International Journal of Modern Agriculture, Volume 10, No.2, 2021
ISSN: 2305-7246

An Investigation into some Soil Indices as Indicators of High Soil Erodibility in Anambra State Southeastern, Nigeria

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Abstract

An Investigation into some soil indices as indicators of high soil erodibility in Anambra State Southeastern, Nigeria looks at the phenomenon from the soil indices perspective. The study identified some soil variables through the analysis of soil samples extracted from different selected areas of the study and their various levels of predictions and contributions to soil erodibility in the study area. The variables are fine sand, coarse soil, silt and clay (particle size distributions), mean weighted diameter (MWD), aggregate stability, soil porosity, organic matter content, Atterberg limits, among others. Primary and secondary data were used for the study, which include geo-physical field visit, measurements, surveys and observations; Satellite imagries, topographic maps, published and non published literatures. Regression analysis was done in SPSS version 25 and the result shows that the model is significant at 0.018 and predicts their various contributions to the dependent variable. The study concludes that the soil analysis result shows the soils across the area to be are highly erodible and prone to erosivity at the dispersion rate (DR) value ranging from 0.429% to 0.865%, assuming soils with a dispersion rate greater than 0.15% are erodible in nature. Soils with low organic matter content are more vulnerable or susceptible to high soil erosivity. Based on the fact that organic matter increases soil stability, the study therefore recommends mulching, cover cropping and re-vegetation of all available bare spaces in the study area; adding organic matter content to the soil which will increase bonding and reduce the direct hitting of raindrop on the soil surfaces thereby reduces the dislodgement of these soils.

Keywords: Investigation, Soil Indices, Indicators, Erodibility, Anambra State

Introduction

Background of the Study

Susceptibility to soil erosion is termed soil erodibility (Salako, 2003). Susceptibility and map analysis are prerequisites to sustainable land use and management, and erosion prevention. Soil erosion is a natural hazard and physical event that has the potential of causing severe damage to man and the environment. Its impact is very devastating, it causes the destruction of farm lands, civil engineering constructions and cutting of underground pipelines and cables that are uncovered by deep gullying (Emeh &Igwe, 2018).

Soil erosion is related with over 85% land use damage in the world, leading to about 17% shortage in food crop production (Olderman, Engelen & Pulles, 1990). To exactly assess the soil erosion is still challenging, partly due to the diverse factors affecting the estimation of soil erosion especially due to the anthropogenic activities. For purpose of this research work, the operational definition to be used is that soil erosion is a geomorphological process where soil and loosed rock materials are carried away transported and deposited by running water elsewhere. There are other natural processes like atmospheric, hydrologic, geologic and biological, and some anthropogenic processes such as regard to technological urbanization like road construction, poorly constructed and maintained drainage facilities, deforestation, among others, as common agents causing the various types of natural hazards that are negatively affects our environment (Areola & Ofomata.1978; Okoyeh, et al., 2014). The level of impact caused by natural disaster on our environment man inclusive, are dependent on the place, the phenomenon strength, human vulnerability and susceptibility in such areas (Areola & Ofomata.1978; Alcantara-Ayala, 2002).

Several erosion types exists in this research area including rill, splash and gully as enunciated by Areola & Ofomata (1978), Ofomata (1985) and other Scholars like Ologe (1971, 1973); Jeje (1978); Sada & Omuta (1979), and Ndulue, et al., (2021) carried out related studies in different parts of Nigeria on soil erosion. Gully erosion is the most pronounced in Anambra State, Southeastern Nigeria which is our study area. Erosion sites are scattered all over the study area including the infamous Agulu-Nanka erosion sites, others are in Awka, Okija, Ekwulobia, Oraukwu, Neni, Adazi-Nnukwu, Nimo, Ukpo, Abagana, Alor, Okpuno, Ojoto, to mention but a few of them (Plate A and B).

The process of soil erosion has to do with the interactions of many diverse and complex biophysical and anthropogenic factors including soil components, slope and gradient, climate and weather elements, land use and other land management practices (Emeh &Igwe, 2018). These aforementioned factors vary in both space and time from one place location to another (Shi, Li, Huang, & Liao, 2013). Shakirudeen, Abiodun, Igwetu & Olubunmi (2018) had it that soil erosion creates serious implication on the quality of water especially in the downstream siltation, with great adverse effect on both biodiversity and ecosystem services which include domestic as well as industrial usage. The study of soil susceptibility to erosion will consider the factors of soil erosion both static and dynamic factors which are slope, land use and land cover, soil erodibility and dynamic factors like Land Surface Temperature (LST), Stream Moisture Index (SMI) and rainfall erosivity.

Soil erodibility can depend also on the soil texture, soil aggregate stability, soil shear strength, infilteration capacity, organic and chemical contents of the soil (Goudie & Kuthyari, 1990; Nwunonwo, 2013; Ndukwe, Okeke, Nwosu, Ibe, Ndukwu & Ugwoti, 2013; Jafar-Zadeh, Garosi, Oustan & Ahmadi, 2014). The thrust of this research is on soil susceptibility to erosion hazards in Anambra State, Southeastern Nigeria based on the soil types and composition.

Plate A: Gully Erosion Site at Behind Ekwueme Square Awka
Source: Authors Fieldwork, (2021)

Plate B: Gully Erosion Site at Ojoto Obofia, Idemili South L.G.A
Source: Authors Fieldwork, (2021)

Study Area

Anambra state is located in southeastern Nigeria, lies between latitudes 6^{o}00′ and 7^{o}00″ N and longitudes of 6^{o}45′ and 7^{o}20′ E with an area coverage of about 4844km^2 (figure 1).

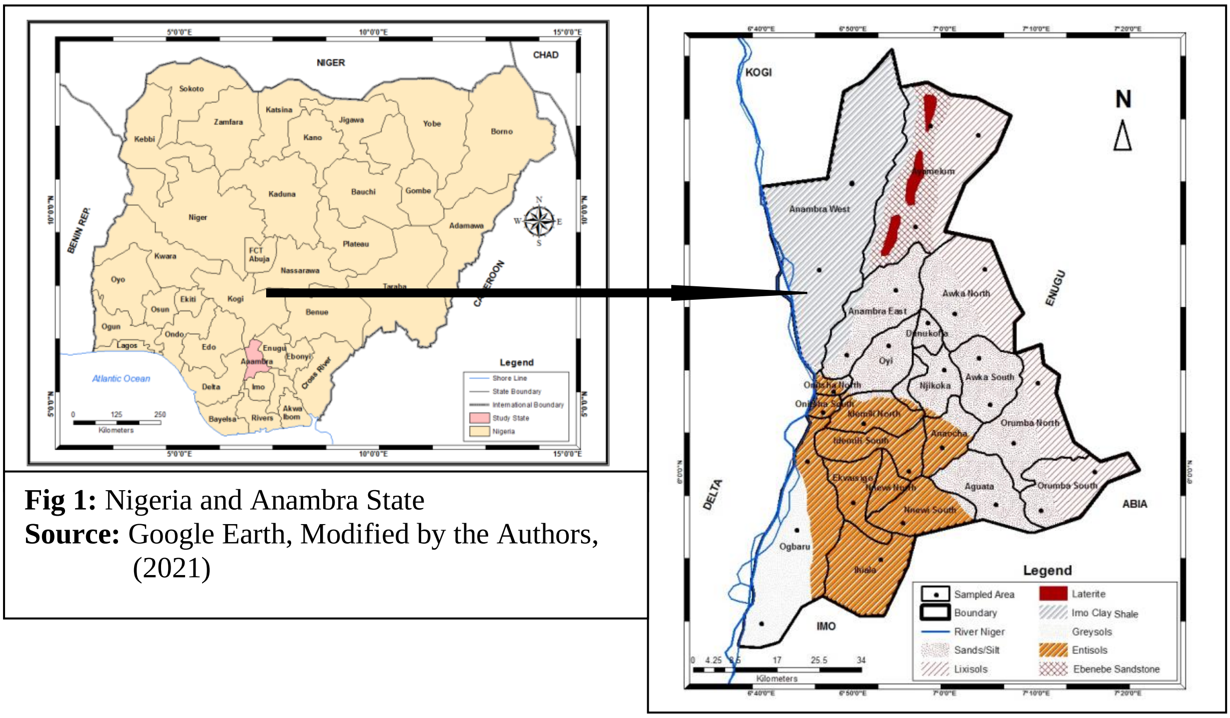

Fig 1: Nigeria and Anambra State
Source: Google Earth, Modified by the Authors, (2021)

It is within the humid tropical rainforest zone of West Africa. Human activities in the state have led to rapid urbanization, infrastructural development like expansion of existing roads and construction of new ones and other forms of primary extractive activities like deforestation and quarrying that have led to the loss of the original ecosystem and biodiversity (Igwe & Egbueri 2018).

The study area experiences two distinct seasons. The rainy season starts from April and ends in October and the dry season starts from November and ends in March respectively. Climate change has exacerbated more problems in area of soil erosion in addition to already anthropogenic inflicted problems on land use (Farauta, et. al., 2012; Igwe & Egbueri 2018).

Anambra State landform is made up of topographically elevated Awka-Orlu Upland and the low-lying plains of the Anambra River Basin. The plains of Anabra River Basin are found at the greater part of the western, northern and northeastern part of the state (Igwe & Egbueri 2018). The Basin is as a result of tectonic disturbances formed during the Santonian upliftment of Albian sediments in the trough of lower Benue. The Formations here include the old Cretaceous deltas with the Nkporo Shale, the Mamu Formation, the Ajali Sandstone and the Nsukka formation of mainly the sedimentary rock depositions (Okoyeh et al, 2014; Igwe & Egbueri 2018 and Ocheli, Ogbe, and Aigbadon, 2021).

MATERIALS AND METHODS

Research Design

This research used both primary and secondary data. The primary data involved frequent geo-physical field visit, measurements, surveys and observations. Global Positioning System (GPS) was used for ground truth verification and soil samples collection for the extraction of soil properties needed for analysis. Secondary data used/consulted include Satellite images, aerial photo, topographic maps, meteorological and population data collected from different governmental and non-governmental organizations, and other published and non published literatures.

Data Collection

Data utilized for this study include: Soil map of Anambra State, administrative map of Nigeria, digital elevation model (DEM), Soil samples, and Landsat images. Multi Staged Random Sampling was used. The study area was delineated into 30 distinct sub-zones to understand the complex nature of the area's landscape. The study area is made up twenty one Local Government Areas and divided politically into 3 Senatorial zones. 30 soil samples were collected randomly in at least every local government area of the state, while also putting into considerations, the different sizes of the senatorial zones. 12 samples were collected from Anambra North (largest land mass), 10 from Anambra Central (second largest land mass) and 8 from Anambra South (smallest land mass) Senatorial Zones respectively. The samples were tested for particle size distributions, while evaluating for erodibility we tested for mean weighted diameter (MWD), aggregate stability, soil porosity, organic matter content, Atterberg limits, among others. These laboratory tests were carried out at the Department of Soil Science, Faculty of Agriculture, University of Nigeria, Nsukka. The locations of the sampled points were identified with the use of global positioning system (GPS) and are represented in the map (figure 1). The soil results were subjected to statistical analysis (Regression) using the statistical package for the social sciences (SPSS) soft ware version 25 to determine and predict the contribution of the various identified soil parameters that can induce or trigger erodibility. The equation is stated thus:

$Y = b_o + b_1X_1 + b_2X_2 \ldots\ldots b_nX_n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ *Eqn (1)*

Where:

Y = Dependent Variable

b_o = Intercept

b_1 = Beta Coefficient

X_1= Independent Variables

DATA ANALYSIS AND DISCUSSION

Soil Data Result

Thirty (30) soil samples were collected and analyzed for particle sizes, soil moisture content and soil dispersion rate among others as discussed below:

Soil Particle Size Distribution (SPSD): The soils across the study area showed that they are predominantly sandy (57% to 89 % sand) with very low clay (8% to 23%) and silt (3% to 28%) contents. It has been reported that soils with more sand composition than clay at the topsoil promote runoff, and are hence erodible (Toy et al., 2002). Evans (1980) also reported that soils with clay contents that is within 9% and 30% are highly erodible and are the most susceptible to erosion. This could explain why the soils in most of the locations in study area are highly erodible and susceptible to water erosion. Generally, clay minerals provide the required bonding within and between the various soil components, which results in the forming of more aggregates stability that reduces soil susceptibility to erosion (Emeh &Igwe, 2018). From our results, the low clay contents of the soils shows reduced tendency of soil particles to bind and form aggregates that can resist the tearing force of rain drops and run offs, thereby making the soil susceptible to soil erosion. Zhang, et al (2004) discovered that there is a significant relation between soil erodibility and clay content, that soils with higher clay content were less susceptible to erosion and vice versa. According to Morgan (1996), heavy clay soils are less erodible compared to light sandy and loamy sands soils. In the same vein, soils with higher silt content were more erodible and this may be true for soils in Ayamelum L.G.A of Anambra state with high silt content of 28%.

Soil Dispersion Rate (DR): Values ranges from 0.429% to 0.865%. The soil dispersion rate (SDR) being an index from the measurement of water dispersible silt, clay and their corresponding forms used to predict soil erosion by water (Igwe and Udegbunam, 2008). According to Igwe and Udegbunam (2008), the ability of the soil to disperse increased with increase in soil dispersion rate. Igwe (2003) has shown that soils with high soil dispersion rate have the potential of eroding more and easily too than soil with lower soil dispersion rate. Parwada and Van Tol (2016) records that the soil dispersion rate was positive and significantly correlated with soil loss indicating that as the soil dispersion rate increases, the rate of soil loss also increases. Middleton (1930), affirmed that soils with dispersion rate greater than 0.15 are erodible in nature, hence the ability of the soil to disperse (dislodge) which leads to soil loss. This result, therefore, indicates that the soils across the study area are highly erodible with high erosivity rate.

Soil Moisture or Water Content (SMC/SWC): Soil moisture or water content of the soils ranges from low < 15% to high >30%. It is important to note that high or very low moisture content leads to high erosion rates (Larionov, et al., 2014). Generally, moderate moisture content has a positive impact on the resistance of finer soils to erosivity and negatively effects coarse-grained soils (Shainberg, et al., 1997). According to Zhang, et al. (2019), high soil water content causes ionic bonds in fine grained soil to break which results in slaking for coarse grained soil. On the contrary, soils with moderate water content are less likely to slake in fine grained soil rather it attracts more particle deposition and cementation for coarse grained soil. However, many researchers affirmed that moderate soil moisture content may favour rapid bonding and strengthening of soil particles (Grissinger, 1966; Hanson & Cook, 1999; Sheinberg, et al., 1997). Larionov, et al. (2014) reported the lowest erosivity rate for a heavy loamy chernozem with an initial water content of 22% – 24%.

Saturated Hydraulic Conductivity (Ksat): The saturated hydraulic conductivity (Ksat) of the soils vary from rapid (12.7 - 25.4 cm hr^{-1}) to very rapid (>25.4 $cmhr^{-1}$) in most of the locations investigated except at Omor and Umumbo in Ayamelum Local Government Areas, that were within the moderately rapid (6.3 - 12.7 cm hr^{-1}) range. Saturated hydraulic conductivity, as a measure of soil permeability is a major factor of soil hydraulic property that affects water flow and the movement of dissolved substances (Zeleke & Si, 2005). Generally, soils with low Ksat in the topsoil layer may not support water movement throughout the soil layers, which result in a large amount of runoff and soil loss (Pons, 2006).

Soil Bulk Density (SBD): Soil bulk density (SBD) which is a measure of soil compaction is one of the main soil physical properties that have been used to indicate soil erodibility. The SBD of the soils ranges from < 1.4 g cm^{-3} (less compaction) in few locations to > 1.5 g cm^{-3} (highly compacted) in most of the locations. Highly compacted soils reduce soil permeability and limit water inflow into the soil layers, resulting in increased runoff volume and soil loss. Evrendilek, et al (2004) had reported that an increase in topsoil bulk density by 10.5% increased soil erodibility by 46.2%. The high SBD obtained in this study could be attributed to low organic carbon contents of the soils.

Soil porosity (SP): Soil porosity (SP) which is the measure of the available pore spaces for water inflow and storage in soil were mostly high ranging from 38.49% – 55.66%. Such high SP will enhance water inflow into the soil layers and consequently reduce surface flow and soil loss. This further confirmed the reports of Lima et al. (2019), that soil erodibility has a negative correlation with soil porosity.

Mean Weighted Diameter (WMD): MWD is the index that characterizes the soil structure macro aggregates by collapsing the aggregate sizes and class distribution into one. Parwada & Van Tol (2016) reported significant negative correlation between soil loss and MWD indicating that as there is an increase in MWD, the rate of soil loss decreases. Most of the MWD values obtained across the study locations are less than 2 mm, which are considered to be “unstable” based on the classification of Le Bissonnais, et al. (2005). These types of soils would be eroded very easily.

Aggregate Stability (AS): The result shows that the aggregate stability (AS) varied from low (below 20 %) to moderate (20% - 55%). This implies that these soils are made up of mostly unstable aggregates which breakdown resulting to the pore collapse and produces finer particles and micro aggregates that contribute immensely to soil erosivity (Emeh &Igwe, 2018). On the contrary, Toy et al. (2002) discovered that soils with aggregate stability have the capacity to resist the direct impact of raindrop, and protect the soil even as runoff occurs. Similarly, Troeh (1980) noted that stable aggregates increase the soil resistance to detachment and transportation agents and in addition, it can improve soil permeability. Wang et al. (2016) and Singh & Khera (2008) found that water stable aggregates (WSA) > 0.50 mm (AS) was significantly negatively correlated with soil erodibility. Generally, soil erodibility decreases with increasing aggregate stability which is related to the organic carbon content, clay content and infiltration capacity (Hudson, 1995; Morgan, 1996). The poor or moderate aggregate stability of the soils can be linked to the low clay and organic carbon contents of the soils. Parwada & Van Tol (2016) had reported that there is a positive linear relationship between aggregate stability and soil organic carbon (SOC). Similarly, our result support the findings by Parfitt, et al. (2002) who also reported that there is a positive correlation between aggregate stability and clay content in soils.

Atterberg Limits: Atterberg limits are the level at which water define the transition of a given soil material from solid to plastic and to liquid states. The test is carried out to cohesive soils with a noticeable silt or clay content, and cannot be done on either sands or silts of much sand content of fraction (Bovis, 1978). Plastic limit indicates where moisture added to clay causes change from a solid to a clay paste (flexible) state while the liquid limit is the amount of moisture that causes clay to change from a solid to a clay paste or viscous fluid state, while the plasticity index (PI), is the difference between plastic limit (PL) and liquid limit (LL) (Reddy, 1999). PI from the soil samples ranges from 3.92% - 20.88% while the plastic limit (PL) ranges from 10.23% - 31.98%. Similarly, the liquid limit (LL) ranges from 15.49% – 43.00%. Generally, the PI, PL and LL are low and could be attributed to the clay type, which is mostly Kaolinite clays, low organic matter, and clay contents of the soils. Zhuang, et al. (2014) also reported that PI, PL, and LL depend on soil properties such as clay and organic matter. Zhuang, et al. (2014) and Deng, et al. (2017) opined that PL and LL had significant and positive correlation with organic matter and by implication; they increase with increasing organic matter content. It has been reported that highly plastic soils generally showed more resistance i.e. less erodible to erosion as compared with low plasticity soils (NASME, 2019). In a similar vein, plastic soils tend to be less erodible than non-plastic soils. When there is an increase in plasticity index (PI), there tend to be an increase in resistance to soil erosion (NASME, 2019). Similarly, as plastic limit (PL) increases, there will be an increase in resistance to soil erosion (NASME, 2019)(table 1).

Soil Organic Carbon (SOC): The chemical composition of soil has an impact on the erodibility of both fine- and coarse-textured soils. The soil result shows that the soils have less than 2% of soil organic carbon content across the sampled locations. The average soil organic carbon content of the soil sampled ranges from 0.17% to 1.81%. According to Evans (1980), soils with less than 3.5% organic carbon content i.e. 2% soil organic carbon content can be considered erodible (Emeh &Igwe, 2018).

Soil Organic Matter (SOM): Soils with soil organic matter content that are very low are susceptible to soil erosion (Brady and Weil 2002), as soil organic matter increases, there will be stability of the soils. Kemper and

Koch (1966) and Greenland et al. (1975) opined that soil organic matter content critical level is at 2%. Critical level below the suggested level will lead to soil structural stability decline (Emeh &Igwe, 2018). Such decline in structural stability increases the susceptibility of the soils to erosion. The poor organic matter contents of these soils makes them to become loose and consequently slides may occur under heavy rainfall that may easily detach the soils.

TABLE 1: Soils Plasticity Index and Levels of Erodibility

Plasticity Index (%)	Soil Type	Level of Plasticity	Level of Cohesiveness	Erodibility Rate
0	Sand	Non Plasticity	Low/Non Cohesive	Highly Erodible
Less than 7	Silt	Low plasticity	Partially Cohesive	Partially Erodible
7 -17	Silt clay	Medium plasticity	Mildly Cohesive	Mildly Erodible
Greater than 17	Clay	High plasticity	Highly Cohesive	Low/Non Erodible

Source: Surendra, R. & Sanjeev, K.B. (2017), Modified by the Authors, (2021)

TABLE 2: Model Summary Output

Model Summary										
					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.761	.580	.391	.10547	.580	3.066	9	20	.018	1.556
a. Predictors: (Constant), SOM (X_{15}), SMC (X_5), MWD (mm) (X_{12}), Silt (X_3), SP (X_8), Ksat (X_6), Clay (X_4), FS (X_1), AS (X_{13})										
b. Dependent Variable: DR (Y)										

Source: SPSS Output

Table 2 above shows the correlation coefficient (R) at .761, which implies that the dependent variables have positive and high correlation. The coefficient of the determination (R^2) is at .580, meaning the percentage prediction of the independent variables to the dependent variable. The independent variables predicted 58.0% of the dependent variable.

TABLE 3: ANOVA

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.307	9	.034	3.066	.018
	Residual	.222	20	.011		
	Total	.529	29			
a. Dependent Variable: DR (Y)						

b. Predictors: (Constant), SOM (X_{15}), SMC (X_5), MWD (mm) (X_{12}), Silt (X_3), SP (X_8), Ksat (X_6), Clay (X_4), FS (X_1), AS (X_{13})

Source: SPSS Output

The ANOVA table shows that the level of significance is 0.018 which is less than 0.05, this mean that the coefficient of determination (R^2) is significant and that the percentage prediction made by the independent variables to the dependent variable are not by chance.

It is important to note here that soil bulk density (X_7) and Atterberg limits (LL (X_9) ,PL (X_{10}) and PI (X_{11})) and soil organic carbon (X_{14})were removed from the statistical analysis result as show in table 3 below because soil bulk density (SBD) has a high multicollinearity and is inversely correlated with Soil porosity (X_8), while Atterberg limits have high multicollinearity with clay (X_4) and soil organic carbon (X_{14}) and also with soil organic matter (X_{15}). Hence the removal of soil bulk density, Atterberg limits and soil organic carbon from the statistical analysis. Coarse sand (X_2) which was among the variables to be analyzed was excluded by the software during analysis.

TABLE 3: Coefficient of Intercept and Independent Variables

Coefficients													
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.510	.363		1.407	.175	-.246	1.266					
	FS (X_1)	.005	.002	.442	2.130	.046	.000	.010	.423	.430	.309	.487	2.052
	Silt (X_3)	-.006	.005	-.233	-1.209	.241	-.017	.005	-.472	-.261	-.175	.566	1.768
	Clay (X_4)	-.018	.007	-.472	-2.426	.025	-.033	-.002	-.572	-.477	-.352	.556	1.800
	SMC (X_5)	.002	.003	.085	.518	.610	-.005	.008	-.221	.115	.075	.783	1.278
	Ksat (X_6)	.001	.002	.133	.680	.504	-.003	.006	.356	.150	.099	.552	1.812
	SP (X_8)	.003	.007	.069	.366	.718	-.012	.018	-.399	.082	.053	.588	1.701
	MWD (X_{12})	.029	.081	.086	.360	.723	-.140	.198	.217	.080	.052	.370	2.706
	AS (X_{13})	-.001	.003	-.069	-.296	.771	-.007	.005	-.002	-.066	-.043	.386	2.588
	SOM (X_{15})	.008	.048	.038	.166	.870	-.093	.109	-.179	.037	.024	.401	2.494
a. Dependent Variable: DR (Y)													

Source: SPSS Output

The coefficient table above shows the individual contribution of the independent variables to the dependent variable and is used to explain the multiple linear regression equation which is thus:

$Y = b_o + b_1X_1 + b_2X_2 \ldots\ldots b_nX_n$…………………………………………………….………*Eqn (1)*

Where:

Y = Dependent Variable

b_o = Intercept

b_1 = Beta Coefficient

X_1= Independent Variables

The multiple linear regression equation will be thus:

$$SDR(Y)=b_0+FS(X_1)+Silt(X_3)+Clay(X_4)+SMC(X_5)+Ksat(X_6)+SP(X_8)+MWD(X_{12})+AS(X_{13})+SOM(X_{15})$$

The dependent variable (Y) is the Soil Dispersion Rate (SDR) and the independent variables are fine sand (X_1), silt (X_3) and clay (X_4) (PSD), From the above result, the correlation coefficient (R) is .761 which shows strong positive correlation between Soil Dispersion Rate (SDR) and PSD, SMC (X_5), Ksat (X_6), SP (X_8), MWD (X_{12}), AS (X_{13}), SOM (X_{15}). The coefficient of the determination (Adjusted R Square) is 0.391, which is 39.1% of the variation of Soil Dispersion Rate (SDR) around the mean explained by the independent variables. Based on this result, the multiple linear regression equation will be thus:

Soil Dispersion Rate (SDR) (Y) = 0.510 + 0.005 (X_1) - 0.006 (X_3) - 0.018 (X_4) + 0.002 (X_5) + 0.001 (X_6) + 0.003 (X_8) + 0.029 (X_{12}) - 0.001(X_{13}) + 0.008 (X_{15}).

The linear equation above means that the value .510 is the base constant; that is, the value of Soil Dispersion Rate (SDR) before the effect of changes in any of fine sand, silt, clay, SMC, Ksat, SP, MWD, AS, SOM begins to occur. The regression equation summarizes the mathematical relationship between the dependent variable (Y) and all the other independent variables X^1, X^2 …X_n). Therefore, the coefficient of X_1 (0.005), means that for every unit increase in fine sand, there will be an increase in Soil Dispersion Rate (SDR) by 0.005, holding all the other independent variables (silt, clay, SMC, Ksat, SP, MWD, AS, SOM) constant. This means that if there is more of fine sand in the study area, soil dispersion rate will be high and subsequently high erosivity. The coefficient of X_3 (- .006) means that for every unit increase in silt, there will be a decrease of Soil Dispersion Rate (SDR) by .006, holding all the other independent variables (fine sand, clay, SMC, Ksat, SP, MWD, AS, SOM) constant. This means that if there is more of silt in the study area, soil dispersion rate will be low because of binding nature of silt and subsequently low erosivity. The coefficient of X_4 (- .018) means that for every unit increase in clay, there will be a decrease in Soil Dispersion Rate (SDR) by .018, holding all the other independent variables (fine sand, silt, SMC, Ksat, SP, MWD, AS, SOM) constant. This means that if there is more of clay in the study area, soil dispersion rate will be reduced because of bonding nature associated with clay and therefore low erosivity. The coefficient of X_5 (0.002) means that for every unit increase in SMC, there will be an increase in Soil Dispersion Rate (SDR) by 0.002, holding all the other independent variables (fine sand, silt, clay, Ksat, SP, MWD, AS, SOM) are constant. This means that if there is increased soil moisture content in the soils of the study area, soil dispersion rate will increase as moisture softens the soil and make it easily breakable thereby increases erosivity. The coefficient of X_6 (0.001) means that for every unit increase in Ksat, there will be an increase in Soil Dispersion Rate (SDR) by 0.001, holding all the other independent variables (fine sand, silt, clay, SMC, SP, MWD, AS, SOM) constant. This means that if there is increased saturated hydraulic conductivity (Ksat) of the soils in the study area, soil dispersion rate will increase and subsequently increase erosivity. The coefficient of X_8 (0.003) means that for every unit increase in SP, there will be an increase in Soil Dispersion Rate (SDR) by 0.003, holding all the other independent variables (fine sand, silt, clay, SMC, Ksat, MWD, AS, SOM) constant. This means that increase in soil porosity, will increase soil dispersion rate thereby increasing erosivity. The coefficient of X_{12} (0.029) means that for every unit increase in MWD, there will be an increase in Soil Dispersion Rate (SDR) by 0.029, holding all the other independent variables (fine sand, silt, clay, SMC, Ksat, SP, AS, SOM) constant. This means that as mean weighted diameter increases, space in the soils also increases thereby increasing soil dispersion rate and subsequently erosivity. The coefficient of X_{13} (- 0.001) means that for every unit increase in AS, there will be a decrease in Soil Dispersion Rate (SDR) by 0.001, holding all the other independent variables (fine sand, silt, clay, SMC, Ksat, SP, MWD, SOM) constant. This means that high aggregate stable soil will decrease the rate of dispersion as well as decrease erosivity. The coefficient of X_{15} (0.008) means that for every unit increase in SOM, there will be an increase in Soil Dispersion Rate (SDR) by 0.008, holding all the other independent variables (fine sand, coarse sand, silt, clay, SMC, Ksat, SP, MWD, AS,) constant. This means that increase in soil organic matter will increases soil dispersion rate, but does not however increase erosivity. Humus attracts living organisms to the soil, these organisms till the soil, breakdown the organic matter that encourages vegetation growth. The presence of vegetation and their roots bind the soil and discourage erosion except in areas where erosion has gone out of control that requires other sophisticated engineering measures.

The Variance Inflation Factor (VIF) of the variables in the model shows the values to range from 1.278 to 2.706. This implies that the interpretation and prediction with this result is precise. VIFs between 1 and 5 suggest that there is a moderate correlation, but not severe enough to warrant corrective measures. (Frost, 2017; Ndulue, 2018)

CONCLUSION

The study has established that the Soil Dispersion Rate (SDR) is positive and has a significant correlation with soil loss, which indicates that as the Soil Dispersion Rate (SDR) increases, soil erodibility rate also increases. In other words, the higher the Soil Dispersion Rate (SDR), the higher the ability of the soil to disperse (dislodge) and lead to soil loss. The soil analysis result indicates that the soils across the study area are highly erodible and susceptible to erosion at the value range from 0.429% to 0.865%, if soils having a dispersion rate greater than 0.15% according to Middleton (1930) are erodible in nature.

The statistical analysis result, therefore shows that increase in fine sand, soil moisture or water content, saturated hydraulic conductivity (Ksat), soil porosity, mean weighted diameter (MWD), and soil organic matter content, increases dispersion rate as well as soil erosivity while increase in silt, clay and aggregate stability, on the contrary decreases dispersion rate and soil erosivity as well. The statistical analysis predicts soil organic matter to increase dispassion rate contrary to the assertion of Brady & Weil, (2002) that soils with relatively low organic matter content are more vulnerable or susceptible to water erosion and the position of Kemper & Koch (1966) and Greenland et al. (1975) that soil organic matter content critical level is at 2%, below which there will be decline in soil structural stability and increase susceptibility to soil erosion.

Absence of soil organic matter content in soils makes them to become loose (friable) and consequently slides under high intensive heat or heavy rainfall that renders them easily detachable. However, the presence of soil organic matter content attracts soil living organisms that break the soils thereby increasing soil dispersion rate that encourages quick natural re-vegetation. It is in this context that the study therefore recommends mulching, cover cropping and physical re-vegetation of all available bare spaces in the study area. Adding soil organic matter content will increase bonding and reduce the direct pounding of raindrop on the surface of the soil thereby reducing the dislodgement of these soil surfaces.

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