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FIELD MEASUREMENT OF FACTORS RESPONSIBLE FOR SOIL EROSION IN TROPICAL NIGERIA

***Adama Oluwakayode .O, Adekomaya, Oludaisi and Giwa Solomon. O**

Department of Agricultural & Mechanical Engineering, Olabisi Onabanjo University, Ibogun Campus
*(*Corresponding authors:leyekayadama@gmail.com, oludaisiyetunde@gmail.com,)*

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ABSTRACT
The soil erosion factor K, is the quantitative expression of inherent successof a particular soil to erode at different rates when the other factors that affect soil erosion are standardized. This study was carried out based on a completely randomized design to determine the erodibility of three different plots under two management conditions (one left bare of vegetation, and the other planted with Grain Amaranth). Runoff and soil loss measurements were measured after every rainstorm. Results revealed that measured K on the vegetable plots does not indicate much variation on the three plots, but were slightly lower than measured K on the bare plots. Plot 1 recorded the least erodibility (0.0424 for the vegetable plot and 0.0549 for the bare plot), while plot 3 had the highest with (0.0492 for the vegetable plot and 0.0684 for the bare plot respectively). The percentage sand content on all runoff plots decreased slightly after the experiment was concluded. So also was the organic matter content. Examination of chemical properties of the soil before and after the studies revealed that the top soil of the runoff plots showed lower organic carbon content, available Nitrogen and Phosphorus content, the exchangeable Potassium on all the runoff plots were lower after soil erosion, the same thing for Magnesium and Calcium.Plot 3 recorded the highest runoff and soil loss and hence the highest erodibility these may be attributed to its higher slope steepness of 3% when compared to those of plots 1and 2 which has slope steepness of 2% each.

Keywords- *Erodibility, erosion,soil structure, runoff and soil loss.*

INTRODUCTION

Soils are the basis of our existence in the past, present and through the foreseeable future . Itis upon the soil that all activities are carried out be it agricultural orconstructional, social or recreational. Once this topmost layer of soil is eroded, it is always difficult to reclaim. Detachment and transport of soil particles via wind and/or water forces termed soil erosion as reported by (Panagos *et al*., 2012),is a global problem especially in vulnerable and fragile environments (Bagarello *et al*., 2012), (Manyiwa and Dikinya,2013). Soil erosion has widespread and serious negative effects on agricultural production, water quality, biodiversity, useful life of reservoir dams and many other environmental risks (Pazhouhesh *et al*., 2011). A worldwide estimation showed that arable land is lost at a rate of more than 10million hectare per year (Bagarello *et al*., 2012)and this poses a serious threat especially in agriculture-based countries like Nigeria and Ghana. Therefore,determination of soil vulnerability to erosion is a key prerequisitefor soil erosion prediction andchoosing a suitable management practice that is gear toward land sustainability.

The Universal Soil Loss Equation (USLE) developed by (Wischmeier and Smith,1978), is an empirical soil erosion model used by professionals and technicians to predict soil loss in water erosion(Bagarello *et al*., 2012), (Vaezi *et al*., 2010). USLE and its successor the Revised Universal Soil Loss Equation (RUSLE) are technology baselike a number of other erosion models such as SWAT, ACNPS, Watem/Sedem and EPIC(Auerswald *et al*.,2014). and both are related to rain erosivity factor (R), soil erodibility factor (K), slope length factor (L), slope steepness factor (S), crop management factor (C) and support practice factor (P), (Wang *et al*., 2001). Among these factors, soil erodibility factor (K) is oneof the key factorsrequired for soil erosion determination and/or prediction across the world (Zhang *et al*., 2007).Moreover, it strongly correlated with soil loss as reported by(Tejada and Gonzalez, 2006)Soil erodibility factor K,is related to the integrated effects of rainfall, runoff and infiltration on soil loss and is commonlycalled the soil erodibility factor (K) which represents the effect of soil properties and soil profile characteristicson soil loss(Renard *et al.,* 1997). The K factor used as an indicator of erosion measurement, because of its susceptibility to particulate detachment and transport by erosion agents,(Manyiwa and Dikinya, 2013).

Erodibility are those soil properties that affects infiltration and permeability and others that determine the effects of the dispersion, splashing, abrasion and the transporting forces of rainstorm and runoff, soil structure and stability are closely related to these properties but are difficult to measure (Wischmeier, 1978). Various empirical equations for the computation of erodibility index K abound, and they include the following;

I. The Dispersion Ratio K$= \frac{\%Silt + \%\,Clay\,in\,undispersed\,Soil}{\%\,Silt + \%\,Clay\,after\,dispersion\,of\,soil\,in\,water}$ ..(1)

II. Clay Ratio k $= \frac{\%\,silt + \%\,clay}{\%\,clay}$ ....(2)

III. Erosion Index$= \frac{Dispersion\,Ratio}{Colloidal\,Content/Moisture\,Equivalent\,Ratio}$ .....(3)

IV. Instability Index $= \frac{\%\,silt + \%\,clay}{\%\,aggregate > 0.2mm\ after\ sieving}$ ..(4)

Other characteristic associated with soil erodibility isdetachment, which describes the ease with which soil particles can be detached. It is a direct function of particle size that is to say the bigger the size, the easier they are detached(Lar, 1986). Soil transportability is another characteristic, which is associated with erodibility, and it describes the ease with which the particles can be transported after detachment. It is an indirect function of the particle size(Adeniran, 1998). The risk of soil erosion is very highin the study site where this experiment was carried out dueto frequent, heavy and intense rainfall, usually accompanied by increase runoff. This runoff alsodetaches and transport soil particles down the slope. (Jayeiola, 1984)

Erodibility is the resistance of the soil to both detachment and transport. The soil erodibility factor K is the quantitative expression of inherent succesibility of a particular soil to erode at different rates when the other factors that affect soil erosion are standardized. Erodibility varies with soil texture, aggregates, stability, shear strength, soil structure, infiltration capacity, and soil depth, organic matter content and chemical constituents (Hudson and Jackson, 1989).

These study aims to show the relationship between runoff and soil loss, and to evaluate the soil erodibility factorfor the study site and also to show the difference in soil loss in field planted with a test crop and that left bare.

MATERIALS AND METHODS

Research Site Description

The site chosen for this study was informed by the frequent, heavy and intense rainfall usually accompanied by high volume of runoff with high risk of soil erosion. The experiment was conducted at the National Horticultural Research Institute (NIHORT), Ibadan, Oyo State, Nigeria. The site has an altitude of 168m above mean sea level and lies roughly between (Longitude 3° and 6° E and Latitude 6° and 8° N). It has an average annual rainfall of about 1300mm (Jaiyeola, 1984). The rainfall is bimodal with a relatively short dry season (November-March) followed by a relatively long wet season (April-October) with a short dry spell in between. The original vegetation is characterized by a semi-deciduous lowland rain forest (Afolayan, 2000).However, these have been destroyed through continuous cultivation and are replaced by secondary forest, derived savannah thicket and cultivated crops. The soils in the study site fall into three major soil type via Iwo, Egbeda and Okemesi (Afolayan, 2000). They are termed Alf sol under the World Great Soil Group. The soils are majorly sand to slightly clayed sand top soil underlying by clayed sand to sandy clay sub-soil. The textural characteristics of the soil range from sand to sandy clay as common with most of the soils developed on complex Basement in the Western parts of Nigeria (Jaiyeola, 1984). The textural characteristics of the soils conducted in 1984 are given in Table 1, at 0-10cm, 10-25cm and 25-40cm depths, respectively.

Land Preparation

Three different locations were selected as experimental plot for the measurement of soil erodibility, and they werelabelled as plot 1, plot 2 and plot 3 respectively. The plots were cleared and ridged using traditional implements; cutlass and hoe known as manual tillage. The long continuous ridge type beds were made on each of the three plots, overall, eight ridges were made on each plot and each plot has seven furrows. The length andbreadth of each plot were measured using the standard developed by (Wischmeier and Smith 1978)with the aidof a measuring tape, and results were recorded.

Rainfall Data

During the period of this study, daily rainfall data was recorded at the meteorological station of the institute, which was about 40m from plot 3, and 150m from plots 1 and 2 respectively. Also from the meteorological station, the record of the monthly and annual rainfall data for the past ten years prior to the time of the study wereprovidedby the meteorological station.

Soil Analysis

Soil sample was taken within the top 0-10 cmand 10-20cm depth from various locations within each of the plots. The soils from plot 1, 2 and3 were mixed thoroughly and taken to the laboratory for soil physical as well as chemical analysis before planting was done after the land preparation. The results of the soil physical as well as chemical analysis carried out on each plot were recorded.

Soil Erodibility

The erosion or soil loss of two soils under the same environment and management conditions are usually observed to be different due to their inherent characteristics. Soil erodibility factor for each runoff plots were measured using the Universal Soil Loss Equation (USLE), as develop by (Wischmeier and Smith 1978) and results were recorded.

RESULTS AND DISCUSSION

Table 1 shows the textural characteristics of the soil in the study site, as giver by (Jaiyeola, 1984) years before the commencement of the study and after the series of test carried out on the experimental plots, we have the following results: Table 2 soil textural characteristics of the plots conducted just before the commencement of the experiment, Table 3 is the soil textural analysis of the plot conducted onthe experimental plots, immediately after the experiment was conducted. Table 4 is the runoff, soil loss and erodibility factor for each test plots, Table 5 is the soil chemical analysis of the runoff plots conducted before the commencement of the experiment while Table 6 is the soil chemical analysis conducted after the study. Table 7 is the percentage aggregate on each sieve size.

The runoff (in litres) on each plot during the course of this study is shown in Figure 1 and soil loss (in Kg) on the experiment plots is illustrated in Figure 2. The erodibility factor K for plot 1 was 0.0424 for the vegetated portion and 0.0549 for the portion left bare, for plot 2 it is 0.0467 for the vegetated portion and 0.0601 for the bare portion and for plot 3, erodibility is 0.0492 on the vegetated part and 0.0684 on the bare portion. Also, the total runoff generated in the course of the study was 739.5litres on plot 1 bare and 639.5litres on the vegetated part, on plot 2 the bare portion generated 1020.0 litres of runoff while the vegetated part generated 948.0 litres and plot 3 vegetated part generated 1065.5litres of runoff and the portion left bare generated the highest 1100.0 litres of runoff. The total soil loss all through the study period for plot 1 bare is 22.52Kg and 28.926Kg for the vegetated portion, for plot 2 total soil loss on the bare portion is 31.640Kg and 24.659Kg on the vegetated part while plot 3 again recorded the highest soil loss on both the vegetatedand bare portion with 36.488Kg and 54.066Kg respectively.

The soil textural characteristics show a difference in composition at the completion of the experiment. Taking sand composition for analysis at 0-10cm depth, the initial percentage sand composition before the commencement of the experiment was 79.2% Table 2 and after the experiment, it turned to 72.2% Table 3 that is to say 7% of sand has eroded away. The result is not different at 10-20cm depth with initial final sand content of 74.2% and 69.2% respectively. Also, there were changes in the pH values before and after the studies so also in the organic matter content, Nitrogen, Available Phosphorus, calcium, magnesium, potassium, sodium, iron, manganese, copper and zinc.

Table 1 shows the soil textural characteristics of the study site as conducted by Jayeiola in (1984) to give us an idea of the soil textural characteristics some years prior to the study. The soil physical analysis (percentage sand, silt and clay) was carried out before the commencement of the experiment (Table 2), and immediately after the experiment was concluded (Table 3). The results shows a decrease in sand content and an increase in silt content for all plot which is similar to results obtained by (Abioye, 1987), this is so because the sand are easily carried away by agents of erosion when compared to silt which are not easily detached nor transported. Table 4 shows the runoff generated on the runoff plots in the course of the studyRunoffs in the bare plots were higher than the vegetable plots in all the plots considered. This is similar to results obtained by(Evans, 1980), (EL-Swaity and Daugher, 1982) and (Abiyo, 1987). The vegetated portion of the plots acts as a cover for the soil hindering the movement of runoff downstream. The soil loss in the bare plots were also higher on the three-runoff plots as compared to those of the vegetable plots, as earlier explained, the vegetation acts as cover against the direct imparts of rain drops on the soil thereby reducing the detachment ability of the erosive tendencies of tropical rainstorms (Jayeiola, 1984) and this also prevent the runoff from transporting the detached soil particles over any appreciable distance.

The runoff and soil loss on plot 3 was higher than plots1 and 2 due to its higher slope(Table 2), and is similar to results obtained by (Foster *et al.*, 1987), (Adeniran, 1998). The sand content of each of the runoff plot decreased while the clay and silt contents increased for all runoff plots. This effect is readily noticeable on the runoff plots left bare after manual tillage. The strong bond holding the silt and the clay particles together makes them difficult to be detached from the soil mass, whereas the weak bond between the sand particles makes them easily detachable. The results shows that plots 1and 3 has higher change in sand quantity between 0-10cm depth Tables 2 and 3, while plot 3 records the highest change in sand quantity between 10-20cm depth. Soil erosion has little effect on the bulk density in all the runoff plots Tables 2 and 3. The soil chemical analysis (pH, organic matter content, available phosphorus, nitrogen, calcium, magnesium, potassium, sodium, iron, manganese, copper and zinc), carried out before the commencement of this study as presented in Table 5 while Table 6 present the soil chemical analysis after the study. The results shows an increase in the pH after the completion of the experiment for the three runoff plots, there was a decrease in the organic matter content as well as the available phosphorus, also all the macro nutrients elements (Ca, Mg, K, Na) analysed in this study all showed lesser values after the experiment this may be attributed to losses as a direct consequence of soil loss. The micro nutrients element showed a similar results but not as pronounced as that of the macro nutrients element. The soil physical analysis of percentage aggregate on each sieve size was also determined for each of the runoff plots (Table 7).

CONCLUSION

From the calculation, the soil erodibility factor Kfor each runoff plot does not show appreciable difference. Plot 1 has the lowest erodibility factor followed by plot 2, with plot 3 recording the highest erodibility factor, and this may be attributed to the fact that plot 3 has the highest slope (3% compared to plot 1 and plot 2 which has 2% each).The soil physical characteristics of sand, silt and clay content is the dominant factor in determining soil erodibility factor K.

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Table 1: Textural characteristics of the soil conducted in 1984 at the National Research Institute Ibadan, Nigeria.

Soil Depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-10	77.39	6.11	16.50
10-25	61-05	8.32	30.63
25-40	75-68	13.53	10.78

Source: Jaiyeola, 1984: National Horticultural Research Institute soil map.

Table 2: Soil physical analysis of the runoff plots conducted before the commencement of the experiment.

Runoff Plot	Soil Depth (cm)	Sand %	Silt %	Clay %	Bulk Density (g/cm3)	Plot Slope (%)
1	0-10	79.2	5.4	15.4	1.69	
	10-20	74.2	6.4	19.4		2
2.	0-10	77.2	5.4	17.4	1.56	
	10-20	75.2	7.4	17.4	1.57	2
3.	0-10	75.2	6.4	19.4		3
	10-20	72.2	7.4	20.4		

Table 3: Soil physical analysis of the runoff plot conductedafter the completion of the experiment.

Runoff Plot	Soil Depth (cm)	Sand %	Silt %	Clay %	Bulk Density (g/cm3)	Slope (%)
1	0-10	72.2	9.4	18.4	1.69	2
	10-20	69.2	10.4	20.4		
2.	0-10	73.2	7.4	19.4	1.51	2
	10-20	70.2	9.4	20.4		
3.	0-10	68.2	8.4	23.4	1.56	3
	10-20	66.2	8.4	25.4		

Table 4: Run-off, Soil loss and Erodibility factor k for the test plots.

	PLOT 1		PLOT 2		PLOT 3	
	Vegetable	**Bare**	**Vegetable**	**Bare**	**Vegetable**	**Bare**
Run-off (litres)	**693.50**	**739.50**	**948.50**	**1019.50**	**1065.50**	**1099.50**
Soil Loss (kg)	**1116.35**	**1446.30**	**1232.95**	**1582.00**	**1824.40**	**2703.00**
Erodibility factor k	**0.0424**	**0.0549**	**0.0467**	**0.0601**	**0.0492**	**0.0684**

Table 5: Soil chemical analysis of the runoff plots conducted before the commencement of the experiment

Runoff Plot no	Soil Depth cm	Ph	N (%)	O/C (%)	A/P PPM	Ca Meg/100g	Mg Meg/100g	K Meg/100g	Na Meg/100g	Fe P.PM	MN P.P. M	Cu P.P.M	Zn P.P.M
1	0-10	7.1	0.17	0.82	5.3	0.5	0.47	0.08	0.21	18.4	23.63	0.82	20.5
	10-20	6.4	0.09	1.02	7.3	0.3	0.49	0.20	0.34	21.2	25.81	0.85	21.5
2	0-10	6.7	0-11	0.49	4.2	0.5	0.39	0.10	0.20	24.3	26.2	0.97	21.2
	10-20	6.1	0.11	0.11	0.7	6.2	0.40	0.31	0.53	26.4	29.2	1.10	20.4
3	0-10	6-8	0.08	0.51	5.6	0.5	0.45	0.07	0.20	17.6	20.1	0.75	18.5
	10-20	6.1	0.07	0,51	6.3	0.3	0.27	0.21	0.32	22.2	23.4	0.71	19.8

Table 6: Soil chemical analysis of the runoff plots conducted after the completion of the experiment

Runoff Plot no	Soil Depth cm	pH	N (%)	O/C (%)	A/P PPM	Ca Meg/100g	Mg Meg/100g	K Meg/100g	Na Meg/100g	Fe Meg/100g	MN P.P.M	Cu P.P.M	Zn P.P.M
1	0-10	5.6	0.16	0.97	6.5	0.7	0.53	6.09	0.19	20.3	24.78	0.93	22.5
	10-20	5.7	0.19	1.12	11	0.4	0.75	0.21	0.25	21.1	27.82	0.97	22.6
2	0-10	6.0	0-12	0.59	4.3	0.6	0.44	0.11	0.23	26.4	28.1	1.04	22.1
	10-20	5.9	0.16	0.81	9.9	0.5	0.65	0.27	0.23	28.4	31.5	1.21	21.4
3	0-10	6-1	0.07	0.55	6.7	0.7	0.49	0.08	0.21	18.4	20.9	0.77	20.2
	10-20	6.0	0.09	0,53	11.	0.5	0.69	0.19	0.24	20.5	23.6	0.85	20.9

Table 7: Percentage aggregate on each sieve size (mm)

Plot	0.125	0.350	1.00	2.00	4.00	Erodibility
1	13.4	14.6	10.7	1.0	0.3	0.0424
2	13.3	19.0	5.3	1.1	0.4	0.0467
3	13.6	18.0	6.0	2.2	0.7	0.0492

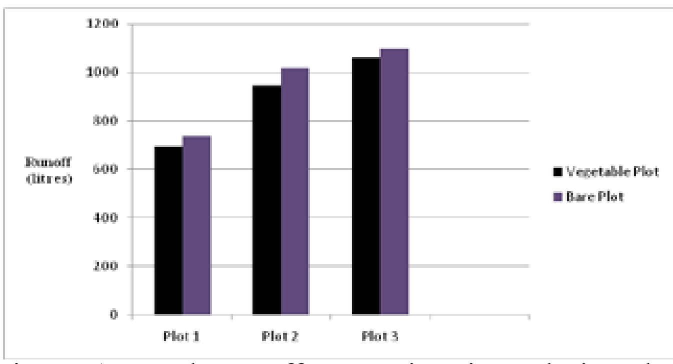

Figure 1: Total Runoff Water in Litres during the period of the experiment.

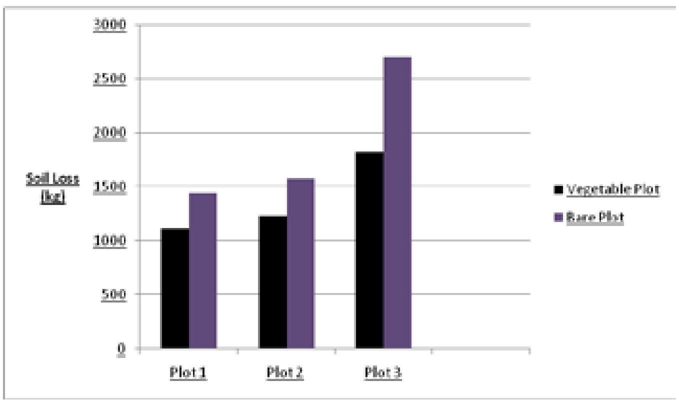

Figure 2: Total Soil Loss in Kg during the period of the experiment.