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THE USE OF SOME SOIL AGGREGATE INDICES TO ASSESS POTENTIAL SOIL LOSS IN SOILS OF SOUTH-EASTERN NIGERIA

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A b s t r a c t. Six aggregate indices and some soil properties were evaluated to predict potential soil loss in soils of Southeastern Nigeria. Of the aggregate indices tested, dispersion ratio (DR), Wischmeier's erodibility index (K), clay dispersion index (CDI) and clay flocculation index (CFI) ranked higher than geometric mean diameter (GMD) and mean-weight diameter (MWD) in predicting potential soil loss. Some aggregate indices found to correlate well with soil loss are in order of decreasing predictability CFI>CDI>DR>GMD≥MWD while organic carbon, % clay content and Fe_20_3 are some soil characteristics that predict the potential of these soils to erode fairly accurately. Dispersion and flocculation are shown to be influenced by metal-organic complexes which often leads to increased potential soil loss.

K e y w o r d s: soil loss, erodibility, aggregate indices, flocculation, texture

INTRODUCTION

In Southeastern Nigeria, soil erosion is believed to be related, among other factors to the nature of soils. Investigations on the effects of soil texture on soil erosion processes by Holy [7] showed that sandy soils are least susceptible to erosion because they are highly permeable and resist the kinetic energy of water at low consistence.

Bryan [3] compared the erosion indices and favours aggregate stability as the most efficient. He used the proportion of water-stable non-primary aggregates larger than 0.5 mm contained in the soil as an indicator of erodibility; the greater the proportion, the more resistant is the soil to erosion. Obi *et al.* [13] observed that in Southeastern Nigeria the soil aggregate stability technique was the least satisfactory index for determining erodibility of soils.

Apart from the use of silt/clay ratio of van Wambeke [20] as index of weathering, Morgan [12] associated high ratios with erodible areas where the continual removal of the soil allows insufficient time for a high degree of weathering to occur. Elwell [6] observed that on a fersiallitic clay soil in Zimbabwe, the mean-weight diameter and WSA < 2 mm were highly significant in explaining variations in soil loss. Mbagwu [10] in South Nigeria evaluated the relative erodibility values of soils formed on a toposequence by use of various erodibility indices and observed clay ratio, dispersion ratio, Wischmeier's erodibility index (K) and dispersion index gave a better estimation of simulated soil loss than other indices studied.

A number of authors (El-Swaify and Dangler [5], Schwertmann and Taylor [16]) confirmed that soil properties such as dithionite extractable iron are important in predicting Wischmeier's K-values. Singer *et al.* [17] noted that dithionite extractable iron was a property important in prediction of soil erodibility in addition to soil physical properties.

Other indices and soil properties which predict the degree of soil erodibility exist. The major objective of this work is to identify the major soil aggregate indices that could be used to make inferences on the potential of soils in Southeastern Nigeria to erode.

MATERIALS AND METHODS

The twenty-five soil samples used for this study differ in their physical and chemical properties (Tables 1 and 2) and were collected from different parts of Southeastern Nigeria. The soils are formed mainly on sedimentary geological materials while kaolinite is the dominant clay mineral. All the samples were collected from a 0-30 cm level.

Particle size analysis was done using Bouyoucos hydrometer method described by Day [4]. In this determination, soils were first dispersed with distilled water without any dispersing agent. A second portion of the sample was treated with dithionite-citrate-bicarbonate (DCB) as described by Aguilera and Jackson [1] in order to remove Fe_2O_3 for proper dispersion. This was followed by addition of sodium hexametaphosphate before physical agitation of the suspension. Thereafter the necessary measurements were taken.

Wischmeier's erodibility (K) was read off from Wischmeier and Smith [22] nomograph using analytical information.

Clay flocculation index (CFI)=

$$[\%\ clay_{(DCB)} - \%\ clay_{(H_2O)} / \%\ clay_{(DCB)}] \times 100$$

Dispersion ratio (DR) =

$$\%\ silt + \%\ clay_{(H_2O)} / \%\ silt + \%\ clay_{(DCB)}$$

Clay dispersion index (CDI) =

$$[\%\ clay_{(H_2O)} / \%\ clay_{(DCB)}] \times 100$$

Table 1. Textural and aggregation properties of the soils

Soils	Clay	Silt	Sand	Textural class	O.C.	Fe_2O_3
		(%)			(%)	
Oseakwa	14	4	82	sl	1.48	0.62
Akili Ozizor	46	38	16	c	3.11	2.35
Osamala	22	16	62	scl	1.08	1.71
Oroma etiti	56	20	24	c	2.79	4.08
Umuewelu	36	40	24	sc	3.51	1.76
Ezillo	10	12	78	sl	1.12	0.26
Abakaliki	26	2	72	scl	0.68	0.36
Okija	16	2	82	sl	0.48	0.72
Ogurugu	10	14	76	sl	0.84	0.08
Nenwe	34	10	56	scl	0.84	0.44
Ifite Ogwari	28	56	16	cl	1.60	2.18
Umueje	32	48	20	cl	3.11	1.17
Umumbo	34	30	36	cl	1.28	0.70
Omasi	22	62	16	sil	2.35	0.98
Adani	28	56	16	sicl	1.96	1.64
Nsukka	22	2	76	scl	1.88	0.29
Obollo Afor	30	4	66	scl	1.12	0.50
Nteje	14	4	82	sl	0.52	0.50
Awka	12	6	82	ls	0.84	0.10
Idodo	44	40	16	c	3.59	3.02
Ukehe	22	2	76	scl	1.24	0.47
Abor	16	4	86	sl	0.64	0.98
Nachi	20	4	76	scl	1.44	1.16
Nanka	28	2	70	scl	0.96	0.15
Nwfija	8	2	90	ls	0.76	0.42

sl - sandy loam; c - clay; scl - sandy clay loam; ls - loamy sand, cl - clay loam; c - clay; sil - silty loam; sicl - silty clay loam; O.C. - organic carbon.

Table 2. Some physical and chemical properties of the soils

Property	Range	Mean	CV (%)
Clay (%)	8.0 - 56	25.2	48
Silt (%)	2.0 - 62	19.2	106
Total sand (%)	16.0 - 90	54.4	51
Bulk density (Mg m^{-3})	1.14 - 1.88	1.5	15
pH KCl	3.76 - 5.30	4.3	11
Organic carbon (%)	0.48 - 3.59	1.6	62
Total nitrogen (%)	0.032 - 0.248	0.092	64
Exchangeable cation (cmol kg^{-1})			
Na^+	0.06 - 0.20	0.08	33
K^+	0.13 - 0.96	0.36	74
Ca^{2+}	0.7 - 10.8	2.2	103
Mg^{2+}	0.3 - 8.4	2.3	92
Al^{3+}	0.0 - 5.2	1.0	112
H^+	0.0 - 2.4	0.9	82
CEC	2.5 - 39.5	9.9	87
Avail. P (mg kg^{-1})	2 - 18	6.3	67
Fe_2O_3 d (%)	0.1 - 3.02	1.1	93

Mean weight-diameter (MWD) was determined using the method of van Bavel [19] as modified by Kemper and Chepil [8] and calculated using the following relationship:

$$MWD = \sum \bar{x}_i w_i$$

where $\bar{x}$ - mean diameter of each size fraction (mm), w - the proportion of the total sample weight occurring in the corresponding size fraction.

Geometric mean diameter (GMD) was calculated according to the following:

$$GMD = \exp\left[\sum w_i \log \bar{x}_i / \sum w_i\right]$$

where w_i - the weight of aggregates, $\bar{x}$ - average diameter, $\sum w_i$ - total weight of the sample.

Organic carbon was determined by the wet combustion technique of Walkley and Black [21] while Fe_2O_3 was determined by dithionite-citrate-bicarbonate method [11].

RESULTS AND DISCUSSION

Ranking of soils in order of potential erodibility (Table 3) shows the relative ranking of erodibility of the soils with 1 indicating most erodible and 25 being the least erodible. This is primarily achieved by arranging the soils in order of predictability using simple correlation.

From the ranking however, it is observed that only few indices were in agreement in their predictive ability of some soils. The dispersion ratio (DR) shows that soils with less clay content are most erodible. This same trend is also observed for clay dispersion index (DI), clay flocculation index (CFI) and Wischmeier's K-value. However, the mean-weight diameter (MWD) and the geometric mean diameter (GMD) indicated that their rankings are not related to texture or clay content.

Bazzoffi and Mbagwu [2] observed that matching the soils they studied with their textural classes, there was no agreement as to the degree of erodibility. In the present study it is observed that textural class had no direct relationship with erodibility, whereas the % clay and % total sand contents had a lot of influence on the ranking. From the overall ranking it is suggested that DR, K, CDI and CFI are better predictive indices.

Evaluation of the indices

Table 4 presents a correlation matrix of the erodibility-stability indices and soil properties.

Clay flocculation index (CFI) showed a significant correlation coefficient with potential soil loss (K) and may be the best index which described the degree of soil loss. The implication of this is that CFI alone could be used to predict soil erosion hazard and as CFI increases there is a corresponding increase in erosion hazard. CFI also correlates significantly with CDI (-0.99) at 0.1 % level of significance. DR and CDI are all negatively correlated with estimated soil loss (Table 4). Although these assertions do not agree with some theories but when viewed from the fact that these soils are mainly topsoils where organic matter is relatively high. These organic materials, according to Schnitzer and Kodoma [15], and Tan [18], have the capacity to chelate or complex metal ions such as Fe^{3+} and Al^{3+}. The chelates are temporarily withdrawn from the soil solution. This situation can lead the soil to

Table 3. Ranking of soils in order of significant predictability

Soils	DR	CDI	K	CFI	MWD	GMD	Overall* ranking
Oseakwa	5	10	24	10	10	13	11
Akili Ozizor	21	22	22	22	18	16	24
Osamala	17	13	22	13	1	4	10
Oroma etiti	15	25	21	25	2	5	20
Umuewelu	21	20	19	20	3	6	18
Ezillo	16	12	13	12	17	12	17
Abakaliki	10	16	13	16	7	2	8
Okija	9	8	8	8	4	9	4
Ogurugu	11	17	11	17	15	8	13
Nenwe	14	19	25	19	5	9	19
Ifite Ogwari	18	18	16	18	21	25	21
Umueje	18	7	16	7	23	7	12
Umumbo	24	15	16	15	8	3	14
Omasi	25	21	8	21	22	19	22
Adani	23	23	15	23	24	23	25
Nsukka	12	8	12	8	20	21	14
Obollo Afor	12	2	5	2	12	15	5
Nteje	3	6	5	6	15	20	7
Awka	2	1	5	1	13	16	2
Idodo	20	24	20	24	14	14	22
Ukehe	7	4	8	4	19	22	8
Abor	4	4	2	4	9	18	3
Nachi	6	11	4	11	25	24	14
Nanka	7	14	2	14	11	1	6
Nwfija	1	3	1	3	5	11	1

* 1 - most erodible; 25 - least erodible.

Table 4. A correlation matrix of indices of structural stability/soil loss and other soil properties

	Fe_2O_3	O.C.	GMD	MWD	CFI	K	CDI	DR
DR	0.50**	0.66**	-0.16	0.09	0.65***	-0.47**	0.68***	-
CDI	0.77***	0.67***	-0.28	-0.11	-0.99***	-0.51**	-	
K	-0.46**	-0.44**	0.25	0.24	0.53**	-		
CFI	-0.78***	-0.67***	0.30	0.13	-			
MWD	-0.20	0.05	0.82***	-				
GMD	-0.29	-0.27	-					
OC	0.71***	-						
Fe_2O_3	-							

* Significant at 0.05 probability level; ** Significant at 0.01 probability level; *** Significant at 0.001 probability level; O.C. - organic carbon.

erode even when high, as was shown in the present studies. Another possibility, as was discussed by Tan [18], is that the metal-organic complexes tend to disperse easily at low electrolyte concentration and this increases the soils capacity to disperse. The low values of the correlation coefficient between the indices and the estimated soil loss could be due to the fact that the soil loss values are estimated from analytical data and not from empirical determination. Mbagwu [10] obtained a positive correlation coefficient between soil loss and DR. Although the MWD and GMD were used in the ranking of the soils in stability order, they did not correlate very well with the estimated soil loss. Their relationship with other indices are also not good. In terms of erosion prediction, these indices can be ranked in order of high to low predictability based on the correlation matrix:

CFI > CDI > DR > GMD ≥ MWD.

Elwell [6] and Mbagwu [10] made similar ranking to evaluate the predictive ability of the erodibility indices they tested.

Fe_2O_3 correlated significantly with other indices except MWD and GMD. However, the only information derived from these relationships is that Fe_2O_3 controls flocculation and deflocculation properties of the soils thereby affecting the degree of estimated soil loss. It does not however, affect the size of aggregates. Panayiotopoulos and Kostopoulou [14] observed that there is a relationship between aggregation and polyvalent cations. The trend in Fe_2O_3 was also observed in organic carbon indicating the contribution of organic carbon in the deflocculation-flocculation process and also the prediction of soil loss. Organic carbon could also be used for predictive purposes as postulated by Mbagwu *et al.* [9] since it significantly correlates negatively with potential soil loss (r=-0.44).

CONCLUSIONS

1. Dispersion ratio (DR), Wischmeier's erodibility (K), clay dispersion index (CDI) and clay flocculation index (CFI) ranked higher in predicting potential soil loss than geometric mean diameter (GMD) and mean-weight diameter (MWD). Also % clay content rather than textural classes had a direct relationship with potential erodibility.

2. Correlation matrix shows that the indices could be placed in order of high predictability of potential soil loss to the least:

CFI > CDI > DR > GMD ≥ MWD.

3. Organic carbon and Fe_2O_3 controls flocculation and deflocculation properties of the soils and affected estimated soil loss. However, the size of aggregates are not affected by these materials. Finally, dispersion and flocculation are shown to be influenced by metal-organic complexes often leading to increased potential soil loss.

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