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Estimating Erodibility Factor in Soils of Uyo, South-South Nigeria

Unwana Udoumoh[1], I. Fubara-Manuel[2], Precious Ehiomogue[3], Akanimo Ekpo[4*] and Anana Unyime[3]

[1]Department of Agricultural and Food Engineering, University of Uyo, P.M.B 1017 Uyo, Akwa Ibom State, Nigeria
[2]Department of Agricultural and Environmental Engineering, Rivers State University, Rivers State, Nigeria
[3]Department of Agricultural and Bio-resources Engineering, Michael Okpara University of Agriculture, Umudike, P.M.B 7267 Umuahia, Abia State, Nigeria
[4]Department of Agricultural and Bio-resources Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

**Corresponding author*

Abstract

Soil erosion is a result of many factors such as rainfall intensity steepness of slope, length of slope, vegetative cover, soil erodibility factor as well as anthropogenic influences. Among these factors, soil erodibility is considered an essential parameter since it governs the ease with which soil particles are detached and transported by water. At the centre of this study is the determination of the erodibility factor (otherwise known as K factor) in the Wischmeier Universal Soil Loss Equation (USLE). The erodibility was determined by measuring four basic parameters closely related with the soil physical status: soil texture, soil structure, soil permeability, and organic matter content of the soil. Twenty four samples of surface and sub-surface soils were collected from three gully erosion sites in Uyo watershed which were used to measure the above mentioned parameters in order to determine the K-factor. Using the model developed by Wichmeier and Smith (1978), the K factor was calculated for each soil sample when appropriate data are entered in a proper sequence. The permeability class as well as soil structure codes were determined using the United States Department of Agriculture (USDA) document published in 1983. The Wischmeier equation, among many erosion models, seems obviously to be the most realistic one, because it considers all the possible soil factors affecting soil erodibility. The K factor values obtained were found to be between 0.269Mg.h.MJ^{-1}mm^{-1} to 0.325Mg.h.MJ^{-1}mm^{-1}, which means that there is a slight variation in Uyo soils with respect to their behaviour towards erodibility or consequently towards erosion. It was discovered that the most significant variable or parameter on soil erodibility was silt and coarse sand whereas the less significant variable was clay. This study reveals the proneness and susceptibility of soils with high silt content to structural breakdown and consequently erosion.

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Keywords

Erodibility, K-factor, USLE, Erosion, Watersheds.

Introduction

The initiation and development of gully erosion in any part of the word, is dependent on some factor; these include among others climate parameters: rainfall erosivity, wind, temperature, and soil characteristics (mainly erodibility), geology, vegetation, topography and anthropogenic activities. According to Udosen (2013), a gully is any eroded channels so wide that it cannot be crossed by a wheeled vehicle or eliminated by plugging. Gully erosion has been reported by a number of researchers, including Udosen (2013) in Akwa Ibom State, Essien and Essen (2012) in Akwa Ibom State, Iorkua (1999) in Makurdi; Eze and Effiong, (2010) in Calabar, Soufi and Isale H (200I) in Iran, etc. It is imperative to emphasise that gully erosion leads to destruction of farmlands, buildings, roads as well as the development of bad land topography and soil depletion.

Soil erosion is described as detachment and removal of surface particles from soil as a result of wind or rainfall. Soil, as the most important component of an ecosystem, can secure the food production, enhance the water resources and promote the biodiversity and carbon sequestration (Novara *et al.,* 2016) if it is well managed (Mol and Keestra, 2012). The main parameter in soilm erosion is the inherent soil characteristics, which is called soil erodibility factor. Type and rate of soil erosion/ loss in an area depend on different factors including climate, geomorphology, soil type and land use (Taleshian, 2018).

Soil erodibility (k) factor has been used recently as an indicator of erosion (Parysow *et al.,* 2003; Tejada and Gonzalez, 2006; Zhang *et al.,* 2007) because of its susceptibility to particulate detachment and transport by erosion agents such as wind and water. In practice, k represents an integrated average annual value of the total soil and soil profile reaction to a large number of erosion and hydrological processes (Bonilla and Johnson, 2012). The K-factor is one of the key parameters required for soil erosion prediction across the world (Zhang *et al.,* 2007). Therefore assessment of erosional losses is the basis for effective conservation planning and management of the vulnerable ecosystems.

To forecast soil loss rate, several equations have been prepared. The Universal Soil Loss Equation (USLE) model is a well-known method which is extensively used to predict and determine the factors affecting soil loss (Lal, 1988; Wischmeier and Smith 1978; Devatha *et al.,* 2015). The USLE model is a simple empirical model which has been developed based on multiplying five erosion factors including soil erodibility (K-factor), soil erosivity (R), topography (LS), land cover (C) and Conservation practice (P). Amongst the USLE factors, soil erodibility is the most impressive factor for assessing the soil susceptibility to erosion and it is necessary for estimating soil loss in USLE (Wischmeier, 1979; Taleshian, 2018). The Universal Soil Loss Equation (USLE) has been useful in predicting the average rate of soil loss due to water erosion from agricultural lands (Wischmeier and Smith, 1978). In the early 1990s the basic USLE was updated and computerized to create an erosion prediction tool called the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.,* 1997). The RUSLE uses the same basic factors of the USLE although some are modified and better defined. The predicted soil loss A = RKLSCP, where; R = rainfall erosivity; k = soil erodibility; L= slope length; S = slope gradient or steepness; C = vegetal cover and management, and P = erosion control practices.

Although the USLE has been widely used to predict K-factor in many studies (Vaezi *et al.,* 2008; Vaezi *et al.,* 2010; Shabani *et al.,* 2014), it may not be applicable to all soils with different soil forming processes. The L and S as inherent landscape characteristics cannot be changed easily by anthropogenic activities, unless, there are soil conservation practices. The R, C, and P are dependent on weather conditions and anthropogenic activities. Therefore, the k-factor is more strongly related to soil physical characteristics (Taleshian, 2018). Soil erodibility (k) factor is applicable to most tropical soils (El-Swaify and Dangler, 1976; Roose, 1977) and was found to strongly correlate with soil loss (Tejada and Gonzalez, 2006). The erodibility (k) factor reflects the ease with which the soil is detached by splash during rainfall and/or by surface flow especially on sloping areas (Angima *et al.,* 2003). According to Toy *et al.,* (2002), soils with larger sand and silt proportions are more vulnerable to water erosion due to lack of stability of soil particles. Similarly, soils with relatively low organic matter content are very vulnerable to water erosion (Brady and Weil, 2002) since organic matter increases the stability of soil.

The inherent susceptibility of a soil to water erosion expressed as soil erodibility factor (K) in the Universal Soil Loss Equation (Wischmeier and Smith, 1978), can be determined (i) directly by field measurements under natural rainfall using the "unit plot" technique (Wischmeier and Smith, 1961, (ii) by rainfall simulator (Meyer and McCune 1958) or (iii) by estimation from easily measured soil properties using the nomograph of Wischmeier *et al.,* (1971). Erodibility (K) as defined in the Universal Soil Loss equation is computed by the ratio of annual soil loss in tons per acre to EI_{30} computed on a unit plot. The soil loss is monitored on a unit plot that is 22m long, on a 95% slope in continuous fallow and is tilled up and down the slope and kept free of vegetation for at least two (2) consecutive years (Wischmeier and

Smith, 1978; Bagarello *et al.*, 2009). That is, the unit plot is continuously maintained in a clean fallow condition with tillage performed upslope and downslope. During the period of soil loss measurement, the plot is ploughed and placed in conventional corn seeded condition each spring and tilted as needed to prevent vegetative growth and severe surface crusting. When all these conditions are met, then slope length (L), Crop factor (C), and Conservation practices (P) each equal unity, and $K = \frac{A}{EI}$ where, $K = \frac{\text{ton x acre x hour}}{\text{EIhudreds of acre x foot-ton x inch}}$, A = soil loss in t/acre, $EI = \frac{\text{Erosivity factor in foot-ton x inch}}{\text{acre x hour}}$.

However, direct measurement of erodibility (K) as described above represents the combined effects of all soil properties that significantly influence the ease with which a particular soil is eroded by rainfall and runoff, if not protected. Because of the high cost of field installations and time involved, direct measurements of erodibility have been made on some bench-mark soils in USA (Schwab *et al.*, 1993). Since field measurements are expensive, difficult and sometimes hard to be conducted in the large scale, researchers have developed pedotransfer functions which indicate a relationship between certain soil property and readily available soil properties to predict soil erodibility (Panagos *et al.*, 2012; Ostovari *et al.*, 2015; Ostovari *et al.*, 2016). Wishmeier and Mannering (1969) proposed an erodibility equation, utilizing fifteen (15) soil properties and their interactions. The equation is as stated below: M = (% SILT + VFS)(100-% clay). When the silt fraction does not exceed 70%, it was described by the following equation: K = M. The prediction accuracy, however, was improved by including information on organic matter, soil structure and permeability as expressed below, where, k = erodibility, M = (%SILT -VFS)(100-% clay), A = % organic matter content, B = soil structure code, C = permeability class.

In subsequent studies the soil properties were reduced to four, namely texture, organic matter, structure and permeability. Furthermore, Wishmeier and Smith (1978) found that very fine sand(VFS) is comparable in erodibility to silt sized particles. Hence, (VFS) was transferred to silt fractions to describe a particle size parameter designated ‘M”. The United State Department of Agriculture (USDA) erodibility nomograph solves this equation when appropriate data are entered in a proper sequence.

Since K-factor is widely considered as a significant parameter in soil erosion/ sediment process simulation models (Zhu *et al.*, 2010), numerous attempt to simplify the K-factor evaluation procedure have been carried out in the past and simplified relationships have been proposed for predicting k-factor. And according to Roose (1977) the USLE nomograph (Wiscmeier *et al.*, 1971) can be used to estimate k-factor of tropical soils as well as soils from the temperate region (Obi *et al.*, 1989; Vaneslande *et al.*, 1984), with exception of soils that were gravelly covered with rocky debris that acts as protective mulch.

Whereas there are a number of factors of erosion, this study does not intend to cover all the factors of soil erosion. Rather it focuses on the erodibility (K) factor in assessing soil erosion in Uyo, South-South Nigeria.

Materials and Methods

Study area

The study was conducted in three gully erosion sites located at Uyo old village road, Anua Uyo, and university of Uyo (Uniuyo) permanent site, situated between latitudes $5^{o}1^{1}$ N and 5^{o} 3^{1} N and longitude 7^{o} 55^{1}E and $8^{0}05^{1}$ E within the tropical rainfall forest belt with evergreen vegetation (see Fig. 1 and 2).

Uyo is the capital city of Akwa Ibom State and presently occupies a total land mass of 1,250,000km^{2} of which a substantial percentage is used for agriculture. About 50, 000 ha of its area are affected by gully erosion, with gully sites and ravine wide spread over the area (SLUK-Ak, 1989). The geological formation in Uyo is the coastal plain sands.

The dominant forest types in Uyo include the saline water swamp, fresh water swamp forest and the rain forest. The state lies North of the Equator and within the humid tropics and has a mean annual temperature between 26-27^{o}C and has two distinct seasons: the wet season (April to October)and the dry season (November to March).The annual rainfall fringes from 2,000mm on the northern fringe to over 3,000mm along the coast (Essien AND Essien 2012).

Sampling and analysis of soils

A total of twenty four (24) soil samples were collected at depth intervals of 0-20cm (surface soil) and 20-40cm (subsoil) at three positions: upper, middle and lower positions of each of the gullies. The fourth sample which served as a control sample was taken about 100-m away from the edge of each gully at the middle gully position. The soil samples were randomly collected from each location with the aid of a linen tape which was stretched along gully wall layer profile from top to bottom of gully. The soil samples were analysed to determine the erosion factors by subjecting them to laboratory analysis. Soil samples were collected during the month of April, 2016. At each erosion site of sampling, coordinates were taken with a handheld garmin etrex legend HCK GPS to reference the exact location of the sampling points in the field, so that, soil samples of about 2kg were removed with the aid of an auger and hand shovel and subsequently stored in polythene bags for onward transfer to the laboratory for analysis. Sampled soils were analysed for particle size distribution, particle density, porosity, bulk density, porosity and organic carbon content. Prior to soil analysis, samples were oven-dried at a temperature of 105°C and plant residues were removed. The Bouyocous hydrometer method of particle size analysis was described by Kroetsch and Wang (2008), was used in determining three fraction (sand, silt and clay) of sampled soils. The cylinder method was applied to find bulk density in undisturbed samples (soils), that is using the mass- volume relationship:

$B_d \frac{M_s}{V_t}$ . . . . . .(1) as described by Haretal. (2008),

where B_d is the bulk density (g/cm^3). M_s is the mass of dry soil (g); V_t is the total volume of soil(cm^3). The total volume of the soil was calculated from the internal dimensions of the cylinders. Determination of particle density was done through the method presented by Blake and Hartage (1986). Soil porosity was estimated from particle density and bulk density using the formula below, as presented by Danielson and Suther land (1986);

$n = 1 - \left(\frac{P_b}{P_p}\right)$ Where n, P_b, and $P_p$are values of soil porosity, bulk density (g/cm^3), and particle density (g/cm^3) respectively. Permeability analysis was done by the method described by American society for testing and materials (ASTM)$^{\Delta - 2434}$ standard test and computed as:

$K = \frac{QL}{A.t.h}$.......(2)

where
k= coefficient of permeability (m/s)
L= length of specimen (soil column) (m)
Q= discharge rate is volume of discharge per time (m^3/s)

A = cross sectional area of permeameter (lml=m^3= $\frac{\pi D^2}{4}$);
D = inside dismeter of the permeameter
h = hydraulic head difference across L
t = time of percolation (minutes)

Determination of soil organic content (DC) was done using the Walkley-Black method (Walkley and Black, 1934). The organic carbon content obtained using this method was converted to organic matter contest (OMC) using the relation: OM = 1.72OC (Buttafuoco *et al.*, 2012).

Estimation (Determination) of USLE K-Factor

Erodibility factor, otherwise known as k-factor is a complex concept and it is influenced by many soil properties, which can reflect the soil residence to erosion (Buttafuoco *et al.*, 2012). The four most crucial soil variables or properties that control K-factor are: soil texture, soil structure, organic matter content, permeability and chemical composition. (Duiker *et al.*, 2001; Veihe 2012; Sanchis *et al.*, 2008; Morgan, 2009 and A.N Belasin *et al.*, 2007). K-factor can be calculated via the USLE which is frequently used to calculate soil loss based on other factors gained from the simulated or natural rainfall data (experimental) (Wischmeier and Smith, 1979). Direct determination of erodibility using standard plots is the best way and eventually leads to a high accuracy of soil loss prediction. However this method is time and labour consuming. Therefore since field measurements are expensive, difficult and sometimes hard to be conducted in the large scale, researchers have developed pedo-transfer functions which indicate a relationship between certain soil property and readily available soil properties to predict soil erodibility (Panagos *et al.*, 2012; Ostovari *et al.*, 2015; Ostovari *et al.*, 2016). The soil erodibility factor k for a series of benchmark soils was obtained by direct soil loss measurement from fallow plot located in many U.S States (Swab *et al.*, 1993).

To estimate soil erodibility factor in soils of Uyo watershed, the USLE nomograph, published by Wischmeier *et al.*, and Smith (1978) was used as in equation (3).

K =

$$[2.173 \times 10^{-4}(12 - a)M^{1.14} + 3.25\,(b - 2) + 2.5\,(c - 3)]$$

/100 ……..(3)
where;

K is the erodibility factor as it is determined in the universal soil loss equation $(Mg.h.MJ^{-1}mm^{-1})$, M is the product of (100-clay%) x (very fine sand (0.05 – 0.1mm) + % silt), a refers to organic matter (%). Very fine sand was measured through wet sieving method with 270 mesh sieve (Kemper and Rosenau, 1986), b is the soil structure code, and c is the soil permeability class. The soil structure code and soil permeability class are both obtained from USDA published document based on soil texture (Wischmeier *et al.*, 1971) as shown in table 1 and 2 respectively

Statistical analysis

Result of the soil analysis was presented using description statistics inclusive of mean, range, standard deviation, coefficient of variation. The descriptive data was further subjected to ANOVA test to establish whether there is significance difference in the soils physical properties between the gully sites under study. Pearson's coefficient and multiple regression analysis were used to establish relationship between the soil properties and estimated soil erodibility index(especially those that have interacted to produce the predicted values of k). The computer package that was used for the descriptive statistics and the Pearson's correction analysis was SPSS 20.0 version 2011, while the multiple regressive analysis was done with the use of MINTAB 11.0.

Results and Discussions

The results obtained were discussed based on the different soil properties studied. Physical and analytical chemical data generated from the main sampling points and the control point appear similar. Therefore, the results and discussion were presented as comparative analysis among the studied gully sites.

Soil characteristics

To establish the relationship between physical properties of soil and soil erodibility, the sampled soils were analysed and the summary of the results presented in table 1.

Data presentation of soil properties

Data in table 3 show that the mean values of coarse sand were 57.6, 70.4 and 60.6% in Anua, Uniuyo, and Uyo village road upper location, respectively, and were generally high, compared to 23.9, 13.6 and 22.7% fine sand content in the upper location of perspective gully sites. This implies that the large proportion of coarse sand or total sand (TS) indicates soil fragility and low content of colloidal materials mainly clay, and therefore low resistance to erosion by splash and shear stress. The ease of splash and dispersion in the soils is thus indicated by the low contents of the silt and clay fractions in all sites. The low contents of the silt and clay particles may indicate that the clay separate may not be an importance inorganic aggregation material in the soils. The soils of the gully sites were similar in texture being either sandy loam or loamy sand in the surface (0 – 20cm) or subsurface (below 20cm). Thus, because of the sandy texture, only a small proportion of rain water may escape as unconcentrated surface wash (surface flow). However, Hortonian overland flow may occur where the intensity of rain is larger than the rate of infiltration. In other words, soil texture (proportion of clay, silt and sand particles in the sites) has two effects on soil erosion. The first is in its influence on infiltration entry of water into the soil. When rainfall infiltrates rapidly runoff is minimal. For example, sandy textured soils have large pores that allows much of the rain water to soak right into the soil. Sandy soils are known to have good infiltration and drainage. Clay textured soil have small pores that do not allow water to soak into soil fast. Clay soils are known to have poor infiltration and drainage. Second, particles vary in their ease of detachment. Silt particles are most easily detached because they are small, and they do not easily form aggregate. The low potential for surface sealing due to the low permeable and that much of rain water infiltrates the soil profile to deeper layers causing chemical dispersion, and because the soil at lower depth has low strength, enhancing gully development, it can be seen from table 3 that the textual classification of the study area indicates loamy sand as the dominance soil of the study area. Among the various texture class that exist in the textural triangle (see figure 3).

Only three classes, namely, loamy soil, sandy loamy and sand, existed in the study area. The physico-chemical properties of the soils at the study sites are shown in table 4.

The soils of the gully erosion sites were generally characterized by moderately high values of bulk density, averaging 1.23, 1.35, and 1.40g/m^3 respectively in the upper locations of Anua, Uniuyo, and Uyo village road gullies, respectively. Although the soils comprise predominantly quartz mineral particles, as shown by the high total sand content, reflecting the nature of the parent material, they may be structurally loose, friable in consistence and less cohesive, and therefore explain their permeable nature. This may also be explained by the moderately high values of macrospores in the soils. Soil pH in water averaged 4.05, 4.09, and 4.24 in the upper location of Anua, Uniuyo and Uyo village road gullies respectively, which were moderately acidic. Soil organic content level varied from an average value of 1.65gkg^{-1} in the upper location to 1.71gkg^{-1} in the Uniyo upper location and 1.42gkg^{-1} in the Uyo village road gully location, which is slow to moderate permeability class. Soil organic content which is converted to organic matter with the multiplication of the coefficient of 1.72, is considered to be the main binding and stabilizing agent for micro-aggregates and hence macro-aggregates, affecting soil structure and stability

The pattern of similarity in the physic-chemical properties of the soils at the study locations is also demonstrated by the observed values of the intrinsic permeability, which averaged 0.79, 0.26 and 1.37cm/h, which were slow to moderate, generally. The pattern of differences in the physico-chemical properties indicates that the gullies were similar in terms of the underlyling lithological materials.

Soil erosion problem could not be due to soil water flux density which is rapid (K_{sat}) within the profile, but the flux density of storm rain-water with the potential for Hortorian flow in excess of the shear strength of the soil. However, the surface-free water vanishes from the surfaces of agricultural soils following the cessation of rainfall, indicating the drainage effectiveness of the macro-pore system. Consequently the erosion problem could not necessarily be due to the characteristics of the soils but also the overwhelming effect of the high energy and intensity of rain storms in the area.

Soil erodibility factor

Based on the computations from equation (3), the K factor value ranged from 0.0269Mg.h.MJ^{-1}mm^{-1}to 0.0325Mg.h.MJ^{-1}mm^{-1}, with the mean value of 0.02949Mg.h.MJ^{-1}mm^{-1}.

Table.1 Soil structure code (classification)

Type of soil structure	Soil structure code (Index)
Very fine granular soil (<1mm)	1
Fine granular (1 – 2 mm)	2
Medium or coarse granular soil (2 – 5mm)	3
Massive (Blocky, platy, columnar, primitive	4

Table.2 Soil permeability code (Classification)

Permeability type (cm/h)	Permeability code (Index)
Very slow infiltration (<0.125)	6
Slow (0.125-0.5)	5
Slow to moderate (0.5 – 2)	4
Moderate (2 – 6.25)	3
Moderate of rapid (6.25 – 12.5)	2
Rapid ie high (>12.5)	1

Table.3 Soil Texture Analysis of Soils of Gully erosion sites in Uyo

Location	Coarse sand (%)			Fine Sand (%)			Silt (%)			Clay (%)			Textural Class
	Mean	Std dev	Std error	Mean	Std dev	Std error	Mean	Std dev	Std error	Mean	Std dev	Std error	
Anua–U	57.59^{b}	0.35	0.25	23.86^{ab}	0.35	0.25	4.04^{de}	0.09	0.06	10.44^{ab}	0.43	0.31	LS
Anua - M	51.95^{c}	1.12	0.80	24.78^{a}	0.12	0.09	4.21^{cde}	0.03	0.02	10.93^{ab}	1.32	0.93	“
Anua - L	61.31^{b}	2.01	1.42	24.19^{ab}	0.24	0.17	4.76^{cd}	0.18	0.13	10.88^{ab}	1.63	1.15	“
Anua- C	61.98^{b}	3.53	2.50	23.80^{ab}	0.09	0.07	4.97^{c}	0.29	0.20	11.89^{a}	0.34	0.24	“
UNIUYO - U	70.41^{a}	0.26	0.18	13.64^{c}	1.86	1.32	3.88^{e}	0.31	0.22	9.31^{b}	0.45	0.32	“
UNIUYO- M	69.76^{a}	6.95	4.92	13.87^{c}	0.20	0.14	3.89^{e}	0.11	0.08	10.16^{ab}	1.32	0.93	SL
UNIUYO - L	75.03^{a}	0.29	0.21	13.46^{c}	2.26	1.60	4.45^{cde}	0.61	0.43	10.58^{ab}	0.40	0.29	SL
UNIUYO – C	71.92^{a}	0.79	0.56	14.34^{c}	0.12	0.09	4.72^{cd}	0.57	0.41	9.76^{b}	0.55	0.39	LS
Uyo Village Road. U	60.65^{b}	0.34	0.24	22.7^{ab}	2.15	1.52	8.29^{b}	0.49	0.35	9.72^{b}	0.02	0.02	“
Uyo Village Road. M	61.39^{b}	1.44	1.02	24.82^{a}	0.26	0.19	9.17^{a}	0.09	0.06	9.42^{b}	0.27	0.19	“
Uyo Village Road. L	61.57^{b}	0.35	0.25	21.88^{b}	0.28	0.20	9.56^{a}	0.45	0.32	9.66^{b}	0.81	0.58	S
Uyo Village Road. C	61.68^{b}	1.53	1.09	24.62^{a}	0.69	0.49	8.13^{b}	0.02	0.02	9.79^{b}	0.11	0.08	LS

Mean values were obtained from duplicate determinations. Means followed by different superscripts are significantly ($p<0.05$) different. U=Upper part of gully; M = Middle part of gully; L = Lower part of gully; C = Control; SL = Sandy Loam; LS = Loamy sand; S = sand

Table.4 Other physico-chemical properties of soils of gully erosion sites in Uyo

Location	Bulk density g/m^3			Porosity (%)			Permeability cm/h			Permeability class	pH			Total organic content		
	Mean	Std dev	Std error	Mean	Std dev	Std error	Mean	Std dev	Std error		Mean	Std dev	Std error	Mean	Std dev	Std error
Anua - U	1.23^{ab}	0.01	0.01	51.95^{bc}	0.07	0.05	0.79^{d}	0.03	0.02	**Very slow**	4.05^{abc}	0.21	0.15	1.65^{abcd}	0.09	0.07
Anua - M	1.37^{ab}	0.25	0.18	51.34^{c}	0.15	0.11	0.63^{def}	0.06	0.04	“	4.15^{abc}	0.13	0.10	1.84^{abcd}	0.28	0.20
Anua– L	1.29^{ab}	0.03	0.02	51.69^{bc}	2.11	1.49	0.76^{de}	0.02	0.02	**Slow**	4.61^{ab}	0.59	0.42	1.55^{bcd}	0.46	0.33
Anua– C	1.29^{ab}	0.02	0.02	51.79^{bc}	0.26	0.19	0.69^{def}	0.08	0.06	**Very slow**	5.01^{a}	0.55	0.39	1.94^{abc}	0.03	0.02
UNIUYO - U	1.35^{ab}	0.09	0.06	54.50^{abc}	0.40	0.28	0.26^{f}	0.06	0.04	“	4.09^{abc}	0.45	0.32	1.71^{abcd}	0.11	0.08
UNIUYO- M	0.80^{b}	0.59	0.42	56.60^{a}	4.82	3.41	0.30^{f}	0.10	0.07	“	3.80^{bc}	0.42	0.30	1.92^{abc}	0.27	0.19
UNIUYO - L	1.66^{a}	0.15	0.11	58.27^{a}	0.20	0.14	0.43^{def}	0.09	0.06	“	4.02^{bc}	0.22	0.16	1.39^{cd}	0.29	0.21
UNIUYO – C	1.21^{ab}	0.09	0.07	56.87^{a}	0.62	0.44	0.36^{ef}	0.11	0.08	“	4.53^{ab}	0.30	0.21	2.06^{ab}	0.50	0.36
Uyo Village Road. U	1.40^{ab}	0.03	0.02	54.70^{abc}	0.10	0.07	1.37^{c}	0.20	0.14	Slow	4.24^{abc}	0.10	0.07	1.42^{cd}	0.03	0.02
Uyo Village Road. M	1.33^{ab}	0.29	0.21	55.26^{abc}	2.07	1.46	1.79^{ab}	0.43	0.30	**Very slow**	3.98^{bc}	0.14	0.10	1.42^{cd}	0.09	0.07
Uyo Village Road. L	0.90^{ab}	0.87	0.62	56.76^{a}	0.77	0.55	1.96^{a}	0.25	0.18	“	3.33^{c}	0.47	0.34	1.29^{d}	0.16	0.12
Uyo Village Road. C	1.53^{ab}	0.12	0.09	55.69^{bc}	0.62	0.44	1.45^{bc}	0.22	0.16	“	4.29^{abc}	0.68	0.48	2.19^{a}	0.04	0.03

Mean values were obtained from duplicate determinations. Means followed by different superscripts are significantly ($p<0.05$) different. U= Upper part of gully; M = Middle part of gully; L = Lower part of gully; C = Control

Table.5 Summary of descriptive Statistics of soil samples from erosion sites in Uyo

Soil properties	N	Range	Min.	Max.	Mean	Std. error	Std. Deviation	Skewness	Coefficient of variation
Coarse Sand (%)	24	24.08	51.15	75.23	63.77	1.37	6.73	0.27	0.11
Fine Sand (%)	24	13.24	11.86	25.10	20.49	1.01	4.95	-0.70	0.24
Silt (%)	24	6.22	3.66	9.88	5.84	0.45	2.20	0.76	0.38
Clay (%)	24	3.13	9.00	12.13	10.21	0.19	0.94	0.85	0.09
Bulk Density (g/cm^3)	24	1.48	0.28	1.76	1.28	0.07	0.33	-1.92	0.26
Porosity (%)	24	9.81	50.20	60.01	54.62	0.54	2.63	0.18	0.05
Permeability (cm/h)	24	1.91	0.22	2.13	0.90	0.12	0.59	0.81	0.66
pH	24	2.40	2.99	5.39	4.17	0.10	0.51	0.23	0.12
Total Organic Carbon	24	1.24	1.17	2.41	1.70	0.07	0.34	0.29	0.20
Organic matter content (%)	24	2.14	2.02	4.16	2.9240	0.11971	0.58644	0.292	0.20
K_{USLE} ($Mg\ h\ MJ^{-1}\ mm^{-1}$)	24	0.0056	0.0269	0.0325	0.02949	0.000311	0.0015248	0.341	0.05

N= number of soil samples

Table.6 Correlation of soil properties

		Coarse Sand	Fine Sand	Silt	Clay	Bulk Density	Porosity	Permeability	PH	TOC	Organic Matter	K_{USLE}
Coarse Sand	R	1										
Fine Sand	R	-0.863**	1									
	Sig.	0.000										
Silt	R	-0.251	0.459*	1								
	Sig.	0.237	0.024									
Clay	R	-0.098	0.212	-0.380	1							
	Sig.	0.648	0.321	0.067								
Bulk Density	R	-0.060	0.078	-0.001	-0.079	1						
	Sig.	0.781	0.716	0.997	0.715							
Porosity	R	0.704**	-0.568**	0.254	-0.326	-0.195	1					
	Sig.	0.000	0.004	0.230	0.120	0.361						
Permeability	R	-0.433*	0.605**	0.925**	-0.218	-0.062	0.137	1				
	Sig.	0.035	0.002	0.000	0.305	0.772	0.524					
pH	R	-0.049	0.194	-0.276	0.462*	0.203	-0.454*	-0.312	1			
	Sig.	0.822	0.365	0.192	0.023	0.342	0.026	0.137				
TOC	R	0.080	-0.088	-0.331	0.299	-0.136	-0.058	-0.306	0.325	1		
	Sig.	0.710	0.682	0.114	0.156	0.526	0.788	0.146	0.121			
Organic Matter	R	0.079	-0.088	-0.331	0.299	-0.137	-0.058	-0.306	0.324	1.000**	1	
	Sig.	0.712	0.683	0.114	0.156	0.524	0.786	0.145	0.122	0.000		
K_{USLE}	R	0.184	-0.074	0.103	-0.254	0.057	0.086	0.000	-0.039	-0.680**	-0.680**	1
	Sig.	0.389	0.730	0.634	0.232	0.790	0.691	0.999	0.855	0.000	0.000	

N = 24. **. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). TOC Total organic carbon. R = Pearson correlation. Significance = 2-tailed

Table.7 Regression analysis of soil erodibility factor for Uyo watershed estimated with USLE

Equation no.	Dependent variable	Regression equation	R^2	Adjusted R^2	RMSE	MSDR
1	K	Y = 0.0106 +0.000838 Fine Sand +0.000014 Coarse sand +0.000826 Silt -0.000214 Clay -0.000012 Bulk density - 0.00253 Organic matter	1.00	0.99	0.00005960	3.55199E-09
2	K	Y = 0.0172 +0.000145 SAND	0.022	0.00	0.002023	0.000004092
3	K	Y = 0.0354 - 0.00218 Organic matter	0.595	0.528	0.001301	0.000001693
4	K	Y = 0.0752 - 0.00164 Organic matter - 0.00261 Bulk density - 0.00151 Silt - 0.00567 Clay + 0.00054 Porosity	0.759	0.157	0.001738	0.000003022
5	K	Y = 0.0699 - 0.00145 Organic matter - 0.00152 Bulk density - 0.00032 Silt - 0.00329 Clay	0.734	0.340	0.001491	0.000002224
6	K	Y = 0.0351 - 0.00226 Organic matter + 0.00043 Bulk density	0.604	0.445	0.001410	0.000001988
7	K	Y = 0.0287 - 0.00187 Organic matter + 0.00054 Bulk density + 0.00058 Silt	0.627	0.347	0.001530	0.000002341
8	K	Y = 0.0627 - 0.00136 Organic matter - 0.00123 Bulk density - 0.00289 Clay	0.730	0.527	0.001303	0.000001697

Figure.1 Akwa Ibom State showing the study area

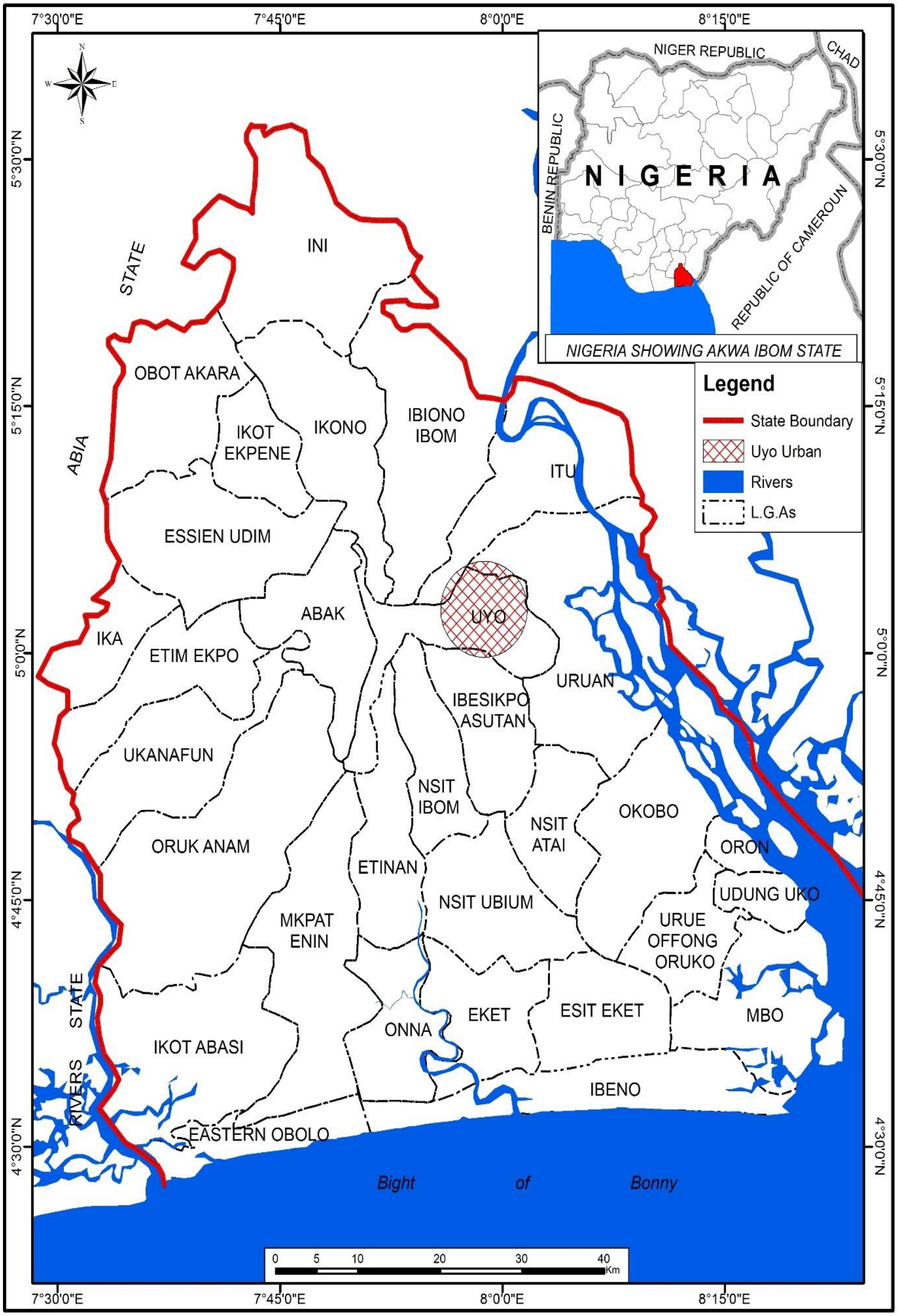


Figure.2 Uyo Urban showing Gully Sites (Sample Locations)

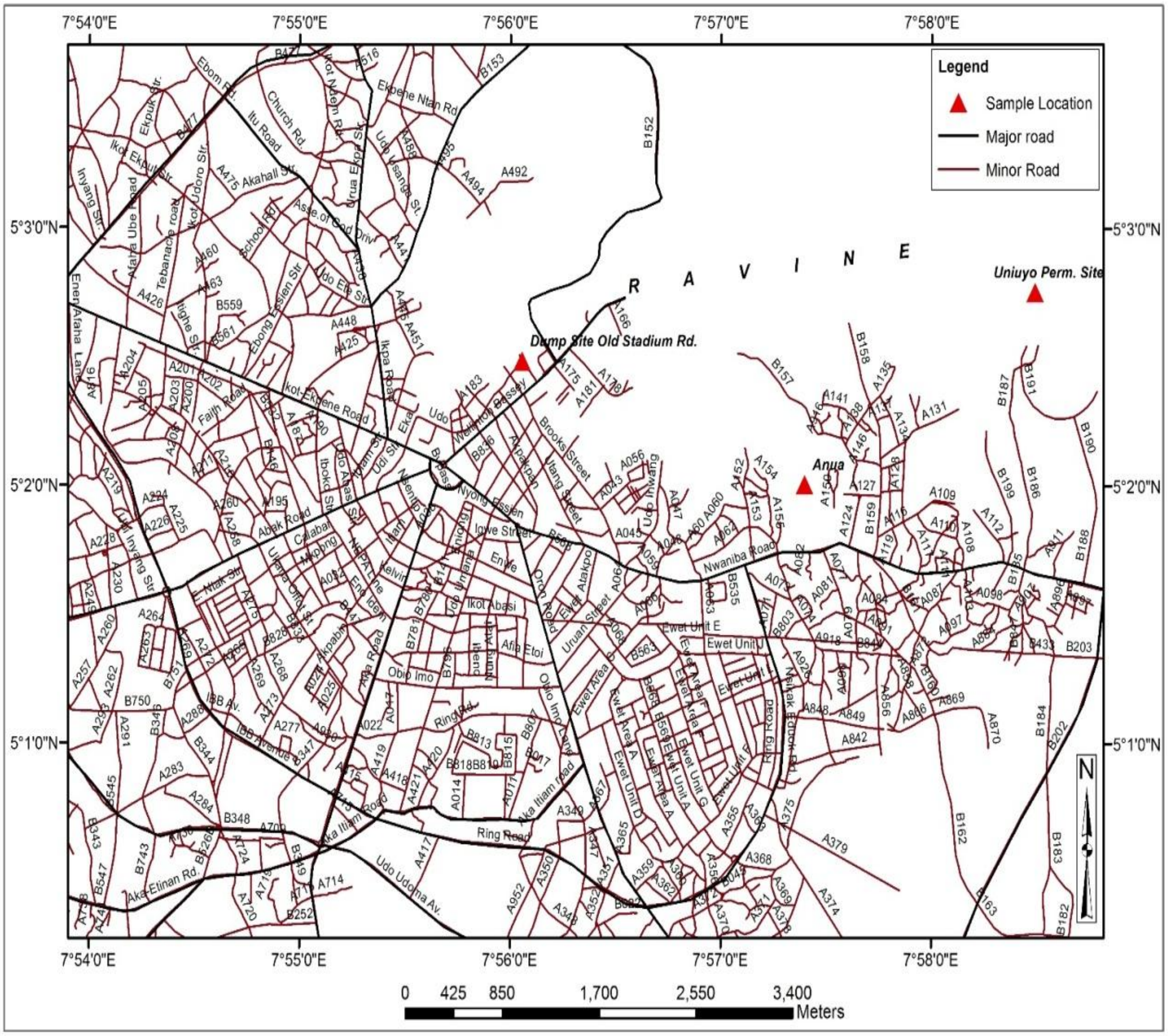
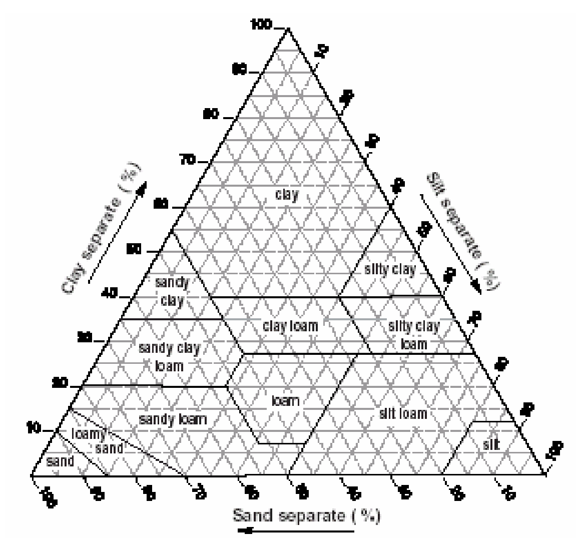


Figure.3 Soil Textural Triangle, (NRCS, 2014)



The resulting value of K-factor were low (0.0277 to 0.0271Mg.h.$MJ^{-1}mm^{-1}$) in the Uyo village road gully site and gradually increase (0.284 to 0.0313Mg.h.$MJ^{-1}mm^{-1}$) in the Uniuyo Annua gully sites. Thus probably, could be due to the effect of the vegetative cover in the Uyo village road gully site without increase organic matter content, which ultimately lower K-factor. Based on the classification used by Le Roux *et al.*, (2016), the studies field was considered as having low to high soil erodibility

Table 5 shows the summary of description statistics of soil samples from erosion sites in Uyo. All the examined soil properties were found to be normally distributed with an estimated skewness coefficient which rises from – 1.92 for bulk density to 0.85 for clay particle. According to Virgillio *et al.*, (2007), a dataset is considered to be normally distributed when skewness coefficients are between – 1 and 1. Over the sample area, mean value of OM were 1.70$\pm 0.07\%$ while mean value of observed soil texture (clay, silt, fine sand and coarse sand) were 10.2$\pm 0.19\%, 5.85 \pm 0.46, 20.49 \pm 1.01\%$ and 63.77$\pm 1.37,$ respectively.

The coefficient of variation (CV) showed observed variation in the sampled soil properties. The coefficient of variation value ranged from a minimum of 0.11 to a maximum of 0.66. As a way of assessing variability, permeability was seen to show the highest variation while porosity indicated a weak variation. The coefficient of variation for erodibility was found to be 0.05, with standard deviation of 0.00152488.

Relationships between use K-Factor and soil characteristics

Pearson's correlation was used to establish the veracity of the relationship existing between selected soil properties and erodibility factor, and the result is summarized in table 6. Results indicate that the soil properties which showed positive relationship (i.e positive correlation) with soil erodibility are coarse sand, silt, bulk density, porosity and permeability, while fine sand, clay pH, TOC (Total Organic Carbon) and Organic Matter Content (OMC) show negative relationship (i.e negative correlation) with soil USLE K-factor. However, OMC has a negative and significant correlation with USLE k-factor. That is, for TOM, $r = -0.680,$ at $p < 0.01$.

It is an established fact that organic matter content increases the stability of soils, thereby reducing its susceptibility to erosion. Therefore, the negative significant correlation between organic matter content and USLE k-factor collaborates the role of organic matter in soil stability. A similar statistical significant relationship was found to exist between organic carbon content (which can be converted to organic matter content by multiplying OC to 1.72) and erodibility factor.

Further analysis of the relationship between soil erodibility and soil properties was performed using multiple regression analysis and the resulting outcome was summarized in table 7. The analysis revealed sand content alone to account for the 22% of the variation in soil erodibility. Organic matter and bulk density account for about 60% of the variation, whereas organic matter, bulk density, clay, and silt, together explained approximately 73% of the variation in soil erodibility. The inclusion of silt increased the variability of soil erodibility from 60% to 73% indicating the essential role silt plays in the soil erosion process. Wischmeier and smith (1978) observed similar finding when they ascribed soils with high silt content to be more erodible. Porosity did not turn to be of much influence on soil erodibility as the addition of this parameter (porosity) only explained 76% (difference of about 3%) of the variation in soil erodibility. Jointly, however, soil properties inclusive of sand, silt, bulk density, porosity, and organic matter explained about 100% of the variability in soil erodibility. This finding agrees with previously established facts which alluded to the influential role played by both intrinsic and extrinsic soil properties to the soil erosion process (Torri *et al.*, 1997). The best regression equation in this study (see table 7) is equation 1, which gave an R^2 of 1.0.The choice of the best regression equation was made based on statistical measure of the lowest root mean square error(RMSE) and the largest Pearson's coefficient (R^2).

Conclusion

The Wischmeire equation was applied to successfully determine the soil erodibility with respect to select soil properties. The k-factor was found to be between 0.026 to 0.0325 (the maximum value being about 1.25 times greater than the minimum value),indicating a slight variability of Uyo soils according to their behaviour toward erodibility and consequently towards erosion. The estimated k-factor had the highest values at Anua gully site and Uniuyo gully site, while the lowest values of the soil erodibility factor was observed in the Uyo old village road gully site. The results of the study show that the soils have high sand content and low silt and clay content. The susceptibility of the soils to erosion was found to be significantly dependent on the high sandy texture and low content of silt and clay. This is so because the sand particles are easily dispersed and detached than the silt and clay particles which has the tendency to adhere to form large, heavy aggregates that can resist erosion. The results of this study can be used to make recommendation of the k-factor in future soil erosion studies of data scarce similar areas of Uyo.

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