EFFECT OF VEGETATIVE COVER AND SLOPE ON SOIL LOSS BY EROSION USING RAINFALL SIMULATOR

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ABSTRACT

Top soil is very important for crop production but it is usually washed away in the tropical countries like Nigeria by erosion due to heavy rainfall with high intensity. In this study, a rainfall simulator was used to determine the quantity of soil loss (sediment load) from a bare soil and vegetative cover soil under different slopes. The slopes of the land for plots 1 to 5 for a bare soil varied from 5.20 to 9.7 % but for a vegetative cover soil (grown with grasses), the slopes varied from 2.8 to 3.2 %. The uniformity coefficient and drop velocity of the rainfall simulator used were 84.4 % and 8.156 m/s, respectively. The soil of the experimental site was sandy loam and the area of coverage by rainfall simulator was 3 by 3 m. Soil loss (sediment load) for a vegetative cover soil for slopes 2.8, 2.9, 3.0, 3.1 and 3.2 % were 0.252, 0.358, 0.350, 0.371 and 0.422 kg, respectively. Soil loss from a bared soil for slopes 5.2, 6.7, 9.0, 9.6 and 9.7 % were 1.045, 1.070, 1.100, 2.266 and 3.121 kg, respectively. Vegetative cover soil with grasses reduced the runoff volume and soil loss. Runoff volume and soil loss increased as slope of the land increases.

Keywords: erodibility, erosion, erosivity, rainfall simulator, soil loss,

INTRODUCTION

Erosion is a serious problem in the tropical countries like Nigeria due to heavy rainfall with high intensity which is common in tropics. The problem of erosion is a dual problem because the land from where soil is removed and the place where soil particle is deposited are destroyed. Many arable lands have been destroyed as a result of washing away of the top soil to another place. Some places such as farm land, urban areas and roads (highways) have been destroyed especially in the southern parts (south east, south south and south west) of Nigeria.

Erosion causes loss of the top soil and reduces the fertility of the agricultural soil (Baven, 2004). Erosion is usually influenced by erosivity and erodibility. The potential ability of rainfall to cause soil erosion is termed erosivity while the vulnerability of soil to detachment by the impact of rainfall and transportation of the soil particles by the runoff is called erodibility (Schwab, *et al*., 1993). There is need to quantify soil loss from a given area so that different measures of controlling erosion could be put in place to avert erosion problem in Nigeria. Vegetation intercepts and retards overland flow and increases surface detention thereby reducing the peak runoff rates. The consequence of soil erosion is degradation of arable land thereby reducing soil fertility and rendered the soil as unproductive land for agriculture. Man has no control over the natural rainfall properties such as rainfall intensity, drop size and duration of rainfall but preventive measures could be put in place to prevent soil erosion.

KINETIC ENERGY OF RAINFALL

The kinetic energy of a moving object is given in Equation (1) but Hudson (1963) derived expression for kinetic energy of rainfall for temperate and tropics which are given in Equations (2) and (3).

$$K.E = \frac{1}{2}MV^2$$

(1)

where *K.E* is kinetic energy of the moving object (J), *M* is the mass of the object (kg) and *V* is the velocity at which the object is moving (m/s).

$$K.E = 11.9 + 8.70 \log I$$

(2)

$$K.E = 30 - \frac{125}{I}$$

(3)

where *K.E* is the kinetic energy of the rainfall (J/m^2/mm) and *I* is the intensity of rainfall (mm/h).

Erosivity index (R) is the product of kinetic energy of rainfall (E) and maximum rainfall intensity that occur in thirty minutes (I_{30}) as given in Equation (4)

$$R = EI_{30}$$

(4)

SOIL LOSS EQUATION

The quantity of soil loss annually from a catchment is usually determined from a general equation popularly called Universal Soil Loss Equation (USLE). The USLE in Equation (5) given by Wischmeier and Smith (1978) and also expressed by Schwab *et al*. (1993) is a good model that is commonly used in Soil and Water Conservation Engineering for predicting or quantifying annual soil loss in ton/ha/yr.

$$A = R \times K \times L \times S \times C \times P$$

(5)

where A is the average annual soil loss from a given area (ton/ha/yr), R is the rainfall and runoff factor (erosivity index), L is the slope-length factor of the land, S is the slope-steepness factor, C is the cropping or cover management factor and P is the soil conservation practice.

Objectives of this study were to:

(i) quantify soil loss from bared soil and vegetative cover soil using a rainfall simulator.

(ii) estimate runoff volume from the bared soil and vegetative cover soil using a rainfall simulator.

MATERIALS AND METHODS

The experimental site was 80 m away from the dam which was located at the downstream end of University of Ilorin dam. Ilorin lies on the latitude 8^{o}30¹N and longitude 4^{o}35¹E at an elevation of about 340 m above mean sea level (Ejieji and Adeniran, 2009). Ilorin is in the Southern Guinea Savannah Ecological zone of Nigeria with annual rainfall of about 1,300 mm. The wet season begins towards the end of March and ends in October while the dry season starts in November and ends in March (Ogunlela, 2001). Size of each plot (5 plots) was 3m by 3m and the gradient along the plot was regular and free of local depressions. The vegetative cover soil with grasses had slopes of 2.8, 2.9, 3.0, 3.1 and 3.2 %. The bared soil had slopes of 5.2, 6.7, 9.0, 9.6 and 9.7 %. The boundary area was demarcated with wooden plank to guides the runoff and sediment load to the collection point. The wooden plank was 20 cm above the ground surface and 10 cm deep below the ground surface. A broad collector 1.2 m long and 30 cm wide was placed at the outlet of each of the plot to convey the runoff and sediment produced by the rainfall simulator into a drum put in a pit. The collector guides the runoff from the rainfall simulator boundary into the drum installed in a pit below ground surface as shown in Figure 1. A pump was used to pump water into the rainfall simulator which comes out through the 100 shower roses of the simulator as shown in Figure 2. The operation of the rainfall simulator on bared soil and vegetative cover soil were shown in Figures 3 and 4.

Figure 1: Rainfall simulator and drum in the pit on a bared soil for runoff and soil sediment

Figure 2 Pump for pumping water into the rainfall simulator

Figure 3 Rainfall simulator in operation on a bared soil

Figure 4 Rainfall simulator in operation on a vegetative cover soil

DETERMINATION OF RUNOFF VOLUME AND SOIL LOSS FROM THE AREA

The components of rainfall simulator were put together and simulator was placed on the adjustable frame set at 1.65 m above the ground surface. The pumping machine was connected to the inlet pipe of the simulator to supply water for the simulator. The pumping machine was switched on and the simulator supplied water to the experimental plot for 10 minutes as shown in Figure 3. The runoff and sediment from the plot flows into the drum in the pit. The runoff volume produced from each plot was determined using a graduated bucket of 13 litres capacity. The sediment load in the runoff in the drum was removed oven dry in an electric oven set at 105 ^{o}C for 24 hours. The mass of the oven dry soil (sediment load) was determined from the weighing balance. Infiltration rate of the soil in experimental site was measured using double ring infiltrometer.

RESULTS AND DISCUSSION

The runoff volume produced from bared soil varied with slopes of the land. Sediment load also increased as slope of the land increases as shown in Table 1. This means that high slope promotes soil erosion on the same bared soil as shown in Table 1. The runoff volume and sediment load from vegetative cover on the different slopes also revealed that the higher the slope the higher the runoff volume and higher soil loss from the area as shown in Table 2.

Infiltration rate which was the amount of water that entered the soil within rainfall simulator boundary for the bared soil and vegetative cover soil were shown in Tables 3 and 4. Vegetative cover allowed water to remain on the soil for longer time and larger volume of water entered the soil as infiltration on the vegetative cover soil than the bared soil. This means that cover crop can reduce runoff rate and impede rate of soil erosion from the farm land and in urban area. The results indicated that cover crop which is relatively cheap could be used in some parts of Nigeria to prevent erosion as stated by Schwab *et al*. (1993).

Table 1: Runoff volume and sediment load (soil loss) from a bared soil on different slopes

Plot	Slope (%)	Runoff (m^3)	Sediment(kg)
1	5.2	95.0×10^{-3}	1.045
2	6.7	93.7×10^{-3}	1.070
3	9.0	96.6×10^{-3}	1.100
4	9.6	99.4×10^{-3}	2.266
5	9.7	101.0×10^{-3}	3.121

Table 2: Runoff volume and sediment load from a vegetative cover soil on different slopes

Plot	Slope (%)	Runoff (m^3)	Sediment(kg)
1	2.8	67.0×10^{-3}	0.252
2	2.9	71.2×10^{-3}	0.358
3	3.0	69.2×10^{-3}	0.371
4	3.1	73.1×10^{-3}	0.371
5	3.2	75.0×10^{-3}	0.422

Table 3: Infiltration rate, initial and final moisture contents of from a bared soil on different slopes

Slope (%)	Bared soil		
	i (mm/h)	Θ_1 (%)	Θ_2 (%)
5.2	216	10.8	37.1
6.7	218	12.2	40.0
9.0	213	10.6	38.4
9.6	204	11.3	35.3
9.7	194	11.2	32.1

i = infiltration rate, Θ_1 = initial soil moisture content and Θ_2 = final soil moisture content

Table 4: Infiltration rate, initial and final moisture contents of soil from a vegetative cover soil on different slopes

Slope (%)	Vegetative cover soil		
	i (mm/h)	Θ_1 (%)	Θ_2 (%)
2.8	282	11.2	28.2
2.9	277	12.8	26.7
3.0	269	10.1	26.9
3.1	251	9.9	35.9
3.2	264	10.4	26.4

i = infiltration rate, Θ_1 = initial soil moisture content and Θ_2 = final soil moisture content

CONCLUSIONS

The coefficient of uniformity of the rainfall simulator was 84 % which was within the recommended value. Slope of the land increases runoff rate and high sediment load. Vegetative cover crop retards runoff flow velocity and reduced erosion.

RECOMMENDATION

Cover crops should be planted on bare soils in some parts of the country to reduce rate of erosion and prevent destruction of arable land. Land levelling should be done on high sloppy land to reduce runoff rate and reduce erosion problem on the farm and roads.

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