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FACTOR ANALYSIS OF SOIL SPATIAL VARIABILITY IN GULLY EROSION AREA OF SOUTHEASTERN NIGERIA: A CASE STUDY OF AGULU- NANKA- OKO AREA.

***OSADEBE, C. C and +AKPOKODJE, Enuvie G.**
* Nigerian Building and Road Research Institute, P.M.B. 1055, Ota, Ogun State.
+ University of Port Harcourt, P.M.B. 5323 Choba, Port Harcourt, Rivers State

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Abstract
The effect of soil characteristics on gully development and distribution has made it desirable to determine the spatial variability of its physical and chemical properties. This paper examines the spatial variability of soil properties and factors contributing to the general pattern of variability in Agulu- Nanka- Oko gully complex, Southeastern Nigerian. Five (5) gully locations and nine (9) gully profiles were selected for the investigation. Fifty one (51) soil samples were collected along the gully walls of the profiles. These soil samples were analyzed in the laboratory by standard methods (ASTM and British Standard) for soil index properties and chemical properties. The soil samples were collected at depths between 1.2 meters and 21.3 meters, where there are changes in soil types based on textural characteristics. The data were subjected to descriptive and factor analysis. The results of the statistical analyses show that there were marked contrasts in the level of variability of the soil properties. The coefficient of variation ranged from 1.24% to 47.16%. The factor analysis revealed that the variability of the soil properties is mainly due to four factors namely; chemical properties, moisture content, textural characteristics and organic carbon.

Key words: Factor, analysis, spatial, variability, soil, gully

INTRODUCTION

A common characteristic of soils is the high variability of its physical and chemical properties. This high variability makes it difficult to select properties to characterize and classify the soil. The effect of soil characteristics on gully development and distribution makes it desirable to determine the spatial variability of its physical and chemical properties.

The assessment of soil variability has been undertaken by many researchers (Hudec et al,. 1998; Akpokodje et al,. 1986; Nwajide & Hoque, 1979; Okagbue & Ezechi, 1988; Ofomata, 1988). Commonest statistical technique used by Hudec et al (1988) was the descriptive statistics in terms of mean, standard deviation, and coefficient of variation. Though, these techniques were able to depict the overall variability and also revealed some useful variability pattern of the soil properties, they could not account for the source of variability in the soil properties. The introduction of factor analysis technique as one of the statistical techniques will reveal factors contributing to the soil variability (Adebayo, 1997). Factor analysis technique enables us to reduce large data set to a smaller set of factors that may be taken as source of variation accounting for the observed interrelation in the data. The objective of this paper is to highlight the variability of soil properties in a gully area and to find the specific factors contributing to the overall pattern of soil variability.

General Description

The study area lies between latitude 6^o $10^/$ and 6^o $05^/$N and longitude 7^o $00^/$ and 7^o $08^/$ E (Fig.1). The area has a tropical wet and dry climate with a mean annual rainfall of about 2000mm (Akintola, 1986). The study area falls within the tropical rain forest belt which is characterized by growth of tall trees amidst thick undergrowth (Udo, 1978). Isolated patches or remnants of typical forest exist in some parts of the area. The soil of this area belongs to the ferralsol soils (Agboola 1979) which comprise of the red and brown soils derived from sandstone and shale.

MATERIALS AND METHODS

Five (5) gully locations and nine (9) gully profiles were selected for the study. The soil samples were collected at depths between 1.2 meters and 21.3 meters, where there are changes in soil types based on textural characteristics along the gully walls of the profile. Fifty one (51) soil samples were collected from the field and analyzed in the laboratory using standard methods (American Society for Testing Materials (ASTM) and British standards (BS) methods for soil index properties.

In the study, fifteen (15) variables (organic carbon, cation exchange capacity, pH, iron oxide III, silica, maximum dry density, dispersion time, % sand, % silt/clay, particle size fraction less than 1.18mm, optimum moisture content, degree of saturation, dry density and porosity) of the fifty one (51) soil samples were used to identify element interrelationship and associations in correlation matrix. In order to reduce the source of variation into few distinct factors, the data were subjected to factor analysis. The analysis was performed using Statistical Package for Social Sciences (SPSS, 1999). Principal component extraction method was used to reduce the variation in the data into these factors. The factor analysis identified a relatively small number of factors that could be used to represent relationships among set of many interrelated variables. However, to transform complicated initial matrices into a simple factor structure and enhance the interpretability of the factors, the rotation phase of the factor matrix was conducted orthogonally using varimax algorithm (Davies, 1973). Using principal component matrix, the eigenvalues associated with each factor was calculated. These represent the amount of total variance accounted for by the ith factor. The proportion of the total variance accounted for by factor i was evaluated using the relationship. The proportion of total variation due to factor i $= \frac{\lambda_i}{n}$; i = 1, 2, - - - - 15 -------1

where λ_i *represents the eigenvalue of the ith factor and n represents the total number of variables in the set.*

The factors with eigenvalues greater than 1.0 were extracted (Kaiser, 1974). To identify the components, the component pattern matrix was sorted and ranked such that variables with loadings on the same component were grouped together. Small factor loadings were omitted from the factors.

RESULTS AND DISCUSSION

Soil Properties Variability

The statistical summary showing the mean, standard deviation and coefficient of variation (CV) for all the measured properties are presented in Table 1. The levels of variation as shown by the coefficient of variation results reveal the differences in the nature of the soil properties in this area.

The textural characteristics exhibited relatively low levels of variability. Fraction 1.18mm is the least variable of the textural properties with coefficient of variation of 1.24%. Sand also exhibited low level of variation of 5.50%

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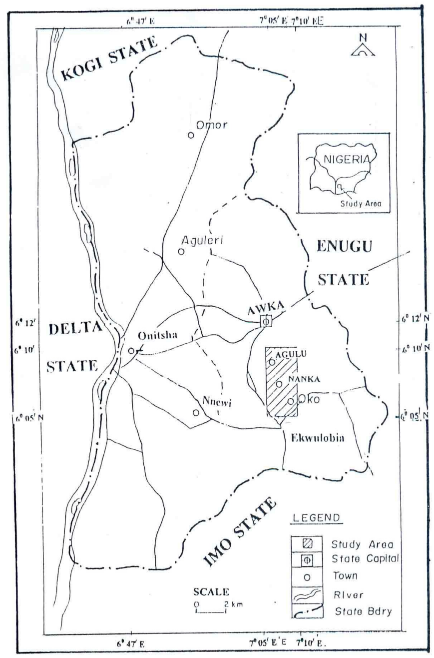

Fig. 1 : Map of Anambra State Showing the Study Area

Table 1: Summary of Descriptive Statistics of Soil Index and Chemical Properties of Agulu- Nanka- Oko gully Area

Variable	Mean± SD	Range	C v (%)
OC (%)	2.48±0.55	1.64-3.80	26.42
CEC	0.65±0.24	0.55-0.72	30.46
pH	6.48±0.22	5.41-7.21	6.0
Fe_2O_3	23.81±6.85	1.28-38.27	28.77
SiO_2	46.83±7.33	31.48-57.13	15.66
Maximum dry density (kg/m^3)	1890±5.3	1820-1999	2.80
Dispersion time (secs)	111±24	62-142	21.19
% Sand	78.6±4.3	70.9-87.4	5.50
% Silt/Clay	21.4±4.4	12.6-29.1	20.56
Particle size fraction < 1.18 mm(%)	98.6±1.2	94.6-100.0	1.24
Optimum Moisture Content (%)	11.7±3.1	4.7-18.3	26.60
Moisture Content (%)	6.18±2.91	2.12-13.30	47.16
Degree of Saturation	0.21±0.10	0.08-0.44	45.58
Dry density (kg/m^3)	1501.17±68.63	1329.66-1628.70	4.57
Porosity	0.44±0.026	0.39-0.50	5.87

while silt/clay proportion is moderately variable with CV of 20.56%. Among the index properties of the soil, maximum dry density is the least variable with CV of 2.80%. Moisture content is the most variable with CV of 47.16%. The dispersion time is moderately variable with CV of 21.19%. The chemical properties exhibited relatively moderate levels of variability. The Fe_2O_3 is the most variable with CV of 28.77% while SiO_2 is the least variable with CV of 15.66%. Generally, the textural characteristics show less variability than other physical properties.

Factor Analysis of the Soil Properties

The result of the descriptive statistics (Table 1) has shown that the soil properties exhibited varied degree of spatial variability. Prior to the factor analysis, the initial correlation matrix was generated among the soil properties (Table 2).

This approach enables an understanding of the type and extent of relationships between the soil properties. The Eigenvalue structure of the soil properties are shown in Table 3. In line with Kaiser (1974) suggestion, only the factors with eigenvalues greater than unity were retained. This implies that only the first four factors in the table were retained. These four factors accounted for over 71% of the total variance in the sample. In order to obtain a clear and consistent pattern of variation, the four factors extracted were orthogonally rotated using the varimax method. The loadings on each of the rotated factors are shown in Tables 4 and 5. The first factor exhibited high positive loadings on organic carbon, cation exchange capacity and pH. This component is considered to represent the organic carbon since there is a linear relationship between organic carbon and the other two properties as shown in Table 2.

The second factor shows high positive loading on Fe_2O_3, SiO_2 and MDD. This factor is considered to represent chemical properties since Fe_2O_3 and SiO_2 correlated positively with MDD. The third factor contains high negative loading on sand and high positive loading on silt/clay, fraction 1.18mm and OMC. This factor reflects textural characteristics since there is significant negative correlation (r = -1.00) between sand and silt/clay and between sand and OMC (r = -0.40) and positive correlation between silt/clay and OMC (r = 0.40).

Factor four loaded positively high on moisture content, degree of saturation, dry density and porosity. This factor is considered the moisture content because moisture content correlated positively with degree of saturation, and porosity and negatively with dry density.

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Table 2: Correlation Matrix of the Soil Properties

	OC	CEC	pH	Fe_2O_3	SiO_2	MDD	Dis time	Sand	Silt/ Clay	Pp118	OMC	Moist Cont	Degree of Sat	Dry Density
OC														
CEC	0.97													
pH	0.51	0.55												
Fe_2O_3	-0.10	0.55	0.3											
SiO_2	-0.04	-0.07	0.38	-0.13										
MDD	0.17	-0.09	0.31	0.38	-0.18									
Distim	0.72	0.17	0.39	0.06	-0.40	0.29								
Sand	0.05	0.70	-0.05	0.01	0.17	-0.08	-0.34							
Silt/Cl	-0.05	-0.07	0.05	-0.01	-0.17	0.08	0.35	-1.0						
Pp118	0.58	0.07	0.62	-0.07	-0.32	0.14	0.76	-0.41	0.42					
OMC	0.55	0.61	0.57	-0.27	0.08	0.03	0.53	-0.40	0.40	0.53				
Moist	0.10	0.54	0.08	0.03	-0.24	0.25	0.57	-0.01	0.02	0.42	0.29			
DegSa	-0.06	-0.02	0.04	0.04	-0.20	0.17	0.47	-0.0	0.01	0.33	0.20	0.97		
DryDe	-0.64	-0.17	-0.18	0.0	0.29	-0.25	-0.57	0.06	-0.06	-0.51	-.42	-0.39	-0.15	
Pority	0.64	0.61	0.18	-0.0	-0.29	0.26	0.57	-0.06	0.06	0.51	0.42	0.39	0.15	-1.0

OC – Organic Carbon, CEC – Cation exchange capacity; MDD – Maximum dry density; Distim=Dispersion time; pp118- Particle size fraction less than 1.18mm; Silt/C= silt & clay fraction; OMC- Optimum Moisture Content; Moist= Moisture Content; Deg Sa=Degree of Saturatio; DryDe=Dry density;Pority=Porosity

Table 3: Principal Factor Final Statistics

Factor	Eigenvalue	% Variation
1	3.219	29.653
2	2.328	18.703
3	1.638	13.279
4	1.024	9.760
5	0.984	6.365
6	0.602	3.459
7	0.533	3.832
8	0.501	3.414
9	0.403	3.289
10	0.364	2.008
11	0.292	1.775
12	0.245	1.344
13	0.218	1.212
14	0.175	0.974
15	0.0855	0.933

Table 4: Rotated Factor Pattern of the Soil Properties

Variables	Factor 1	Factor 2	Factor 3	Factor 4
OC	0.972	-0.0843	-0.097	0.102
CEC	0.970	-0.0682	-0.0458	0.0749
pH	0.958	-0.0399	-0.0898	0.137
Fe_2O_3	-0.0244	0.796	0.0062	0.160
SiO_2	0.0281	0.778	-0.260	0.0464
MDD	-0.144	0.765	-0.346	0.112
Dispersion time	0.191	0.644	0.0334	0.0139
Sand	0.0610	-0.0433	-0.845	0.327
Silt/Clay	-0.0359	0.0413	0.630	-0.213
Fraction 1.18mm	0.340	0.0785	0.621	-0.205
OMC	0.222	0.0266	0.545	-0.302
Moisture content	0.0255	0.0476	0.0348	0.881
Degree of saturation	-0.0488	-0.0448	0.0366	0.834
Dry density	0.0340	0.0712	0.124	0.707
Porosity	-0.0486	0.127	0.346	0.685

Table 5: Sorted and blanked rotated factor matrix

	Factor			
Rotated Factor matrix	**1**	**2**	**3**	**4**
OC	0 972			
CEC	0.970			
pH	0.958			
Fe_2O_3		0.796		
SiO_2		0.778		
MDD		0.765		
Dispersion time		0.644		
Sand			-0.845	
Silt/Clay			0.630	
Fraction 1.18mm			0.621	
OMC			0.545	
Moisture content				0.881
Degree of saturation				0.834
Dry density				0.707
porosity				0.685

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CONCLUSION

With the rotated factor solution discussed above, the distinctive role of the different soil properties in soil spatial variability was clearly revealed. Thus, the spatial variability of the soil properties in this area appears to derive mainly from the differences in organic carbon, chemical properties, textural characteristics, and moisture content. This implies that the most useful factors that would be considered in a detailed survey and control of gully in the area would be organic carbon, chemical properties, textural characteristics and moisture content of the soil.

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