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Soil Erosion Studies on Micro Plots

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Abstract:- Soil erosion is one of the most serious environment degradation problem. However reliable measurement of erosion remains limited and estimates of soil productivity are even rarer. Nevertheless, identification and assessment of erosion problems could have an important role in influencing better land use and conservation practices. Rainfall simulators are considered as effective aids in soil conservation research. Simulators make it possible to produce predetermined storms at any desired time and location. Laterite soils are by far the most important soil group occurring in Kerala and cover the largest area. The objective of this study was to estimate soil loss and runoff of laterite soil at different land slopes under simulated rainfall conditions. The soil loss and runoff increased with increase in the rainfall intensity for different slopes studied.

Keywords:- Soil erosion, rainfall simulators, soil loss, runoff

I. INTRODUCTION

Soil erosion is a two phase process consisting of the detachment of individual particles from soil mass and their transport by erosive agents such as running water and wind [3]. When sufficient energy is no longer available to transport the particles, a third phase (deposition) occurs.

The amount of erosion from raindrops has been linked to the rainfall characteristics such as the rainfall intensity, drop diameter, impact velocity and rainfall kinetic energy. The size, distribution and shape of rain drops influence the energy, amount and erosivity of rainstorm. Median drop size increases with the increase in the rainfall intensity [1].

Rainfall simulators have been used to accelerate research in soil erosion and runoff from agricultural lands, high ways etc. Simulated rainfall as water applied in a form similar to natural rainfall [2].

The limitations of these types of rainfall simulators are that continuous jets of rain hit the soil at particular points below the drop former, which may not happen in nature and close spacing of drop formers adopted for getting a better uniformity resulted in high rainfall intensities than desired [6].

Researchers studying runoff and soil loss from rainfall have recognized the desirability of using rainfall simulators to supplement and expedite their investigations. The use of a rainfall simulator enables nearly immediate evaluation of carefully controlled plot conditions as well as observations of the erosion process involved. Basic characters of a natural rain storm which are required to be simulated in a laboratory are rainfall intensity, uniformity of distribution of raindrops, drop size and rainfall velocity approaching the terminal velocity of the natural rainfall.

II. MATERIALS AND METHODS

Micro soil loss plots were established to study the rill erosion process. The soil is reddish brown and belongs to the textural class of sandy clay loam. The experimental set up consisted of three unit's viz., the runoff plot, the rainfall simulator and the runoff-sediment collection unit. Two runoff plots, one on flat land and other on land with a slope of 3 per cent and each with a size of 3.5x2.5 m were prepared. The rainfall simulator designed and fabricated could apply the desired rainfall over the runoff plot. The runoff containing the sediments was collected at the outlet for analysis. The designed rate of water was applied over the runoff plot using the rainfall simulator.

Design and fabrication of rainfall simulator

A rainfall of desired intensity was produced by using microsprinklers of maximum discharge capacity of 160 litre per hour with a wetted circle diameter of 3 m. A framework was fabricated to support the sprinkler heads with the dimension of 3.5 m x 2.5 m using aluminum pipe of diameter 1.91cm [5]. The pipes were joined at the corners using an elbow. The frame work was supported by legs of height 1m at the four corners. A 4 cm long GI pipe was welded to the elbow and the legs were connected to it. Two transverse pipes were joined to the frame using a T- joint made of GI pipe.

The microsprinklers used for the study has a maximum discharge capacity of 160 litre per hour with a wetted circle diameter of 3 m. The sprinkler unit was connected to the lateral and mounted onto the framework. The spacing between the sprinklers was adjusted in order to get maximum intensity and uniformity within the study area. The simulated rainfall could produce rainfall of intensities varying from 3.33 to 4.52 cm/h.

Testing of rainfall simulator:
Intensity

The pressure of supply water was kept as 0.5 kg/cm². The entrapped air was removed and the simulator was operated freely for 10 minutes. Twenty four catch cans of 13 cm diameter were placed at a grid spacing of 50 cm x 50 cm, simultaneously while raining. The unit was operated for 10 minutes. The volume of water collected in each can was recorded. The volume of water collected was converted into its equivalent depth. The test was repeated for supply pressure of 1.0, 1.5, 2.0 kg/cm² respectively. The intensity was calculated for each supply pressure of water.

Uniformity

The pressure of supply water was kept at 0.5 kg/cm². The entrapped air was removed. Catch cans of 13 cm diameter were placed in the rain at 24 grid stations at an interval of 50 cm x 50 cm. The unit was operated for 10 minutes. The volume of water collected in each can was recorded and was converted into its equivalent depth
of rainfall. . The uniformity coefficient (Cu) percent was calculated using the Christiansen's formula;

$$Cu = 100[1 - \frac{\Sigma x}{mn}]$$

Where,

Cu - uniformity coefficient, %
m - Average value of all observations, mm
n - Number of observations
x - Numerical deviation of individual observations from the average application rate.

The uniformity coefficient was calculated for the inner area of size 3.5 m x 2.5 m. The experiment was repeated for various intensities of rainfall.

Erosion study:
Erosion Plot Layout

Each erosion plot selected for the study was 2.5 meter wide and 3.5 meter in length. The plots were delineated at its four sides by raising the soil level to form bunds. The bunds were raised to a level such that the water falling over the plot does not over flow to the surrounding area. At the top of the erosion plot, the bunds were made into right angles for the corners. At the bottom edge of each plot the bunds were angled across the slope towards a triangular tray made of 22 gauge GI sheet. The runoff generated in the plot was directed to a collector using the triangular tray. The tray had a cover made of the same material to prevent the simulated rain falling outside the test plot from mixing with the runoff. The outlet of the tray was directed to a pit of size 1 m x 1 m x 1 m. The runoff was collected in suitable containers placed in the pit.

Study of soil loss and runoff

The experimental plot was exposed to a simulated rainfall of intensity 3.33 cm/h by adjusting the pressure of water supply. A wet run was given until a steady state of runoff generated in the plot. The runoff with eroded soil was collected in a vessel placed below the narrow channel of the triangular tray in the pit, for a period of 5 minutes. The amount of runoff was recorded. The same procedure was repeated for rainfall of intensities 3.7, 4.07 and 4.52 cm/h and collected the corresponding runoff with eroded soil.

Computation of sediment load

The runoff sample was allowed to settle for a period of one week. Then the clear water was removed and the sediment was separated by evaporation technique. The weight of the sediment was recorded. The test was conducted for rainfall of intensities3.33, 3.70, 4.07 and 4.52cm/h. The same procedure was repeated for the second plot.

Development of rills

The development of rills in terms of number and length was monitored at each interval of time during the rainfall. The procedure was conducted for the selected intensities of rainfall at different land slopes.

III. RESULTS AND DISCUSSIONS

The simulator was tested to determine the intensity and uniformity of application of the rainfall produced. After the performance evaluation of the simulator, it was used for erosion studies on Laterite soil.

The developed simulator was used in the study of erosion from a plot of size 3.5 m x 2.5 m. Study of the texture and consistency was done. The soils were subjected to erosion and runoff studies using the rainfall simulator fabricated. The soil loss and runoff were measured at the selected intensities of rainfall on slopes.

Effect of intensity of rainfall on soil loss

Experiments were conducted to study the effect of intensity of rainfall on soil erosion. Intensities of rainfall selected were 3.33, 3.70, 4.07 and 4.52 cm/h. Tests were conducted at the selected intensities on the two test plots. The results obtained are presented in Table 5. It was found in flat land that, there is a maximum soil loss of 27.48 kg/ha/h at an intensity of 4.52 cm/h. The soil loss reduced to23.10 kg/ha/h when the intensity reduced to 3.33 cm/h.

In the second plot of 3 % slope there is a maximum soil loss of 36.74 kg/ha/h at an intensity of 4.52 cm/h. The soil loss reduced to 30.67 kg/ha/h when the intensity reduced to 3.33 cm/h. Graphs plotted between soil loss and intensity of rainfall for each plot is shown in Fig.1.

Effect of land slope on soil loss

To study the effect of land slope on soil erosion, experiments were conducted on a flat land and on a land with 3 per cent slope. Experiments were conducted at intensities of 3.33, 3.70, 4.07 and 4.52 cm/h on the two test plots. It was found that there is maximum soil loss in the second plot compared to flat land. The results obtained are presented in Table 5.

Empirical equation for soil loss

With the agreement provided by the previous study by developing empirical equations to study soil loss and runoff [4], we prepared multiple regression equations relating soil loss, intensity of rainfall and land slope were developed for each test plots.

Table 1: *Effect of intensity and land slope on soil loss*

plot	Intensity (cm/h)	Soil loss (kg/ha/h)
Flat land	3.33 3.70 4.07 4.52	23.10 23.78 25.37 27.48
Slop 3%	3.30 3.70 4.07 4.52	30.67 31.48 34.56 36.74

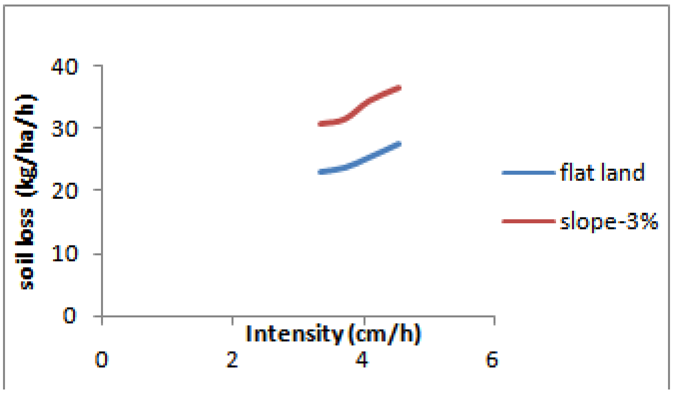

Fig 1*: Effect of intensity and land slope on soil loss*

The equations are:
Flat land: $\mathbf{E = 1.738\ I^2 - 9.900\ I + 36.74}$ $\mathbf{(R^2 = 0.996)}$
Slope – 3%: $\mathbf{E = 1.310\ I^2 - 4.889\ I + 32.21}$ $\mathbf{(R^2 = 0.970)}$

Effect of intensity of rainfall on runoff

Tests were conducted to study the effect of intensity of rainfall on runoff on the two test plots. Simulated rainfall intensities of 3.33, 3.7, 4.07 and 4.52 cm/h were applied on each plot. Graph plotted between runoff and intensity for each test plot is shown in Fig.2.

In the case of flat land, the runoff obtained for an intensity of 3.33 cm/h was 87.77m^3/ha/h. On increasing the intensity to 4.52 cm/h the runoff increased to 104.28 m^3/ha/h. In the case of land with 3 % slope, there is maximum runoff of 131.66 m^3/ha/h at an intensity of 4.52 cm/h. The runoff reduced to 115.20 m^3/ha/h when the in intensity reduced to 3.33 cm/h.

Effect of land slope on runoff

To study the effect of land slope on soil erosion, experiments were conducted on a flat land and on a land with 3 per cent slope. Experiments were conducted at intensities of 3.33, 3.70, 4.07 and 4.52 cm/h on the two test plots. It was found that there is maximum runoff in the sloppy land when compared to flat land. The results obtained are shown in Table 6.

Empirical equation for runoff

Multiple regression equations relating soil loss, intensity of rainfall and land slope were developed for each test plots.

Table 2: *Effect of intensity and land slope on runoff*

plot	Intensity (cm/h)	Runoff (m^3/ha/h)
Flat land	3.33	87.77
	3.70	93.26
	4.07	98.74
	4.52	104.28
Slope-3%	3.33	115.20
	3.70	120.69
	4.07	126.17
	4.52	131.66

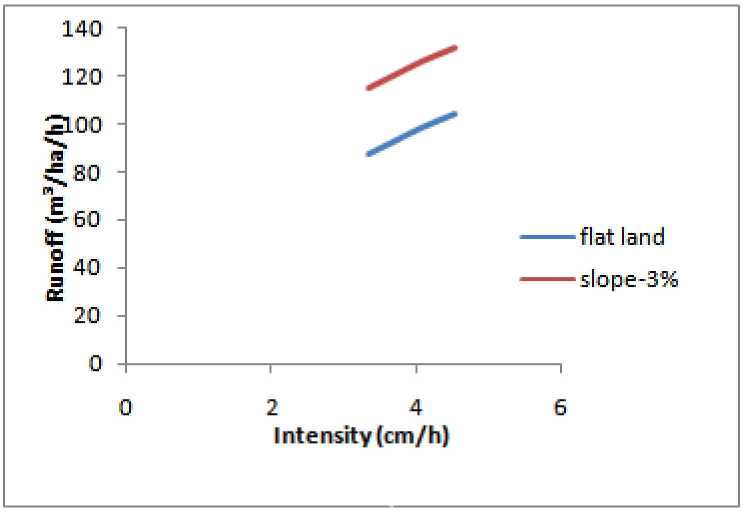

Fig 2: *Effect of intensity and land slope on runoff*

The equations are ,
Flat land: $\mathbf{Q = -1.713\ I^2 + 27.39\ I + 15.48}$ $\mathbf{(R^2 = 0.997)}$
Slope –3%: $\mathbf{Q = -1.789\ I^2 + 27.95\ I + 41.91}$ $\mathbf{(R^2 = 0.999)}$

IV. SUMMARY AND CONCLUSION

The major threat for sustainable crop production is soil erosion. Erosion leads to a reduction in soil quality and soil nutrients and thus decreased agriculture productivity. Another concern with erosion is an increase of turbidity of runoff which has an adverse effect on the quality of surface water and sedimentation in reservoirs and canals. Rainfall is considered as the most important agent responsible for erosion. Rain drops cause the soil to be splashed and flowing water carries the detached particles.

Artificial rainfall was simulated using microsprinklers. A rectangular framework made of aluminium pipe was fabricated, to support the entire sprinkler unit. The water supply to the simulator was taken from a storage tank having 2000 L capacity. A centrifugal pump operated by an electric motor was used to lift water from the storage tank. A pressure gauge of 0-6 kg/cm^2 range was fixed in the discharge line and the pressure of water supply was controlled by means of two gate valves in the discharge line of pump.

Experiments were conducted to study soil loss and runoff from the two plots at rainfall intensities of 3.33, 3.70, 4.07 and 4.52 cm/h. The soil loss increased with increase in the intensity of rainfall for the two runoff plots. A general trend of increase in the soil loss with increase in the slope was observed for all the simulated intensities of rainfall.

Empirical equations were developed for estimating soil loss and runoff for various intensities of rainfall and land slopes. The equations are:

Flat land:

$$\mathbf{E = 1.738\ I^2 - 9.900\ I + 36.74 \quad (R^2 = 0.996)}$$

$$\mathbf{Q = -1.713\ I^2 + 27.39\ I + 15.48 \quad (R^2 = 0.997)}$$

Slope – 3%:

$$\mathbf{E = 1.310\ I^2 - 4.889\ I + 32.21 \quad (R^2 = 0.970)}$$

$$\mathbf{Q = -1.789\ I^2 + 27.95\ I + 41.91 \quad (R^2 = 0.999)}$$

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