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CHARACTERISTICS OF OLDER GRANITE DERIVED SOILS AS AFFECTED BY VEGETATION AND SLOPE, NIGERIA

Influence de la végétation naturelle et de la pente sur les sols dérivés de l'Older Granite au Nigeria

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RESUME

Certaines propriétés physiques et chimiques des sols sur l'Older Granite dans le Nord du Nigeria sont envisagées en fonction de la couverture végétale et de la pente du terrain. Le profil pédologique est marqué par la nature de la roche-mère et de l'intensité de l'érosion. La texture des horizons superficiels est rarement plus lourde que celle des limons sableux mais les horizons inférieurs sont enrichis en argile et constituent des sols limoneux fins. La concentration en éléments nutritifs est faible à très faible tandis que le sol est légèrement acide. En passant de la savane à la forêt, il existe une tendance nette pour les sols à devenir moins grossiers et plus riches en matière organique avec une désaturation en base accentuée. De même, il apparaît également une tendance vers un sol moins grossier, plus riche en matière organique et en éléments nutritifs lorsque l'on se dirige vers le bas de certains versants.

ABSTRACT

Some physical and chemical properties of soils derived from Older Granite located at different bioclimatic environments and slope conditions in northern Nigeria were examined with a view to evaluating the pedogenic significance of vegetation and slope. The soil profile reflects the character of the soil forming material and an active denudational system. Texturally, the surface soils are rarely heavier than a sandy loam but subsoils are generally enriched with some clay to give fine loamy soils. The nutrient contents are low and the soil reaction weakly to moderately acidic. There is a clear tendency for the soils to become less coarse, higher in organic matter content and to be characterized by more base desaturation under Forest than under Savanna. Similarly, on particular slopes, there is a tendancy for the texture to become less coarse and to be higher in organic matter content and nutrient elements as one moves downslope.

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INTRODUCTION

Dokuchaev is credited with the hypothesis that the soil profile is the integrated expression of parent material, climate, topography, living organisms and the age of the landscape. Where all these factors do not vary, the soil will be the same; when any one of them is changed, the soil will change. This hypothesis has not only become accepted but it has become the only principle of universal value in soil mapping (DENT & YOUNG, 1981).

In order to assess the role played by each of the soil forming factors, the relationship between the soil characteristics and the factors must be scrutinized, both carefully and preferably quantitatively. To do this, one would idealy study each of the factors whilst holding the effects of all the others constant. The independent consideration of the factors for an area may be unnecessary, however, in view of the very high degree of correlation between some of the factors .

The objective of this study is to examine the status of some physical and chemical properties of soils derived from Older Granite in Nigeria and to evaluate how these properties are affected by vegetation and slope factors. In specific terms, the study examines and compares some selected physico-chemical properties of Older Granite derived soils under the Guinea Savanna, Derived Savanna and Forest bioclimatic environments, and slope conditions. The information so obtained is expected to be helpful to both the pedologist and planner in understanding the soils better.

STUDY AREA

Data were collected along slope transects in three vegetation zones, namely, Forest, Derived Savanna and Guinea Savanna, in Kwara State. The general location of the sites is shown in figure 1. The forest cover has emergent species like *Celtis spp.*, *Triplochton sclerocylon* and *Chlorophora excelsa* together with shrub and herb undergrowth. The tree stratum of the Derived Savanna is dominated by species such as *Isoberlina doka, Monotes kerstingii* and *Uapaca togoensis.* Grasses in this zone are mostly perennial, growing only in the rainy season and usually in clumps. The vegetation of the Guinea Savanna zone is similar to that of the Derived Savanna but the trees are shorter and the grasses growing mainly in tussocks, with bare ground between them.

The geology of the study area is Older Granite. The granite, which is coarsed-grained has the following average composition: 72 % SiO_2, 13.5 % Al_2O_3, 5 % K_2O, 3.5 % NaO_2 and 6 % others. Physiographically, the sites fall within the High Plains of Yorubaland (UDO, 1970) and consist of rolling to gently undulating terrains traversed by shallow perennial, seasonal and intermittent streams. The landscape is occasionally broken by inselbergs and isolated plateaux capped by lateritic ironstones.

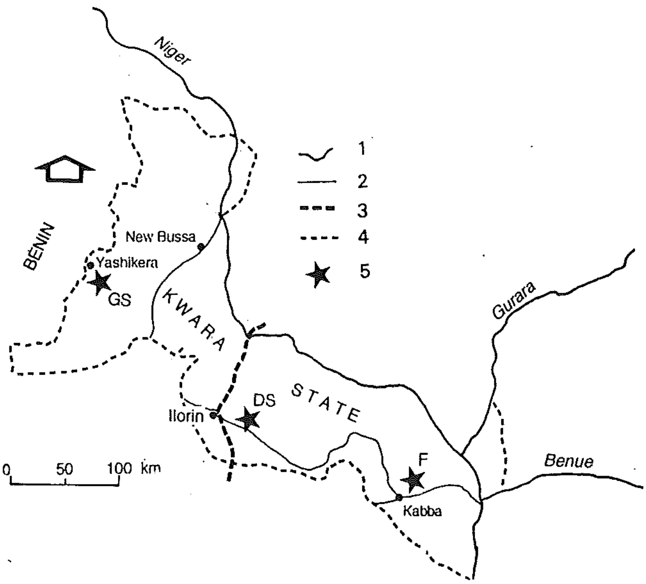

Fig.1. - Location map
1 : river; 2 : road; 3 : railroad; 4 : limits of Kwara state; 5 : studied sites.
F : Forest; DS : Derived Savanna; GS : Guinea Savanna

METHODOLOGY

Soil sample collection and slope mesurement

Three slope transects, located 2-3 km apart were surveyed in each of the vegetation zone. The survey involved slope angle measurement at 10m interval using Abney level and measuring tape, and soil sampling by augering at the 10m interval nodes at two standard depths: 5-10cm and 20-30cm. Table I summarizes the results of the slope angle measurements. Ninety-one soil sampling points all together were involved. The soil samples obtained were air dried, pass through a 2mm sieve and the fine earth fraction used for laboratory analysis.

Soil sample analysis

Soil particle size distribution was measured by pipette and sieving methods, organic matter content by the Walkley and Black Oxidation method and total nitrogen by the Kjeldhal Digestion method. The exchangeable Ca and Mg were estimated on the Perkin Elmer absorption spectro-photometer, using strontium to prevent interference from phosphorous. Exchangeable Na and K were measured on the Techniocon Autoanalyser by flame emission spectroscopy. The pH was measured by the use of pH meter in Soil : Water ratio of 1 : 2.5 while the CEC was assessed by summation method (F.A.O.1970)

Tab.I. - Slope characteristics and number of sample points under each vegetation cover

		Guinea Savanna	Derived Savanna	Forest
No of sample		31	32	28
Slope angle	X	2.4°	9.9°	5.7°
	SD	*2.9°*	*6.0°*	*4.6°*
Slope form		rectilinear, slighty convex near the base	concave, slighty convex crest	concave, slighty convex crest

X= Mean , *SD* = Standard deviation

RESULTS AND DISCUSSION

The mesured soil properties and the effect of vegetation cover.

Table II gives a summary of the measured soil properties and the observed relationships between the properties and vegetation cover.

a.- texture

The texture of the soils is generally sandy, although more clayey at the subsoil. The sandy texture of the soils is a reflection mainly of the high quartz content and the coarse-textured nature of the parent rock. The more sandy texture of the topsoil may be ascribed to strong eluviation, termite activity, and/or selected removal of fine particles, especially clay, by erosion (LEOW & SMITH, 1981).

In the topsoils, all the particle-size fractions reveal significant differences between the vegetation zones at the 0.05 probality level, except the silt, but in the subsoil, only coarse sand reveals significantly different values. In general, soils of the Guinea Savanna zone are more sandy than those from the Forest zone while those under the Derived Savanna are intermediate. This may mean an increasing chemical weathering and formation of clay-size materials and/or less removal of the finer materials in surface wash as vegetation cover increase.

Looking at the textural variation in greater detail, it is noticeable that under the Derived Savanna condition, there is more coarse sand than fine sand in the topsoils, and more fine sand than coarse sand in the subsoils. Under the Forest and Guinea Savanna conditions, however, fine sands predominates in the two layers. This may be a reflection of much steeper slopes in the Derived Savanna as compared to the Forest and the Guinea Savanna areas (Tab.I). On such much steeper slopes, one would expect surface denudation to be more rapid and the differential removal of fine earth fractions from surface soils more efficient than on the gentler slopes under the Forest and Guinea Savanna (MORGAN, 1973 , 1979). In addition, the soils on steeper slopes should be less developed than those on gentler slopes and thus ther would have been less cominution of the coarser sand fraction (LEOW & SMITH, 1981).

Table II.- Measured soil properties under different vegetation cover

		Topsoil				Subsoil			
		GS	DS	F		GS	DS	F	
No of samples		*31*	*32*	*28*		*31*	*32*	*28*	
<u>Texture</u>									
Sand	X	72.6	69.6	64.5	*	65.2	61.1	59.2	
	SD	*23.2*	*16.0*	*15.5*		*11.7*	*21.4*	*13.0*	
Coarse	X	30.8	38.3	26.4	*	28.6	22.5	21.2	*
	SD	*9.2*	*11.5*	*4.5*		*7.8*	*11.0*	*3.9*	
Fine sand	X	41.8	31.3	38.2	*	36.6	38.7	38.0	
	SD	*13.8*	*8.5*	*8.0*		*6.3*	*11.2*	*8.8*	
Silt	X	18.6	17.4	18.3		18.3	21.5	20.3	
	SD	*4.3*	*2.6*	*3.8*		*3.1*	*5.4*	*5.2*	
Clay	X	9.5	12.9	17.2	*	17.0	17.2	20.4	
	SD	*3.9*	*3.7*	*6.0*		*6.8*	*5.6*	*5.1*	
<u>Organic matter and nitrogen (%)</u>									
Organic matter	X	1.79	2.05	2.63	*	1.09	1.15	0.62	
	SD	*0.81*	*1.14*	*1.93*		*0.33*	*0.21*	*0.07*	
Nitrogen	X	0.43	0.35	0.30		0.11	0.16	0.09	
	SD	*0.22*	*0.20*	*0.35*		*0.03*	*0.05*	*0.01*	
<u>Exchangeable cations (m.e./ 100 g of soil) and pH</u>									
Na	X	0.14	0.19	0.09		0.23	0.35	0.04	*
	SD	*0.11*	*0.10*	*0.05*		*0.20*	*0.25*	*0.4*	
K	X	0.32	0.36	0.15	*	0.47	0.62	0.08	*
	SD	*0.28*	*0.20*	*0.11*		*0.30*	*0.33*	*0.03*	
Ca	X	3.32	2.14	2.55	*	3.52	3.75	1.76	*
	SD	*1.67*	*1.60*	*1.15*		*2.31*	*2.44*	*0.73*	
Mg	X	2.14	2.06	1.37	*	2.66	2.43	1.24	*
	SD	*1.70*	*2.34*	*1.04*		*2.50*	*2.00*	*0.81*	
CEC	X	7.28	8.24	8.96	*	3.73	5.61	5.58	
	SD	*5.10*	*6.11*	*6.30*		*1.82*	*3.65*	*3.64*	
pH	X	6.47	6.27	6.22		6.42	6.30	6.13	
	SD	*1.32*	*1.60*	*0.75*		*1.18*	*0.89*	*0.90*	

GS, DS & F refer to Guinea Savanna, Derived Savanna and Forest, respectively.
X = mean, *SD* = Standard deviation
* refers to significant differences between the vegetation cover at the 0.05 probality level

One other factor which might aeolian addition of fine sand (and silt) to the soils. In a recent article, McTAINSH (1983) has described a distinctive spatial pattern of aeolian deposition of materials within the upland soils of central northern Nigeria.

b.- organic matter and nitrogen content

The organic matter content of the topsoil show a distinctive increase in value from the Guinea Savanna, where the vegetation cover is less dense, to the Forest condition where the vegetation cover is more dense. Dense vegetation cover not only has greater capacity to generate litter but by shading the soil surface helps to prevent accelerated mineralization of organic matter and organic matter losses through surface wash (WALTER, 1971, ALLISON, 1973).

In contrast to the topsoil, difference in the subsoil organic matter content between the vegetation belts are insignificant at the 0.05 probability level. This feature, together with the rather more gradual drop in mean organic matter content in the subsoil under the savanna conditions, as compared to forest, can be explained in terms of the fibrous root system of grasses which could permeate the soil more intimately and which, upon decay, would leave the resulting organic matter fairly well distributed within the soil profile. The forest vegetation on the other hand can generate greater weight of leaves on the surface but characteristically has the greater proportion of its fine rootlets at very near the surface. Only a thin layer of the surface soil under forest is thus enriched with organic matter through rootlet decay (WALTER, 1971; ALLISON,1973).

The nitrogen content reveals no significant differences between the vegetation zones at the 0.05 probability level, either in the topsoil or in the subsoil. One thing the result seems to suggest, however, is greater losses of the element, presumably through immobilization and perhaps leaching, under the forest cover than under the savanna cover (ALLISON, 1973).

c.- exchangeable cations, CEC and pH

Under the savanna conditions, there are higher mean values of exchangeable cations in the subsoils than in the topsoils but in the forest, the reverse is the case. The comparatively higher values of the ions in the subsoils of the savanna cover may be attributed to the lower capacity of grasses to recycle nutrients onto the surface horizons. Whilst decaying grass roots may distribute carbon more evenly in the soil, they usually do not pump up nutrients as efficiently as forest vegetation would do (NYE, 1955). They also have less time to protect the soil against leaching due to the inevitable time lag between the onset of the rainy season when heavy showers occur and the development of suitable root system.

All the exchangeable cations reveal significantly different values under the different vegetation types at the 0.05 probability level. The general picture moreover is that of an increase in mean value from the Forest to the Guinea Savanna. Presumably, the major factor responsible for such a distintive pattern is the same as that outlined to explain the variation of nitrogen content.

A major consequence of the low clay content of the soils is low CEC. Thus although the soil acidity may be considered to be near optimal for the availability of major nutrients (FORTH, 1979), the low CEC of the soils may mean an inadequate basis for the retention of added nutrient.

The variation in the CEC parallels that of the organic matter content. Furthermore, analysis of variance reveals significant differences in CEC between the vegetation zones at the 0.05 probability level only in the topsoils.

Reflecting presumably the low values of exchangeable cations, the reaction of the soils is moderately to weakly acidic. The differences betwen the vegetation zones are insignificant at the 0.05 probability level. This may be because of the highly leached, generally coarse texture nature of the soils.

Slope parameters

The relationships between slope and soil properties were examined in two ways. First, soil properties are related to slope gradient. Secondly, the measured slope angles are subdivided into upper, middle and basal slope and the soil properties on these slopes positions examined. The upper slope is defined as the slope element extending from the interfluve to where the slope becomes steeper than 5 degrees. The basal slope is the slope extending from the valley center to where the slope is steeper than 5 degrees and the middle slope is that between the upper slope and the basal slope (LEOW & SMITH, 1981).

a.- variation in soil properties with slope gradient

All the soil properties reveal significant correlation with slope gradient, at least in one of the two layers, under the Derived Savanna (Tab. III). While the sand fractions show positive correlation, the silt and clay fractions, organic matter, nitrogen, exchangeable cations and pH show negative correlations.

Tab. III. - Simple correlation coefficient values between slope gradient and soil properties

Soil properties	All vegetation zones		Guinea Savanna		Derived Savanna		Forest	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Sand	0.11	0.09	0.19	0.13	0.42*	0.31*	0.34*	0.10
Coarse sand	0.15	- 0.18	0.32*	0.16	0 .21	0.43*	0.21	0.13
Fine sand	0.19*	0.10	0.15	0.08	0.56*	0.30*	0.22	0.17
Silt	- 0.16	- 0.25*	- 0.24	- 0.19	- 0.29*	- 0.25	0.21	- 0.11
Clay	- 0.17	- 0.13	- 0.20	0.18	- 0.55*	0.40*	- 0.10	- 0.24
Organic matter	- 0.05	- 0.16	0.09	- 0.13	- 0.33*	- 0.28*	0.07	- 0.05
Nitrogen	- .06	- 0.14	- 0.20	0.08	- 0.13	- 0.34*	0.03	0.06
Exch. K	0.12	- 0.15	- 0.14	0.07	- 0.17	- 0.38*	0.04	- 0.18
Exch. Na	- 0.11	- 0.09	- 0.16	0.12	- 0.32*	- 0.45*	- 0.11	- 0.18
Exch. Ca	- 0.08	- 0.14	- 0.18	- 0.15	- 0.42*	- 0.36*	0.11	0.03
Exch. Mg	- 0.08	- 0.13	- 0.32*	0.13	- 0.18	- 0.33*	- 0.24	- 0.06
CEC	- 0.14	- 0.17	- 0.19	0.15	- 0.42*	- 0.30*	- 0.11	- 0.20
pH	0.12	0.09	0.20	0.12	0.31*	0.09	0.17	0.22

*=Significant at the 0.05 probability level

The increase in textural coarseness and and the decrease in exchangeable bases with increase in slope gradient may be attributed to increase in slope wash and lateral eluviation of materials as slope gradient increases (JAHN, 1967; MORGAN, 1973, 1979).

In contrast to the Derived Savanna, there is no consistent or significant relationship between the soil properties and slope angle at the 0.05 probability level under the Forest and Guinea Savanna, presumably because of the relatively low range of slope angles.

Table IV. - Variation in measured soil properties with slope position

		Topsoil				Subsoil		
		Upper	Middle	Lower		Upper	Middle	Lower
No of samples		27	35	29		27	35	29
Texture								
Sand	X	72.9	68.8	63.9	*	64.1	61.2	60.1
	SD	*20.4*	*20.6*	*16.0*		*13.5*	*16.5*	*20.4*
Coarse sand	X	35.0	31.6	26.8	*	27.6	23.7	24.9
	SD	*14.0*	*1.7*	*12.9*		*9.7*	*4.5*	*7.5*
Fine sand	X	38.5	37.2	36.2		36.5	37.5	35.2
	SD	*13.5*	*9.3*	*10.1*		*14.5*	*16.9*	*7.7*
Silt	X	15.9	18.2	21.1	*	19.1	20.3	20.5
	SD	*2.4*	*5.7*	*7.0*		*2.5*	*3.9*	*4.1*
Clay	X	11.1	13.6	16.9	*	16.7	18.8	19.0
	SD	*2.8*	*2.7*	*5.9*		*4.7*	*4.1*	*6.1*
Organic matter and nitrogen (%)								
Organic matter	X	1.96	2.12	2.34	*	0.87	0.92	1.07
	SD	*0.90*	*1.06*	*1.42*		*0.34*	*0.33*	*0.50*
Nitrogen	X	0.23	0.33	0.53		0.09	0.13	0.42
	SD	*0.21*	*0.20*	*0.44*		*0.02*	*0.02*	*0.07*
Exchangeable cations (m.e. 100 g of soil) and pH								
Na	X	0.10	0.14	0.17		0.18	0.22	0.22
	SD	*0.08*	*0.11*	*0.09*		*0.13*	*0.08*	*0.04*
K	X	0.18	0.26	0.32	*	0.07	0.33	0.36
	SD	*0.11*	*0.18*	*0.22*		*0.06*	*0.24*	*0.23*
Ca	X	2.03	2.39	3.64		2.25	2.62	4.15
	SD	*0.73*	*1.62*	*1.95*		*1.91*	*1.55*	*2.65*
Mg	X	1.61	2.13	1.83	*	1.80	2.49	2.05
	SD	*1.03*	*1.66*	*1.04*		*0.95*	*1.67*	*0.94*
CEC	X	7.09	8.29	9.09	*	4.51	5.71	5.83
	SD	*2.25*	*6.40*	*6.82*		*0.98*	*2.33*	*2.25*
pH	X	6.21	6.34	6.41		6.22	6.03	6.67
	SD	*0.93*	*1.11*	*1.20*		*1.10*	*1.52*	*1.30*

Upper, Middle and Lower refer to slope positions.
X =mean, *SD* = Standard Deviation
* refers to significant difference between slope position at the 0.05 probability level.

b.-variation of soils properties with slope position

1) texture

In the top soils, all the the particle size fractions, except the fine sand, show significant differences between the slope positions (Tab. IV). The general trend is that of a downslope decrease in the sand fractions and an increase in the silt and clay fractions. Such a distinctive pattern could be as a result of downslope transport of fine materials enriching soils in downslope areas with these materials and depleting those near the crest of the same. It could also be in part the result of greater weathering and production of clay-size particles in the lower slope positions (OLLIER, 1970; SWAN, 1970).

A close look at the data reveals, however, that there is no consistant variation in the particle size fractions downslope. Such features may be attributed to the presence of micro-relief features on the dominant slope, or the presence of large stones and/or tussocky vegetation which tend to result in the reorganisation of surface runoff into anastomosing rills and consequently the slope materials.

The variation of particle sizes in the subsoils is similar to that of the topsoils but none of the particle size fractions reveals significantly different values between the slope positions at the 0.05 probability level.

When the samples were examined in the context of the three vegetation belts, the results obtained were not much different from the overall picture. The only exception is in the Derived Savanna belt where only the total sand and coarse sand fractions reveal significantly different values between the slope positions in the topsoil. This may mean that over these steeper slopes, the finer materials are removed relatively faster by slope wash and/or interflow.

2) organic matter and chemical nutrient

In both the topsoils and subsoils, the organic matter and nitrogen contents show a downslope increase in mean value, suggesting a downslope transport of materials. The difference between the slope positions is significant however only for organic matter in the topsoils. When examined against the vegetation factor, these materials reveal significant differences between the slope positions only in the topsoils under the Guinea Savanna and Forest conditions, although the trend downslope is generally the same as the overall trend.

Except for Mg, the pattern of the exchangeable cations downslope is quite similar to those of the organic matter and nitrogen. The differences between the slope positions are significant however only with respect to K and Mg in the topsoils and Ca in the subsoils. When examined in the context of vegetation zones, all the cations show significantly different values at least in one of the layers, except K under Guinea Savanna and Mg under Derived Savanna. The general trend is a downslope increase.

The soil pH reveals no significant different values between the slope positions.

CONCLUDING REMARKS

From the results obtained, the overall impression is one of soils whose properties reflect complex interactions between controlling parameters. It is suggested, however, that the factor of parent rock is more important in determining the soil characteristics than vegetation and slope factors. In spite of the significant differences between the vegetation zones and slope positions, all the soils are sandy, low in nutrient elements and acidic in reaction. This seems to support the practice of using parent rock as the basis for soil mapping in many tropical and subtropical countries, at least at the reconnaissance level.

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