International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 8, Issue 7 (September 2013), PP. 42-48

Erodibility and Runoff Potential of Three Well Defined Series of Laterite Soils in Kerala under Simulated Rainfall Conditions

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Abstract:- Soil erosion is one of the most serious environment degradation problems. However reliable measurement of soil erosion remains limited and estimates of soil productivity are even rare. Identification and assessment of erosion problems play an important role in influencing better land use and conservation practices. Rainfall simulators are considered as an effective tool in soil conservation research. Simulators make it possible to produce predetermined storms at any desired instant and location. Laterite soils are by far the most important soil group occurring in Kerala. The present study was undertaken to estimate the erodibility and runoff potential of the three well-defined series of laterite soils, viz. Mannamkulam series, Naduvattom series and Vellanikkara series under various simulated rainfall intensities and land slopes. The results of the study showed that soil loss and runoff increased with increased rainfall intensity for all the slopes in all the selected soil types. A general trend of increase in soil loss and runoff with slope was also observed in all the three series of soils studied.

Keywords:- Erodibility, Runoff Potential, Laterite soils, Rainfall simulators

I. INTRODUCTION

One of the principal reasons for low productivity in agriculture is the progressive deterioration of soil due to erosion. The major factors affecting the soil erosion are rainfall erosivity, soil erodibility, land slope and extent and nature of plant cover. Soil erosion by rain involves the transport of soil particles by a number of processes. Particle transport by drop splash and surface water flow may occur in series or in parallel or together depending on the size and topography of an eroding area. Erosion is a primary source of sediment that pollutes streams and fills reservoirs there by reducing their capacity and useful life. Erosion also adds to the removal of valuable plant nutrients with the runoff.

In Kerala, it is estimated that out of 2.248 lakh hectares of cropped land 1.757 lakh hectares are in need of conservation measures. Severe erosion occurs in the sub-humid and humid areas due to high rainfall and improper management of land and water. The problem of soil erosion and consequent depletion of soil fertility in the State is due to high intensity rainfall and undulating topography of cultivated land. Much of the variations in soil loss appeared to be related to variations in runoff, slope steepness and antecedent rainfall (McIsaac and Mitchell (1992)

Rainfall simulator, a device to produce rainstorms of desired characteristics has been widely used as a research tool in soil erosion studies because of unpredictable, infrequent and random nature of natural rainfall (Hudson1993). Most of the soil erosion by water occurs during and immediately following a relatively few rainstorms, which may occur almost at any time. Erosion research under such conditions has numerous limitations. Simulated rainfall may be applied at selected intensities, for known durations and land treatment conditions. Such control is much greater than with natural rainfall. Research data regarding soil loss from laterite soils are few. This study will provide valuable information in estimating soil loss from laterite soils, which can be effectively used in planning land use and conservation methods. This study is aimed to study the erodibility and runoff potential of the selected series of laterite soils under simulated rainfall conditions using modified version of existing rainfall simulator developed by Kurien and George (1993).

II. MATERIALS AND METHODS

An oscillating hypodermic needle type rainfall simulator and a soil trough were fabricated to conduct the erosion studies. The rainfall simulator designed by Kurien and George (1993) was modified to conduct the studies. The rainfall simulator consists of a drop former unit mounted on an angle iron framework, power transmission system and water supply unit. The drop former unit consisted of 18-gauge hypodermic needle fitted on a 20mm diameter GI pipe network as shown in fig.1. The network had four transverse pipes and each transverse pipe was fitted with 44 needles. The drop former unit was made to oscillate at the rate of 13 oscillations per minute. A centrifugal pump operated by an electric motor was used to supply the water from a tank to the rainfall simulator. A pressure gauge of 0-2 kg/cm^2 range was fixed in the discharge line of the pump and the pressure of water supply was controlled by means of two valves in the discharge line.

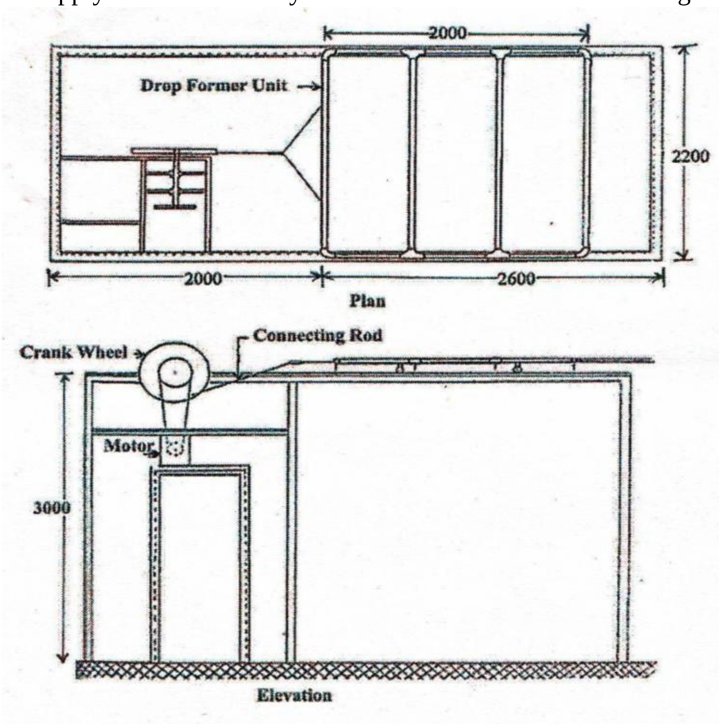

Fig. 1 Schematic diagram of rainfall simulator two valves in the discharge line.

The simulator was tested for different intensities of rainfall by changing the water supply pressure with the help of the by- pass control valve. The simulated raindrop size was determined by flour – pellet method and the uniformity coefficient (Cu) was calculated using Christiansen's formula for different intensities of rainfall.

Soils belonging to different series viz. Mannamkulam, Naduvattom and Vellanikkara were collected from their specific locations. Physical properties of these soils were determined and the particle size distribution curves were plotted. The liquid and plastic limits of the soils were determined by standard methods.

For the runoff study, a soil trough with adjustable legs was designed to hold the soil at required slopes based on the work of Ghosh and Jarret (1994). Figure 2 shows the soil trough designed for the experiment. Soil was filled in the trough and was allowed for natural compaction by exposing to rainfall for several days. Studies were conducted under various rainfall intensities corresponding to the water supply pressures of 0.2, 0.3,0.4,0.5 and 0.6 kg/cm^2 at 5 slopes varying from 5 to 25 percent for each series of soil.

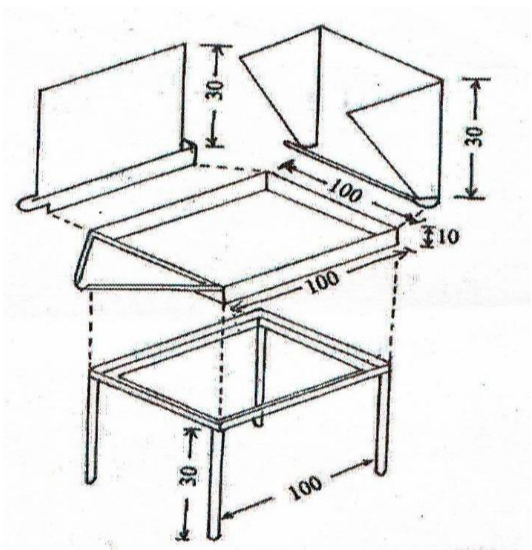

Fig.2. Soil trough with stand

The experimental plot was exposed to simulated rainfall of different intensities by adjusting the water supply pressure. A wet run was given for a period of 30 minutes. The runoff with eroded soil for a period of 5 minutes was collected in a vessel placed below the runoff spout. For computing sediment load, the runoff sample was allowed to settle for a period of one week. Then the clear water was drained and the sediment was separated by evaporation technique. The weight of the sediment was recorded. The test was repeated thrice for each series of soil to get the average value and the process was repeated by varying the slopes and rainfall intensities. Particle size analysis of the eroded soil samples obtained from all slopes at 23 cm/h intensity for each series of soils were carried out.

Results and Discussion

The simulator was tested for various intensities of rainfall by changing the water supply pressure. It was found that the intensity increased with the increase in supply pressure (Fig.3). From the test results, a relationship was established between the water pressure and intensities of rainfall.

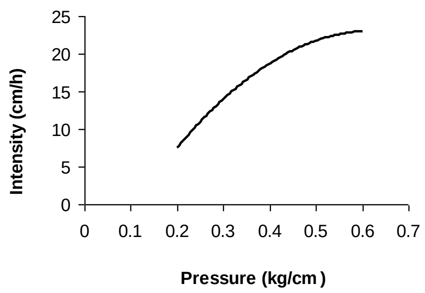

Fig.3 Supply Pressure Vs Intensity curve.

The relationship is

$$I = -87.205\ P^2 + 108.61\ P - 10.786 \qquad (R=0.99)$$

Where,

I - Intensity of rainfall, cm/ h

P- Supply pressure, kg/cm^2

R – Coefficient of regression

The simulated raindrop size was determined by flour pellet method. The droplet size decreased with increased intensity of rainfall. Christiansen's uniformity coefficient was worked out for different intensities. Higher uniformity coefficient was obtained at higher intensity and the results are given in table 1. The particle size distribution curves showed that all these soils are coarse grained and the particle size distributions are similar.

Table 1. Relationship between intensity of simulated rainfall with droplet size and Uniformity

Sl. No.	Intensity (cm/h)	Mean droplet size (mm)	Uniformity (%)
1	7.41	2.60	88.10
2	14.05	1.85	89.81
3	18.63	1.75	90.43
4	21.71	1.50	91.10
5	23.00	1.30	91.53

Studies were conducted under water supply pressures of 0.2, 0.3, 0.4, 0.5 and 0.6 kg/cm^2 and the corresponding rainfall intensities were 7.41, 14.05, 18.63, 21.71 and 23.00 cm/h respectively. Soil loss increased with increase in the intensity of rainfall under different slopes in all three series of soils studied. When compared to Vellanikkara series and Mannamkulam series, the soil loss from Naduvattom series was low. The nature of the curves obtained for the three series of soils for all the slopes studied were similar. (Fig.4) A general trend of increase in the soil loss with increase in the slope was observed for all the soils under different simulated intensities of rainfall. (Fig.5). Empirical equations were developed for estimating the soil loss under various intensities of rainfall and land slopes for the selected series of soils.

Runoff increased with increase in intensity of rainfall under different slopes in all three series of soils studied. The maximum runoff was obtained from the plot of Naduvattom series. The nature of the curves obtained for the three series of soils for all the slopes studied were similar. (Fig.6) A general trend of increase in runoff with increase in the slope was observed for all the soils under different simulated intensities of rainfall for a particular value of slope and the nature of the curves obtained for the three series of soils were similar. (Fig.7). Empirical equations were developed for estimating the soil loss and runoff under various intensities of rainfall and land slopes for the selected series of soils.

The equations developed are

E = 1167.797 **I** + 835.109 **S** – 21686.07 (R= 0.90)
Q = 65.016 **I** + 16.747 **S** – 235.923 (R= 0.99) for Mannamkulam series.
E = 324.766 **I** + 112.799 **S** – 3212.219 (R= 0.97)
Q = 74.542 **I** + 19.434 **S** – 394.323 (R= 0.99) for Naduvattom series.
E = 1115.662 **I** + 431.064 **S** – 11512.284 (R= 0.98)
Q = 58.742 **I** + 26.837 **S** – 310.019 (R= 0.99) for Vellanikkara series.

Where,

E = Soil loss in kg/ha/h
Q = Runoff in m^3/ha/h
I = Intensities of rainfall in cm/ h, ranging from 7.41 cm/h to 23 cm/h
S = Land slope in %, ranging from 5% to 25%

Statistical analysis was carried out with the help of the computer package ‘ Systat 8.0’ for checking soil loss between three series of soils studied. There was no significant difference in soil loss between Mannamkulam series and Vellanikkara series. But there was significant difference in soil loss between Mannamkulam series and Naduvattom series and also in Vellanikkara series and Naduvattom series. From the analysis it was seen that there was no significant difference in runoff between three series of soils studied.

Particle size analysis of the eroded soil samples obtained from all slopes at 23 cm/h intensity for each series of soils were carried out and it was observed that the particles of size more than 4.75 mm were not present in the eroded samples from lower slopes and were found in small quantities for higher slopes for all three series of soils. This may be due to the less time of exposure to the rain, as the particles detached might not have got the opportunity time to travel to sediment collectors. Particles finer than 75 micron was more in the case of Naduvattom series of soil.

III. SUMMERY AND CONCLUSION

The major concern with erosion is an increase in turbidity of runoff which has an adverse effect on the quality of surface water and sedimentation in reservoirs and canals. Severe erosion occurs with high rainfall due to improper management of land and water. Rainfall is considered as the most important agent responsible for erosion. An oscillating hypodermic needle type rainfall simulator and a soil trough were fabricated for the study. The results of this study showed that soil loss and runoff increased with increase in the rainfall intensity for all slopes in all types of selected series of soils. A general trend of increase in soil loss and runoff with increase in the slope was observed for all the three series of soils. Statistical analysis showed that there was no significant difference in soil loss between Mannamkulam series and Vellanikkara series. But there was significant difference in soil loss between Mannamkulam series and Naduvattom series and also in Vellanikkara series and Naduvattom deries. In the case of runoff, no significant difference was observed between these three series of soils. Particle size analysis of the eroded soil samples showed that particles finer than 75 micron was more in the case of Naduvattom series, which is in agreement with the low soil loss from this series of soil.

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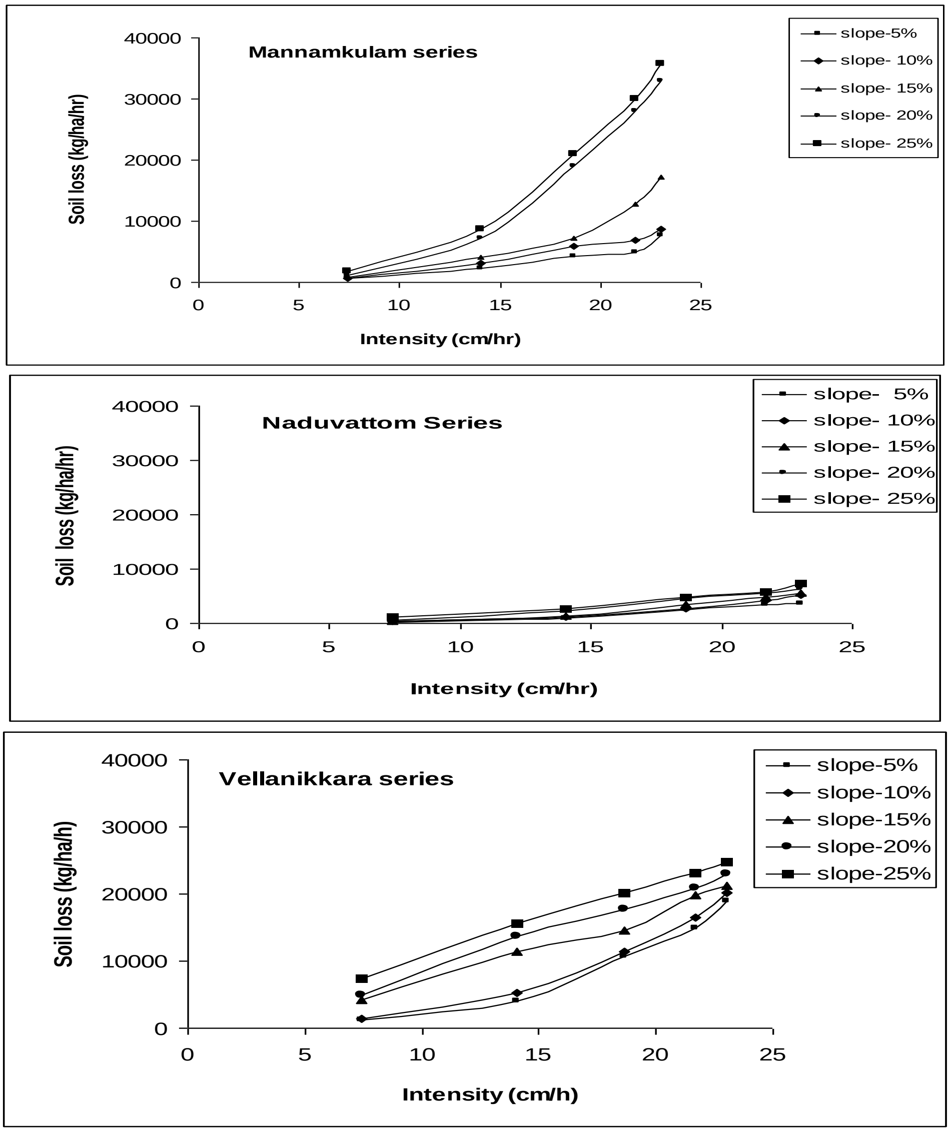
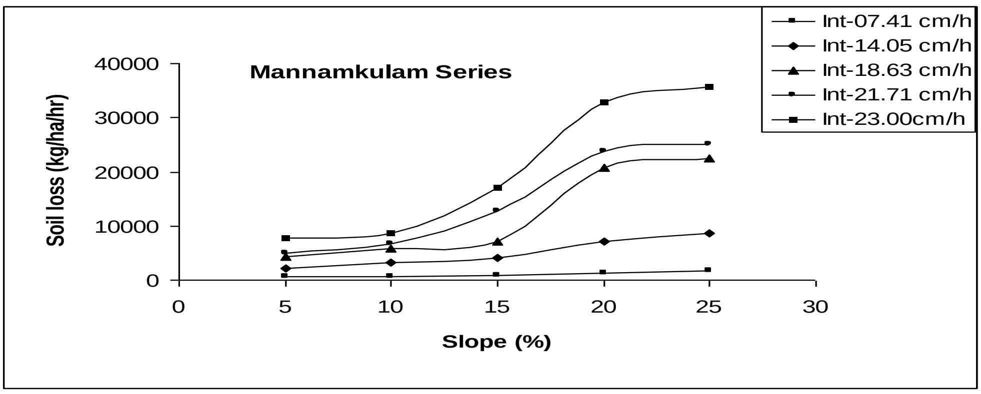


Fig. 4. Effect of intensity of rainfall on soil loss in different series of soils.



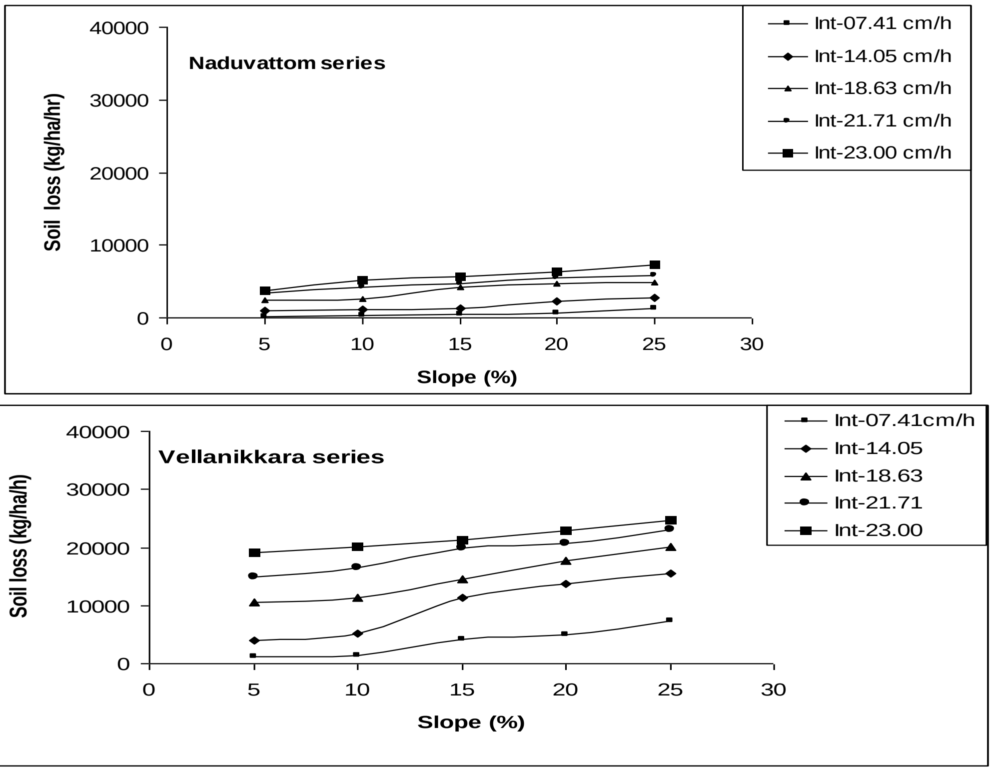
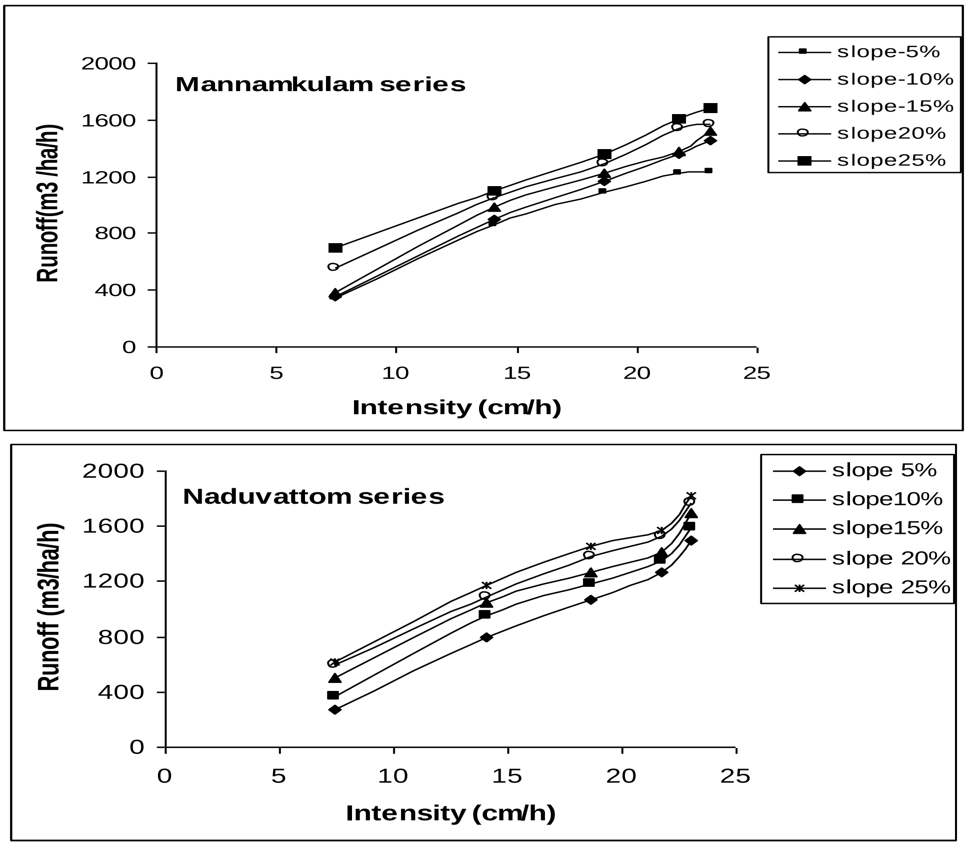


Fig. 5. Effect of land slope on soil loss in different series of soils.



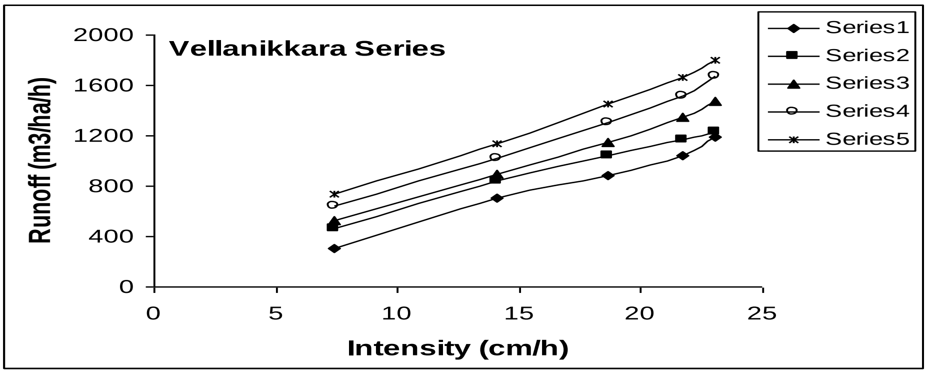


Fig. 6. Effect of intensity of rainfall on runoff in different series of soils.

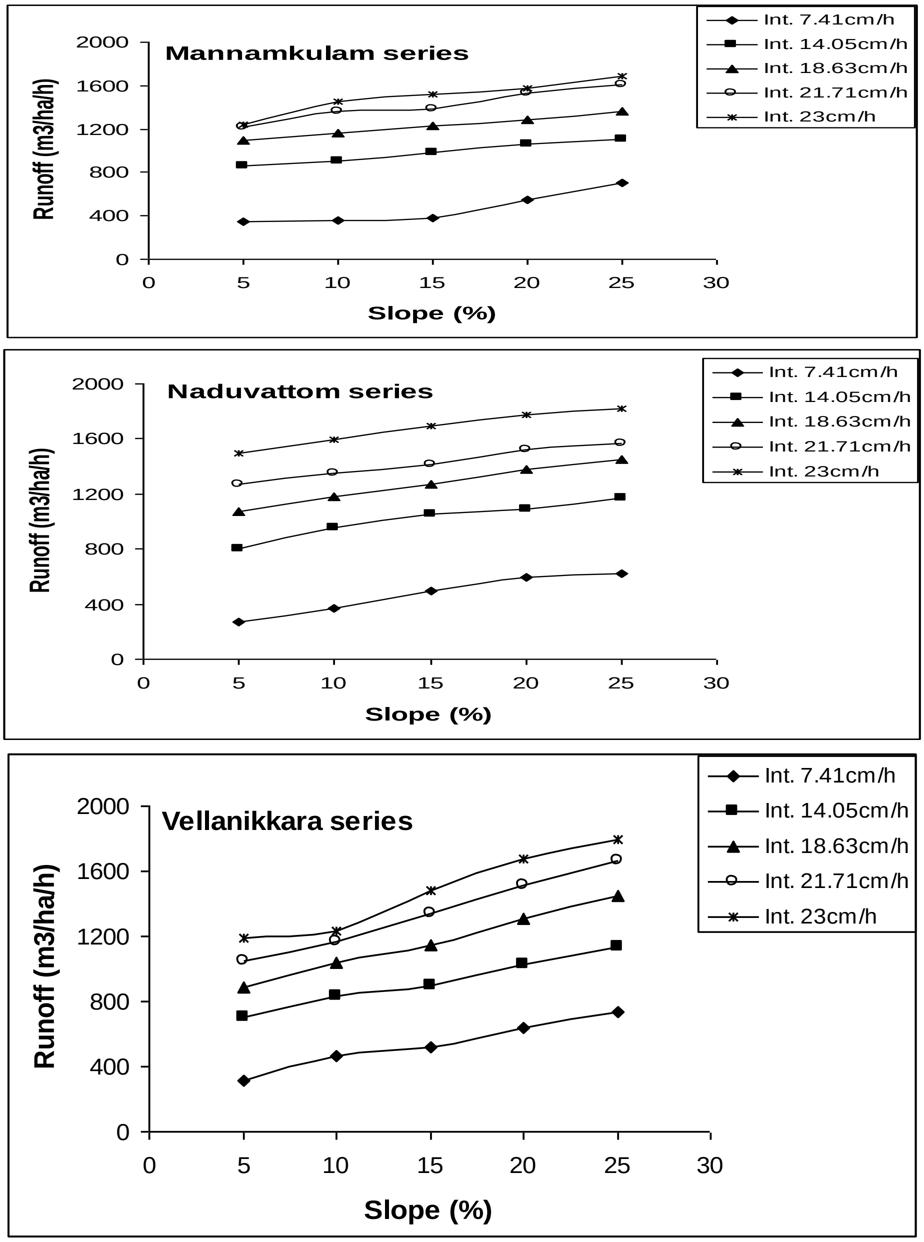


Fig. 7. Effect of land slope on runoff in different series of soils.