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Soil Erodibility Status In Etekwo River Basin In Akwa Ibom State, Nigeria

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ABSTRACT
The focus of this study is to determine the erodibility status of surface materials in the 3rd order streams of the coastal plain sands in the Etekwo river basin which is a tributary of Qua Iboe river basin system. The erodibility status of the soil was determined using the nomograph developed by Wischmeier and others. Soil samples were drawn from the top soils and all the samples were taken from fallow lands. The derived erodibility (K) values were then regressed on organic matter, clay, silt, silt/clay, and stream length. The result of the correlation coefficient at 95% significant level indicated a significant relationship between K-factor and stream length (r = 0.63), silt/clay (r = 0.47), organic matter (r =-0.47), silt (r = 0.48). The stepwise multiple regression analysis revealed that stream length is the most important parameter that determined the K-factor. The coefficient of determination was 52% for all the independent variables, and 40% for stream length alone. Thus, all the soil physical properties explain only 12% variation in K-factor. Therefore, the drainage basin morphometric parameters are more important than the physical properties of soil in the study area.
Keywords: Soil Erodibility, Etekwo River Basin, Stream length, Tributary, Akwa Ibom State

INTRODUCTION
Whenever the land surface is exposed to the external geomorphic processes of erosion, these exposed surfaces respond to the denudational forces at different rates due to certain intrinsic characteristics inherent in them (Oyegun, 1984; 1997; Abua & Abua, 2013). Normally, the singular act of erosion by running water in most soils constitutes a problem to land management. The damage caused by erosion often depends on the extent at which the surface materials resist detachment and entertainment by both raindrop impact and overland flow (Ofomata, 1985; Udosen, 2008; Abali & Abua, 2016).
The rate at which soil responds to the agents of erosion is known as soil erodibility. Morgan (1979) defines erodibility as the resistance of the soil to both detachment and transport. According to Babalola (1988), soil erodibility is one among various factors that affects soil erosion. This is stated in the Universal Soil Loss Equation (USLE):

$$A = R\,K\,L\,S\,C\,P \qquad \text{- - - - (equ. 1)}$$

Where:

A = Soil loss per unit area
R = Rainfall factor
K = Soil erodibility factor

L = Length of slope
S = Slope gradient
C = Cropping management
P = Erosion control practice

The USLE is a model designed to predict the long time average soil loss in runoff from specific fields in specific cropping and management system. The erodibility factor (K) is a quantitative expression of the inherent susceptibility of a particular soil to erosion.

Soil erodibility is influenced by various factors among which include aggregate stability, shear strength, infiltration capacity, organic matter, chemical content, soil structure, vegetative cover and soil texture. The textural nature of soil is an important factor that affects erodibility. The percentage sand silt and clay present in the soil affects erodibility. Large particles of soil are resistant to transport than fine particles. Clayey soil form an aggregate which possess resistance to soil erosion. Soils with low infiltration capacity are often exceeded resulting in rapid runoff which erodes the soil. The reverse is the case in soils with high infiltration capacity. The organic matter and chemical constituents of the soil are important because of their influence on aggregate stability. While high organic matter and chemical content allows for more resistance, low organic matter and chemical content reduces resistance of soil on erosion. Chemical contents act on disintegrate the soil particle, whereas organic matter forms aggregate alongside with clay particles.

According to Holy (1980), investigations have shown that under the same condition chernozerm soils which have a crumb structure and considerable cohesion are most resistant to erosion, while brown soils which usually do not have a highly developed soil structure and have lower cohesion show lower resistance and podzolic soil with loose structure and incohesion of soil particles show least erosion resistance. When soils are stripped bare by removing the vegetative cover, they are less resistant to erosion.

The experience in the humid tropical environment (and elsewhere) suggests that, the best approach to soil management is the river basin approach. This is due to the fact that the various components of the river basin viz, geology, soil vegetation, relief, and climate are interrelated and they operate together as a whole (Abua & Abua, 2013). However, there are certain edaphic factors that actually determine the rate of soil erosion in any particular basin. These parameters include the physiochemical properties of the soil such as the granulometrical composition, bulk density, soil property, shear strength as well as the organic matter content, infiltration rate, soil structure and other chemical constituents of the soil.

Furthermore, it is difficult to predict the nature of relationship between some of these parameters as most important factor (soil physical properties) will depend on the local environmental factors. It is against these limitations that this study seeks to ascertain the most important predictor variable(s) that affects soil erosion in the study area. Ordinarily, it could be challenging to determine the degree of susceptibility of soil to erosion on the field. In view of the foregoing, the erodibility status of Etekwo river basin would be determined indirectly using the K-factor (after Wischmeier et al, 1971). Actually the aim of this research is to determine the erodibility status of the surface materials in Etekwo drainage basin of Akwa Ibom State – Nigeria.

Study Area

Etekwo river basin which is a tributary of Kwa Iboe river in the South South part of Nigeria, lies between longitudes $7^0 45^1$E and $8^0 00^1$E and Latitudes $4^0 45^1$N and $5^0 00^1$N. It drains part of the central Akwa Ibom State at Udoe in Ibesikpo Asutan Local Government Area. It empties itself into Kwa Iboe river westward at Ndiya in Nsit Ubium Local Government Area. Tributaries of the main stream drains Nsit Ibom, Nsit Ubium, Nsit Ata and Ibesikpo Asutan Local Government Areas (see fig. 1). Etekwo river basin falls under the rolling sandy plains in Akwa Ibom State. The landscape is low lying. A major physical feature of this zone is the scarcely drainage network which permits the development of extensive river interfluves of gentle rolling landscape. The river valleys are usually broad.

By virtue of its location, the study area falls within the humid tropics with abundant rainfall and temperatures. The mean annual temperature lies between 26^0C and 28^0C while the mean annual rainfall ranges from 2000m to 3000mm. The wet season usually begins in March and last till early November. During the beginning of the rains the streams are heavily silted with accumulated weathered material from the basin. By July, when the basin receives maximum rainfall, the streams are in spate. During dry season spanning December to February, the volume of water drops and is only sustained by ground water. The relative humidity is quite high all year round with annual mean values ranging between 75% and 95%. Naturally, the maximum humidity is recorded in July, while the minimum occurs in January. This is as a result of the influence of the tropical air mass in July and January respectively.
The rainforest which used to occupy the area has been removed through decades of intense human activities such as farming, lumbering, fire wood exploitation, road expansion, and so on. Today the rainforest is found in the fresh water swamp (i.e. fresh water swamp) which is not part of the study area. The vegetation forms found on higher ground with better drainage are those that can be described as a mosaic of farmlands, farm crop plots, tree plantations and bush fallow of diverse duration.
Musoil cover of the area is part of the tertiary coastal plain sands of the Benin formation (Petters et al., 1994). The soils are deep with loamy sand to loam surface over clay loam to subsoils. The soils are acidic have low cation exchange capacity and low base saturation. They are deeply weathered and koatinite is more common place than any other clay types.

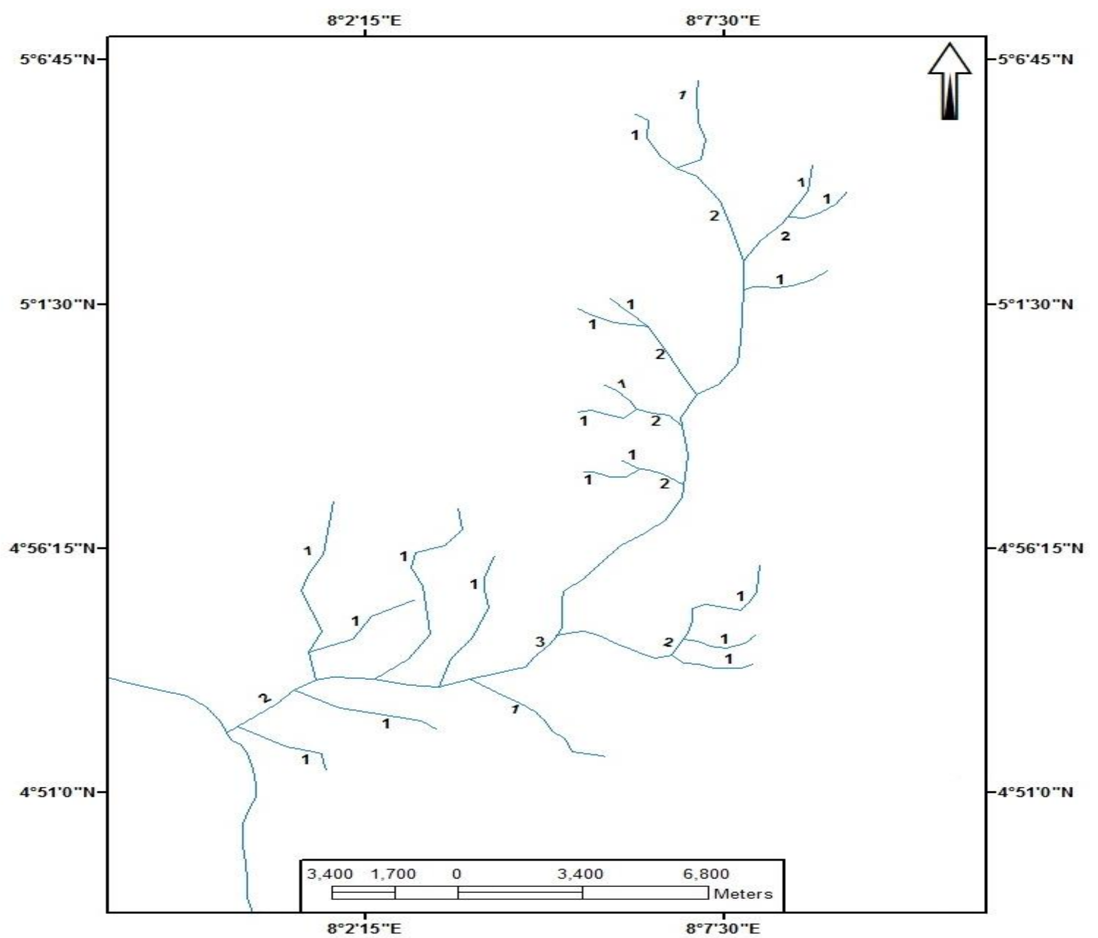

Figure 2: Kwa Iboe River Basin

MATERIALS AND METHOD

To ensure that the drainage basin is adequately represented, the systematic sampling technique was adopted in choosing the sampling sites. Soil samples were taken at two places from the 1st order 1 stream basin with a metal cylinder of diameter 10cm to a depth of 5cm (fig. 2). The method used in this research is the stream ordering proposed by Gravelvis, advocated by Horton (1945) and modified by Strahler (1950). Strahler designated any finger-tip stream belongs to order one. These streams usually join together to give rise to order two streams. Continuing, two order two stream join at a confluence to become order three stream. Hence, two streams of the same order join to form a stream system of the next higher order (Oyegun, 1997; Eze and Abua, 2002) (see fig. 2).

Map work analysis was achieved through declination and calculation of the river catchment characteristics set out in tables 1 and 2. Map work data also covers those of distance from river source using map of scales 1:250,000 and 1:75,000. The topographic maps were used for catchment basin delimitation and location of certain features. Calculating the ground equivalence of the channel length from Fig. 1, the channel was then interpolated into the figure using the denominator of the map scale, length of channel and orientation of the contours as guides. Having interpolated the channel onto the figure, the contours along the ridge crest down to the river mouth were bisected perpendicular by line segments which were joined together to form catchment boundary (Fig. 1). The area of the basin catchment was therefore, calculated to be 186.375km^2. The morphometric properties (the total stream length of the 1st, 2nd and 3rd order streams) in the study area were computed (see tables 1 and 2 and fig. 2).

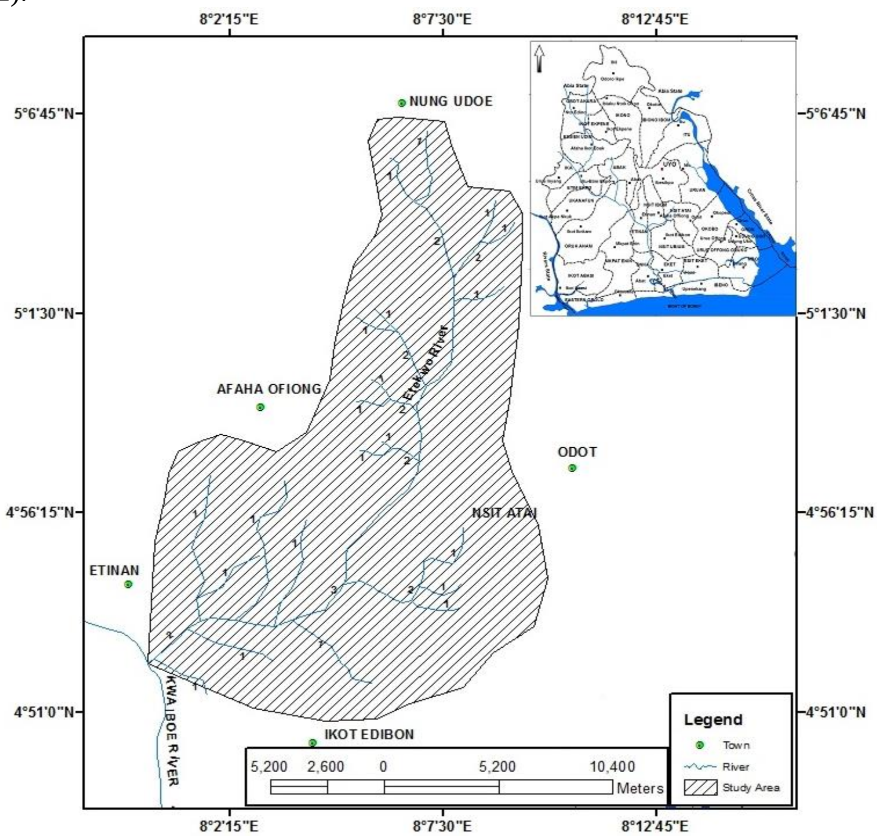

Figure 1: Stream Orders

Erodibility measurement

The Wishmeier's nomograph was used for the measurement of K-factor. The nomograph uses five soil parameters in the measurement. These are:

Percentage silt + Very fine sand
Percentage sand
Organic matter content
Soil structure grade
Permeability class
These parameters are entered into the nomograph with their respective values.

Laboratory Analysis (Granulometerical Analysis)

Bouyoucus hydrometer method was used to determine the particle sizes of the sample and their class name or texture of the soil from textural triangle sodium hexanetal phosphate dispersing agent was used as a reagent. Walkley-Black wet oxidation method was used to determine the percentage organic matter content of the sample. The procedure measures active or decomposable organic matter content of the sample. The carbon in the plant residues and humus is oxidized but the carbon present as graphite or charcoal is not. From 90 to 95% of total carbon in the soil is oxidized and measured using potassium dichnomate ($K_2C_2O_7$), concentrated sulpheric acid (H_2SO_4) and ferrous complex as an indicator.

Data Analysis

The pairwise correlation analysis was chosen using the SPSS computer package. It measures the strength of relationship between variables. The pearson's product moment correlation analysis is given by:

$$r = \frac{N\sum XY \quad - \quad \sum X \sum Y}{\sqrt{n\sum x^2 - (\sum x)^2 \quad n\sum y^2 - (\sum y)^2}} \quad - \quad - \quad - \text{ (equ. 2)}$$

Where r = correlation coefficient
x and y = The two variables of interest
$\sum$ = summation

In addition the multiple regression analysis was also employed. In multiple regression, the effect of numerous independent variables

$X_1X_2X_3\ldots..X_4$ are measured on a single independent variable Y. This implies that

$$Y = +(X_1X_2X_3\ldots..X_4) \quad - \quad - \quad - \text{ (equ. 3) where}$$

Values for $Y = a + b_1x_1 + b_2b_x + b_3x_3 + \ldots b_nx_n$

Where Y = dependent variable
a = Intercept
$b_1b_2b_3b_a$ = Slope of the independent variables
$x_1x_2x_3x_a$ = Independent variables

The step wise option was chosen using SPSS computer package to identify the most significant predictor variable to enable us to test the hypothesis.

RESULTS AND DISCUSSION

The stream order (u) reflects the degree bifurcation of streams. The streams number (NU) is the number of individual stream segment of that order. The bifurcation ratio (Rb) describes the ratio of the number of streams in one order to the number of streams in the next higher order. In the basin area, there are 21 1^{st} order, 7 2^{nd} order and 1 3^{rd} order stream. The bifurcation ratio is given by the formula:

$$Rb = \frac{Nu}{Nu + 1} \quad - \quad - \quad - \quad - \quad \text{(equ. 4)}$$

Where Rb = Bifurcation ratio

Nu = Number of Nu + 1 stream segment in a given order
Nu + 1 = Number of streams of the reset higher order.

This means that on the average for every second order stream there are 3 first order streams. And since the river basin is a 3rd order stream, there are 7 2nd lower streams and one 3rd order stream. The wide variation in the bifurcation ratio is due to the elongation of the drainage basin (see Table 1)

Table 1: Morphometric Properties of the Study Area

U	NU	Rb	LU Stream length (km)	Area (km^2)	Average LU
1	21		36.25		1.73
2	7	2.63	10.03		1.43
3	1	3.5	26.2		26.2
		x5	Total 72.48	186.375	

The total stream length of 1st order stream is 36.25km and a mean value of 1.726km. The standard deviation from the mean and variance is 1.404km and 1.971km respectively. The range is put at 4.35km with a maximum 46.5km and minimum 0.3km.

Table 2: 1st Order Stream Length Variability

Stream (km)	Mean (%)	S.D.	C.V. (%)	Range	Min (%)	Max (%)
36.25	1.726	1.404	81.34	4.35	0.3	4.65

The total stream length of 2nd order stream is 10.03 and an average of 1.43km. This shows that there is no much difference between the stream length of 1st order and 2nd order. The mean stream length for the basin is 2.499. (see Table 2).

Soil Erodibility Status

From the Wischmeier's nomograph (Fig. 3), the soil erodibility index (K – factor) measured gives a mean of 0.062 for the active Etekwo river basin. The standard deviation value is 0.015 with 24.19% co-efficient of variation and range of 0.06 (see Table 3). The K-factor value to an extent is considered low for the area under bush fallow in the drainage basin.

Table 3: Variability of K-factor in the Study Area

Mean	S.D	Range	C.V	Mode	Min.	Max.
0.062	0.015	0.060	24.19%	0.055	0.015	0.095

The coefficient of variation (C.V) shows that the K-factor does not vary much under bush fallow system. The reason for the low K-value can be attributed to the effect of the dense vegetation cover. The vegetation cover promotes high permeability because of plant roots that creates pore spaces in the soil which allows water to seep through the soil rapidly. It also encourages the built-up of organic matter content in the soil since organic matter are derived from decayed leaves and twigs.

Table 4: Variability of Edaphic Factors in the Study Area

Variable	Mean %	S.D	C.V (%)	Range
Organic matter	3.871	0.563	14.50	2.11
Clay	7.743	3.034	39.18	9.50
Silt	7.329	2.951	40.26	12.20
Silt/clay	1.042	0.615	59.02	2.74
Coarse sand	62.587	6.07	9.70	21.40
Fine sand	18.743	1.844	9.84	6.30

Source: Researchers' Fieldwork, 2009.

From table 4, the mean value for organic matter is 3.871% with standard deviation (S.D) 0.563. The coefficient of variation is 14.5% which means that there is little variation in the organic matter content. The high mean value of organic matter is as a result of the vegetative cover which naturally increases the organic matter of soil as earlier stated.

The mean clay value is small (x=7.743). This is related to the type of soil that the samples were drawn from as the percentage silt content is equally low with mean value of 7.329% and coefficient of variation 40.26%. The silt/clay ratio shows a high variation with coefficient 59.02% and the mean value of 1.042. These indicate that the silt fraction vis-à-vis clay is highly variable. This may be related to the extent of weathering as well as the severity of erosion in the study area.

The high mean value of coarse sand (x = 62.58) is due largely to the type of soil (i.e. coastal plain sands). These are loose, unconsolidated sediments in which fine particles are easily removed. It is more or less uniform with a coefficient of variation of 9.70%. Fine sand has a mean value of 1.844 and low coefficient of variation of 9.84%.

The Relationship Between Soil Parameters, Stream Length and K-Factor

The Pearson's product moment correlation coefficient (pair-wise) was used to establish the relationship between and among the K-factor.

Table 5: Bi-variate Correlation Matrix

	Clay	F/sand	K-factor	O M	C/sand	Silt	Silt/Clay	Stream
Clay	1.00							
F/sand	0.40	1.00						
K-factor	0.01	0.34	1.00					
O M	0.38	0.18	-0.47*	1.00				
C/sand	-0.91*	0.53*	-0.20	-0.27	1.00			
Silt	0.43	-0.04	0.48*	-0.16	-0.64*	1.00		
Silt/Clay	-0.38	-0.34	0.47*	-0.43	0.10	0.64*	1.00	
StreamL	0.15	-0.13	0.63*	-0.39	-0.22	0.53*	0.34	1.00

*Significant at 0.05 level

The correlation coefficient (r) of 0.63 between K-factor and stream length shows a positive linear relationship which is significant at 95% confident level. Theoretically, this means that the longer the stream channel, the less susceptible the soil to erosion. This is due to the fact that long stream channels have gentle slopes that reduce the velocity of runoff as such erosion of the soil is reduced. This is in consonance with deduced theoretical postulate which sees short stream channels having steep slopes with high velocity of runoff thereby increasing erosion rate. There is a significant relationship at 95% confidence level between K-factor and silt (r = 0.48) and silt/clay ratio (r = 0.47). The later confirms studies reported by Morgan (1979). This means that the higher the silt and silt/clay values, the higher the K-factor. However, organic matter is inversely correlated (r = -0.47). This confirms the generally accepted fact that the higher the organic matter content, the lower the K-factor and vice-versa.

Inter Relationship between Soil Parameters

Coarse sand and clay has a very high inverse correlation coefficient (r) of -0.91 which is significant at 95% confidence level. This can also be observed between coarse sand and silt (r = -0.640, silt/clay and silt are positively correlated with r = 0.64).

Hypothesis Testing

The data on a set independent variable viz; organic matter, clay, silt, silt/clay ratio and stream length were regressed on the dependent variable K (erodibility factor).

The stepwise multiple regression analysis shows that stream length is the most important independent variable with a regression coefficient of 0.63. The equation is given by:

$$Y = 0.0503 + 0.6292x_1 + e \quad - \quad - \quad - \quad \text{(equ. 5)}$$

The coefficient of determination of the model is 40% which implies that 40% of the overall variation in K-factor is explainable by variation in stream length.

Table 6: Stepwise Multiple Regression Analysis of Factors Controlling K-factor

Independent Variable	**Correlation coefficient (R)**	**R2**	**Remark**
Stream length	0.63	40%	Sig. at 95% level
Organic matter Clay Silt Silt/clay Stream length	0.72	52%	Sig. at 95% level

Source: Researchers' Fieldwork, 2009.

The multiple regression model for all the independent variable is 0.72 with coefficient of determination 52%. This means that all the edaphic properties listed in table 6 explain only 12% of the variation in K-factor. The remaining 48% can be attributed to vegetation and land management.

CONCLUSION

Soil erodibility status is an important factor in the determination of soil loss and predicting erosion rate of a particular soil for the ultimate purpose of soil management. Therefore, it is expedient for research to be carried out in various soil to guide in landuse management.

Based on the result of this study, the bush fallow system in the basin has low erodibility statues due to rapid infiltration rate and high organic matter content. The situation can be reversed if the vegetation is cleared and used for other purposes such as agriculture, road etc. As such there will be marked increase in the erodibility meaning that the area will be exposed to erosion. Already less land are being put under bush fallow due to increase in population as such in order not to suffer erosion hazard, the following are recommended:

(a) Increasing the soil infiltration capacity of the soil to reduce runoff;
(b) Improving aggregate stability of the soil by increasing organic matter content
(c) Protecting the soil with vegetated cover to reduce rain drop impact;
(d) Tarring of roads and providing paved channel for surface flow.

The infiltration capacity can be increased by cultivating cover crop whose root system will allow for infiltration, and also protect the surface from direct rain drop impact. For aggregate stability; green manure should be added to agricultural lands especially where mineral fertilizer are used to improve fertility. The continual use of mineral fertilizer without organic manure may lead to structural deterioration of the soil and thus increase erodibility.

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