led to loss of nutrient as a result of soil erosion. Local carbon and nitrogen processes are also affected leading to variability of soil properties, (Hobbie, 1996) and this affects organic matter content (Bhatti, *et al.,* 1991) and soil degradation. It became necessary to investigate variability in properties of river slope soils being used for cultivation due to scarcity of arable soils in Amaigbo, Imo State. This study therefore, the properties and variability in soils of a river slope in Amaigbo, Southeastern Nigeria was investigated.

2.0 Materials And Methods

2.1 Study Area

The study was conducted along the slope of a river in Amaigbo, Nwangele, Imo State, Nigeria. The study area lies between Latitude 5° 35' N and Longitude 7° 34' E and lies within lowland (Ofomata, 1975). The area has a bimodial rainfall pattern with a mean annual rainfall of about 2000 mm with peaks in July and September and a brief dry spell in August. The temperature is uniformly high with mean monthly average of 29 °C. It has typical rainforest vegetation which has lost its original nature due to population increase and consequent anthropogenic activities. Farming, hunting and fishing are the major socio-economic activities of the area. Farmers raise mounds to avoid seasonal waterlogging. Crops grown there are cassava and oil palm.

2.2 Field Studies

Land units were delineated based on three (3) physiographic features namely upperslope, midlsope and footslope. Three pedons were dug and each profile pit was located in each physiographic unit. Pedons were linked with the aid of a transect at an inter-pedon distance of 100 metres. Soil samples were collected based on horizon differentiation. Soil samples collected were air-dried, crushed and sieved using 2 mm sieve, preparatory to laboratory analysis.

2.3 Laboratory Analyses

Particle size distribution was estimated by hydrometer method (Gee & Or, 2002). Soil organic carbon was measured by wet digestion (Nelson & Sommers, 1996). Soil pH was measured with an electrode on a 1:2.5 soil-water ratio (Hendershot *et al.,* 1993). Exchangeable base were extracted with ammonium acetate (NH_4OAc). Exchangeable calcium and magnesium were determined by ethylene diamineatra acetic acid titration method while exchangeable potassium and sodium were estimated by flame photometer (Jackson, 1962). Total nitrogen was determined by microkjeldal method (Bremner, 1996) while available phosphorus was determined by Bray II method (Olsen & Sommes, 1982).

2.4 Data Analysis

Coefficient of variation and correlation analysis were performed on the soil data. Coefficient of variation was used to ascertain the variability of soil properties while correlation was used to estimate the relationship among soil properties. Ranking of variability was done using the method of Aweto (1982) as follows: Little variation (CV < 20 %), Moderate variation (CV = 20-50 %), High variation (CV > 50 %).

3.0 Results and Discussion

Results of the study showed high sand content at the upper slope (75.24 %) which decreased down the river slope and high clay and silt content at the midslope and footslope (32.7 % and 27.89 %) respectively (Table 1). This is attributed to the parent material of the area which is alluvium. Also, the high clay and silt content at the midslope and footslope could be as a result of the pedogenic processes involving loss of silt and clay-sized particles from the upper slope down the river slope (Onweremadu & Uhuegbu, 2007). Pedogenesis of alluvial soils may be highly influenced by changes in water table due to alteration of rainy and dry seasons characteristic of the study area (Onweremadu *et al.,* 2008).

Table 1: Physical Property of the Studies Soil

Horizon	Depth cm	Sand	Silt %	Clay	TC
			Upperslope		
Ap	0-10	76.24	11.56	12.2	SL
AB	10-30	76.24	7.56	16.2	SL
Bt	30-70	74.24	7.56	18.2	SL
BC	70-120	74.24	6.56	19.2	SL
	Mean	75.24	8.31	16.45	
			Midslope		
Ap	`0-15	66.24	10.56	23.2	SCL
AB	15-35	34.24	28.56	37.2	CL
Bt	35-70	32.34	28.26	39.2	CL
BC	75-110	48.24	20.26	31.2	SCL
	Mean	45.24	22.06	32.7	
			Footslope		
Ap	0-15	46.24	42.56	11.2	L
AB	15-35	44.24	23.56	32.2	SCL
Bt	35-70	44.24	23.56	32.2	SCL
	Mean	45.95	27.89	26.2	

SL = Sandy Loam, SCL = Sandy Clay Loam, CL = Clay Loam, TC= Textural class

Table 2 shows the result of the chemical properties of the studied soils. The result showed that soils were moderately acidic with pH ranging from the mean value of 5.44 to 6.08 from upperslope to footslope. The acidic nature of soils could be due to excessive rainfall prevalent in the area which leads to the leaching of the basic cations leaving the acidic cations (H^+ and AI^{3+}). The exchangeable bases (Ca, Mg, K, Na) were low in the study site and increased down the slope from upperslope to footslope. The exchangeable (Ca, Mg, K, Na) bases were found highest at the footslope. This due to the slopy nature of the land which led to the loses of these nutrients from upland and then deposited at the footslope (Onweremadu *et al.,* 2007). Land use influences soil erosion on a slope (Dong *et al.,* 1998) as sediments may be forced to be deposited at the footslope (Onweremadu, 2007).

Table 2: Chemical Properties of the studied sites

Horizon	Depth (cm)	pH	Exchangeable bases (H_2O)	Ca	Exchangeable acids Mg	K	Na	H Al cmolkg^{-1}	TEB	TEA %	ECEC	OM	BS	TN	Av.P mgkg^{-1}
							Upperslope								
Ap	0-10	5.76	2.10	0.50	0.05	0.03	8.0	0.8	2.68	8.80	11.42	2.67	23.34	0.04	9.80
AB	10-30	5.43	1.10	0.17	0.06	0.03	2.0	23.2	1.36	25.60	26.96	1.10	5.04	0.030	10.50
Bt	30-70	5.27	0.60	0.17	0.05	0.03	1.6	28.4	0.85	30.00	30.85	0.76	2.76	0.020	15.54
C	70-120	5.28	1.90	0.33	0.03	0.01	1.6	25.6	2.27	27.20	29.47	0.58	7.70	0.080	9.80
	Mean	5.44	1.43	0.29	0.05	0.03	3.3	19.5	1.79	22.90	24.69	1.28	9.71	0.050	11.41
							Midslope								
Ap	0-15	6.37	2.10	0.83	0.07	0.02	1.6	0.0	3.02	1.60	4.62	3.41	65.37	0.105	12.88
AB	15-35	5.52	1.50	4.13	0.12	0.02	4.4	23.2	5.76	27.60	33.36	3.37	17.37	0.109	9.24
Bt	35-75	5.47	2.00	0.66	0.09	0.02	6.4	32.0	2.77	38.40	41.17	1.51	6.73	0.054	8.40
BC	75-110	5.36	0.70	1.65	0.07	0.02	6.8	28.0	2.44	35.20	37.64	1.04	6.48	0.032	7.28
	Mean	5.68	1.58	1.82	0.09	0.02	4.8	20.9	3.48	25.70	29.20	2.33	23.96	0.073	9.45
							Footslope								
Ap	0-5	5.91	3.50	0.83	0.13	0.02	2.8	0.0	4.48	5.60	10.08	2.13	44.44	0.016	13.02
AB	15-35	5.76	3.40	0.66	0.11	0.02	4.8	2.8	4.19	10.80	14.99	0.69	27.95	0.023	8.40
Bt	35-70	6.58	1.20	0.17	0.06	0.03	4.4	6.0	1.46	4.40	5.86	0.62	24.91	0.022	5.53
	Mean	6.08	2.70	0.55	0.10	0.23	4.0	2.93	3.38	6.93	10.31	1.16	32.43	0.035	8.89

TEA = Total exchangeable bases, TEA = Total exchangeable acids, ECEC = Effective Cation exchange capacity
O.M = Organic matter, B.Sat = Base saturation, TN = Total nitrogen, AV.P = Available phosphorus, Ca = calcium,
Mg = Magnesium K = Potassium, Na = Sodium

Organic matter content was high at the midslope (2-33 %). The high organic matter at the midslope may be due to the influence of land use. Land use influences soil erosion on a slope as sediments may be forced to be deposited (Dong *et al.,* 1998). Micro topographical features such as hills, stone old mounds, terrace and water storage depression on middleslope can deter further movement down (Onweremadu, 2007). The low OM at the footslope (1-16 %) may be attributable to high mineralization of organic matter on soil cultivation due to land use. Total nitrogen was high at the midlsope (0.073 %) when compared to that at the footslope. (0.035 %). The high TN recorded at the midslope was a reflection of its high organic matter and the influence of land use. The low TN at the footslope may be attributed to intensive cultivation of the soils which increases the rate of mineralization of the organic matter. Available phosphorus was high at the upslope (11.41 $mgkg^{-1}$) when compared to that at the midslope (9.45 $mgkg^{-1}$) and footslope (8.89 $mgkg^{-1}$). The high Av. P at upperslope may be due to the influence of land use (use of organic and inorganic fertilizer) at the upperslope by farmers. The low phosphorus at the footslope may be attributed to the fixation of phosphorus by iron (Fe) and aluminum (Al) oxides. In addition to this, P is chemically bound by the surface of the clay mineral (Chen & Zhang, 1991).

Results on the variability of each of the soil properties tested (sand, clay, pH, OM, TN and B. sat) are recorded in Table 3. Sand content has low variation in upperslope CV = 2.66 %); moderate variation in the footslope (20.11 %) and high variation in the midslope (CV = 109.39 %). The high variation of clay at the footslope (60.07 %) in attributed to the pedogenesis of alluvial soils where the clay sized fractions are detached and easily transported and deposited down the slope. Organic matter varied highly in the three physiographic units (129.24 %, 92.18 %, and 140.70 %). This could be due to land use, landscape position, and fluvial depositions (Onweremadu *et al.,* 2008) leading to high variation of organic matter. The pH value varied little in both upperslope and midslope (CV = 8.66 % and 11.96 % respectively), while in footslope, pH had high variation (CV = 87.12 %). High CVs were recorded for total nitrogen and base saturation in all the physiographic units (CV = 101.89 %, 65.98 %, 125.71 %; and 166.01 %, 201.27%, respectively) with the exception of footslope which has moderate variation in base saturation (CV = 45.82 %), suggesting that a number of factors such as soil type, vegetation type, management history, age and microclimate may also be important in explaining

Table 3: Variability of selected soil properties

Soil Properties	Mean	CV (%)	Ranking
		Upperslope	
Sand	75.24	2.66	LV
Clay	16.45	32.60	MV
pH	5.44	8.66	LV
OM	1.28	129.24	HV
TN	0.05	101.89	HV
B. Sat	9.71	166.01	HV
		Midslope	
Sand	45.24	109.39	HV
Clay	32.70	38.07	MV
pH	5.68	11.98	LV
OM	2.33	92.18	HV
TN	0.07	65.98	HV
B. Sat	23.96	201.27	HV
		Footslope	
Sand	45.91	20.11	MV
Clay	26.20	60.07	HV
Ph	6.08	87.12	HV
OM	1.16	140.70	HV
TN	0.04	125.71	HV
B. Sat	32.43	45.82	HV

CV = coefficient of variation, OM = organic matter
TN = Total nitrogen, B.sat = base saturation
MV = moderate variation, HV = high variation, LV = little variation

variability of this soil. Landscape position influences runoff, drainage, and temperature and soil erosion. All these affect local carbon and nitrogen processes (Hobbie, 1996) and the variability of soil properties is large in complex hills (Miller *et al.*, 1988), especially in organic matter content (Bhatti *et al.*, 1991).

The relationships among selected properties are shown in Table 4. The result shows that pH had a positive significant relationship with OM in all the physiographic units suggesting that increase in pH increases organic matter content (r = 0.96, 0.78, 0.99, P < 0.05). Also, pH had significant positive relationship with available P in both midslope and footslope (r = 0.97, 0.95 P < 0.05) while in the upperslope, it had no significant correlation with available P. Such results have been reported between adoption and some pH (Brennan et al., 1994; Dodor & Oya, 2000; Khare et al., 2004). The significant relationship between P and soil pH is an asset in soil management as status of soil pH can be used to predict P-availability and unavailability for crops. This is critical since P-anions react quickly with some cations say Al, Fe and Ca to become less soluble even with slight pH change. Organic matter had significant positive relationship with available P in footslope (r = 0.94) while in upperlsope and midslope OM had no significant relationship with available P.

Table 4: Relationship among selected properties of soils in the study site

Soil properties	r
Upperslope	
OM Vs Av. P	0.39^{NS}
pH Vs OM	0.96*
pH Vs TEB	0.60^{NS}
pH Vs Av. P	0.54^{NS}
Midslope	
OM Vs Av. P	0.02^{NS}
pH Vs OM	0.78*
pH Vs TEB	0.06^{NS}
pH Vs Av. P	0.97^{NS}
Footslope	
OM Vs Av. P	0.94^{NS}
PH Vs OM	0.99*
pH Vs TEB	0.62^{NS}
pH Vs Av. P	0.95*

OM = organic matter, TEB = total exchange base, Av.P = available phosphorus

$P < 0.05$ = Significant, NS = Non significant

Soil properties differed in their degree of variability among the physiographic units. Sand content had low variation in the upperslope, high variation in the midslope and moderate variation in the footslope. Clay varied highly in the footslope, pH varied highly in the footslope while OM varied highly in the three physiographic units. Soil pH had a significant positive relationship with OM and available phosphorus. More intensive sampling from landscape delineation and inclusion of more variables will provide more accurate and reliable representation of soil properties at regional scales.

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