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Determination of Soil Erodibility (*K*) Factor Derived from Different Geologic Formations of Akwa Ibom State

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Abstract

The onsite and offsite effect of erosion has caused it to be considered as a global issue. For erosion to occur there must be soil erodibility and rainfall erosivity. Different geologic formations give rise to different types of soil and this has affect their responses to an erosive event. Five (5) geologic formations were identified within the study area. This study assessed the erodibility of soils from different geologic formations. Soil samples were taken at a depth of 0-10, 10-20, 20-30 cm for standard laboratory analysis. The fine sand, silt, clay, organic matter and permeability of the soils obtained from the different geologic formations were used to determine their erodibility indices using Wischmeier and Smith model. The results obtained shows that Alluvium geologic formation has an average K factor of 0.150 tons MJ^{-1} hmm^{-1}. Ameki had an average K factor of 0.131 $MJmmha^{-1}hr^{-1}yr$. Benin had an average K factor of 0.130 tons MJ^{-1} hmm^{-1}. Imo had an average K factor of 0.147 tons MJ^{-1} hmm^{-1}. Ogwashi had an average K factor K of 0.127 tons MJ^{-1} hmm^{-1}. The results show that soils within the study area are vulnerable to erosion.

Keywords: Geologic Formation, Soil Erodibility, Soil Erosion, RUSLE/USLE

1.0 INTRODUCTION

Soil loss is considered a global issue due to its on-site and off-site effects on the environment and its resulting effects on the socioeconomics of the populace [1, 2, 3]. Climate, environmental and management parameters combine together to cause soil erosion. Considering the revised universal soil loss equation (RUSLE)/universal soil loss equation (USLE) empirical model, the climate and environmental variables are represented by the rainfall-runoff erosivity (*R*), soil erodibility (*K*) and slope length and steepness (*LS*), while the management variable is represented by the cover management *C* and land management *P* factor [4, 5, 6].

Soil comprises of minerals, organic matter, nutrients, moisture and micro-organisms that supports the ecosystem [7]. Soil erosion is a natural phenomenon which involves the removal and transportation of soil materials through the action of erosive agent such as water, wind, gravity and human disturbances [8, 9, 10]. The alteration of the environment by soil erosion through the reduction of fertile topsoil, washing away of crops, pollution of nearby surface water, destruction of farmlands and homes is a function of the ability of the soil to be detached and washed away by an erosive agent such as wind or water [9, 11].

The washing away of the top soil is carried out in layers and goes deep as it progresses, thereby reducing the soil depth and exposing the root of the plant, which has resulted in poor crop yield, damage of farmlands, siltation and pollution of nearby surface water [1, 9]. [12, 13] observed that land use and soil depth have an effect on soil properties. Soil erodibility denoted by *K* is an important index in the soil erosion model used in evaluating the susceptibility of soil to erosion [6, 14, 15]. Soil erodibility is the ability of soil to resist detachment and transportation of soil particles by an erosive event [15, 16]. The precise study and evaluation of soil erodibility is important in understanding soil erosion regularity, predicting soil loss and evaluating land productivity for conservational purposes [17].

The physical and chemical properties of the soil have been known to affect the soil stability which is an important property governing erodibility [18, 19]. Geologic formation influences the type of soil formed and their response to the actions of an erosive event. Several authors have studied soil erodibility using soil properties

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such as; organic content, soil structure, permeability and soil aggregate as shown by [5, 6, 20, 21].

Other authors have used the stability of soil aggregates in studying the erodibility of soils. The influence of parent materials on the soil formed has been studied by several authors considering their physicochemical properties [22, 23]. Other researchers studied the influence of the geologic formation on the erodibility of the soils formed [24, 25]. The susceptibility of different groups of soil in some parts of Eastern Nigeria has been studied by [26] using different intensities of simulated rainfall. A comparative study has been carried out using water erosion prediction project (WEPP) and European soil erosion model (EUROSEM) in modeling soil loss susceptibility [27].

Although, the formation of soil is influenced by several factors that form the processes of soil, it is imperative to understand the soils formed from each respective geologic formation for proper understanding of its soil erodibility indices with respect to its geologic formation. In Akwa Ibom state, several geologic formations have been identified by several authors, as such, it is necessary to understand how the different soils formed from their respective parent materials responds to an erosive event. This will give an insight into the erodibility indices of the respective soils for conservative planning of the soil for environmental sustainability.

Therefore, the objectives of this study are to determine the soil properties affecting the soil erodibility of the different geologic formations and their respective erodibility indices at different depths.

2.0 MATERIALS AND METHODS

2.1 Study Area

The location of the study is Akwa Ibom state, Nigeria. The study area is located within the trigonometric boundaries of 4°32’ and 5°33’ north latitude and 7°25’ and 8°25’east longitude. The climate is divided into two seasons. The wet season last from April to October and the dry season last from November to March. The annual total rainfall ranges from 1875mm to 2500mm with a mean annual temperature that varies between 21°c and 29°c and a relative humidity of 60% and 85%.

2.2 Description of the Geologic Formation

The detailed geologic map of the study was obtained from the Cross River Basin Development Authority. The map was scanned, geo-referenced and digitized for the study as shown on Figure 1. Five geologic formations were identified within the study area. Table 2.1 shows the area coverage of the total surface area and the respective size of the different geologic formations. Five (5) geologic formations cover the study area, these are: Alluvium formation – lithologies consists of sands, silts, clay, shale and gravels. Ameki Formation – lithologies are clastic sedimentary rocks consisting mainly of lignites conglomerates with interbedded sandstones, and shales. Benin Formation - consists principally of sands, gravels, clays, shales (lignites). Imo Formation - consists of clay-shales with intra-formational sand bodies. Ogwashi formation – consists of sand, gravels, interstices of clay interbedded with sandstone.

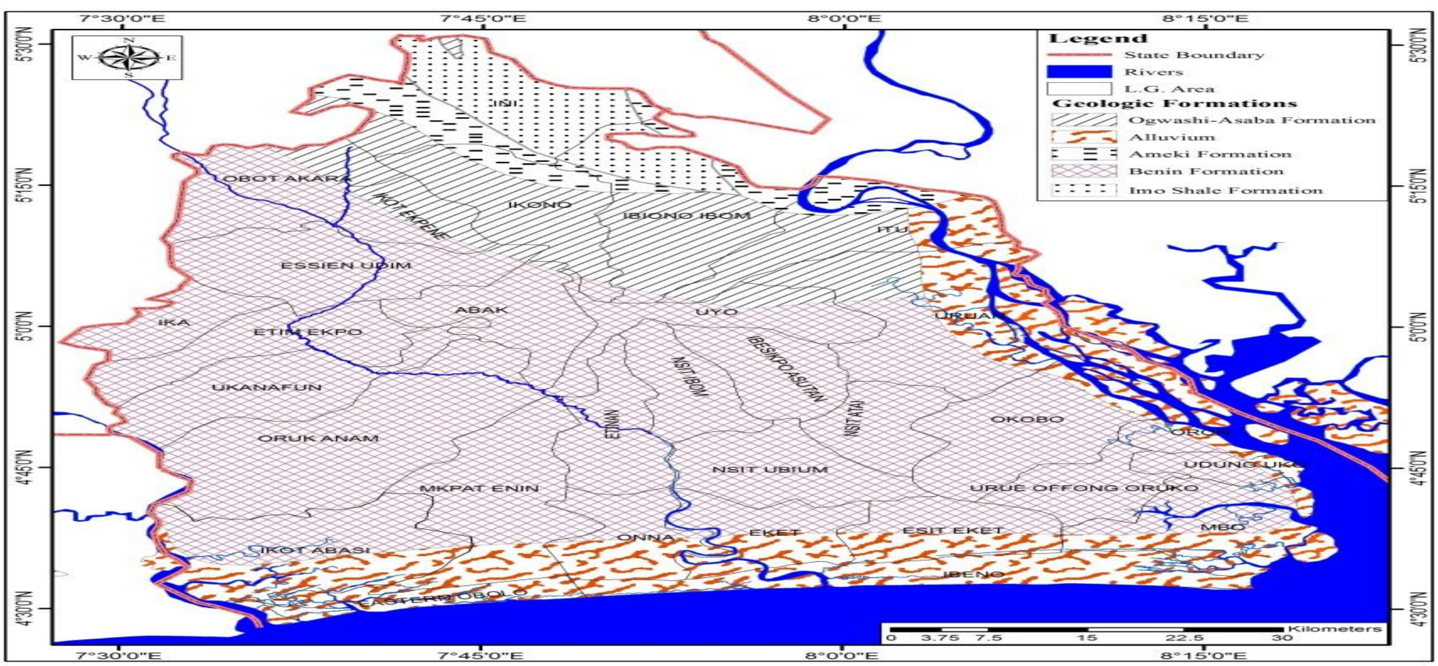

Figure 1: Geologic Map Formation of the Study Area

Table 2.1: Geologic Formation Coverage of Akwa Ibom State

Geologic Formation	**Area covered (Ha)**	**Area covered (%)**
Alluvium	144396.82	20.47
Ameki	29886.59	4.24
Benin	421706.4	59.8
Imo	26253.91	3.72
Ogwashi	82991.83	11.77
Total	705235.55	100

2.3 Field Sampling

In each geological formation, 15 soil samples were collected randomly from a representative location within the 5 geologic formation using soil auger within the depth of 0-10, 10-20 and 20-30 cm soil depth guided by the geologic map. Undisturbed core samples were also collected for bulk density and porosity determinations. A total of 90 samples were generated for laboratory analysis.

2.4 Laboratory Analysis

The methods used in carrying out the laboratory analysis are briefly discussed as stated below.

Particles size distribution was carried out by the Bouyoucos hydrometer method [28].

Soil structure codes were determined by using core samplers as described by [13] and grouped according to Table 2.2.

Table 2.2: Structural Class Indices of Soils

Soil Structure	**Class Index**
Very fine granular (<1mm)	1
Fine granular (1 – 2mm)	2
Medium or coarse granular soil (2 – 5mm)	3
Massive (Blocky, platy, columnar, primitive	4

Source: Udoumoh *et al.*, (2018).

The permeability class test of the soil samples were carried out using the constant head permeameter as described by [29] and classified using Table 2.3

Table 2.3: 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 i.e. high (>12.5)	1

Source: Wischmeier and Smith, (1978).

Organic Matter was determined by using the wet digestion method of Black [30].

Percentage organic matter was calculated by multiplying the percentage organic matter with Van denmelen's correction factor.

$$\%\, organic\ matter\ = \%\, organic\ carbon\ x\ 1.724 \quad (1)$$

Where; 1.724 is the Vandenmelen's correction factor.

2.5 Methods

2.5.1 Soil Erodibilty (K) Factor

The results of the analyzed soil samples in the study area were used to determine the soil erodibility of the soils derived from different geologic formation of the study. Table 2.4 shows the standard erodibility indices of soils used as a guide for the study. K-values (tons MJ^{-1} hmm^{-1}) were computed [9, 31] and subsequently, the K factor map was generated.

$$k = \frac{2.173 \times 10^{-4}\,(12 - OM) \times M^{1.14} + 3.25\,(S - 2) + 2.5\,(P - 3)}{100} \quad (2)$$

Where *OM* is the organic matter (%),

S is soil structure class, P is permeability class

M is aggregated variable derived from the granular soil texture:

M = (%Modified silt) × (%silt+%sand), and the modified silt (Msilt) is a percentage of grain size between 0.002 and 0.1 mm.

Table 2.4: Standard Erodibility Indices

Group	K factor	Nature of soil
I	0 – 0.1	Permeable out wash well drained soil slowing permeable substrater
II	0.11 – 0.17	Well grained soils in sandy gravel material
III	0.18 – 0.28	Well grained soils in sandy gravel free material
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: Wischmeier and Smith, (1978).

3.0 RESULTS AND DISCUSSION

3.1 Results

3.1.1 Soil Properties That Determine Soil Erodibility (K Factor) across the Geologic Formations of Akwa Ibom State.

Table 3.1 presents the analyzed soil parameters that are used in modeling the soil erodibility (*K Factor*) of the RUSLE/USLE model. These properties affect the soil erodibility across the different geologic formations and were obtained at a depth of 0-10, 10-20, 20-30cm. The results of the percentage content of fine sand (Fs) obtained across soils of the different geologic formations across the study area ranges from 13.98 to 29.90, Alluvium had the highest percentage fine sand content within the range of 29.83 to 29.90, Ameki ranges from 23.75 to 26.20, Benin had a range of 13.98 to 26.25, Imo had a range of 21.01 to 21.19 and Ogwashi geologic formation had the least percentage content of fine sand with a range of 19.76 to 19.97. The soils of the different geologic formation had percentage silt (Si) content of 2.88 to 20.00. Alluvium had the highest percentage silt of 19.76 to 20.00, Ogwashi had 8.31 to 8.60, Imo had a range of 6.12 to 6.27, Benin had a range of 5.17 to 5.69, , while. Ameki was found to be the lowest with a range of 2.88 to 2.89.

The clay (Cl) content of the soils for the different geologic formations of the study area ranges from 10.14 to 18.48. Alluvium had the highest clay content ranging from 18.43 to 18.48, Imo had a range of16.95 to 17.23, Ogwashi had a range of 13.65 to 13.88, Ameki had a range of 10.16 to 10.45 and Benin had the lowest clay content with a range of 10.14 to 11.04. The organic matter content of the soils across the different geologic formation is given as 3.78 to 7.94, soils derived from Ameki had the highest organic matter content ranging from 3.78 to 7.94, Ogwashi had an organic matter ranging from 5.38 to 7.14, Imo had a range of 6.28 to 6.93, Alluvium had a range of 5.34 to 6.01, while soils from Benin had the lowest organic matter content ranging from 4.5 to 5.82. The soil structure code (Sc) of soils obtained from the different geologic formations ranges from 2 to 4, Alluvium had the lowest structure code of 2, Ameki, Benin and Ogwashi had a structure code of 3, while soils from Imo had the highest structure code of 4. The permeability class of the soils derived from the different geologic formations of the study area ranges from 2 to 3 across the depths sampled, Ameki, Benin, Imo and Ogwashi had a permeability class of 3, while soils obtained from Alluvium had a permeability class of 2.

Table 3.1: Soil Properties That Determine Soil Erodibility (*K Factor*) across the Geologic Formations of Akwa Ibom State.

Eologic Formation	Depth (cm)	Fs (%)	Si (%)	Cl (%)	OM	SC	Perm Class
AL	0 - 10	29.83	20.00	18.43	6.01	2	2.00
AL	10 - 20	29.90	19.83	18.48	5.64	2	2.00
AL	20 - 30	29.89	19.76	18.46	5.34	2	2.00
Mean		29.87	19.86	18.46	5.66	1.77	1.77
SD		0.04	0.12	0.03	0.34	0.02	0.02
CV		0.13	0.62	0.14	5.93	1.13	1.13
AM	0 - 10	26.20	2.88	10.16	7.94	3	3.00
AM	10 - 20	25.28	2.88	10.29	7.49	3	3.00
AM	20 - 30	23.75	2.89	10.45	3.78	3	3.00
Mean		25.08	2.88	10.3	6.40	3	2.69
SD		1.24	0.01	0.15	2.28	0	0.06
CV		4.94	0.20	1.41	35.65	0	2.04
BE	0 - 10	14.27	5.17	11.04	5.82	3	3.00
BE	10 - 20	13.98	5.22	10.14	4.5	3	3.00
BE	20 - 30	26.25	5.69	10.15	5.18	3	3.00
Mean		18.17	5.36	10.44	5.17	3.07	2.87
SD		7.00	0.29	0.52	0.66	0.07	0.12
CV		35.01	1.43	2.58	3.47	0.35	0.60
IM	0 - 10	21.19	6.27	13.88	6.93	4	3.00
IM	10 - 20	21.05	6.21	13.74	6.58	4	3.00
IM	20 - 30	21.01	6.12	13.65	6.28	4	2.00
Mean		21.08	6.2	13.76	6.60	3.77	2.47
SD		0.09	0.08	0.12	0.33	0.02	0.11
CV		0.45	1.22	0.84	4.93	0.53	4.47
OG	0 - 10	19.97	8.60	17.23	7.14	3	3.00
OG	10 - 20	19.85	8.43	17.07	6.76	3	3.00
OG	20 - 30	19.76	8.31	16.95	5.38	3	3.00
Mean		19.86	8.45	17.08	6.43	2.92	2.54
SD		0.11	0.15	0.14	0.93	0.09	0.04
CV		0.31	0.43	0.41	14.41	0.25	0.12

AL: Alluvium, AM: Ameki, BE: Benin, IM: Imo, OG: Ogwashi, Fs: Fine Sand, Si: Silt, Cl: Clay, OM: Organic Matter, SC: Structure Code

3.1.2 Soil Erodibility of Different Geologic Formations of Akwa Ibom State.

Table 3.2 presents the soil erodibility indices of the soils obtained from the different geologic formation across the study area. In Alluvium geologic formation, the *K factor* ranged from 0.141 to 0.159 tons MJ^{-1} hmm^{-1} with an average of 0.150 tons MJ^{-1} hmm^{-1} across the depths. In Ameki, *K factor* ranges from 0.103 to 0.171 tons MJ^{-1}hmm^{-1} with an average of 0.131 tons MJ^{-1} hmm^{-1} across the depths. In Benin, The value of *K* obtained across the depths varies from 0.103 to 0.170 tons MJ^{-1} hmm^{-1} with an average of 0.130 tons MJ^{-1} hmm^{-1} across the depths. In Imo, the value of *K* ranges from 0.135 to 0.155 tons MJ^{-1} hmm^{-1} with an average of 0.147 tons MJ^{-1} hmm^{-1} across the depth. In Ogwashi, *K* ranges from 0.115 to 0.144 tons MJ^{-1} hmm^{-1} with an average of 0.127 tons MJ^{-1} hmm^{-1}across the depth.

Table 3.2: Soil Erodibility of Different Geologic Formation of Akwa Ibom State.

Geologic Formation	Depth (cm)	K (tons MJ^{-1} hmm^{-1})	$K_{Average}$ (tons MJ^{-1} mm^{1})
AL	0 – 10	0.141	
AL	10 – 20	0.151	0. 150
AL	20 – 30	0.159	
AM	0 - 10	0.108	
AM	10 - 20	0.114	0. 131
AM	20 - 30	0.171	
BE	0 - 10	0.103	0. 130
BE	10 - 20	0.117	
BE	20 - 30	0.170	
IM	0 - 10	0.150	0. 147
IM	10 - 20	0.155	
IM	20 - 30	0.135	
OG	0 - 10	0.115	0. 127
OG	10 - 20	0.121	
OG	20 - 30	0.144	

AL: Alluvium, AM: Ameki, BE: Benin, IM: Imo, OG: Ogwashi, K: Soil Erodibility.

3.2 Discussions

3.2.1 Implication of Geologic Formation on the Selected Soil Properties that affects Soil Erodibility

From the results obtained in Table 3.1, it shows that the properties of the soils across the study area differ slightly across the selected depth and the geologic formations which are similar to the findings of [12, 25]. The slight variation is based on the geology of the study area which are acted upon by similar soil forming properties such as climate, vegetation, microorganisms, plants and time, as such the similarities between the different geologic formations. A similar finding was made by [24]. The result of fine sand across the depth and geologic formation of the study area shows that the study area is basically sandy soil [25, 32]. Alluvium geologic formation had the highest value of fine sand and Silt content which shows its mode of formation and activities on the flood plain [23]. Ameki had the lowest silt content which shows that the geologic formation is basically sandstone [25].

Benin, Imo and Ogwashi had similar range. Clay content occurs in all the geologic formation, which shows that clay serves as a binding factor to soil particles [13, 31]. Organic matter is a function of the land use pattern [13]. Benin formation recorded a low value of OM, while the remaining geologic formation had a high value of OM. The exploitation, over cropping and continual usage has caused the reduction in the organic of the soil [13, 31]. The soil structural code across the different geologic formation of the study shows that soils within the study area are fine granular, medium, coarse granular blocky, platy, massive. This shows that soils within the study area are well aerated and sandy nature across the geologic formation. While the permeability class shows that soils within the study area ranges from slow to rapid. This result shows the nature of the soil and its arrangement for easy passage of water which aids in reducing runoff and increase percolation of water.

3.2.2 Soil Erodibility K Factor across the Different Geologic Formation

Table 3.2 shows that the erodibility of the soils across the depth of the geologic formations differs. The *K* values obtained shows that soils within the study area are easily erodible [31]. According to the standard erodibility indices, the average *K* value of the soils obtained from the different geologic formation signifies that the soils falls under group II as grouped by [6] which shows that the soils within the study area are well grained soils in sandy environment. The soil erodibility index across the depths of the geologic formation shows that the soils erode faster from the top to the bottom [13]. However, the average erodibility indices are similar across the geologic formations of the study area with a value ranging from 0.127 to 0.150 tons MJ^{-1} hmm^{-1} across the geologic formations. Fig. 3.1 shows the spatial distribution of soil erodibility *K factor* across the geologic formations of the study area.

4.0 CONCLUSION

Soil erosion is a serious environmental concern that has raised concern for various studies across the world. Soil erodibility has been modeled for effective soil conservation. Fine sand, silt, clay, organic matter, soil structure code and permeability class has been used to model the erodibility of soil. The study shows that geologic formation has an effect on the erodibility of the soils formed, and the erodibility of the soils increases with depth. The average soil erodibility indices obtained in the study area shows that the soils obtained from the different geologic formations of the study area are vulnerable to the erosive power of rainfall as shown on Figure 2.

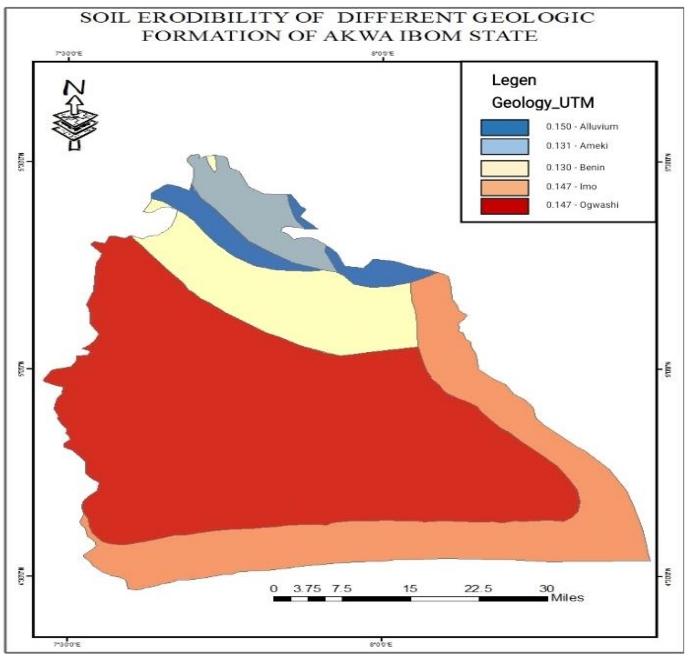

Figure 2: Spatial Distribution of *K* Factor across the Different Geologic Formations of Akwa Ibom State

Soils of the Benin geologic formations are most susceptible soil to erosion, followed by Ogwashi, Imo, Alluvium and Ameki being the least vulnerable within the study area.

Therefore, adequate protection measures should be taken for soil erosion control through land and crop management practices.

REFERENCES

[1] Schoonover, J. E. and Crim, J. F. "An Introduction to Soil Concepts and the Role of Soils in Watershed Management". *Journal of Contemporary Water Research & Education*. 154, 2015, pp.21-47.

[2] Adimassu, Z., Mekonnen, K., Yirga, C. and Kessler, A. "Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia". *Land Degradation & Development*, 25, 2014, pp.554-564.

[3] Angassa, A. "Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia". *Land Degradation & Development*, 25, 2014, pp.438–451

[4] Ajibade, F. O., Nwogwu, N. A., Adelodun, B., Abdulkadir, T. S., Ajibade, T. F., Lasisi, K. H., Fadugba, O. G., Owolabi, T. A. and Olajire, O. O. "Application of RUSLE integrated with GIS and remote sensing techniques to assess soil erosion in Anambra State, South-Eastern Nigeria". *Journal of Water and Climate Change*, 11(1), 2020, pp.407-422.

[5] Kalhoro, S. A., Xu, X., Chen, W., Hua, R., Raza, S. and Ding, K. "Effects of Different Land-Use Systems on Soil Aggregates: A Case Study of the Loess Plateau (Northern China)". *Sustainability*. 9, 2017, pp.1-16.

[6] Wischmeier, W. H. and Smith, D. D. *Predicting rainfall erosion losses – A guide to conservation planning*. Agriculture handbook no. 537. Washington, D. C., USA: Department of Agriculture, 1978.

[7] Sebastian, A., Bora, L., Steve, L. and Bernd, H. "Conventional and Organic Farming: soil erosion and conservation potential for row cultivation". *Geoderma* 12, 2014, pp.23-32.

[8] Gunawan, G., Dwita, S., Herr, S. and Sulostiowemi, W. "Soil Erosion Estimation Based on GIS and Remote Sensing for Supporting Integrated Water Resources Conservation Management". *International Journal of Technology*, 2 (3), 2013, pp.147-156.

[9] Okorafor, O. O., Akinbile C. O., Adeyemo A. J. "Determination of Soils Erodibility Factor (K) for Selected Sites in Imo State, Nigeria" *Resources and Environment*, 8(1), 2018, pp.6-13

[10] Novara, A., Keestra, S., Cerda, A., Pereira, P., Gristina, l. "Understanding the role of soil erosion on co-2- c loss using 13c isotropic signatures in abandoned Mediterranean agricultural land". *Science of Total Environment*, 550, 2006, pp.330-336

[11] Shougang, Z., Na, L. and Ruishe, Q. "The Application and Study of GIS in Soil Erosion Model". *Advances in Sciences and Engineering*, 6(2), 2014, pp.31-34.

[12] Fetene, E. M. and Amera, M. Y. "The Effects of Land Use Types and Soil Depth On Soil Properties Of Agedit Watershed, Northwest Ethiopia". *Ethiopian Journal of Science and Technology,* 11(1), 2018, pp.39-56.

[13] Ajibola, Y. H., Gbenro, O. P. and Khadijah, L. A. "Land use effects on soil erodibility and hydraulic conductivity in Akure, Nigeria". *African Journal* of *Agricultural Research*, 13(7), 2018, pp. 329-337.

[14] Zhang, K. L., Shu, A. P., Xu, X. L., Young, Q. K. and Yu, B. "Soil Erodibility and Its Estimation for Agricultural Soils in China*"*. Journal of Arid Environments, 1, 2008, pp.1-10.

[15] Shi, Z. H., Fang, N. F., Wu, L., Wang, L., Yue, B. J. and Wu, G. L. "Soil erosion processes and sediment sorting associated with transport mechanisms on steep slopes". *Journal of Hydrology*, 2012, pp.123–130.

[16] Abidin, R. Z., Sulaiman, M. S. and Yusoff, N. "Erosion risk assessment: A case study of the Langat River bank in Malaysia". *International Soil and Water Conservation Research*, 5, 2017, pp. 26-35.

[17] Dorici, M., Costa, C. W., Prado de Moraes, M. C., Piga, F. G., Reinaldo Lorandi, R., Augusto de Lollo, J. and Moschini, L. E. "Accelerated erosion in a watershed in the southeastern region of Brazil". *Environmental Earth Sciences*, 75, 2016, pp.1301.

[18] Zimmermann, A., Schinn, D. S., Francke, T., Elsenbeer, H. and Zimmermann, B. "Uncovering patterns of near-surface saturated hydraulic conductivity in an overland flow-controlled landscape". *Geoderma*, 195&196, 2013, pp. 1–11.

[19] Reichert, J. M., Norton, L. D. and Favaretto, N. "Settling velocity of soil aggregates, aggregate stability, and interrill erodibility of ten clays soils", *Soil erosion research* for the 21st century, pp.529–532, 2001.

[20] Reichert, J.M., Norton, L.D. and Favaretto, N. "Settling Velocity of Soil Aggregates, Aggregate Stability, and Interrill Erodibility of Ten Clay Soils", 2001.

[21] Uzoma, K. C. and Onwuka, B. M. "Variations in Aggregate Stability and selected Soil Chemical Properties Under Different Land Use Systems in Ikpe Ikot Nkon, Southeastern, Nigeria". *Agricultural Research & Technology: Open Access Journal*, 17(5), 2018, pp.556036.

[22] Durigan, M. R., Cherubin, M. R., de Camargo, P. B., Ferreira, J. N., Berenguer, E., Gardner, T. A., Barlow, J., Dias, C. T. S., Signor, D. and Junior, R. C. O. "Soil Organic Matter Responses to Anthropogenic Forest Disturbance and Land Use Change in the Eastern Brazilian Amazon". *Sustainability*, 9, 2017, pp.379.

[23] Ihem, E. E., Nkwopara, U. N., Ndukwu, B. N. and Onwudike, S. U. "Macro-Aggregate Stability of Soils under Selected Parent Materials in Imo State, Nigeria". *Int'l Journal of Agric. and Rural Dev.* 20(2), 2017, pp.3121.

[24] Udoh, B. T. and Akpan, U. S. "Characteristics and Classification of Soils as Influenced by Parent Materials in South-Eastern Nigeria". *Nigerian Journal of Agriculture, Food and Environment*. 11(3), 2015, pp.102-108.

[25] Ogbonnaya, I. and Johnbosco, C. E. "The Characteristics and the Erodibility Potentials of Soils from Different Geologic Formations in Anambra State, Southeastern Nigeria". *Journal Geological Society of India*, 92, 2018, pp.471-478.

[26] Ogban, P. I. "Structural Stability and Erodibility in Soils Formed on Different Parent Materials in Southern Nigeria". *Nigerian Journal of Agriculture, Food and Environment*. 13(4), 2017, pp. 63-74.

[27] Obeta, I. N. and Adewumi, J. K. "Soil Loss in Samaru Zaria Nigeria: A Comparison of Wepp and Eurosem Models" *Nigerian Journal of Technology (NIJOTECH)*, 32(2), 2013, pp. 197-202.

[28] Madubuike, C.N. and Chukwuma, G.O. "Soil Groups Relative Susceptibility to Erosion In Parts Of South-Eastern". *Nigeria Nigerian Journal of Technology*, 24(1), 2005, pp. 94-99.

[29] Day, P. R. "Particle fractionation and particle size analysis". *Chap 43 in method of soil analysis, Part 1. Black, C. A (ed). American society of Agronomy, Madison, Development and Production, Journal of the Indian Association of Sedimentologists*, 22, 1965, pp 545–567.

[30] Emeka-Chris, C. C. "Determination of Erodibility Index (K) Of Soil in Michael Okpara University of Agriculture, Umudike". *The International Journal of Engineering and Science* (*IJES*), 3(12), 2014, pp 30-38.

[31] Black, C. A. *Method of soil analysis*; American society of Agronomy, Madison WI., pp.978, 1965.

[32] Udoumoh, U., Manuel, F., Ehiomogue, P., Ekpo, A. and Unyime, A. "Estimating Factors in Soils of Uyo, South-South, Nigeria". *International Journal of Current Research and Academic Review*, 6(11), 2018, pp. 23-38.

[33] Okoji, and Moses, M. A. J. "Adoption of Agroforestry for Soil Conservation in Akwa Ibom State, Nigeria". *Journal of Sustainable Agriculture*, 13(1), 1998, pp. 5-13.