Spatial Variability of Soil Properties in the Obudu Mountain Region of Southeastern Nigeria

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Abstract

This study examined the spatial variability of soils in the Obudu Mountain regions of southeastern-Nigeria. Data for this study were obtained from direct field measurements, topographic maps and laboratory analysis of the area. Twelve soil samples were collected from six topographic gradients (2.5, 27.5, 22.5, 17.5, 12.5 and 7.5 per cent) located within the study area. The soil samples were collected with a soil auger at depths of 0-15 and 15-30cm, parceled, labeled and taken to the laboratory for analysis of selected physico-chemical properties. The different topographic gradients were deduced from the topographic map of the area and ground-truthed with an abney level. Soil texture ranged from sandy loam to loamy sand with per cent sand having means of 63 and 66 respectively. The soil in the area is dominated with sand fraction. Soil reaction is slightly acidic, with moderate distribution of organic carbon and low total nitrogen contents (mean values for 0-15 and 15-30cm depths; 6.20 and 5.90, 0.80 and0.70, and 0.10). Available phosphorus is also low being less than 8 ppm in all the slope gradients. Percentage base saturation was high (>50% across the sample points) across the sampled slope positions. The coefficient of variation indicated that chemical properties were more variable than the physical properties with exchangeable calcium being the most variable (57.1 per cent) for surface layers and exchangeable sodium (88.9 per cent) for subsurface layers. The result revealed variations in soil properties among the landscape segments which were probably due to the topo-sequence characteristics in soils. However, there was no consistence in the sequence of distribution of particle size fractions from the crest to the valley floor. Slope position and gradients influence the distribution of soils in the area but its spread was not consistent from the crest to the valley floor. Hence, it is recommended that farming activities on the slope should be reduced to minimize the risk of environmental hazards.

Key words: Southeastern Nigeria, toposequnce, correlation, soil properties and Obudu Mountain

Introduction

Spatial heterogeneity of soil properties in any given landscape is a fact that has become well established. The variability, laterally and vertically, results from the impact of the soil-forming factors, namely, climate, vegetation, topographic setting, parent material, and time (Jenny, l980; Birkeland, 1999). Such attributes exert decisive influence on soil development processes and the way water flow in landscape (Johnson *et al*. 2000; Fu *et al*. 2003; Rezaei and Gilkes 2005b). For instance, the concept of catena describes the spatial organization of soil types along the hill slope. Topography is central to the catena concept for soil development (Hook and Burke, 2000), which is characterized by leaching and redistribution of elements and soil material along hill slopes. The effect of topography is more pronounced on young and rolling soils than on old and level ones (Birkeland, 1999; Fisher and Binkley, 2000). The direction of the slope (i.e. the aspect) influences the amount and intensity of solar radiation to which a location is exposed and subsequently the temperature regime, which affects soil's biological and chemical processes as well as evaporation. On a typical mountain slope (stable slopes and homogeneous vegetation), soil characteristics generally vary gradually along the slope, whereas they exhibit little differences at equal elevations (Luc, et. al, 2002).

Topographical features such as curvature, slope, and upslope area influence the hydrological conditions of a location and generate different soil moisture conditions and flow patterns. Topography is both an internal and external factor in pedogenesis as it influences or is a consequence of soil formation (Temgoua *et al*., 2005). However, soil-landscape relationships could often be hidden by parent material. Soils developed from basement complex rocks cover wide expands of mountain terrains in Cross River State. The Obudu plateau and the Oban hills are the only Precambrian basement out crops in southeastern Nigeria (Ekwueme, 2003). It is in recognition of this that this study aimed at investigating the variability of soil characteristics within homogeneous parent material in the Obudu Mountain slopes.

Materials and Method

Site characteristics

The study area is the Obudu Mountains located in the Obanliku Local Government Area of Cross River State, southeastern Nigeria (Fig. 1). It lies between Longitudes $9^o\ 22^{'}\ 00^{''}$ and $9^o\ 22^{'}\ 45^{''}$ E, and Latitudes $6^o\ 21^{'}\ 30^{''}$ and 6^o 22' $30^{''}$ N, with an approximate area of $104sqm^2$, and a height of about 1576m above sea level (Ekwueme, 2003). Obudu Plateau is bounded in the north by Benue State, northeast by the Republic of Cameroon, to the southeast by Boki Local Government Area in Cross River State of Nigeria.

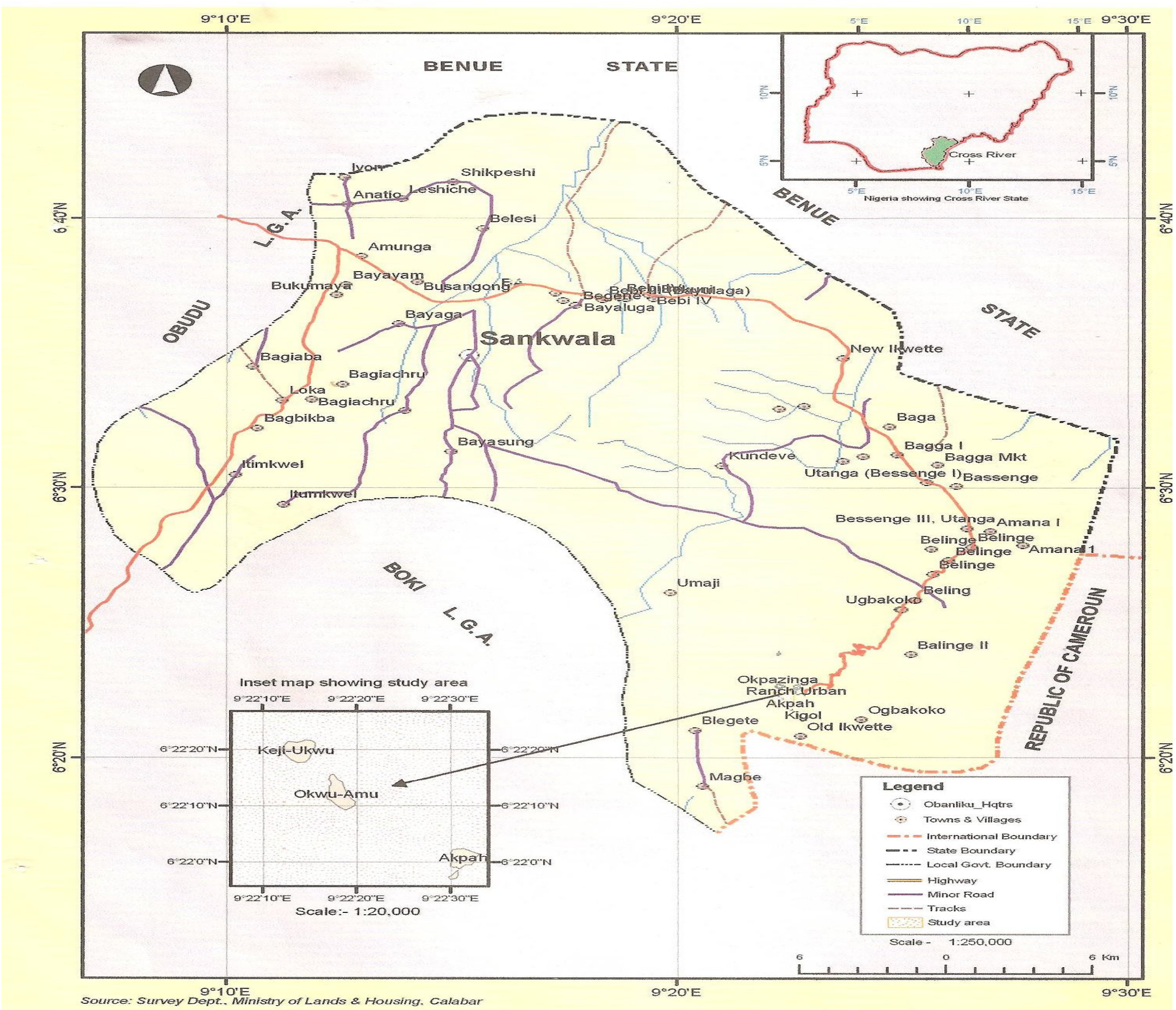

Fig. 1 Map of Obanliku Local Government Area showing the study area

The area is situated within the tropics but it has a climate that is likened to temperate region with mean daily temperature range between 15^0C and 22^0C. It has a mean annual rainfall of about 4300mm with highest rainfall of about 76.2cm usually recorded in August while the lowest of 0.76cm is usually recorded in December (Mabugunje, 1983).

The Obudu Plateau is part of the Precambrian Basement Complex of Nigeria (Ekwueme, 2003). It is a giant spur forming the western prolongation of the Cameroon Mountains into the Cross River plains of southeastern Nigeria.

Field Methods

The Obudu mountain was stratified into six ranges, which are; the summit slope (Su), the shoulder slope (Sh), base slope (Bs), the toe slope (Ts), middle toe slope (Mts), and the lower toe slope (Lts) using topographic map of the area. An abney level was employed to confirm the various topographic gradients along the soil catena from the summit to the lower toe slope.

Soil samples were collected from the median point of each of the landforms (slopes). For instance, data for the summit slope which ranges from 0-5 were obtained from slope gradient point of 2.5. For the shoulder slope, soil samples were collected at slope gradient of 27.5. Soil samples were also collected at the base, toe, middle toe and lower toe slopes representing slope gradients of 22.5 per cent, 17.5 per cent, 12.5 per cent and 7.5 per cent, respectively. Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms as described by Young *et al,* (1992).

A total of twelve samples were obtained as cores taken with a soil auger at 0-15 and 15-30 cm depths of the soil. These layers are considered the most productive of soil layers that exert the greatest effect on crop yield and geomorphologic processes (Aweto and Enaruvbe, 2010). All samples were assumed to be independent of one another.

Laboratory Methods

The soil samples were taken to the laboratory, air-dried, crushed and sieved using a 2mm-sized sieve mesh. Particle size analysis was carried out by Bouyoucos (1962) hydrometer method. Soil pH was determined in 1:2 soil/water ratios by use of glass electrode pH meter. The Walkley and Black method as outlined by Juo (1979) was used to determined organic carbon content. Available phosphorus was determined by Bray No. I method (Bray and Kutz 1945). Exchangeable cations were extracted with NH_4OAC (pH 7). Potassium and sodium were determined by the flame photometry while calcium and magnesium contents were measured by EDTA titration method. Also, total nitrogen was determined by kjeldale digestion method (Jackson, 1962). The base saturation percentage was computed using the formula:

$$\text{Base Saturation (\%)} = \frac{\text{Total bases}}{\text{ECEC}} \quad \text{X } 100$$

Variation in soil properties was determined by the coefficient of variability. The coefficient of variation, which is the standard deviation expressed as the percentage of the mean (Udofia, 2002) was computed for each soil property in order to ensure that it's degree of variability can be directly compared with those of other soil properties.

Results and discussion

The results for this study are presented in tables 1 and 2. Tables 1 show the means, standard deviations and coefficients of variation of properties of the top soil while Table indicates the same parameters for the sub soil measurements.

With respect to sand fraction, the soil exhibited moderate to little variation from the topsoils to the subsoil as indicated by the coefficient of variation of 25 % and 15.3%; silt particle exhibited high variability (40.3%) at the surface than at the subsurface (27.9%), while clay fraction exhibited a very high coefficient of variation of 52.9% (surface soil) and 67.9% (subsurface soil). This high coefficient of variation of clay minerals in both surfaces is probably attributed to local pedogenetic factors such as variation in slope gradients particularly between gentle and sharply inclined slopes (Fasina, 2004). In the present study, a soil property is regarded as showing little variation if it's coefficient of variation is less than 20%, moderately variable if the CV is ranged from 20 to 50% and highly variable if it's coefficient of variation is above 50 per cent (Aweto, 1982).

Table 1: Mean, standard deviations and coefficients of variation of the properties of soils at 0-15 cm layer

soil variables	mean	standard deviations	coefficients variation
Sand (%)	63.30	16.40	25.9
Silt (%)	17.60	7.10	40.3
Clay (%)	19.10	10.10	52.9
pH (H_2O)	6.20	0.50	8.1
pH (KCl)	5.30	0.60	11.3
Organic Carbon (%)	0.80	0.20	25.0
Organic Matter (%)	1.30	0.40	30.8
Total Nitrogen (%)	0.10	0.02	20.0
Available Phosphorus (PPM)	4.40	0.90	20.5
Exchangeable Calcium (cmol/kg)	4.90	2.80	57.1
Exchangeable Magnesium (cmol/kg)	1.80	0.60	33.3
Exchangeable Potassium (cmol/kg)	0.30	0.10	33.3
Exchangeable Sodium (cmol/kg)	0.60	0.20	33.0
Cation Exchange Capacity (cmol/kg)	9.30	2.90	31.2
Base saturation (%)	89.0	3.90	4.4

Source: Authors' analysis, 2013

Table 2: Mean, standard deviations and coefficients of variation of the properties of soils at 15-30 cm layer

Soil variables	mean	Standard deviations	Coefficients variation
Sand (%)	66.20	10.10	15.3
Silt (%)	14.70	4.10	27.9
Clay (%)	18.70	12.70	67.9
pH (H_2O)	5.90	0.80	13.6
pH (KCl)	4.80	0.90	18.8
Organic Carbon (%)	0.70	0.30	42.9
Organic Matter (%)	1.20	0.60	50.0
Total Nitrogen (%)	0.10	0.03	30.0
Available Phosphorus (ppm)	3.50	1.20	34.3
Exchangeable Calcium (cmol/kg)	5.60	4.40	78.6
Exchangeable Magnesium (cmol/kg)	1.70	0.50	29.4
Exchangeable Potassium (cmol/kg)	0.40	0.20	50.0
Exchangeable Sodium (cmol/kg)	0.90	0.80	88.9
Cation Exchange Capacity (cmol/kg)	9.90	5.60	56.6
Base saturation (%)	86.00	3.10	3.6

Source : Authors analysis, 2013

With exception of soil pH and base saturation, the chemical properties of the topsoil and subsoil are moderately and highly variable with coefficient of variation that generally exceeded 30%. The topsoil was generally moderately variable with exchangeable Mg, K, and Na having coefficients of variation of 33 % each. While Exchangeable Na, Ca, K, CEC and Organic Matter were the most variable chemical properties of the subsoil with coefficients of variation of 88.9%, 78.6%, 56.6% and 50.0% respectively. The least variable chemical property at both surfaces was base saturation with coefficient of variation of 4.4% and 3.6% for topsoil and subsoil respectively. Variations in the organic matter and nutrient contents of the top and sub soils are related to land use, site agricultural history and geomorphological processes in the area. This study confirms the fact that soil processes controlling variability of the characteristics may be different at different scales. At the farming scale, this variability has been inconsistence in distribution across slope segment and depths. However, it clearly revealed that variability in agricultural land uses influences the distribution of soil chemical properties in the Obudu Mountain slopes.

In general, the physical properties of the sampled soils were less variable than the chemical properties. The findings of this study are similar to the outcome of Areola (1974) who also observed that soil physical properties tend to be less variable than the chemical properties. The comparatively moderate coefficients of variation of soil exchangeable cations in the study area reflect homogenous lithology, the soils having been formed from the same basement complex parent material (Ekwueme, 2003).

Conclusion

The result revealed that topography influences the distribution of soil physical and chemical properties across the different slope positions. However, the distributions were not consistent in terms of increases from the crest to the valley floor and in soil depths. Sand particle was observed to be dominant across the landscape segments, but at the lower foot slope, surface samples recorded very high values of clay. The result of soil nutrients showed that they were low in status. However, only organic carbon and cation exchange capacity were moderate in contents. The percentage base saturations were remarkably high across the slopes and soil depths. Higher variations were recorded in chemical properties than for their physical counterparts. This variability is probably due to the topo-sequence characteristics in soils. However, there was no consistence in the sequence of distribution of particle size fractions from the crest to the valley floor. Agricultural activities in the area could escalate the already observed variation and could lead to structural instability. Structural instability could eventually lead to mass movement and other environmental hazards. Hence, it is recommended that farming activities on the slope should be reduced to minimize the risk of environmental hazards.

References

Areola**,** O. (1974). Photo-interpretation of land facets as a soil mapping technique. Geoforum, 24. Pp 25-38.

Aweto, A.O. (1982)Variability of upper slope soils developed on sand stone in south western Nigeria. *Nigeria Geographical Journal NO 1& 2 Vol. 25.*

Aweto, A.0, and Enaruvbe (2010) Catenary Variation of Soil Properties under Oil Palm

Plantation in South Western Nigeria. *Ethiopian Journal of Environmental Studies and Management Vol.3 No.1 2010, pp1-7.*

Birkeland, P.W., (1999). Soils and Geomorphology. Oxford Univ. Press, New York. 430 pp.

Bray, R. and Kurtz, T. (1945). Determination of total organic and available forms of phosphorus. *SSSA; 59, 39-45.*

Bouyoucus, G. (1962) Hydrometer Method, Improved for Making Particle Size Analysis of Soils. *Agrono. Journal. 54: 464-465.*

Essoka, A. (2008). Soil variation over basement complex slopes in parts of Cross River plains, southeastern Nigeria. Unpublished Ph.D. dissertation, Department of Geography, Ahmadu Bello University, Zaria.

Ekweume, B. (2003) *The Precambrian Geology and Evolution of the South Eastern Nigeria Basement Complex.* Calabar: University of Calabar Press.

Fasina, A. (2004). Influence of land utilization types on topsoil properties of an ultisol in Southwestern Nigeria. *Journal Sustainable Agriculture and Environment. 6:171-178.*

Fisher, R.F., Binkley, D.,(2000). Ecology and management of forest soils. John Wiley and Sons, New York. 512 pp.

Fu B., Wang J., Chen L, Qiu Y. (2003). The effects of land use on soil moisture variation in the Danangou catchment of the Loess Plateau, China – Catena, 54: 197–213.

Hook, P.B., Burke, I.C., (2000). Biogeochemistry in a shortgrass landscape: control by topography, soil texture, and microclimate. Ecology 81 (10), 2686–2703.

Jackson, M.L. (1962). *Soil chemical analysis.* Prentice Hall, New York.

Jenny, H., (1941). Factors of soil formation. McGraw Hill, New York.

Jenny, H., (1980). The Soil Resource—Origin and Behavior. Springer, New York. 377 pp.

Johnson C.E., Ruiz-Mendez, J.J., Lawrence G.B. (2000). Forest soil chemistry and Terrain attributes in a Catskill watershed – Soil Sci. Soc. Am. J. 64: 1804–1814.

Jou, A.S.R (1979). Selected methods of soil analysis. IITA manual N0 1pp35-38.

Luc S, Bernard C., Christophe P. and Baxter V. (2002). Impact on Sahelian runoff of stochastic and elevation-induced spatial distributions of soil parameters. *Hydrol. Process.* 16, 313 332 (2002)

Mabugunje, A. (1983). Nigeria: Physical and Social Geography in Africa, South of the Sahara, 12th Edition, 760-770.

Rezaei S.A., Gilkes R.J. (2005b). The effects of landscape attributes and plant community on soil chemical properties in rangelands – Geoderma, 125: 167–176.

Temgoua, E., Tchapnga, H.D., Tanawa,E., Guenat, E., and Pfeifer, H. (2005). Groundwater fluctuations and foot slope ferricrete soils in the humid tropical zone of southern Cameroon. *Hydrol. Process.* 19, 3097-3111.Limited.

Young, F.J., R. Hammer, and J. Matta, E. (1992). Confidence intervals for soil properties based on differing statistical assumptions. (*In* G.A. Millikin and J.R. Schwenke (editors.) *Applied statistics in agriculture)* 4th Annual Kansas State Univ. Conf., 27–28 Apr. 1992, Manhattan, KS. Kansas State Univ. Manhattan.