

## Effect of Land Slope and Rainfall Intensity on Splash Erosion under Simulated Rainfall Condition

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**Abstract:** Soil erosion is a global problem that threatens the natural resources seriously. Soil erosion is one of the major threats to agricultural productivity and environmental quality, especially water and soil. With increasing amount of soil loss at the hill slope scale, agricultural productivity is decreasing and environmental quality is deteriorating. Splash erosion is recognized as the first stage in a soil erosion process. The importance of the soil erosion problem and its impact on soil management and conservation led to this study, in which an attempt has been made to study splash detachment process for various combinations of land slopes and rainfall intensities with the help of rainfall simulation system and modified Morgan's splash cup. The study was conducted under laboratory condition by using rainfall simulation system, capable of generating artificial rainfall almost similar to natural rainfall. The clay soil was used to study the splash erosion. Uniformity coefficient of simulated rainfall was above 70 per cent for all the six rainfall intensities viz. 7.75, 5.80, 4.23, 3.28, 2.04 and 1.07 cm h<sup>-1</sup>. The directional splash soil loss rate (kg ha<sup>-1</sup>), i.e. upslope and down slope were found increasing with increase in rainfall intensity and land slope. The rate of increase in down slope splash was comparatively more than upslope. The highest soil splash i.e. 16369 kg ha<sup>-1</sup> was observed for combination of 10 per cent land slope and 7.75 cm h<sup>-1</sup> rainfall intensity in clay soil for the various combination of slope and rainfall intensity.

**Key words:** Clay soil, rainfall intensity, splash erosion, simulated rainfall

### INTRODUCTION

In recent years agriculture and food production have intensified the soil erosion due to population increase and human activities transformation, so that about 75 billion tons of soils are eroded from lands each year discussed by Bayramin *et al.* [1]. Water erosion is a process by which soil aggregates and primary particles are detached from the soil matrix, transported down slope by raindrops and flowing water, and deposited under certain energy-limiting conditions. Four basic detachment and transport processes have been identified, including detachment by raindrops, detachment by flowing water, transport by raindrops, and transport by flowing water. Splash erosion is recognized as the first stage in a soil erosion process that results from the impact of rain drops. Soil particles are separated

by rain drops and are transmitted by runoff. Splash process can cause movement of soil particles, which show less cohesive forces shown by Wuddivira *et al.* [2].

Splash erosion is a complex process including the detachment of soil particles by raindrops followed by splash transport of a part of the detached particles. Splash is responsible for initiating water erosion, since it is the first erosion to occur when an erosive rainfall event takes place; though soil erosion is usually associated primarily with surface runoff, other studies have shown that under certain topographical conditions, soil detachment is influenced more by raindrop impact than by overland flow. Rose [3], observed that soil loss increases ten times when water is applied as a spray in comparison with the same application rate

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as surface flow. Therefore, although surface runoff is usually considered the major soil moving agent, raindrop erosion also plays an important role in not only detaching the soil particles but also causing soil movement even before the runoff starts as discussed by Quansah, [4].

One very effective approach to the study of soil erosion processes and the analysis of possible remedial strategies involves the use of rainfall simulator. Drop velocity is important in designing a rainfall simulator. Drops from natural rainfall are at terminal velocity when they hit the soil surface ; Meyer and McCune, [5]. Therefore, a rainfall simulator must create drops of adequate size and velocity to simulate the same condition, indicating the importance between an adequate and related fall distance and drop size distribution. Direct relationship exists between drop diameter and fall distance discussed by Laws, [6]. The classical method for quantifying splash erosion relies on the use of splash cups, or small traps that collect soil particles detached and transported by splash (Morgan, and Legout *et al.*, [7, 8].

The importance of the soil erosion problem and its impact on soil management and conservation led to the recent study, in which an attempt has been made to study splash detachment process for various combination of land slopes and rainfall intensities with the help of rainfall simulation system and modified Morgan's splash cup. The present research work was undertaken during 2013 in the Department of Soil and Water Conservation Engineering, Dr. A. S. College of Agricultural Engineering, MPKV, Rahuri. The following objectives selected for the experiment viz. to study the effect of land slope on splash erosion, to study the movement of splashed material in vertical and horizontal directions under different rainfall intensities, to develop the device for measurement of splash erosion.

## MATERIAL AND METHODS

The experimental set up consists of rainfall simulation system, modified Morgan's splash cup and cover for protecting the cup (Fig. 1).



Figure 1: Complete arrangement for quantification of Splashed soil

A turbine nozzle is used for simulation of rainfall. The height of nozzle is kept 4.2 m from the ground surface. Lance was connected to the PVC pipe. The details of nozzle are given as below. Version Standard: 61mm body with  $\text{Ø}1.0$  mm with ball joint. Materials - brass, made by company Shree Parmeshwar Machine Tools (PMT), Vavdi, Rajkot (Gujarat) with an excellent micronization. A pressure gauge having a dial diameter of 6 cm was mounted on main supply line on a lance just near the nozzle to monitor the water pressure. In the present study, the pressure was varied from 0.2 to 2.8  $\text{kg cm}^{-2}$  at an equal increment of 0.1  $\text{kg cm}^{-2}$ . Calculations for rainfall intensity were based on amount of water collected during each time interval. Rainfall intensity was calculated for water pressure range from 0.2 to 2.8  $\text{kg cm}^{-2}$  at an increment of 0.1  $\text{kg cm}^{-2}$ . The required water pressure at increment of 0.1  $\text{kg cm}^{-2}$  was adjusted using flow regulating valve. The total quantity of water received through the nozzle at desired water pressure was collected in plastic bucket for 2 minute duration. This study was conducted with six rainfall intensities i.e. 7.75, 5.80, 4.23, 3.28, 2.04 and 1.07  $\text{cm h}^{-1}$  for five different land slopes i.e. 1, 3, 5, 7 and 10 %. The Clay textured soil was used for the experiment.

The uniformity coefficient of simulated rainfall was determined for all selected rainfall intensities using relationship developed by Christiansen [9]. The raindrop size was determined by 'flour pellet' method discussed by Hudson, [10]. Modified Morgan's splash cups were fabricated by changing the diameter of catching tray as 600 mm and keeping

all other dimensions same. The floor of the catching tray was replaced with a wire mesh sheet covered with muslin cloth. This will allow free drainage of the rainwater whilst still allowing the collection of splashed particles. Two semicircular rings were made with G.I. wire to fix the muslin cloth over catching tray properly and for easy replacement of muslin cloth. When set up on a horizontal surface the apparatus will catch all particles splashed from the soil in the inner cylinder for distances less than the radius of the catching tray (Fig. 2).

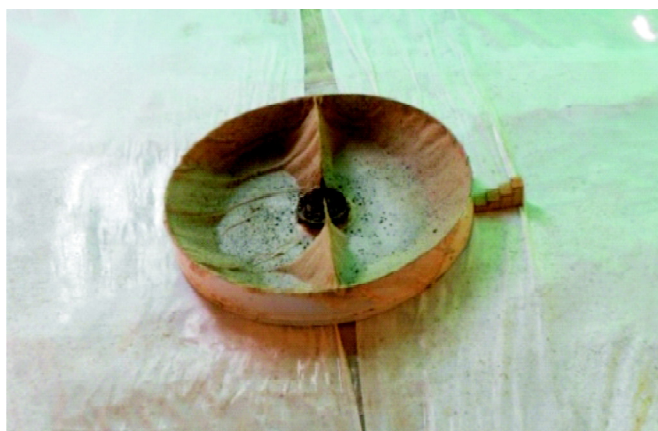


Figure 2: Modified Morgan's splash cup

### **Determination of Splash soil loss**

For estimating the splash soil loss, splashed soil is collected separately from the up slope and down slope compartments of the catching tray. Muslin cloth was used to cover the catching tray. Two separate muslin clothes were used for upslope and down slope compartment. The muslin cloth covered over the floor of catching tray was removed by removing the semicircular G.I. wire frame, and washed with water in a bucket to detach the soil particles. The muslin cloth which was kept below and surrounding the splash cup at a distance about 1.5 m on both sides from the centre of soil plot also removed and washed with water in bucket. This water with splashed soil is taken in sample bottles of 1000 and 1500 ml capacity and kept for 24 hours for settlement of suspended soil particles. The clear suspension was decanted off and remaining sample with little water is stirred thoroughly and filtered. Soil on filter paper was oven dried at 105°C for 24 h and weighed. The upslope and down slope weights combined are a measure of splash detachment. Data

may be expressed on a unit width per unit time or a unit area per unit time basis (Morgan, 1978).

### **Determination of horizontal and vertical movement of splashed soil particles**

The modified Morgan's splash cup was installed on a soil plot by giving the desired slope just below the sprinkling unit (nozzle). Soil plot was covered by muslin cloth of suitable size. Antecedent moisture content at pre-wetted condition was selected. Pre-wetting was done by applying water through the drain for 24 h. The pre-wet soil was immersed in the inner hollow cylinder up to full depth. The six rainfall intensities viz. 7.75, 5.8, 4.23, 2.98, 2.01 and 1.07 cm/h were selected to test the movement of splashed particles with two replications. Simulated rainfall at various rainfall intensities was continued till the runoff takes place from the soil placed in the inner cylinder of length 11 cm. The splashed soil particles from inner cylinder of modified Morgan's cup which marked the stains on muslin cloth.



Figure 3: Vertical Splash board

The range of horizontal movement of splashed soil particles was measured by measuring tape. The vertical splash boards arranged adjoining the modified Morgan's splash cup received the splashed soil particles. The vertical distance was measured, where the soil particles strikes on the graduated marking of the splash board. The horizontal and vertical movements of splashed soil particles were observed under selected six rainfall intensities. The details of vertical splash board are shown in Fig. 3.

## RESULTS AND DISCUSSION

This study was undertaken to observe the soil loss due to splash as influenced by rainfall intensity and land slope for bare soil condition under simulated rainfall. Accordingly, modified Morgan's splash cup with outer diameter 60 cm and partitioned into two compartments i.e. up slope and down slope was used to quantify directional splash. This study was conducted at six rainfall intensities i.e. 7.75, 5.80, 4.23, 3.28, 2.04 and 1.07 cm h<sup>-1</sup> and for five different land slopes i.e. 1, 3, 5, 7 and 10 %. The Clay textured soil was used for the experiment and height of rainfall simulator were kept constant. The suitability of simulator is tested by determining the uniformity coefficients at different rainfall intensities. The time of exposure was maintained up to runoff generation

from soil filled in inner cylinder. The splash soil loss for different combinations of rainfall intensities and land slopes were observed in two replications and the results obtained are described below. The uniformity coefficient of simulated rainfall under different rainfall intensities was 71.80 to 89.75% for rainfall intensities 11.22 to 1.07 cm h<sup>-1</sup>, which are more than 70 % and hence acceptable as discussed by Esteves *et al.* [11]. It is observed that the raindrop size increased with increasing rainfall intensity. The rain drop size observed from 1.48 mm to 3.24 mm for the range of rainfall intensities from 1.07 cm h<sup>-1</sup> to 7.75 cm h<sup>-1</sup> respectively. For different combinations of rainfall intensities and land slopes up to the runoff generation, the soil splash in both the direction i.e. upslope and down slope were collected separately according to the procedure described in material and methods. The collected soil splash in different direction is then converted to splash soil loss rate in kg ha<sup>-1</sup>. The values thus obtained are given in Table 1.

From Table 1, it is found that with increase in land slopes, splash soil loss rate increased for all selected rainfall intensities for the clay soil. The splash soil loss rate increased from 6815 to 16369 kg ha<sup>-1</sup> as land slope increased from 1 to 10 % at 7.75 cm h<sup>-1</sup> rainfall intensity in clay soil. Similar trend

**Table 1**  
Directional splash soil loss rate (kg ha<sup>-1</sup>) at different combinations of rainfall intensity and land slopes in clay soil

Land slope (%)	Direction of splash soil loss	Rainfall intensities (cm h <sup>-1</sup> )					
		7.75	5.8	4.23	3.28	2.04	1.07
1	Up slope	1401	1338	1146	987	–	–
	Down slope	5414	2611	1401	1178	–	–
	Total	6815	3949	2548	2166	–	–
3	Up slope	2420	1401	1465	1242	–	–
	Down slope	6051	3248	1720	1465	–	–
	Total	8471	4650	3185	2701	–	–
5	Up slope	2994	1592	1975	1592	–	–
	Down slope	7070	4395	2420	1847	–	–
	Total	10064	5987	4395	3439	–	–
7	Up slope	3994	2229	2420	1847	–	–
	Down slope	8344	4968	2930	2229	–	–
	Total	12038	7197	5350	4076	–	–
10	Up slope	5796	2994	2739	2166	–	–
	Down slope	10573	5987	3439	2675	–	–
	Total	16369	8991	6178	4841	–	–

was observed for all rainfall intensities with increase in land slope. The maximum value of splash soil loss rates were observed at 10 % land slope, whereas minimum values were observed at 1 % land slope for all selected rainfall intensities. It is revealed from Table 1 with the increase in rainfall intensity, upslope and down slope splash soil loss rates increased for all selected land slopes viz., 1, 3, 5, 7 and 10 %; thus increase in total splash soil loss rate

(up slope + down slope) with increase in rainfall intensity for all given land slopes. Similar results have been obtained and reported by Akurde, [12]. Splash soil loss was not found for the intensities 2.04 and 1.07cm h<sup>-1</sup>. This conclusion confirmed the findings reported by Hudson [13].

From Table 2, it was observed that for all rainfall intensities down slope vertical movement

**Table 2**  
Average vertical movement of splashed material for different land slope and rainfall intensity in clay soil

R.I (cm h <sup>-1</sup> )	V.M (cm)	1 % slope		A.V.M (cm)		3 % slope		A.V.M (cm)		5 % slope		A.V.M (cm)		7 % slope		A.V.M (cm)		10 % slope		A.V.M (cm)		
		R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			
7.75	U.S	70	72	71	68	67	67.5	66	64	65	65	64	64.5	64	62	63						
	D.S	72	71	71.5	74	72	73	78	79	78.5	80	82	81	82	84	83						
5.8	U.S	62	60	61	60	61	60.5	58	60	59	56	55	55.5	55	53	54						
	D.S	65	63	64	67	68	67.5	69	68	68.5	73	75	74	74	76	75						
4.23	U.S	42	41	41.5	41	40	40.5	38	40	39	36	38	37	34	35	34.5						
	D.S	45	48	46.5	46	44	45	48	47	47.5	52	53	52.5	55	56	55.5						
3.28	U.S	24	26	25	21	19	20	20	18	19	18	18	18	16	18	17						
	D.S	26	26	26	28	26	27	30	32	31	32	33	32.5	35	37	36						
2.04	U.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	D.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
1.07	U.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	D.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						

Note: R.I = Rainfall intensity, V.M = Vertical movement, A.V.M = Average vertical movement, U.S = Up slope, D.S = Down slope

**Table 3**  
Average horizontal movement of splashed material for different land slope and rainfall intensity in clay soil

R.I. (cm h <sup>-1</sup> )	H.M (cm)	1 % slope		A.H.M (cm)		3 % slope		A.H.M (cm)		5 % slope		A.H.M (cm)		7 % slope		A.H.M (cm)		10 % slope		A.H.M (cm)		
		R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>			
7.75	U.S	80	79	79.5	77	75	76	74	73	73.5	72	71	71.5	70	68	69						
	D.S	85	87	86	88	89	88.5	90	92	91	95	96	95.5	100	101	100.5						
5.8	U.S	70	68	69	68	66	67	67	65	66	65	64	64.5	60	59	59.5						
	D.S	75	77	76	78	80	79	80	82	81	85	87	86	95	96	95.5						
4.23	U.S	58	57	57.5	55	54	54.5	52	51	51.5	51	50	50.5	50	49	49.5						
	D.S	62	64	63	64	65	64.5	66	68	67	72	74	73	84	86	85						
3.28	U.S	44	42	43	42	40	41	40	39	38	38	36	37	36	35	35.5						
	D.S	48	50	49	52	54	53	55	57	56	60	62	61	68	70	69						
2.04	U.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	D.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
1.07	U.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	D.S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						

Note: R.I = Rainfall intensity, H.M = Horizontal movement, A.H.M = Average horizontal movement, U.S = Up slope, D.S = Down slope

increased with increasing slope and up slope vertical movement decreased with increasing land slope. The observations were taken with selected rainfall intensities 7.75, 5.80, 4.23, 3.28 and 1.07 cm h<sup>-1</sup> for different land slope. The horizontal and vertical movement of splashed soil particles in down slope and up slope directions were observed and tabulated in Tables 2 and 3.

The horizontal spread of splashed soil material was about 100.5 cm in the down slope direction and 69.0 cm in the up slope direction, which is beyond the diameter of modified Morgan's splash cup.

## CONCLUSION

In order to get realistic values of splashed soil loss for detail studies on splash soil erosion processes the dimensions of splash cup need to be increased.

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