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Erodibility index of soils along Ezeagu-Umulokpa road, Enugu state

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Abstract
The destruction caused by soil erosion is seriously attracting attention in South Eastern Nigeria. Erodibility Index(K) of soils along Ezeagu-Umulokpa road in Enugu State was conducted to ascertain the erodibility indices of soil samples at four locations along Ezeagu-Umulokpa road and to predict the level of erosion loss in these four locations. A total of twelve(12) soil samples from four different locations- Ugwueke, Number one Bus Stop, Amansiodo Bus Stop and St. Theresa Catholic Church Oghe along Ezeagu-Umulokpa road were collected using soil cores at varying depths of 0-15cm, 16-30 and 31-45cm respectively. They were collected in poly bags and taken to the laboratory where they were air dried and sieved with 2mm mesh sieve. The soil samples were analyzed for Structural Class Index, Soil Permeability Class Index and Organic Matter Content from which Soil Erodilbility Indices were calculated for soils from the four locations and erosion loss predicted. The results of this analyses showed that number one bus stop had the highest average K value of 0.34 with low mean clay content and Amansiodo Bus Stop had the lowest average K value 0.01 with the highest mean clay content. The average mean erodibility index was calculated to be 0.11 for Ezeagu-Umulokpa road. Number one bus stop had the highest calculated erosion loss value of 73.46tons/ha/yr under constant mean annual rainfall factor R. It is therefore recommended that, soil conservation measures should be carried out at number one bus stop.

Keywords: Soil, Erosion, Erodibility Index, Soil loss, Permeability

1. Introduction

There are alarming cases of soil erosion in many parts of Eastern Nigeria which pose a serious threat to life and economic activities of the region. Soil erosion is a common disaster that can be caused by nature because of the soil properties and also by man as a result of improper environmental management (Ejaz *et al*., 2010). It not only cause severe land degradation and soil productivity loss but, also threatens the stability and health of society in general and sustainable development of rural areas in particular (Tang, 2004; Zheng *et al* 2004; Jing *et al* 2005). Soil erosion is broadly defined as the accelerated removal of topsoil from the land surface through water, wind or tillage (FAO and ITPS, 2015). The rate of water erosion occurring at a site depends, in the first instance, on the rainfall itself (the source of rain splash detachment) and the runoff generated during the rainfall event, which both detaches and transports the eroded soil while wind erosion occurs on bare or nearly bare, level, dry surfaces where the wind velocity is high enough to entrain soil (FAO, 2019). Essentially in assessing soil erosion in fields and farmlands, the soil's potentials for erosion and soil properties that can be managed to minimize erosion need be assessed. In erodibilty studies and the development of erosion models, numerous publications on the effect of soil properties in erosion processes have assisted in better quantifying and defining soil erodibility. Soil Erodibility is a function of complex interactions of a substantial number of the soil's physical properties. Generally, soils that are high in slit, low in organic matter are the most erodible (Bhattacharyya *et al.,* 2016). A soil with high erodibility index will suffer more erosion than a soil with low erodibility index if both are exposed to the same rainfall event (De Vente and Poesen, 2005).

Soil is a basic necessity for agricultural production and other essential uses. Factors that affect the soil also affect agriculture and other benefits from soil therefore; a solution to such factors will increase food production and enhances a good conducive environment for man and other ecological system. Soil erodibility was originally thought to remain essentially constant for a given soil. But with the research processing in great depth, more researchers have discovered that soil erodibility is a relative concept. It is strongly affected by spatially variable, temporally dynamic soil properties and human activities. Soil has different erodibilities under various forms and intensities of erosive force, so the condition of erosive force should be considered for selecting the index of soil erodibility (Song*et al*., 2005). Erosion process takes place gradually in some areas without visible signs. These areas if not checked will be destroyed by erosion, hence, the need for urgent attention. Erosion control processes are quite expensive and therefore require checks at any suspected area routinely to prevent it from growing uncontrollably.

This research will provide information on the erodibility index and level of soil loss from the study areas which will serve as foundation for other researchers that has the intention of researching on this field. It will be a baseline and provide guidelines for other scientist etc. As it is a well known fact that the cost of erosion control is at its peak. It is very important to control the erosion site before it calls for government intervention. Erosion menace is common in rain forest of the world and Umulokpa-Ezeagu road is within this climatic zones. There is the need to provide the erodibility data which will help checkmate erosion in this area. This work is designed to determine the erodibility indices of soil samples along Ezeagu-Umulopka road to predict the level of erosion loss in these four selected study areas.

2.0 Material and methods

2.1 Study Area Description

This work was conducted along Ezeagu-Umulopka road covering a part of Udi and Ezeagu Local Government Area (LGA) of Enugu State . The areas studied are situated in latitude 6° 27^{I} North and longitude 7° 17^{I} East in the tropical rainforest of Enugu, South East Agro-ecological zone of Nigeria. The rain season spans for eight months (from March to October) and dry season starts from November to February. The average annual rainfall is 2281.2mm and the vegetation is of tropical rain forest origin but has been reduced to derived Savannah due to continuous use of land and lumbering (Francisca and Augustina, 2013). Figure 1 is a map of Enugu State showing the study area.

Figure 2.1: Map of Enugu State Showing the study Area

2.2 Data Collection

Completely Randomized Design (CRD) was employed in the collection of samples in this work. A total of twelve(12) soils samples were randomly collected from four (4) different locations along Ezeagu-Umulopka road as represented in the table 1 below. They are; Ugwueke-A, Number one Bus Stop-B, Amansiodo Bus Stop-C and St. Theresa Catholic Church-D. The whole samples were collected from each location at depths of 0-15cm, 16-30cm, 31-45cm respectively. The soil samples were taken to the laboratory for analysis to determine the soil erodibility indices according to the method propose by Wischmeier et al., (1958). The soil samples were randomly collected from the study site using soil cores. The soil samples were collected with poly bags and were air dried and sieved with 2.0mm mesh sieve upon arrival at the laboratory.

Table 2.1: Samples Depths and Locations.

Location	LGA	Village	Soil Depth (cm)		
			0-15	**16-30**	**31-45**
Ugwueke – A	Udi	Eke	1	2	3
No. 1 Bus Stop – B	Ezeagu	Akama-Oghe	4	5	6
Amansiodo Bus Stop – C	Ezeagu	Amansiodo	7	8	9
St Theresa Catholic Church-D	Ezeagu	Iwollo Oghe	10	11	12

2.3 Soil Analysis

Soil erodibility was determined based on Wischmeier and Smith (1963) formula for the determination of erodibility index. This formula made use of some soil characteristics namely: structural class index, permeability class index, organic matter content and % silt + % very fine sand and % Sand (ie 100- clay). This method was used because of its simplicity.

2.3.1 Structural Class Index

The structural class index of the soil was determined based on Wischmeier and Smith (1963) method of erodibility determination. It was determined by taking clods from each plot and at each depths and dropping them from known height of about 1.2 cm watching how the clods got broken for classification as shown in the table 2.

Table 2.2: Structural class indices of soils

Soil Structure	Class Index
Very Fine granular	1
Fine granular	2
Medium or coarse granular	3
Blocky, platy or massive	4

Sourc:A soil erodibility monogragh for farm land construction site by Wischmeier and Smith (1963) .

These numbers above were the structural class indices of different soil samples. The three different depths of each plot were worked on and the average obtained.

2.3.2 Soil Permeability Class Index

The permeability class index of the soil samples were determined based on Wischmeier and Smith (1963) method. This was done by using a cylinder infiltrometer test. In this method, each point location was tested by measuring a known quantity of water (300 ml) and watching how long it takes (in minutes) to infiltrate into the soil at each depths. A constant head permeameter can be used. Table 3 below showed the time to be taken.

Table 2.3: Permeability class indices of soil

Time (mins)	Soil class	Remarks
1-10	1	Sandy soil
11-20	2	Sandy-loam
21-30	3	Sandy-clay-loam
31-40	4	Sandy-clay-loam
41-50	5	Clayey-loam
51-60	6	Clayey soil

2.3.3 Percent Silt + Very Fine Sand and Percent Sand

In determining the percent silt+ very fine sand and percent sand of soil samples, the combined analysis of both sieve and hydrometer test methods were employed for soil samples collected at different depths and locations .The average values were then taken.

2.3.4 Organic Matter Content

The organic matter content of the soil samples was determined at each location and at different depths using the wackley-Bank method. This method is by titrating a known volume of dichromate solution against a solution of known weight of soil. The formula given by Wackley-Bank was used in computing the percentage organic carbon as shown below:

$$\%OC = \text{V}1 - V2 \times 0.003 \times 100 \times F \div W \qquad (2.1)$$

Where,

%OC = Percentage organic carbon
V1= Volume of dichromate
V2= Volume of titrant (ferrous ammonium sulphate)
W= Weight of air-dried soil.
F= Correction factor (usually1.33)

Percentage organic matter was calculated using equation 2.2.

$$\%OM = \%OC \times 1.724 \qquad (2.2)$$

Where,

%OM = Percentage organic matter

2.3.5 Calculation of Soil Erodibility Index

The soil erodibility index was calculated based on Wischmeier and Smith (1969) equation as follows:

$$K = 2.1 \times 10^{-6} \times M^{1.14}(12 - OM) + 0.0325(S - 2) + 0.025(P - 3) \qquad (2.3)$$

Where,
K= Erodibility index of soil
OM = Organic matter content
M = % silt+% very fine sand +% sand (ie 100-% clay).
P = Permeability class index
S = Structural class index

2.3.6 Erosion Prediction

The revised Universal soil loss equation (USLE) by Schwab *et al.*, (1993) was used in calculating the soil losses for the various sampling locations and is given in equation 2.4

$$A = 2.24\, RK \qquad (2.4)$$

Where,
A = Soil Loss in tons/ha/yr
R=. Mean Annual Rainfall Factor
K = Erodibility Index

The mean annual rainfall factor, R was obtained using Roose (1977) in equation 2.5.

$$R = 0.05H \qquad (2.5)$$

Where,
H = The mean annual rainfall in mm.

The mean annual rainfall from 2010 to 2020(11years) is 1929mm for Enugu which is H in equation 2.5 (NIMET, 2010-2020).

3.0 Results and Discussions

3.1 Result Presentation

The results of structural class indices, permeability class indices, % organic matter content, % silt + % very fine sand and % sand of soil sample analyses from four randomly selected locations: Ugwueke -A, Number one Bus

Stop-B, Amansiodo Bus Stop-C and St. Theresa Catholic Church Oghe-D, are presented in tables 3.1, 3.2,3.3 and 3.4 accordingly in their order of arrangement. Locations A and D had the highest average structural index of 3(table 3.1) while location C had the lowest structural index of 1.67.

3.1.1 Soil Structural Class Indices

The structural class indices of all the soils showed that locations A and D had the highest class indices for all depths while location C had the least class index (table 3.1).

Table 3.1: Soil Structural Class Indices

LOCATION A: Ugwueke		
Depth (cm)	**Structure**	**Class Index**
0—15	Coarse granular	3
16—30	Coarse granular	3
31—45	Coarse granular	3
Average	—	3
LOCATION B: Number one Bus Stop		
0—15	Coarse granular	3
16—30	Coarse granular	3
31—45	Fine granular	2
Average	—	2.67
LOCATION C: Amansiodo Bus Stop		
0—15	Very Fine granular	1
16—30	Fine granular	2
31—45	Fine granular	2
Average	—	1.67
LOCATION D: ST. Theresa Catholic Church Oghe		
0—15	Coarse granular	3
16—30	Coarse granular	3
31—45	Coarse granular	3
Average	—	3

3.1.2 Permeability Class Indices

The permeability class indices of all the soils showed that location B had the highest time range (46-56minutes)(table 3.2) with an average of 51minutes while the least is location D which had a time range of (1-11 minutes) with an average of 6minutes. Location A had the highest permeability class index average of 4 while the least average is recorded at location D as 2.

Table: 3.2Permeability Class Indices

LOCATION A: Ugwueke		
Depth (cm)	**Structure**	**Class Index**
0—15	Coarse granular	3
16—30	Coarse granular	3
31—45	Coarse granular	3
Average	—	3
LOCATION B: Number one Bus Stop		
0—15	10	3
16—30	21	3
31—45	26	3
Average	19	3.33
LOCATION C: Amansiodo Bus Stop		
0—15	46	5
16—30	51	2
31—45	56	3
Average	51	3.33
LOCATION D: ST. Theresa Catholic Church Oghe		
0—15	1	2
16—30	6	2
31—45	11	2
Average	6	2

3.1.3 % Organic Matter Content

It was observed that location B had the highest average % organic matter content 3.1032% (Table 3.3) while location C had the lowest average % organic matter of 1.0344%.

Table 3.3:% Organic Matter Content

LOCATION A: Ugwueke		
Depth (cm)	**% Organic carbon**	**% Organic matter**
0—15	0.7	1.2068
16—30	1.2	2.0688
31—45	1.0	1.7240
Average	1.0	1.6700
LOCATION B: Number one Bus Stop		
0—15	1.8	3.1032
16—30	1.7	2.9308
31—45	1.9	3.2756
Average	1.80	3.1032
LOCATION C: Amansiodo Bus Stop		
0—15	0.7	1.2068
16—30	0.5	0.8620
31—45	0.6	1.0344
Average	0.60	1.0344
LOCATION D: ST. Theresa Catholic Church Oghe		
0—15	0.6	1.0344
16—30	0.5	0.8620
31—45	0.8	1.3792
Average	0.63	1.0920

3.1.4 % Silt + % Very Fine Sand + %Sand (100 % Clay)

The % silt + %very fine sand +% sand average was highest for location D with the value of 93.33% (Table 3.4), location A and B had 86.67% while the least was observed at C value 78.33% .

Table 3.4: % Silt + % Very Fine Sand + %Sand (100 %Clay)

Depth (cm)	Very fine sand (0.02—0.1mm)	% Sand (0.1-2.0mm)	% Silt	% Clay	% Very Fine Sand + % Sand (100-% Clay) m
LOCATION A:Ugwueke					
0—15	5	70	5	20	80
16—30	30	30	30	10	90
31—45	10	70	10	10	90
Average	15	56.65	15	13.33	86.67
LOCATION B: Number one bus stop					
0—15	30	30	30	10	90
16—30	30	20	30	20	80
31—45	40	10	40	10	90
Average	33.33	20	33.33	13.33	86.67
LOCATION C: Amansiodo bus stop					
0—15	25	20	25	30	70
16—30	15	20	15	10	90
31—45	20	20	35	25	75
Average	20	20	25	21.67	78.33
LOCATION D: St. Theresa Catholic Church, Oghe					
0—15	10	75	10	5	95
16—30	5	80	5	10	90
31—45	7.5	80	7.5	5	95
Average	7.5	78.33	7.5	6.67	93.33

3.5 Erodibility Indices for the Soil Samples

The results of the erodibility indices of soils were presented in table 3.5. The results showed that Number One Bus Stop had the highest average K value of 0.34 while St. Theresa Catholic Church Oghe had the lowest K value of 0.01. The mean average K value was therefore calculated to be 0.11 which is the erodibility index of soil along Ezeagu-Umulopka road.

Figure 2 showed that Number One Bus Stop had the highest value of erodibility index at the 0-15cm depth with St. Theresa Catholic Church Oghe as the least. At the 16-30cm and 31-45cm depths, Ugwueke had the highest value for erodibility index with Amansiodo Bus Stop as the least respectively. Generally, it was observed that erodibility indices of soils at the sample locations declines with respect to depth.

Table 3.5: Erodibility Indices for the Soil Samples

LOCATION A: Ugwueke	
Depth (cm)	**Erodibility Index(k)**
0—15	0.06
16—30	0.06
31—45	0.06
Average	0.06
LOCATION B: Number one Bus Stop	
0—15	0.3
16—30	0.04
31—45	0.03
Average	0.34
LOCATION C: Amansiodo Bus Stop	
0—15	0.02
16—30	0.004
31—45	0.003
Average	0.01
LOCATION D: ST. Theresa Catholic Church Oghe	
0—15	0.01
16—30	0.01
31—45	0.01
Average	0.01
MEAN ERODIBILITY INDEX (0.11)	

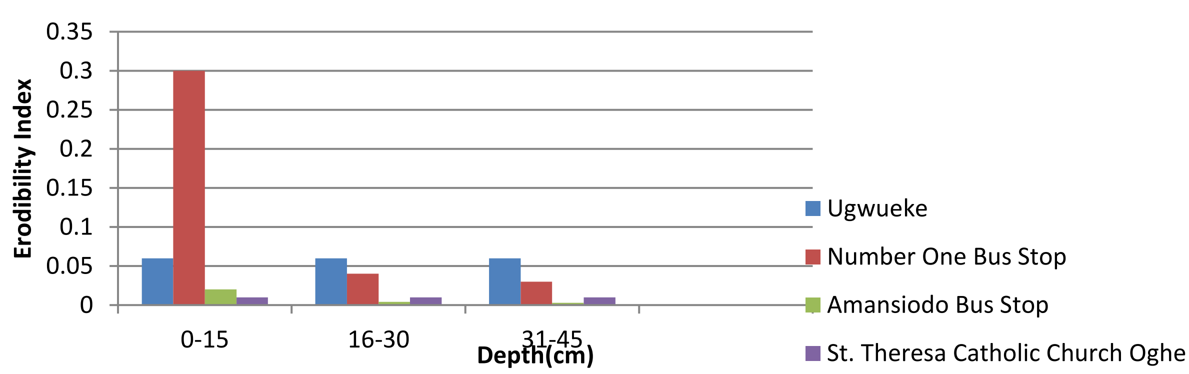

Figure 3.1: A Graph of Erodibility Indices against sample depth of soils from all locations.

3.1.6 Erosion loss

The results of the average annual soil loss at the locations are presented in table 3.6. The results showed the corresponding values of soil loss with the erodibility indices for the locations. Location B has the highest average annual soil loss of 73.46 tons/ha/yr and location C and D had same and lowest soil loss of 2.16 tons/ha/yr, while the mean average value for soil loss was calculated to be 22.69 tons/ha/yr. Figure 3 showed that Number One Bus Stop had the highest value of erosion loss followed by Ugwueke while Amansiodo Bus Stop and St. Theresa Catholic Church Oghe had same least values of erosion loss.

Table 3.6: Calculated Soil Losses at Various Locations Ezeagu-Umulokpa road.

Location	R= 0.05H	K	Erosion Loss A=2.24RK (tons/ha/yr)
Ugwueke -A	96.45	0.06	12.96
Number One Bus Stop -B	96.45	0.34	73.46
Amansiodo Bus Stop -C	96.45	0.01	2.16
St. Theresa Catholic Church Oghe -D	96.45	0.01	2.16
Mean Value	96.45	0.11	22.69

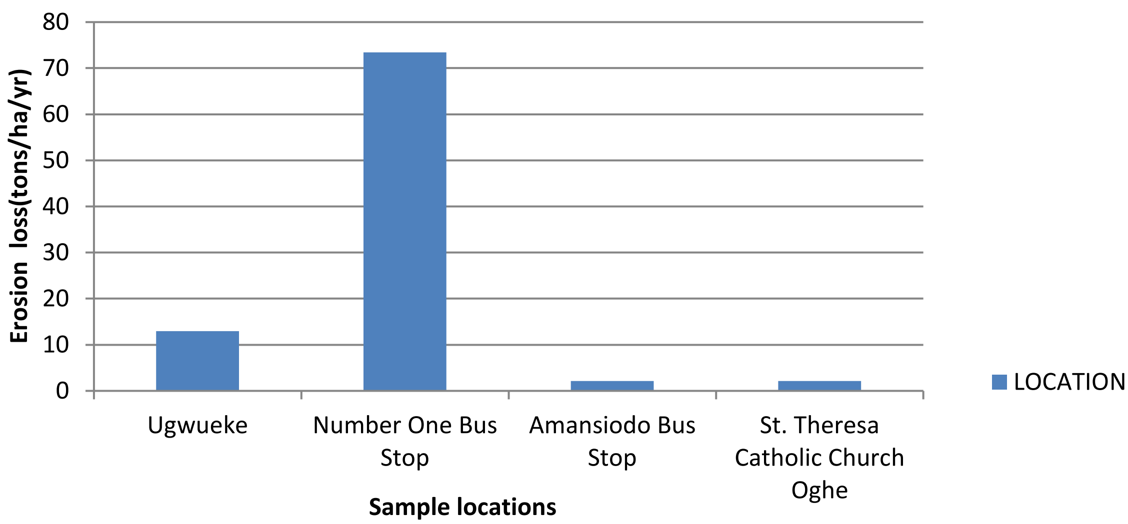

Figure 3.2: A Graph of erosion loss against sample locations.

From the results, it was observed that location B had the highest average K value of 0.34 with low mean clay content and location C had the lowest average K value 0.01 with the highest mean clay content. This result is in line with that of (Emeka, 2014). Soils with higher K value should have lower clay content and are more prone to erosion. Low clay% content results in lower binding forces and poor cohesion. Therefore, the interlocking forces between the grains will be reduced to the detachment by any force whatsoever. But, soils with the lower K values are less erodible. These values of low K index ensure a high cohesion and good interlocking forces which could resist the forces due to detachment and transportation by water. The K-values obtained from this study are slight lower when compared to that of Okafor et al., 2018.

Table 3.7: Standard Erodibility Indices

Group	K-factor	Nature of Soil
i	0—0.1	Permeable glacial outwash well drained soil. Slowing permeable subtrater
ii	0.11—0.17	Well grained soils in sandy gravel free material
iii	0.18—0.28	Graded loams and silt loams
iv	0.29—0.48	Poorly graded moderately fine and fine textured soils
V	0.49—0.64	Poorly graded silt or very fine sandy soil. Well and moderately grained soils.

Source: standard erodibility indices by Olson W. Gerald (1984). Dowden and Culver Inc.

The result of the K-values in this work is also slightly lower when compared with that of Peter et al., 2008. The erosion loss value in this study is relatively close to that of Okafor et al., 2018, with an exception to Number one bus stop (73.46 tons/ha/yr) which is far higher.

According to Olson 1984, comparing the average mean value 0.11 of erodibility indices of soils from this study in all locations with the standard erodibility indices presented in table 3.7, the soil in location A-D lies between 0.11-0.17 range which is classified as well-grained soils in sandy gravel free material and such soil is designed as permeable well drained soil having low permeability. Furthermore, from the calculated erosion value, location B had the highest K value 73.46 tons/ha/yr and also the highest soil loss and location C and D with the lowest K value 2.16 tons/ha/yr has the Lowest soil loss under constant mean, annual rainfall factor R. This implies that the erodibility index of soils in this area is directly proportional to erosion loss.

4.0 Conclusion

The erodibility indices of soils studied along Ezeagu-Umulopka road have shown various erodibility indices for soils at the four locations- Ugwueke location A, Number one Bus Stop location B, Amansiodo Bus Stop location C, St. Theresa Catholic Church Oghe location D, selected for this study. Location B had the highest value 0.13 for mean erodibility and the highest soil erosion loss 73.34tons/ha/yr. Soil with the highest K factor is prone to erosion than soil with lowest and must need adequate soil conservation and proper measures to control erosion.

5.0 Recommendation

It is recommended that;

i. This study is extended down to Olo village in Ezeagu local Government Area of Enugu State to ascertain if soils in the location are prone to erosion.

ii. Soil conservation measures should be carried out at location B.

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