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Estimation of Infiltration Rate, Run- Off and Sediment Yield Under Simulated Rainfall Experiments in Bilodra

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ABSTRACT

The main objective of this study is to measure the effect of slope and grass-cover on infiltration rate, run-off and sediment yield under simulated rainfall area located in the bilodra. An automatic rainfall simulator was designed following Dunne et al (1980) and considering the local conditions. Experiments were conducted on six selected experimental fields of 2 × 2m within the catchment with distinct variations in surface characteristics – grass-covered area with gentle slope, recently ploughed gently sloping area, area covered by crop residue (moderate slope), steep slope, gravelly surface with near flat slope and steep slope with grass-cover. The results indicate subtle to noteworthy variations amongst the plots depending on their slope angle and surface characteristics. An important finding that emerges from the study is that the grass-cover is the most effective measure in inducing infiltration and in turn minimizing run-off and sediment yield. Sediment yields are lowest in gently sloping grass-covered surfaces and highest in bare bad land surfaces with steep slopes. These findings have enormous implication for this area, because over 2/3 area is characterized by bare and steep slopes.

Keywords : Rainfall simulator, infiltration, sediment yield, grass-covered surface, experimental plots.

INTRODUCTION

Controlled experiments under simulated rainfall for studying infiltration and soil erodibility are not a new concept amongst the scientists concerned with soil erosion and land management. However, most of these experiments have been conducted in technologically advanced nations where there is abundant availability of capital, skilled labour and water resources. Although rainfall simulation experiments to evaluate rainfall–run-off relations and soil erosion have been overwhelmingly conducted in Europe and North America; similar studies are practically unknown from South Asia, particularly from the semi-arid region. In India also, very few studies have been reported that focused on infiltration, run-off and erosion studies based rainfall simulator experiment (Bhardwaj and Singh 1992; Singh et al 1999). Rawat et al (1992) and Rawat and Rai (1997) have measured run-off and sediment yield over a period of 2–3 years from micro-watersheds in Kumaun Himalaya under the natural rainfall conditions but studies based on simulated rainfall are very rare in the country. In an agriculture-based country like India, where there is ever increasing pressure of population on land and water resources, such field experiments would be of great help in the proper understanding of the widespread problem of land degradation and soil erosion. In a data-poor country like India, controlled field and/or laboratory experiments under simulated rainfall have several advantages. There are formidable practical difficulties in carrying out such long-term monitoring experiments under natural conditions due to anthropogenic disturbances. Therefore the present investigation aims at studying the control of various land uses on soil erosion and sediment yield under the simulated rainfall conditions. The main objective of this study was to measure the effect of slope and grass-cover on run off, infiltration and sediment yield under simulated rainfall area of Bilodra.

DESIGN OF RAINFALL SIMULATOR

For all the rainfall experiment studies carried out in different parts of the globe, different simulators have been used by different investigators that are designed to suit the local requirements (Tricker 1979; Dunne et al 1980; Roth et al 1985; Bowyer-Bower and Burt 1989; Exeter 1990; Bhardwaj and Singh 1992; Hignett et al 1995; Cerda et al 1997; Singh et al 1999 and Wright et al 2002 and others). Like earlier studies, in this study also while designing the simulator, several factors such as the terrain characteristics, plot size, accessibility to water sources, etc. have been taken into consideration. The rainfall simulator has been designed following Dunne et al (1980). The present simulator, however, is automatic and certain specifications have been modified to suit the present requirements. The simulator consists of a bolted steel frame 3m high (which can be adjusted according to the gradient of the surface) and is 2 × 2m in size. A steel track is suspended along the central line of the structure Four nozzles are attached to a wheeled trolley (1.2mm in diameter) which moves automatically along the track. The track-ends are protected with foam rubber. The trolley is made to traverse a length of 1.9m in <3 seconds. The speed of the movement of the trolley is so adjusted to distribute uniform spray of rainfall all over the experimental plot.

On windy days we shielded the plot by attaching a heavy canvas sheet on the upwind side of the steel frame. A schematic diagram of the end and side diagrams of the suspension and the system used for supplying water to the rainfall simulator has been reproduced from Dunne et al (1980) and Water was supplied to the nozzle from a 500-litre water tank by a 1-HP diesel pump. It suffices for 1-h experiment. The main hose pipe from the pump bifurcates into two. One line goes to the nozzle and the other is connected back to the water tank. A valve is fitted to the return pipe to adjust the pressure and flow rate of the first pipe connected to the nozzle. Repeated observations indicate that after the initial adjustment the pressure generally remains constant during the entire experiment. The nozzles were custom-made. After several trial runs and calibrations, the final simulations were carried out on six plots in the study area, to estimate the rainfall intensity vis-à-vis infiltration rate, run-off rate and sediment yield. To calculate all the above parameters standard procedures were adopted (Dunne et al 1980). The plot specifications and the results of the study are presented in the following section.

STUDY AREA

The present study area is situated at the latitude of 23 31’ 00’ and longitude of 72 39’ 00’’ in Gujarat in Kheda district.

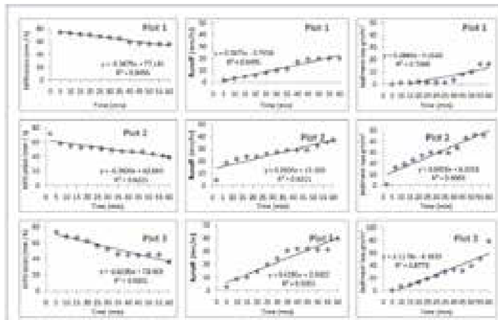
EXPERIMENTAL PLOTS

In order to ensure highest possible accuracy in the estimation of the infiltration rate and the runoff, the experimental plots were designed exactly following Dunne et al (1980). At the lower end of each plot a sheet metal trough received the run-off and sediment, and conveyed them to a collection point. The slope of the metal trough was adjusted to match with the slope of the plot. Extra care was taken so that there is no loss of run-off and sediments.

Installation of the collection trough began with the digging of a 2-m long, 22 cm wide and 25 cm deep trench at the lower end of the experimental plot. A prefabricated metal sheet was placed in the trough and was held firmly against the upslope face by backfilling the trench from all sides. The trough was designed so that when its roof lay horizontal; its floor had a gradient of l0%, which proved to be sufficient to convey all eroded soil rapidly to the outlet. When the trough was firmly in place, a prefabricated sheet metal lip was installed. The lip was first bent so that it had a short limb, about 2–3 cm side, and a broader limb about 20 cm wide. The short limb was driven firmly into the soil at the upper boundary of the strip. In order to ensure a watertight seal between the lip and the topsoil and to prevent any erosion of the contact, a strip of plaster of Paris was used to stabilize the lip as suggested by Dunne et al (1980).

RESULT

The infiltration rate, run-off and sediment concentration plots and regression lines for all the six plots are illustrated and the summary of the results is presented in table It is evident from the figures and the table that the trends displayed by the regression lines are not totally unexpected. In general, the infiltration rates are higher and run-off is lower within the first few minutes of the commencement of the experiments. This pattern, however, reverses as the experiment progresses and continues till the end of the experiment. However, there are subtle differences in the infiltration and run-off rates amongst the plots and noteworthy differences in the sediment yields. The plot-wise results are discussed below.



Plot 1 - Grass covered area, 30 degree slope , Plot 2 – Recently ploughed area , gentle slope, Plot 3 – Crop residue covered area, moderate slope

CONCLUSIONS

Controlled experiments under simulated rainfall conditions have proved to be advantageous as these allow direct comparison of the responses of various land surfaces to same intensity rainfall. Under the controlled rainfall experiment, three plots with different slope and land cover revealed variations in infiltration, run-off and sediment yield response. Infiltration is highest for grass covered area with gentle slope and with steep slope. Run-off reveals an exactly opposite trend. In the initial period of the experiment, crop residue covered areas demonstrated high infiltration, but soon declined rapidly. Observations have shown that if the residue cover is below 90%, it cannot provide full protection to the surface underneath. Ploughed field revealed moderate infiltration and later a gradual decline. Once again the effect on infiltration and sediment removal could be seen which is represented by 6th regression line in. It shows relatively higher infiltration throughout in spite of the steeper gradient. Grass-cover protects the surface from soil erosion very effectively and wherever the grass-cover is absent the surfaces are highly prone to erosion. This finding gain considerable importance in view of the fact that over 2/3 area is characterized by such bare and steep slopes. Similar findings are also presented by Bhardwaj and Singh (1992) during their rainfall experiment study on plots with different characteristics. The authors found that soil loss due to splash erosion is maximum in the case of cultivated land due to loose and easily detachable soil particles, followed by bare land. The soil loss observed from grassed land is found to be 4, 5 and 5, 7 times lower than those measured from the bare and cultivated lands under rainfall intensities of 100mm/h and 200mm/h, respectively. Splash erosion is also found to increase with the increase in rainfall intensity, although the increase is relatively small in the case of grassed land. Soil loss from grassed land is approximately 2, 6 and 2, 5 times lower than those measured from bare and cultivated lands under rainfall intensities of 100mm/h and 200mm/h, respectively, for a period of 30 minutes. During most time of the year, especially after monsoon, a large part of the land surface is covered with grasses. This further implies that if the land slopes are undisturbed and are allowed it to remain under the natural condition of grass cover, the rate of sediment removal would have been remarkably reduced than what is occurring at present due to human activities in the region. Crop residue cover treatment, which is commonly practiced in this area, can provide a complete protection only for a short time that too with the percentage of the cover is >90% (Faniran and Jeje 1983). Highest run-off as well as sediment yield, as expected, is generated from the land slopes. Since severely dissected bare slopes (which are steadily increasing in area due to human activities recently) are more common in the region, the area under investigation warrants immediate attention of the concerned authorities.

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