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Relationship Between Soil Properties and Slope Position in a Humid Forest of South Western Nigeria

[1]T.S. Babalola, [2]A.S. Fasina and [1]Tunku Peter
[1]College of Agriculture, Ahamadu Bello University Zaria, P.M.B 205, Kabba, Kogi-State, Nigeria
[2]Department of Crop, Soil and Enviromental Sciences, University of Ado-Ekiti, Ado-Ekiti, Ekiti State, Nigeria

Abstract: Relationship between slope position and soil properties was studied. Three profile pits were described at three topographic positions identified in the area, Upland (U1), Valley bottom (V) and upland (U2). Samples collected were analyzed for pH, Available phosphorus, Total Nitrogen, organic matter, Exchangeable cations, particle size distribution and percentage gravel. Trend of change and difference in soil properties down the profile depth and across the landscapes position was also studied using graphs. Soil reaction is acidic (3.8-5.8) with low to moderate available phosphorus (3.38-15.75 ppm) and low total nitrogen (0.07-0.16g kg^{-1}). ECEC soil is on the average low (5.26-12.75 Cmol kg^{-1}). The trend of change and difference in soil properties across the slope shows that soil properties differs at the three slope positions (U1, V, U2). The soils in the valley were fertile than the soils located in the upland. The study has thus further established the strong relationship between soil properties and slope position. The major pedogenic process observed to influenced the relationship between slope position and soil properties were mineral weathering, plinthization, erosion process, eluviation-illuviation of clay and oxidation-reduction process.

Key words: Upland, valley bottom, middle slope, pedogenic process, soil properties

INTRODUCTION

The relationship between landscape position and both hydrological and geomorphic processes has been well established for many landscapes (Wysocki *et al*., 2001; Ogunkunle, 1993; Dahiya *et al*., 1984). In the basement complex area there is strong relationship between topographic position and soil (Moorman, 1981). Smyth and Montomery (1962) classify soils of central western Nigeria on the basis of geology and subdivided each association by topographic positions into: Sedimentary soils-formed in situ at crest/upper slopes and drift soils-formed at the lower slopes/Valley by transportation and deposition of materials. The differences in the rate of hydrologic and geomorphic process in various landform positions causes difference in the types and intensity of pedogenic processes and typically result in a non-random distribution of soil taxi and properties in a landscape.

Landscapes position influences runoff, drainage, soil temperature, soil erosion, hence soil formation is affected. Different soil properties encountered along landscapes will affect pattern of plant production, water production and decomposition, which will definitely have effect on carbon and nitrogen content of the soil. Soil physical properties such as clay content distribution with depth, sand content and pH have been shown to be highly correlated with landscape position (Jung *et al*., 2000) while organic matter has been shown to vary with slope position (Miller *et al*., 1998). This study is therefore undertaken to examine how slope position will influence soil properties along a toposequence within the University of Ado-Ekiti Teaching and Research Farm. Results generated in the study will provide useful information for effective land use planning and land management for farmers in the humid forest zone of Southwestern Nigeria.

MATERIALS AND METHODS

The sites: The experimental site was an area of 2.15 hectares located in the University of Ado-Ekiti Campus. It lies between latitude $7°31^{-1}$ and 7°$N. The area has a maximum elevation of 730 metres and relative relief of about 395 m. The mean annual rainfall is about 1367 mm with the raining season occurring between March-October. The mean monthly temperature ranges between 28 and 27°C. The site lies within the rainforest zone. The

Corresponding Author: T.S. Babalola, College of Agriculture, Ahamadu Bello University Zaria, P.M.B 205, Kabba, Kogi-State, Nigeria

topography of the area is high to moderate steep slopes with the highest point having slope not greater than 10%. except for some micro-relief. The terrain gradually slopes towards the valley from the upland rising to upland at the other end of the valley bottom.

The uplands were under cultivation with some arable crops (*Cassava manihot* sp.) *Yam discorea* sp. and *Maize zea* mays) While the valley bottom was under fallow as at the time of the soil survey.

Soil sampling and analysis: The detail rigid grid soil survey of the area was carried out to be able to identify the soil types as located on the topographic position. Three profile pits were dug within each slope position identified on the landscape. The pits were described according to FAO guidelines (FAO, 1977). The soils of each slope position were then classified using FAO/UNESCO soil classification system. The positions they occupied on the slope and the soil classification are as follows. Upland U_1-Plinthic Acrudox (Plinthic ferralsol), Valley bottom (V)-Eutric Gleysols, (Typic Endoaquept) Upland (U_2)-Plinthic ferrasol (plinthic Hapludox). Soil colour was determined at Sampling using the Munsell Soil colour chart. The soil samples were analysed following the guidelines. Properties analyzed for are pH; Avail phosphorus, Organic matter, Exch Ca, Mg, Na and K, sand, silt, clay and gravel.

Statistical analysis: Graphs were plotted to show the trend of changes/differences in some soil properties down the profile depth at different slope positions.

RESULTS AND DISCUSSION

Morphological properties: The soil sequences are from the Upland (U_1) through valley bottom (V) up to Upland (U_2) at the other end of the valley bottom. Data on morphological properties of the pedons at each slope position is presented in Table 1. At U_1 there is progressive lightenen of soil colours from 5YR to 2.5Y and 10YR. This is an evidence of lack of iron at the top soil and influence of Iron-oxides at the sub-soil. The matrix hue 10YR in V shows evidence of fluctuation in water table or gleyic condition and gives an indication that the soils are formed from hill wash (colluvial wash). In U_2 the 7.5YR hue from the surface down to the depth indicates that the soil is well drained. The upper horizons in U_1 and U_2 have a sandy loam texture to depth. This makes the soil to be suitable for arable cropping. The clay loam texture in V down to depth is a characteristic that is typical to soils at the depression (i.e., hydromophic condition) making the water holding capacity to be high, hence high water Table. U_1 and U_2 do not show good structural stability (Table 2), hence it may be prone to erosion. This should be put into consideration in land use planning and management of these soils. There is great concentration of concretions identified at soils located on both U_1 and U_2 and this is an indication of soils formed in situ while soil located on slope V_2 concretions were consciously absent.

Physical properties: Distribution pattern of clay fluctuates with depth across the slope (Fig. 1). There is an increase in clay content down the slope (U_1, V, U_2) while there is a slight decrease in clay content down the profile/depth U_1. The high clay content in V is a common feature. This might have resulted from the effect of soil transportation and deposition of materials rich in clay minerals in the valley bottom.

Profile U_1 and U_2 have dominant sand size fraction (Table 1) which decreases down to V from U_1 and U_2 (Fig. 2). Silt content was considerably low (Table 2). It increases from U_2 to V up to U_1 and fluctuates down the profile depth in U_1 and U_2 (Fig. 3). Percentage gravel increases down the depth (Fig. 4) in U_1 and U_2 and

Table 1: Morphological description of soils at each slope position

Soil depth (cm)	Colour (Hue)	Structure	Texture (By feel)	Consistence	Concretionss
Upland -U_1					
0-20	5Yr	Fcr	SL	Mfr	p,fe.
20-51	10Yr	Fab	SL	dL	p,fe-mn
51-67	10Yr	Mab	SL	dL	p,fe-mn
67-125	2.5Y	Fcr	SL	dL	p,fe-mn
125-132	2.5Y	Fcr	SL	dL	p,fe-mn
132-150	10Yr	Fcr	CL	mfl	a
Valley bottoV					
0.15	2.5Yr	Cab	CL	Mfi	a
15-30	7.5Yr	Fab	CL	Mfi	a
Upland-U_2					
0.8	7.5Yr	Mcr	SL	Mfr	p-fe-mn, a
8-16	7.5Yr	Cab	SL	Mfr	p.g
16-30	7.5Yr	Cab	SL	Mfr	p.g
30-48	7.5Yr	Mab	SL	Mfr	p.g

Key: Structure: m = medium, c = coarse, f = fine, cr = crumbs, ab = angular blochy; Texture: SL = Sandy Loam, CL = Clay Loam; Consistence: D = Dry, M = Moist, L = Loose, fr = friable, fi = firm; Concretions: a = absent, p = present, fe-mn = Iron-Manganese Concretions, g = gravel

Table 2: Soil physical and chemical properties of soil at each slope position

Soil depth	pH (H_2O)	Availp (pm)	Total N	Organic matter	Exchangeable bases ($C\ mol\ kg^{-1}$) Ca	Mg	Na	K	($C\ mol\ kg^{-1}$) Exchange acidity	($C\ mol\ kg^{-1}$) ECEC Soil	% Sand	% Silt	% Clay	% Gravel
Upland -U_1 (Plinthic acrudox/plinthic ferralsol)														
0-20	5.5	3.38	0.08	2.21	1.83	0.32	3.85	0.39	0.03	6.89	74	16	10	0.10
20-51	6.2	11.64	0.09	2.01	1.90	2.43	2.71	0.59	0.56	7.33	74	15	11	2.50
51-67	6.0	11.97	0.07	1.34	0.48	0.81	2.87	0.58	0.50	5.34	74	16	10	4.25
67-125	5.7	15.75	0.07	1.14	0.33	0.65	4.00	0.61	0.20	5.96	79	18	3	5.44
125-132	5.8	14.64	0.07	1.54	0.46	0.24	3.40	0.71	0.30	5.31	77	18	5	6.60
132-150	5.6	11.21	0.08	1.48	1.03	0.73	2.25	0.65	0.40	5.26	59	12	29	8.60
Valley bottom - V (Plinthic ferrasols/phuthic haplidox)														
0-15	3.8	10.99	0.14	7.31	1.35	1.21	2.85	0.33	0.30	12.56	31	34	35	0.60
15-30	4.8	11.32	0.13	4.43	1.48	0.08	2.85	0.44	0.82	12.75	41	27	32	0.20
Upland -U_2 (Eutric gleysols/typic endoaquepts)														
0-8	5.5	10.34	0.14	2.75	1.49	0.24	2.19	0.65	0.30	5.67	67	22	11	0.14
8-16	5.1	10.66	0.15	0.87	1.02	0.41	3.40	0.38	0.10	5.51	61	24	15	1.40
16-30	5.1	9.25	0.16	1.81	0.50	0.41	3.41	0.65	0.30	5.49	63	22	15	2.40
30-48	4.4	13.38	0.15	1.61	1.98	0.32	2.75	0.55	0.20	6.03	67	18	15	3.00

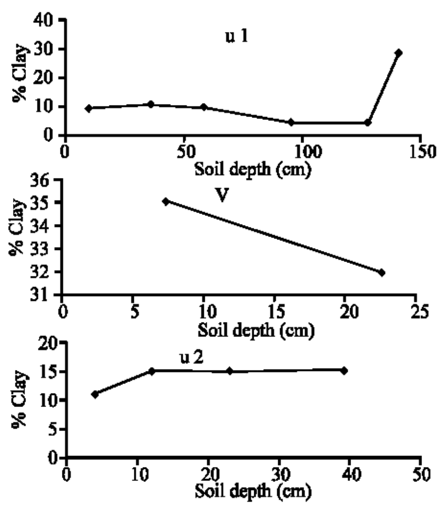

Fig. 1: Relationship between clay and slope position

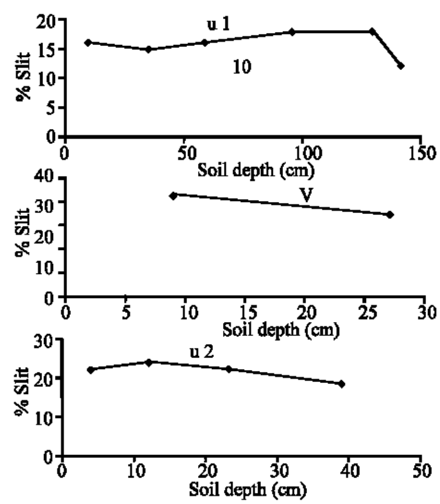

Fig. 3: Relationship between silt and slope position

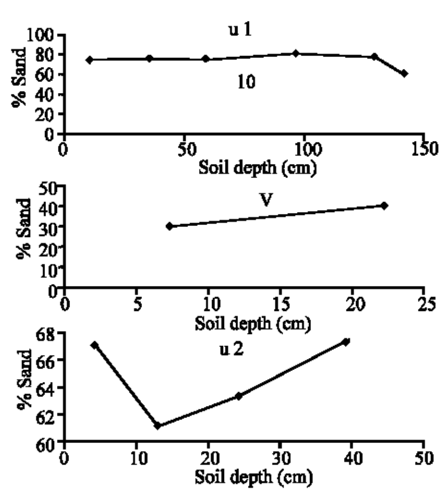

Fig. 2: Relationship between sand and slope position

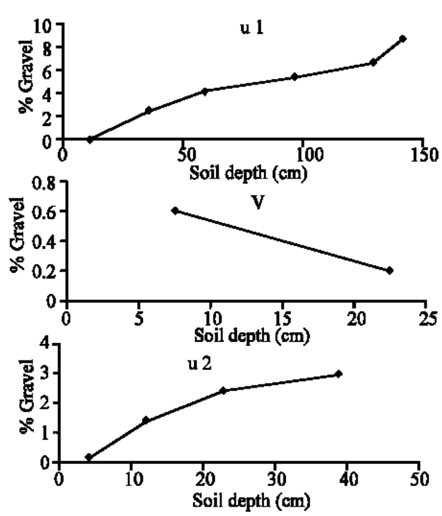

Fig. 4: Relationship between gravel and slope position

this will definitely have effect on root penetration especially for deep feeder crops while it decreases slightly down the profile depth in the valley bottom.

Chemical properties: Table 2 and Fig. 5-10 show data on some chemical properties. Soil pH is acidic at U_1 and U_2 (4.4 - 5.8) down the profile depth. The acidity increases down the slope to V. This is an evidence of strong chemical weathering and leaching of nutrients down the profile. Organic matter is low at U_1 and U_2 while it is very high at V. This may be due to the fact that materials removed from U_1 and U_2 are deposited in V coupled with reducing conditions, which eventually resulted in deep/high organic matter.

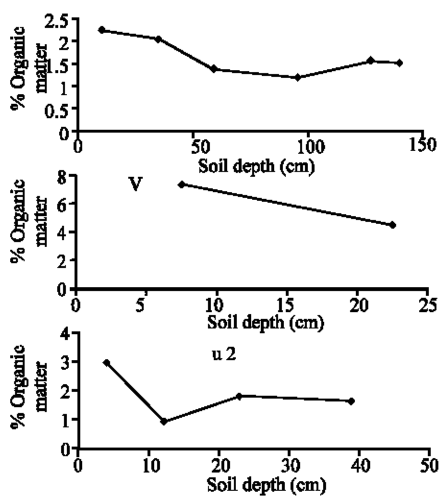

Fig. 5: Relationship between organic matter and slope position

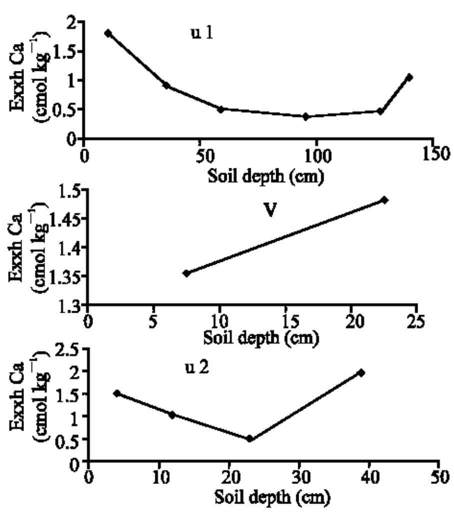

Fig. 6: Relationship between exch Ca (Cmol kg^{-1}) and slope position

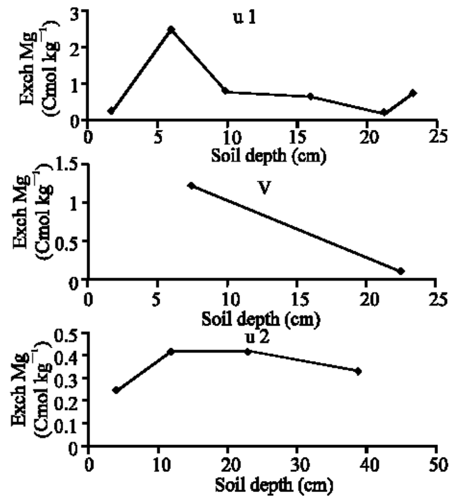

Fig. 7: Relationship between exch Mg (Cmol kg^{-1}) and slope position

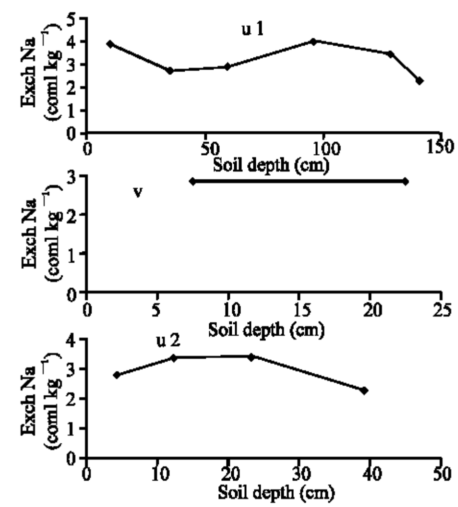

Fig. 8: Relationship between exch Na (Cmol kg^{-1}) and slope position

The decrease encountered in organic matter at U_1 and U_2 with depth indicate no parent material or age discontinuity (Fig. 5).

Flunctuation of exchangeable cations down the depth at the three slope position may be due to leaching from which the soils are formed. Total Nitrogen is low (0.07-0.16 g kg^{-1}) but lower in U_1 than in V and U_2. This conforms with values reported for some Nigerian soils (Ogunwale and Ashaye, 1975; Alboni, 2001.; Fasina, 2001). The ECEC soil is low to moderate (5.26-15.75) on the uplands and moderate at V. This variation across the slope and down the depths indicates the presence of low activity clays in the area. Available phosphorus is low to

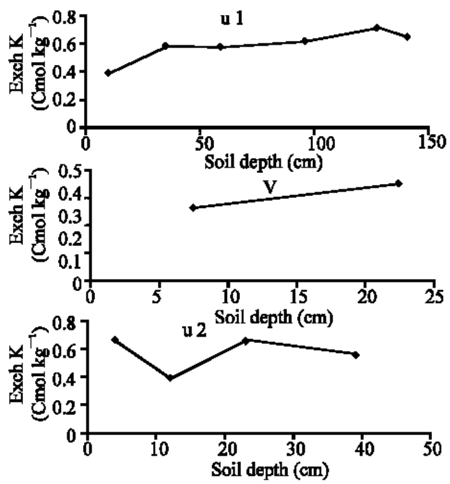

Fig. 9: Relationship between exch K (Cmol kg^{-1}) and slope position

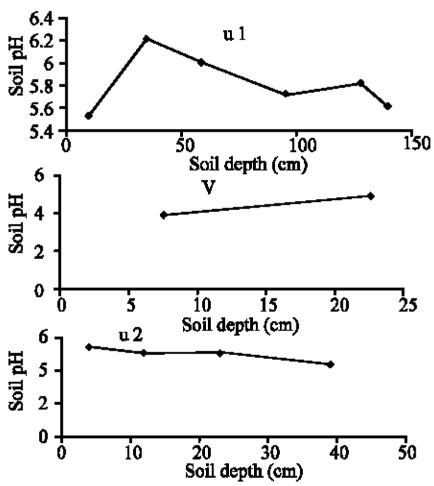

Fig. 10: Relationship between soil pH and slope position

moderate (3.38 - 15.75pp^{m}) across the slope. This suggests that the soil reaction is probably favourable for phosphorus availability in the area.

CONCLUSION

The landscape as a whole in this study is developing in response to the action of the environmental factors acting on the particular parent material. This results in a series of mutually adjusted members whose different properties are caused by drainage conditions, transportation of different eroded materials and mobile chemical constituents. Soil differentiation with slope is not only the result of predogenic processes driven by differences in moisture, leaching and vegetation, but due to geomorphic process that cause erosion in some places and deposition in others as seen in this study. This, study have so far establish strongly the relationship between soil properties and slope position. It has shown how slope position can affect the morphological, physical and chemical properties of soils across a landscape.

REFERENCES

Alboni, V.U., 2001. Characterization of some soils under different land uses along a toposequence in Ibadan, Nigeria. In: ASSET Series, A.1: 51-61.

Dahiya, S., J. Richter and R.S. Malik, 1984. Spatial Variability. A Rev. Int. J. Trop. Agric., 11: 1-102.

FAO, 1977. Guidelines for soil profile description (2nd Edn.), Rome: FAO.

Fasina, A.S., 2001. An evaluation of the predictive power of a soil map from western Nigeria. J. Sustain Agric. Environ., 3: 341-347.

Jung Wang, Bojie tu, Vang Qui and liding chen, 2000. Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in china. J. Arid. Environ., Online at http://www. idealibrary.com., 48: 537-550.

Miller, P.M., M.J. Singer and D.R. Nielsen, 1998. Spatial variability of wheat yield and soil properties on complex hills. Soil Sci. Soc. Am. J., 52: 133-1141.

Moorman, F.R., 1981. Representative of Tosequence of Soils in Southern Nigeria and Their Pedology. In Characterization of Soils in Relation to Their Classification and Management for Crop Production. D.J. Greeland (Ed.), Clarendo Press Exford, pp: 10-29.

Ogunkunle, A.O., 1993. Variation of some soil properties along two toposequence on quartzite schist and Banded Gnesis in Southwestern Nigeria Geo, J., 30: 397-402.

Ogunwale, J.A. and T.I. Ashaye, 1975. Sandstone derived soils of a catena at Iperu, Nigeria. J. Soil Sci., 26: 22-31.

Smyth, A.J. and R.F. Montomery, 1962. Soils and Land Use in Central Western Nigeria. Govt. printer, Govt. of Western Region of Nigeria.

Wysocki, D.A., P.J. Schroeneberger and A.E. Lagary, 2001. Geomorphology of Soil Landscapes. In: Summer, M.E. (Eds.), Handbook of Soil Science CRC Press, Boca Raton, FL<U.S.A., pp: 40.