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A STUDY OF GENERATE EMPIRICAL EVIDENCE OF RUNOFF AND SOIL LOSS IN BLACK COTTON SOIL UNDER DIFFERENT LAND CONFIGRATION IN MALWA REGION OF (M.P) USING RAINFALL SIMULATOR

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ABSTRACT

The estimation of runoff, soil losses and deep percolation loss in black soils with varying degrees of slope under natural rainfall events takes considerable time and effort. The laboratory studies using similitude principle can generate performance parameters of soil conservation structures in relative short time span. Rainfall Simulator has provision of soil depth variation (up to 50 cm) measurement of Soil losses and slope adjustment. The study was performed to investigate the effect of discharge rates and slopes under bare and with barrier conditions on runoff, soil loss, percolation, of water in developed Tilting Rainfall Simulator. The two soil depths of 30 cm and 40 cm for black soils of Research farm National Livelihood Resources Institute, Ratlam (Madhya Pradesh) have been considered. The simulation studies were performed considering three inflow discharge (viz. 0.10, 0.15 and 0.35 lps) and four slopes (viz. 2.0, 4.0, 6.0 and 8.0) in Rainfall Simulator. The duration of each experiment was fixed as 6 minutes and inflow is regulated through control valve. The observations were recorded for runoff, soil loss, and percolation. The Runoff and soil loss have been observed in the range of 64 to 82 per cent of inflow discharge and 0.3580 to 7.324 g/l.

KEYWORDS: *Runoff, Soil Losses, Deep Percolation Loss, Black Soils, Tilting Rainfall Simulator.*

Introduction

Annual soil loss in India was estimated as about 5334 million tonnes (16.4 tonnes / ha /yr) due to agricultural and associated activities. About 1572 million tonnes (4.8 tonnes / ha /yr) soil is carried away into sea as sediment by the different rivers of the country. Likewise, about 480 million tonnes of soil are deposited into various reservoirs of the country. The rate of soil erosion in different soils by sheet erosion is estimated as 4 to 10 tonnes/ ha/year in red soils, 17 to 93 tonnes/ ha/ year in black soils and 4 to 14 tonnes / ha / year in alluvial soils. The rate of soil erosion from gullies is computed as 33 tonnes / ha / year in ravine regions (Dhurvanarayana and Ram Babu, 1983).

Black soils (Vertisols) occupy 72.90 mha in the country and thus form a major soil resource. Major black soil states in our country are Maharastra (29.9 mha), M.P. (16.7 mha), Gujarat (8.2 mha), A.P. (7.2 mha) and Karnataka (6.9 mha). Black soils are also found in Rajasthan, Bihar and U.P. but to a lesser extent. These soils, although are fertile, suffer from severe drawbacks. High intensity rainfall and poor permeability of soil cause erosion and inadequate moisture storage in the soil profile. The black soils are highly erodible without any mechanical measures. Soil loss from black soils has been estimated to be 23.70 to 112.5 tonnes/ha /year with agriculture as main land use (Rama Mohan Rao *et al.* 1990). Madhya Pradesh state is having 44.34 m ha total geographical area, out of which 23 per cent area is Total Degraded and Wasteland Majority of the problematic area is under black soil region and 44 % of total

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geographical area affected by Water Erosion which required immediate technology for treatment. Keeping the above facts in mind, a study was planned to know the effect of stone barrier on runoff and soil loss in black soils under different discharge rate and slopes in simulated channel condition. This information is of importance to develop approaches for reducing erosion at beginning stage from field and improving upon the deep drainage in watercourses. In the present paper, representative verticals of semi arid region of the Karnataka, India was considered for the experiment comparing loose stone barrier and bare soil condition.

Material and Methods

- **Experimental Set up:** The soil was taken from soils of National Livelihood Resources Institute, Ratlam (Madhya Pradesh) lab studies in Rainfall Simulator developed. The soil was uniformly filled up to a depth of 30 and 40 cm in the flume over 10 cm sand cushion. The soil bed was compacted to achieve the field conditions with average bulk density between 1.2 to 1.3 g/cc. The soil bed was leveled with a wooden plank for observation under field capacity conditions. Before each experiment, the soil was saturated and brought to uniform moisture level by allowing the excess water to drain out. This condition was observed after 40 hours of saturation and readings were taken after 48 hours.
- **Parameters for the Simulation Studies**

  The following parameters are taken for the simulation studies:
  - **Soil Depth:** The maximum soil depth ranged from 30 to 40 cm and sub soils from 40 – 90 cm in black soil region of Central India (Bhola and Jayaram, 1977). Therefore, two depths (30 and 40 cm) of soil have been taken up for the study.
  - **Inflow Rates:** The erosive rainfall intensity of 10 year recurrence interval has been reported as 79 mm per hr to 140 mm per hr for the study area (Babu, *et al.* 1979). Therefore, three inflow rates (0.10, 0.15, and 0.35 lps) have been considered for the study to represent peak runoff.
  - **Duration of Inflow:** The normal duration of single storm was found to be around 6 minutes. Therefore, duration of 6 minutes was taken up for the simulation study.
  - **Slope of soil bed surface:** Prevailing land slope in the black soil region of Madhya Pradesh ranges up to 8 per cent. Therefore four slopes (2.0, 4.0, 6.0 and 8.0 %) have been considered for the study.
  - **Height and Cross Section of the Loose Stone Barrier:** Loose stone barrier has been kept at downstream end. The cross section area of loose stone barrier was taken as 9 sq cm with top width of 3 cm, height of 3.0 cm, side slope of 1:0.5 and base width of 5.0 cm. These dimensions are based on estimation made for likely depth of inflow over the soil bed in the percolation tray section.
  - **State of Soil:** The runoff producing characteristics of black soils vary considerably when these soils are in wet condition. But, as far as runoff and soil loss from black soils are concerned, initial moisture content of soil plays a very important role. Therefore, similar soil moisture condition has been maintained for simulation studies.
- **Characteristics**

Characteristics of test soil sample considered of National Livelihood Resources Institute, Ratlam (Madhya Pradesh) series are as follow:

Soil type	Black soils
Soil bed depth	30 cm and 40cm
Bulk density	1.2 to 1.3 g / cc
Particle density	2.65 g / cc
Textural class	clayey
Field capacity	35-40 per cent
Wilting point	18.0 per cent
Hydraulic conductivity	0.8 mm / hr
Soil condition	Field capacity
Water holding capacity	60 to 65 %

Results and Discussion

- **Bare Soil Condition over 30 cm Depth of Soil**

The runoff from the bare soil was observed for the bed slopes of 2.0, 4.0, 6.0 and 8.0 per cent under three Inflow discharges (0.10, 0.15, and 0.35 lps) and the same are Presented in terms of percentage of inflow. The runoff volume (% of inflow) were observed as 64.1, 66.9, 68.15 and 72.80

per cent for slope of 2.0, 4.0, 6.0 and 8.0 per cent respectively for inflow discharge of 0.10 lps. Similarly, runoff were observed as 66.50, 68.60, 71.30 and 75.00 per cent and 68.24, 70.18, 75.00 and 82.00 per cent for 0.15 and 0.35 lps of inflow discharge respectively.

Table 1: Effect of Slope and Inflow Discharge on Runoff under Bare Condition with 30 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Runoff (% inflow)			
0.10	64.10	66.90	68.15	72.80
0.15	66.50	68.60	71.30	75.00
0.35	68.24	70.18	75.00	82.00

Source: Experimental Data 2013

- **Loose Stone Barrier Over 30 cm Depth of Soil**

The effect of loose stone barrier on runoff at 2.0, 4.0, 6.0, and 8.0 per cent slopes under different inflow discharges (0.10, 0.15, and 0.35 lps) are presented in percentage of inflow. The observed runoff volumes were 57.3, 61.00, 63.14 and 68.20 per cent under 0.10 lps Inflow discharge, 61.00, 63.16, 66.14 and 70.68 per cent under 0.15 lps Inflow discharge and 63.28, 65.38, 70.12 and 77.92 per cent of inflow under 0.35 lps Inflow discharge at 2.0, 4.0, 6.0 and 8.0 percent slopes respectively. It was observed that when slope and discharge are increased, runoff also decreased even after putting stone barrier.

Table 2: Effect of Slope and Inflow Discharge on Runoff with Stone Barrier with 30 cm Soil Depth

Slope / Inflow Discharge (lps)	2%	4 %	6 %	8 %
	Runoff (% inflow)			
0.10	57.30	61.00	63.14	68.20
0.15	61.00	63.16	66.14	70.68
0.35	63.28	65.38	70.12	77.92

Source: Experimental Data 2013.

- **Bare Soil Condition over 40 cm Depth of Soil**

The experiment was conducted to evaluate effect of depth of bare soil on runoff considering 40 cm soil depth for the bed slopes of 2.0, 4.0, 6.0 and 8.0 per cent under three Inflow discharges (0.10, 0.15, and 0.35 lps) and same presented in terms of percentage of inflow. The run off (% of inflow) were observed as 63.7, 66.6, 67.95 and 72.7 per cent for slope of 2.0, 4.0, 6.0 and 8.0 per cent respectively for inflow discharge of 0.10 lps. Similarly, runoffs (% of inflow) were observed as 66.24, 68.40, 71.2 and 74.94 per cent and 68.08, 70.08, 75.90 and 81.96 per cent for 0.15 and 0.35 lps of inflow. In case of higher Inflow discharge (0.35 lps) and slope (8 %), runoff was as high as 81.96 per cent of the inflow, which is more or less same as observed with 30 cm soil depth, showing similar trend as that under bare condition, runoff is directly proportional to the inflow discharges and degree of slopes.

Table 3: Effect of Slope and Inflow Discharge on Runoff under Bare Condition with 40 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Runoff (% inflow)			
0.10	63.7	66.6	67.95	72.7
0.15	66.24	68.4	71.2	74.94
0.35	68.08	70.08	75.9	81.96

Source: Experimental Data 2013

- **Loose Stone Barrier Over 40 cm Depth of Soil**

The effect of loose stone barrier on runoff at 2.0, 4.0, 6.0 and 8.0 per cent slopes under different inflow discharges (0.10, 0.15, and 0.35 lps) are presented as percentage of inflow. The runoff observed were 56.8, 60.4, 62.58 and 68.05 per cent under 0.10 lps Inflow discharge, 59.8, 62.56, 65.80 and 70.58 per cent under 0.15 lps discharge and 62.18, 64.68, 70.53 and 77.86 per cent of inflow under 0.35 lps Inflow discharge, at 2.0, 4.0, 6.0 and 8.0 per cent slopes respectively. Therefore, it is observed that as slopes and Inflow discharges increase, runoff percentages of inflow also increase. It has also been observed that stone barrier is more effective up to 4.0 per cent slope with 0.15 lps discharge.

Table 4: Effect of Slope and Inflow Discharge on Runoff with Stone Barrier with 40 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Runoff (% inflow)			
0.10	56.8	60.4	62.58	68.05
0.15	59.8	62.56	65.8	70.58
0.35	62.18	64.68	70.53	77.86

Source: Experimental Data 2013

Effect of Different Inflow Discharge and Slopes on Soil Loss

The set of experiments were performed to measure soil loss for duration of 6 minutes under various simulated conditions. Soil loss was measured under bare and barrier conditions for different inflow rates i.e. 0.10, 0.15, 0.35 lps and under different degree of slopes i.e. 2.0, 4.0, 6.0 and 8.0 per cent respectively under 30 and 40 cm soil depths. The observed values of soil loss under different discharges and slopes are expressed in grams per liter and discussed below:

- **Bare Soil Condition over 30 cm Depth of Soil**

The data on observed values of sediment concentration and their prediction for different Inflow discharges (0.10, 0.15 and 0.35 lps) and slopes (2.0, 4.0, 6.0 and 8.0 %) are presented in grams per liter. The sediment concentration rates were observed as 0.36, 1.26, 2.289 and 5.85 g/l for slopes of 2, 4, 6 and 8 per cent respectively for inflow discharge of 0.10 lps. Similarly, sediment concentrations were observed as 0.86, 1.544, 3.396 and 6.076 g/l and 1.36, 2.2456, 4.136 and 7.324 g/l for inflow discharge 0.15 and 0.35 lps respectively. The sediment concentration was lowest (0.36 g/l) at 2.0 per cent slope with 0.10 lps Inflow discharge followed by 0.86g/l under 2.0 per cent with 0.15 lps Inflow discharge and highest under 8 per cent slope (7.324 g/l) with 0.35 lps Inflow discharge. It is seen from the results that there is an increase in the sediment concentration as the slope increases from 2.0 per cent to 8.0 per cent and discharge increases from 0.10 lps to 0.35 lps. But after 6.0 to 8.0 per cent slope and 0.15 to 0.35 lps Inflow discharge, increase in sediment concentration is very high as compared to 2.0 to 4.0 per cent slope and 0.10 to 0.15 lps discharge.

Table 5: Effect of Slope & Inflow Discharge on Soil Loss (g/l) under bare condition with 30 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Soil loss (g/l)			
0.10	0.3600	1.260	2.289	5.850
0.15	0.8600	1.540	3.396	6.076
0.35	1.3600	2.245	4.136	7.324

Source: Experimental Data 2013.

- **Loose Stone Barrier over 30 cm Depth of Soil**

The effect of loose stone barrier on sediment concentration at 2.0, 4.0, 6.0 and 8.0 per cent slopes 0.10, 0.15 and 0.35 lps inflow discharges are presented in grams per liter. The sediment concentration recorded were 0.135, 0.485, 1.00 and 2.572 g /l under 0.10 lps Inflow discharge, 0.3580, 0.651, 1.61 and 3.589 g/l under 0.15 lps and 0.5780, 1.008, 2.03 and 4.603g/l under 0.35 lps at 2.0, 4.0, 6.0 and 8.0 per cent slopes respectively. The sediment concentration was lowest (0.135 g/l) at 2.0 per cent slope with 0.10 lps followed by 0.35g/l under 2.0 per cent slope with 0.15 lps and highest 4.603g/l under 8.0 per cent slope with Inflow discharge of 0.35 lps. It is seen from the results that there is an increase in the sediment concentration as the slope increases from 2.0 per cent to 8.0 per cent and discharge from 0.10 lps to 0.35 lps.

Table 6: Effect of Slope & Inflow Discharge on Soil Loss (G/L) with Stone Barrier with 30 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Soil loss (g/l)			
0.10	0.135	0.485	1.000	2.572
0.15	0.358	0.651	1.610	3.589
0.35	0.578	1.008	2.030	4.603

Source: Experimental Data 2013

- **Bare Soil Condition over 40 cm Depth of Soil**

The data on observed values of sediment concentration and their prediction for different Inflow discharges (0.10, 0.15 and 0.35 lps) and slopes (2.0, 4.0, 6.0 and 8.0 per cent) are presented in grams per liter. The sediment concentrations in runoff were observed as 0.29, 1.201, 2.28 and 4.83 g/l for slopes 2.0, 4.0, 6.0 and 8.0 per cent for inflow discharge of 0.10 lps. Similarly, sediment concentration in run off were observed as 0.84, 1.539, 3.353, 6.03 g/l and 1.320, 2.225, 4.116, 7.324 g/l for 0.15 and 0.35 lps inflow discharge respectively. The sediment concentration rates found similar trends as observed for 30 cm soil depth. It means that under simulated condition, small changes in the depth of soil have little effect over soil loss. The sediment concentration was found lowest (0.29 g/l) at 2.0 per cent slope with 0.10 lps followed by 0.84g/l under 2.0 per cent slope with Inflow discharge of 0.15 lps and highest at 8.0 per cent slope (7.324 g/l) with inflow discharge of 0.35 lps. It is observed that there is an increase in the sediment concentration as the slope increased from 2.0 per cent to 8.0 per cent and Inflow discharge from 0.10 lps to 0.35 lps. It shows that when slopes and Inflow discharges increase, sediment concentration in runoff also increases.

Table 7: Effect of Slope and Inflow Discharge on Soil Loss (G/L) Under Bare Soil Condition with 40 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Soil loss (g/l)			
0.10	0.2900	1.201	2.280	4.830
0.15	0.8400	1.539	3.353	6.036
0.35	1.3200	2.225	4.116	7.324

Source: Experimental Data 2013.

- **Loose stone barrier over 40 cm depth of soil**

The effect of loose stone barrier on sediment concentration in runoff at 2.0, 4.0, 6.0 and 8.0 per cent slopes under different discharges (0.10, 0.15 and 0.35 lps) are presented in grams per liter. The sediment concentrations in runoff observed under 0.10 lps inflow discharge were 0.096, 0.453, 0.961 and 2.568 g /l; 0.32, 0.631, 1.600 and 3.568 g/l under 0.15 lps Inflow discharge and 0.55, 0.963, 2.00 and 4.568 g/l under 0.35 lps Inflow discharge under 2.0, 4.0, 6.0 and 8.0 per cent slopes respectively. The sediment concentration was lowest (0.096 g/l) at 2.0 per cent slope with 0.10 lps followed by (0.32 g/l) under 2.0 per cent with 0.15 lps and highest (4.568 g/l) at 8.0 per cent slope with Inflow discharge 0.35 lps. It is evident from the results that there is an increase in the sediment concentration as the slope increased from 2.0 to 8.0 per cent and discharge increased from0.10 to 0.35 lps. It shows that when slopes and discharges increase, sediment concentration in runoff also increases under bare as well as stone barrier condition.

Table 8: Effect of Slope and Inflow Discharge on Soil Loss (G/L) under Stone Barrier Condition with 40 cm Soil Depth

Slope / Inflow discharge (lps)	2%	4 %	6 %	8 %
	Soil loss (g/l)			
0.10	0.096	0.453	0.961	2.568
0.15	0.320	0.631	1.600	3.568
0.35	0.550	0.963	2.000	4.568

Source: Experimental Data 2013

Conclusion

The following conclusions are drawn from the research study:

- The developed new Rainfall Simulator is capable to measure percolation losses and also have provision for varying soil depths for lab studies in addition to measurement of runoff, and soil loss.
- It is found that black soils after getting wet, depth of soil is not predominating factor and runoff is observed more or less same for the both depths of 30 and 40 cm considered here in.
- The runoff ranges from 63 to 82 per cent under bare soil where as it ranges 56.8 to 79 per cent under loose stone barrier condition for the inflow discharge range in between 0.10 to 0.35 lps and slope range in between 2.0 to 8.0 per cent. .
- The soil losses were observed more or less identical in case of both 30 and 40 cm soil depth. The soil loss ranges from 0.20 to 7.324 g/l under bare soil condition where as it ranges from 0.096 to 4.0603 g/l under loose stone barrier condition for the discharge range in between 0.10 to 0.35 lps in the slope range in between 2.0 to 8.0 per cent.

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