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ESTIMATING SOIL ERODIBILTY FACTOR K ON UPLAND SOILS OF OBIO-AKPOR IN RIVERS STATE NIGERIA

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Abstract

Soil erodibility factor (K) is one of the most important factor in the Universal soil loss equation which estimates the resistance of soil particles to detachment. The K factor for the upland soils of Obio-Akpor was estimated using the mechanical composition (MC), mechanical ratio (MR), dispersion ratio (DR) and erosion index (EI) models of K determination. Soil samples were collected from cultivated land at 0-10 and 10-20cm depths from 5 communities representing the Obio-Akpor namely: Eneka, Rumuokuta, Rumudomaya, Choba and Elelenwo. their particle size distribution and water holding capacity were determined in the laboratory and fitted into the various models. The soils were generally loamy sand to sandy loam. MR and MC gave higher values of K when compared with those estimated with DR and EI models. Irrespective of the model used, K factor varied with location. Rumuokuta soil had the least mean K values of 2.26 and 2.07 (tonsha^{-1}) at the 0-10 and 10-20cm depth respectively.Elelenwo and Runmuodomaya had higher mean K values of 4.16 and 3.44 (tonsha^{-1}) respectively, at the 0-10cm depth and 3.74 and 3.02(tonsha^{-1}) respectively, at the 10-20cm depth. The DR and EI models showed that the higher the water holding capacity, the lower the estimated K value.

Key Words*: Erodibility , Water holding capacity, Particle size distribution.*

INTRODUCTION

Soil erosion is the detachment and, removal and transportation of soil materials by the action of water, wind and gravity (Lal, 1990, Panagos et. al., 2012, Tya and Oluwaseye 2015 and Richard et. al. 2018). It is a gradual natural process which when accelerated by human activities will cause negative effects on agricultural production, as it causes severe land degradation and soil soil productivity loss (Nyakatawa et. al., 2001, Egbai et.al., 2012, Arab et. al 2010, Arab et. al 2013, Manyiwa and Dikinnya, 2013, and Fashinmirin and Olorunfemi 2014).

Soil erodibilitybfactor is one of the factors of the Universal Soil Loss Equation (USLE), which is a mathematical model used to estimate long-term average annual soil loss by erosion. (Wischmeier and Smith, 1978). It is stated as follows:

$$A = R \times K \times L \times S \times C \times P$$

Where

A = Average annual soil loss
R = Rainfall erosivity factor
K = Soil erodibility factor
S = Slope steepness factor
L = Slope length factor
C = Crop management factor
P = Support practice factor.

Among these factors of the USLE, soil erodibility factor (K) is the most important from the point of view that it determines the susceptibility or resistance of a soil to detachment and subsequent transportation by rainfall or surface flow (Jejada and Gonzalez, 2006, Zhang et. al., 2007, Idah et. al. 2008, and Okoroafor et. al. 2018). Secondly, erosivity factor, which is related to rainfall properties cannot be manipulated.

Texture is the principle factor affecting K, but structure, organic matter and permeability also contribute. A soil with large amount of clay is said to resist erosion (Levy, et. al., 2001, Reichert et.al., 2001, Igwe, et. al., 2002, Dibal et. al., 2014 and Tya and Oluwaseye, 2015).

In the USLE model, K is measured using the average rate of soil loss from the unit plot per the unit rainfall erosivity (Vaezi, et. al., 2011). Two basic methods have been used for K factor determination. The first is direct measurement of K factor from standard plots which is cumbersome and expensive but more accurate (Aina et. al., 1980 and Vaneslande et. al., 1984). The second method is USLE nomograph, which was developed by Wishmeier et. al. (1971). Although this method has low accuracy when compared with the direct method, it has a wide useage because of its low cost and time requirement (Imani et.al., 2014). It is also reported that the nomograph approach over estimated K (Vaezi et. al., 2010 and Vaezi et. al., 2011). Vaneslande et. al., (1984) noted that the nomograph is mainly adapted to soils from the temperate region and has been found to be of limited application in the tropical soils.

Some indices or models have been reported to estimate K in different parts of the Tropics, which include the Clay ratio, Dispersion ratio, Mechanical ratio and

Erosion index (Ezeabasili, *et. al*., 2014). The absence of K factor information for Rivers State soils and its importance in the conservation and management of the vulnerable soils in the terrain; given the high intensity rainfall, informed this study. The objective of this study, therefore, is to estimate K for Obio-Akpor soils, using some indices of erodibility that requires only basic texture data and moisture related properties of the soil

MATERIALS AND METHODS

Study area: The experimental sites includes five major communities in the Obio-Akpor local government area in Rivers state Nigeria. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. Obio-Akpor is in the rain forest zone of Nigeria with a total coverage of 392km^2. It is generally a lowland area with average elevation below 30 metres above sea level. Its geology comprises basically of alluvial sedimentary basin and basement complex. Due to high average annual rainfall (2000mm -2500mm), the soil in the area is usually sandy or sandy loam. It is always leached, underlain by a layer of impervious pan (Eludoyin et. al., 2011). These sites include Choba, Rumuokwuta, Rumuodomaya, Eneka and Elelenwo. The sites had been cropped intensively with mixed cropping to cassava, fluted pumpkin, maize and yam for more than 10 years. The soils at these sites are generally ultisols. (Ayolagha and Ikiroma, 2013)

Soil sampling and analysis: Composite soil samples were collected from three spots in each of the five communities in Obio-Akpor local government area; namely Choba, Rumuokwuta, Rumuodomaya, Eneka and Elelenwo at two depths (0-10cm and 10-20cm). Samples were air-dried and passed through a 2mm sieve. Particle size distribution was determined using the Bouyoucos hydrometer method, as described by Gee and Bauder, (1986). Calgon (sodium hexa metaphosphate) was used to achieve chemical dispersion in one set of samples and distilled water in set.

Water holding capacity was determined using the equation below:

$$WHC = \frac{\text{Weight of saturated soil}}{\text{Weight of oven dried soil}} \times 100\%$$

The data from these analysis was fitted into different erodibility models; to estimate the erodibility factor K for the various soils.

The erodibility models used include:

i. The mechanical composition (MC) model by Bouyoucos (1935). This model, otherwise called the clay ratio, assumes that the clay content in the soil is the binding factor in soil aggregation

$$K = \frac{\%sand + \%silt}{\%clay}$$

ii. Mechanical Ratio (MR) model by Middelton (1930). This method otherwise called the silt/clay ratio, assumes that silt and clay contents of the soil are the binding factors in soil aggregation.

$$K = \frac{\%sand}{\%silt + \%clay}$$

This index has been shown to be accurate only for soils high in silt and clay and hence does not reflect accurately the erodibility of soils with a high sand content. This ratio also indicates a sharp boundary between erodible and non erodible soils, since dispersion ratio values greater than 10 indicates erodible soils and values less than 10 indicate non-erodible soils (Ezeabasili et. al., 2014).

iii. Dispersion Ratio (DR)model by Middelton 2 (1930). This method estimates the ratio of silt and clay in distilled water dispersed sample and silt and clay in Calgon dispersed sample. This ratio is taken to be an expression of the erodibility of the soil.

$$DR = \frac{\%silt + \%clay \text{ in water dispersed sample}}{\%silt + \%clay \text{ in Calgon dispersed sample}}$$

iv. Erosion index (EI). This method is an improvement on the dispersion ratio. It includes the clay content and the water holding capacity (WHC) of the soil as an indication of the erodibility of the soil.

$$EI = DR / (\%clay / ½ WHC)$$

RESULTS AND DISCUSSION

Particle size distribution: The particle size distribution of the soils of the various communities at two depths is as shown on Tables 1 and 2. For the Calgon dispersed sample at the 10-20cm depth, the soils were generally sandy loam to loamy sand; with silt and clay contents ranging between 1.28 to 9.28% and 11.20 and 13.20%, respectively. At the 10-20cm depth, silt and clay content ranged between 0.92 to 7.28% and 13.92 to 19.92%, respectively. Results showed higher coefficient of variability (CV) with silt contents (50.85 -52.23%) than the clay content (15.55 – 20.37%). At both depths and all locations, the clay content was higher than the silt contents. There was generally a decrease in sand contents and increase in clay contents with depth; across all the communities in Obio-Akpor investigated. The clay contents were in the order Rumuokuta > choba > Eneka = Rumuodomaya = Elelenwo at the 0-10cm depth and Rumuokuta > Choba > Eneka > Rumuodomaya = Elelenwo at the 10-20cm depth.

There were significant differences in sand, silt and clay contents of samples dispersed with distilled water and those dispersed with calgon (sodium hexametaphosphate). The sand content of water dispersed sample ranged between 80.80 and 88.70% for 0-10cm depth and 86.70 and 91.52% for 10-20cm depth (Table 2) when compared with 77.52 to 87.52%

for 0-10 cm depth and 75.16 to 85.16% for the calgon dispersed sample (Table 1). This indicates that chemical dispersion with a salt of high zeta potential like calgon, is necessary for complete dispersion of soil samples and therefore more accurate particle distribution data.

Table 1: Particle size distribution of the soils of the various location (Calgon dispersed)

Location	Particle Size Distribution							
	0 – 10cm depth				10 – 20 cm depth			
	% Sand	%Silt	%Clay	Textural class	% Sand	%Silt	%Clay	Textural class
Eneka	83.52	5.28	11.20	Loamy sand	77.16	6.92	15.92	Loamy sand
Rumuokuta	77.52	5.28	17.20	Sandy loam	75.16	4.92	19.92	Sandy loam
Rumuodamaya	81.52	7.28	11.20	Sandy loam	81.16	4.82	13.92	Sandy loam
Choba	77.52	9.28	13.20	Sandy loam	75.52	7.28	17.20	Sandy loam
Elelenwo	87.52	1.28	11.20	Sandy loam	85.16	0.92	13.92	Sandy loam
Mean	81.52	5.68	12.80		78.83	4.97	16.18	
STDEV	4.24	2.97	2.61		4.26	2.53	2.52	
CV (%)	5.20	52.23	20.37		5.41	50.85	15.55	

STDEV- Standard deviation, CV – Coefficient of variability

Table 2: Particle size distribution of the soils of the various location (Water dispersed)

Location	Particle Size Distribution							
	0 – 10cm depth				10 – 20 cm depth			
	% Sand	%Silt	%Clay	Textural class	% Sand	%Silt	%Clay	Textural class
Eneka	87.80	11.20	1.92	sand	91.52	6.00	2.48	sand
Rumuokuta	80.80	17.20	1.92	sand	87.52	12.0	0.48	sand
Rumuodamaya	88.70	11.20	0.08	sand	86.70	13.2	0.10	sand
Choba	84.80	13.20	1.92	sand	87.52	12.0	0.48	sand
Elelenwo	88.70	11.20	0.10	sand	91.52	8.00	0.48	sand
Mean	86.16	12.8	1.19		88.96	10.24	0.80	
STDEV	3.40	2.61	1.00		2.36	3.08	0.95	
CV (%)	3.94	20.37	84.37		2.66	30.08	118.31	

STDEV- Standard deviation, CV – Coefficient of variability

Erodibility values as estimated by different models:

The results of the erodibility factor (K) values as estimated with the different models for the various locations are as shown on Table 3. Generally, the coefficient of variability (CV) of K across the different locations, irrespective of model used, was wide and between 17.49 and 45.06%. The widest variability was observed with the Erosion Index (EI) model. The K values estimated with the mechanical composition (MC) and mechanical ratio (MR) were higher than those estimated with dispersion ratio (DR) and erosion index (EI). However, following the findings of Ezeabasili *et. al.*, (2014) that soils with K value lower than 10 (tonsha^{-1}) are not highly erosive, the soils of Obio-Akpor can be classified as such.

Irrespective of location, K values estimated with MC were higher than those estimated with MR. K values estimated with the MC model was in the order: 7.93 = 7.93 = 7.93 > 6.58 > 4.65 tonsha^{-1} for Eneka, Rumuodomaya, Elelenwo, Choba and Rumuokuta respectively; at the 0-10cm depth. Estimates with the MR model was in the order: 7.01 > 5.07 > 4.41 > 3.45 = 3.45 tonsha^{-1} for Elelenwo, Eneka, Rumuodomaya, Rumuokuta and Choba respectively.

The MC and MR models assume that the silt and clay contents are the determining factor for aggregation and therefore erodibility. This explains the high erodibility factor (K) estimated with MC and MR for the soils of the five locations were high in sand contents than silt and clay; being loamy sand to sandy loam soils. These notwithstanding, results showed that Eneka, Rumuodomaya and Elelenwo soils are more prone to detachment; given their higher K values, when compared with Choba and Rumuokuta soils. The trend of estimated K value, across all locations, was generally the same at the 10-20cm; although the K values were lower at this depth when compared with the 0-10 cm depth. The K values ranged between 4.02 to 6.18 tonsha^{-1} and 3.03 to 5.74 tonsha^{-1} for the MC and MR estimated of K, respectively.

The DR which is an expression of the ratio of silt and clay contents as a function of chemical dispersant and the EI which is an improvement on the DR had much lower values of K (Table 3). At the 0-10cm depth the K values as estimated with DR were in the order 0.85 > 0.61 > 0.58 > 0.56 >0.40 tonsha^{-1} for Choba, Rumuodomaya, Elelenwo, Eneka and Rumuokuta,respectively. For estimated EI estimated K, the values were 2.01, 1.63,1.13,0.99 and 0.55 tonsha^{-1} for Rumuodomaya, Choba, Elelenwo, Eneka and Rumuokuta, respectively. At the 10-20cm depth, the Rumuokuta, Choba and Eneka soils had lower Kvalues, when compared with theRumuodomaya and Elelenwo soils.

Table 3: Erodibility factor (K) values with different models for the soils of the various location

Location	K value (tonsha^{-1}) 0-10 cm depth				10 - 20 cm depth			
	MC	MR	DR	EI	MC	MR	DR	EI
Eneka	7.93	5.07	0.56	0.99	5.28	3.38	0.37	0.56
Rumuokuta	4.65	3.45	0.40	0.55	4.02	3.03	0.50	0.72
Rumuodamaya	7.93	4.41	0.61	2.01	6.18	4.30	0.70	0.90
Choba	6.58	3.45	0.85	1.63	4.81	3.08	0.50	0.69
Elelenwo	7.93	7.01	0.58	1.13	6.18	5.78	0.68	1.17
Mean	7.00	4.68	0.60	1.26	5.29	3.91	0.55	0.81
STDEV	1.44	1.47	0.16	0.57	0.93	1.16	0.14	0.24
CV (%)	20.56	31.49	26.95	45.06	17.49	29.67	25.19	29.20

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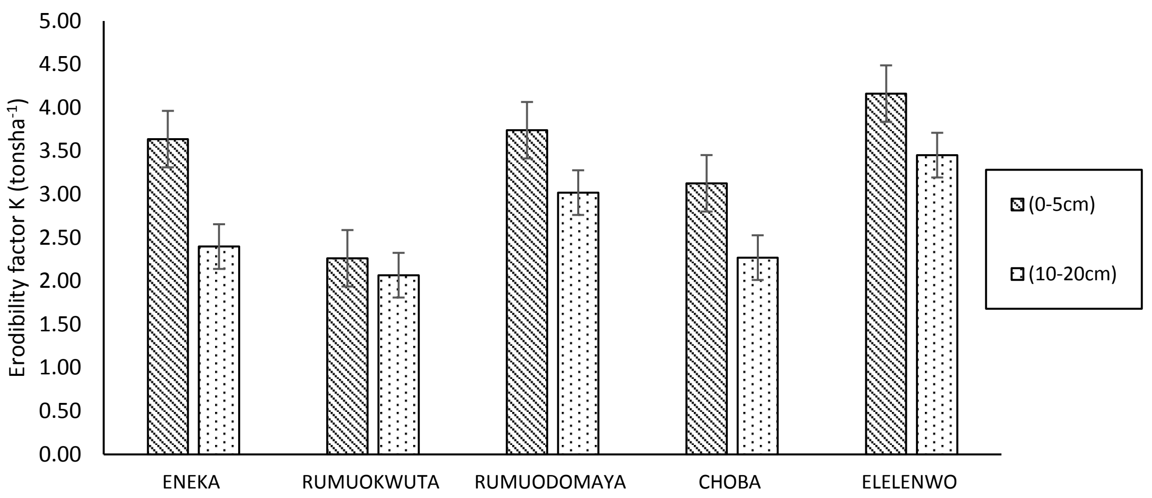

Fig.1: Mean erodibility values across the different models used

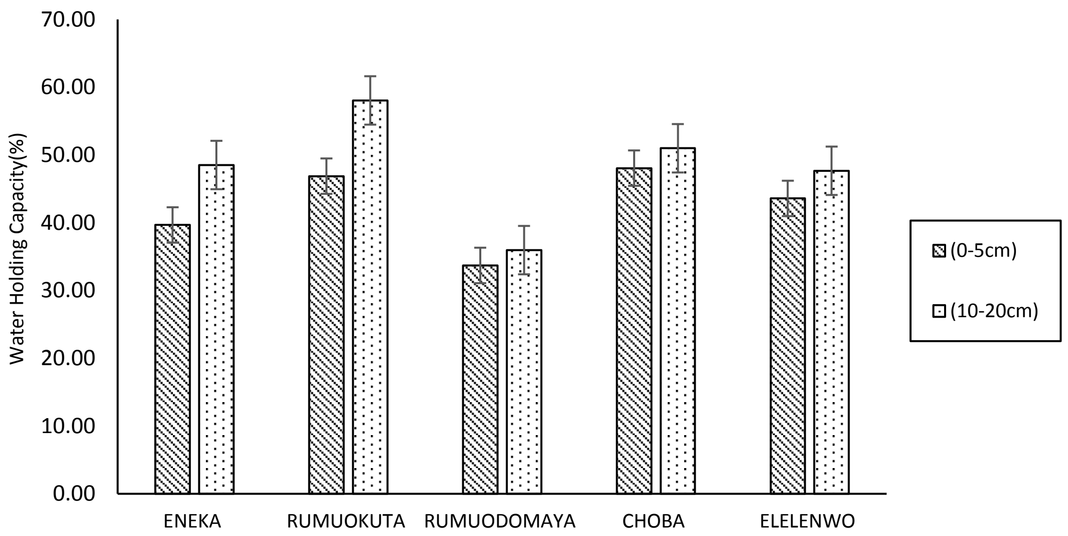

Fig. 2: Water holding capacity of the various locations with depth

STDEV- Standard deviation, CV – Coefficient of variability

The mean K values for the different locations, across the different models used is as shown on Fig.1. results showed that Rumuokuta soils consistently had lower K values, which indicates a lower tendency to detachment of soil particles and therefore erosion. Elelenwo and Eneka soils, on the other hand, had higher tendency for erosion with higher K values

Water holding capacity: In all locations, the water holding capacity (WHC) increased with depth (Fig.2). The WHC at the 0-10cm depth was highest for soils from Rumuokuta and Choba. These were followed by Elelenwo and Eneka and lowest at Rumuodomaya. However, at the 10-20cm depth WHC for Rumuokuta soil were significantly different from those of the other locations; with Rumuodomaya being the lowest. Using the EI model, which puts into consideration the WHC of soils as a factor in determining K, it did appear that the higher the WHC the less the erodible the soil. The Rumuodomaya soils with the highest K factor of 2.01 $tonsha^{-1}$, had the lowest WHC (33.7%) while Rumuokuta soils within the lowest K factor of 0.55 $tonsha^{-1}$had a higher WHC (46.9%).

CONCLUSION

The results of the particle size distribution showed that te Obio-Akpor soils are generally loamy soils, with high percentage of sand fractions and relatively high clay contents.

Irrespective of the model used to estimate erodibilty, K varied with location and depth. Therefore, there cannot be a single determination of K for Obio-Akpor; given this spatial variability.

The model used affected the K value estimated. The MC and MR models, which were dependent on the silt and clay content of the soil gave higher K values than those estimated with DR and EI models; which took into consideration other factors.

For the DR and EI models which made use of the water holding capacity of the soil, it did appear that the higher the water holding capacity, the lower the tendency of the soil to detachment (low K value) and therefore erosion.

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