J. Soil Wat. Conserv. India, **3(3&4):** 99-105, 2004

Runoff Variation Due to Landuse Change in Small Watersheds of Western Ghats

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ABSTRACT

Westerns Ghats form the catchment of all the 44 rivers that sustain the agro-economy of Kerala. A study was conducted to assess the effect of land use on runoff from small watersheds of Western Ghats. Three small mono-culture watersheds, planted with cashew, coffee, tea and one small watershed with dense forest were selected for the study. Analysis of the rainfall and runoff data indicated that nearly 50% of the total rainfall leaves from the mono-culture watershed as runoff, whereas the runoff from dense forested watershed is only about 30% of the rainfall. The infiltration studies indicated that all these watersheds have high infiltration rates, thereby absorbing even the most intense storms of the study period. The soil analysis indicated that the humus content is high. From the soil profile examination of the study region it was observed taht there exists an impermeable clay layer lying below the laterite with an average thickness of 3.5 m located at 7 to 10.5m below the ground surface. The results lead to the conclusion that the infiltered rain water meets the impermeable layer below and then it flows laterally through the soil. This lateral interflow saturates the valley portion of these watersheds and runoff is generated from these source areas. Thus Hortanian overland flow is a rare phenomenon in the observed watersheds and hence landuse change has no significant effect on the runoff produced by the small waterhseds of Western Ghat region.

INTRODUCTION

Kerala has forty four rivers cutting across the land and numerous backwater lakes spread all along the coast. All these rivers originate from Western Ghats and most of them are harnessed for irrigation and hydel power. The Western Ghats has an average elevation of 1000 metres with peaks ranging from 2500 to 3000 metres above mean sea level. The typical natural vegetation of these hills were evergreen forests often interspread with areas of grass and swamps. The pressure of population has resulted in change of landuse from evergreen forests to large scale mono-culture plantations. Such changes often influence the hydrological response of the watersheds. The objective of the present investigation was to study the effect of land use on runoff from such watersheds.

According to Horton (1933), if the rainfall intensity is high as during typical thunderstorms or the soil infiltration capacity is low as in clay soils, the surface water cannot penetrate the soil sufficiently rapidly. The excess water accumulates on the soil surface and then overflows to form a continuous sheet

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of water flowing down the slope. This type of surface runoff is termed as infiltration excess flow or Hortanian overland flow.

Three small monoculture watersheds planted with coffee, cashew and tea and one watershed with dense forest were selected for the study. The objective was to study the effect of land use on water yield from these small watersheds.

MATERIALS AND METHODS

Hydrological monitoring of the selected watersheds including meteorological and stream flow data collection were carried out. The watershed with cashew plantation is situated at 11°37'38" North latitude and 75° 45' 8" East longitude. It is situated in Quilandy Taluk of Calicut district. The area of this watershed is 29.5 ha. and has a leaf shape. The watershed with coffee plantation is situated at 11° 38' 44" North latitude and 76° 10'14" East longitude. It is situated in Sultan Bathery Taluk of Wynad district. The watershed with irregular shape, has an area of 74.87 ha. The watershed with tea plantation is situated at 11° 32'35" North latitude and 76° 02' 46" East longitude. It is situated in Vythiri Taluk of Wynad district. The watershed is nearly hexagonal in shape and the area is 61.74 ha. The dense forested watershed is situated at 11° 33' 00" North latitude and 75° 27' 12" East longitude. It is situated in Quilandy taluk of Calicut district. The area of this watershed is 68.60 ha and has a leaf shape.

The rainfall and runoff measurements were done with the help of rain gauges and stage level recorders. The rainfall and runoff data were collectd and tabulated on weekly basis for three consecutive years. The average weekly values were obtained by taking the average of the weekly values of three years. Soil samples were collected from few representative locations of each watershed to determine the different soil characteristics. The grain size distribution of the soils were determined by sieve analysis. The soil pH was determined using a pH meter and the organic carbon content was also determined. Infiltration studies were conducted in each watershed using double cylinder infiltrometers. The infiltration measurements were taken at two to three representative locations of each watershed and the average values were taken. The different geomorphological factors like form factor, basin circularity, basin elongation and mean basin slope were worked for all the selected watershed.

Form factor (Rf) is the ratio of the basin area (A) to the square of the basin length (L).

i.e. $Rf = A/L^2$.

Basin circularity (R_c) is the ratio of the basin area to the area of a circle having the same perimeter as the basin.

i.e. $R_c = 4 \times \pi \times A/P^2$

P = basin perimeter, m

Basin elongation (R_e) is the ratio of the diameter of a circle whose area is same as the basin area to the length of the basin.

$$\text{i.e.,} R_e = \frac{2(A/\pi)^{1/2}}{L}$$

Where, A= basin area, m^2; L= basin length, m

$$\text{Mean basin slope} = \frac{\text{Total length of contour (m) x contour interval (m)}}{\text{Basin area } (m^2)}$$

The runoff hydrographs were derived for all these watersheds using stage and discharge rating curves. The stage heights at regular time intervals were converted to the corresponding flow rates using the stage discharge rating curves and were then plotted against the corresponding time to get the storm hydrograph.

Table 1: Rainfall and runoff data of the selected watersheds

Week	Cashew watershed		Coffee watershed		Tea watershed		Forested watershed	
	Rainfall (cm)	Runoff (cm)	Rainfall (cm)	Runoff (cm)	Rainfall (cm)	Runoff (cm)	Rainfall (cm)	Runoff (cm)
1	44.60	23.25	12.60	4.50	0.45	0.23	46.10	13.83
2	49.20	26.34	17.20	6.28	4.80	2.32	50.80	14.73
3	7.90	4.39	6.30	2.32	28.00	15.90	8.20	2.34
4	37.20	19.49	0.91	0.31	52.50	25.30	38.90	11.67
5	22.90	12.11	8.55	3.14	13.50	6.40	24.20	7.50
6	7.90	4.55	9.10	3.27	2.30	1.10	8.10	2.20
7	20.53	11.23	0.31	0.11	41.50	19.86	21.68	6.94
8	37.55	20.58	13.90	4.95	18.54	8.90	39.53	12.25
9	3.90	2.04	10.50	3.72	0.58	0.28	4.10	1.19
10	1.39	0.78	2.60	0.95	35.00	16.90	1.81	0.54
11	3.90	2.02	1.30	0.46	27.50	13.20	4.20	1.40
12	4.60	2.60	1.60	0.58	4.20	1.98	5.30	1.67
13	40.90	20.12	1.80	0.60	1.20	0.53	43.10	12.31
14	9.60	5.02	2.75	1.05	6.10	2.92	10.70	3.64
15	12.10	6.72	5.00	0.80	2.50	1.18	14.00	4.50
16	3.45	1.77	7.10	2.57	5.80	2.80	5.20	1.35
17	6.95	3.60	3.80	1.37	4.75	2.31	7.20	1.84
18	5.60	2.92	0.80	0.31	3.20	1.53	6.20	2.20
19	25.20	12.73	0.44	0.16	2.05	0.94	27.10	9.50
20	7.95	4.30	5.60	2.06	3.25	1.57	8.32	2.90

RESULTS AND DISCUSSION

The three years' average weekly values of rainfall and runoff computed for the selected watersheds are given in Table 1.

The maximum intensities of rainfall received by the watersheds during the study period were 13.1 cm/hr, 12.2 cm/hr, 8.0 cm/hr and 7.0 cm/hr for the dense forested, cashew, coffee and tea watersheds respectively. The rainfall-runoff data indicate that all the cultivated watersheds produced nearly 50 percent of the total rainfall as runoff, whereas the dense forested watershed produced only about 30% of the rainfall as runoff. The regression equations relating average weekly runoff with average weekly rainfall were worked out separately for the four watersheds. The equations are,

$Y = 0.522\ X + 0.113$ for watershed with cashew plantation

$Y = 0.361\ X + 0.012$ for watershed with coffee plantation

$Y = 0.489\ X - 0.007$ for watershed with tea plantation

$Y = 0.297\ X + 0.158$ for deep forested watershed

Where$Y$ = Average weekly runoff (cm); X = Average weekly rainfall (cm).

The analysis of the soil samples indicated that the soils of all the watersheds come under coarse grained division as per IS classification. The pH of the soils were 5.87, 5.98, 5.78 and 5.75 and the organic carbon content were 1.94, 1.83, 1.86 and 1.22 percent for dense forested, cashew, coffee and tea watershed respectively. All these soils are acidic and have high organic carbon content (greater than 1 percent). The soil profile study of the region indicates that there is an impermeable clay layer lying below the laterite having an average thickness of

Table 2: Geomorphological characteristics of the watersheds

Watershed	Area	Perimeter (m)	Max. length of stream (m)	Form factor	Basin circularity	Basin elongation	Mean basin slope(%)
Cashew	29.5	2150	650	0.698	0.810	0.943	22.70
Coffee	74.87	4380	1580	0.300	0.490	0.618	24.00
Tea	61.74	3240	1080	0.529	0.739	0.821	25.00
Dense forested	68.60	3760	1100	2.010	0.660	1.561	10.70

3.5 m located at 7 to 10.5 m below the ground surface. The results of infiltration studies indicate that all these watersheds have high infiltration capacity. The basic infiltration rates of the watersheds were 13.2 cm/hr, 12.8 cm/hr, 5.6 cm/hr and 12.0 cm/hr for dense forested, cashew, coffee and tea watersheds, respectively. The different geomorphological characteristics of the selected watersheds are given in Table 2.

The study indicated that though there is marked difference in the geo-morphological characteristics of the small watersheds with different land use, no appreciable difference in the percentage of runoff produced is noticed.

The runoff hygrographs of the watersheds are given in figures 1, 2, 3 and 4. From the hygrographs it was observed that the base flow component is comparatively high for all these watersheds. In case of cultivated watersheds (i.e. planted with cashew, coffee and tea), the hygrographs attained a sharp peak immediately after the rainfalls, indicating steep sloping terrain having low channel storage. The comparatively larger component of base flow is responsible for the production of higher runoff by these watersheds. The hygrographs for dense forested watershed show a considerable time lag between the peak runoff and rainfall. The time lag is very high as compared to that for the cultivated watersheds. This leads to the inference that the dense

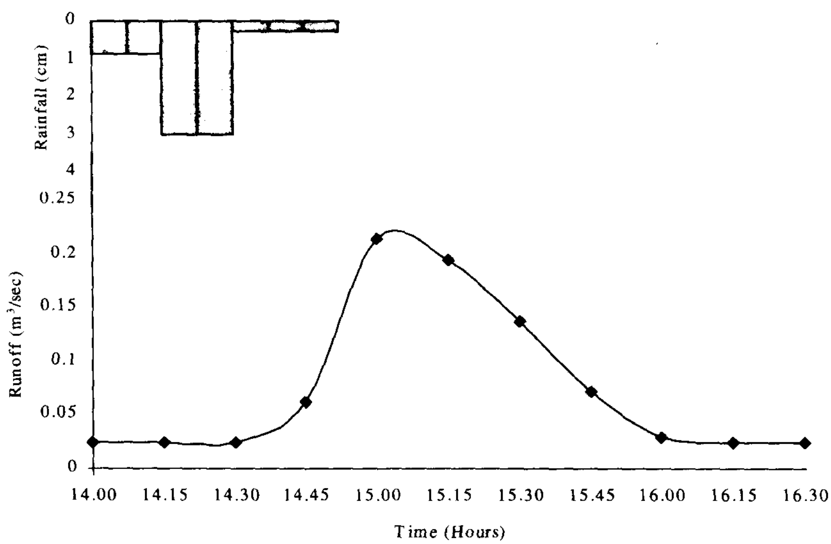

Fig. 1. Runoff hydrograph of cashew watershed

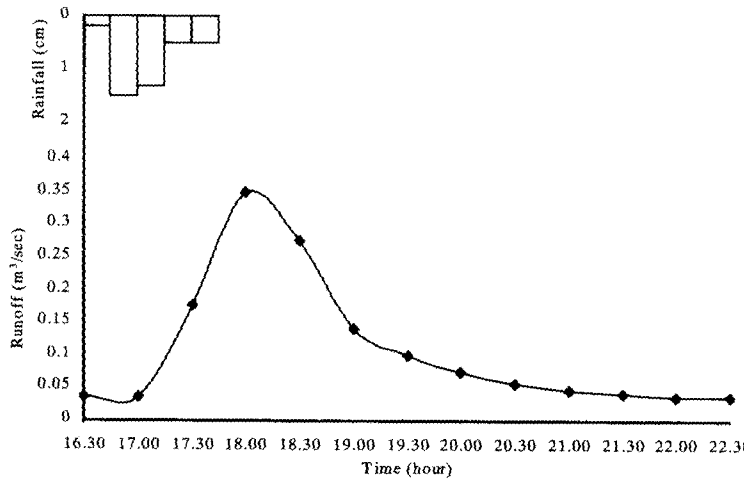

Fig. 2. Runoff hydrograph of coffee watershed

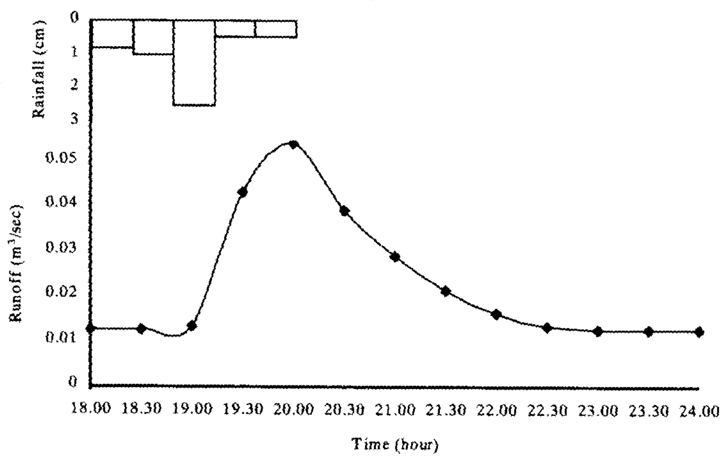

Fig. 3. Runoff hydrograph of tea watershed

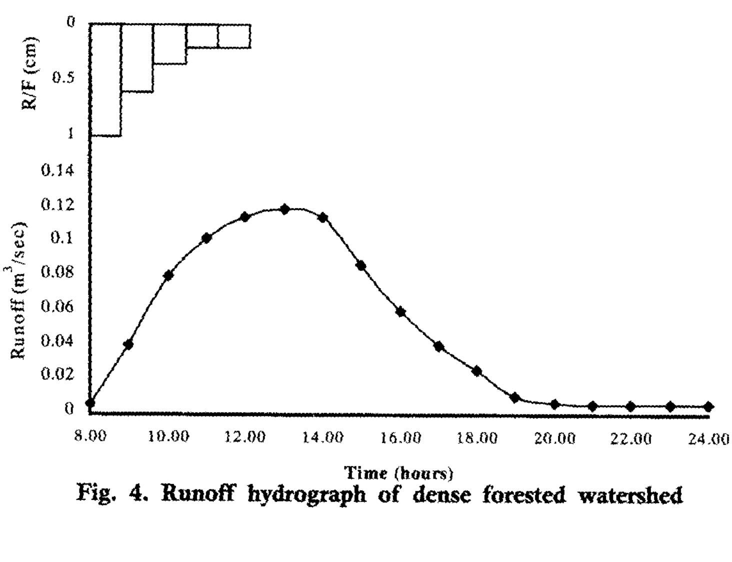

Fig. 4. Runoff hydrograph of dense forested watershed

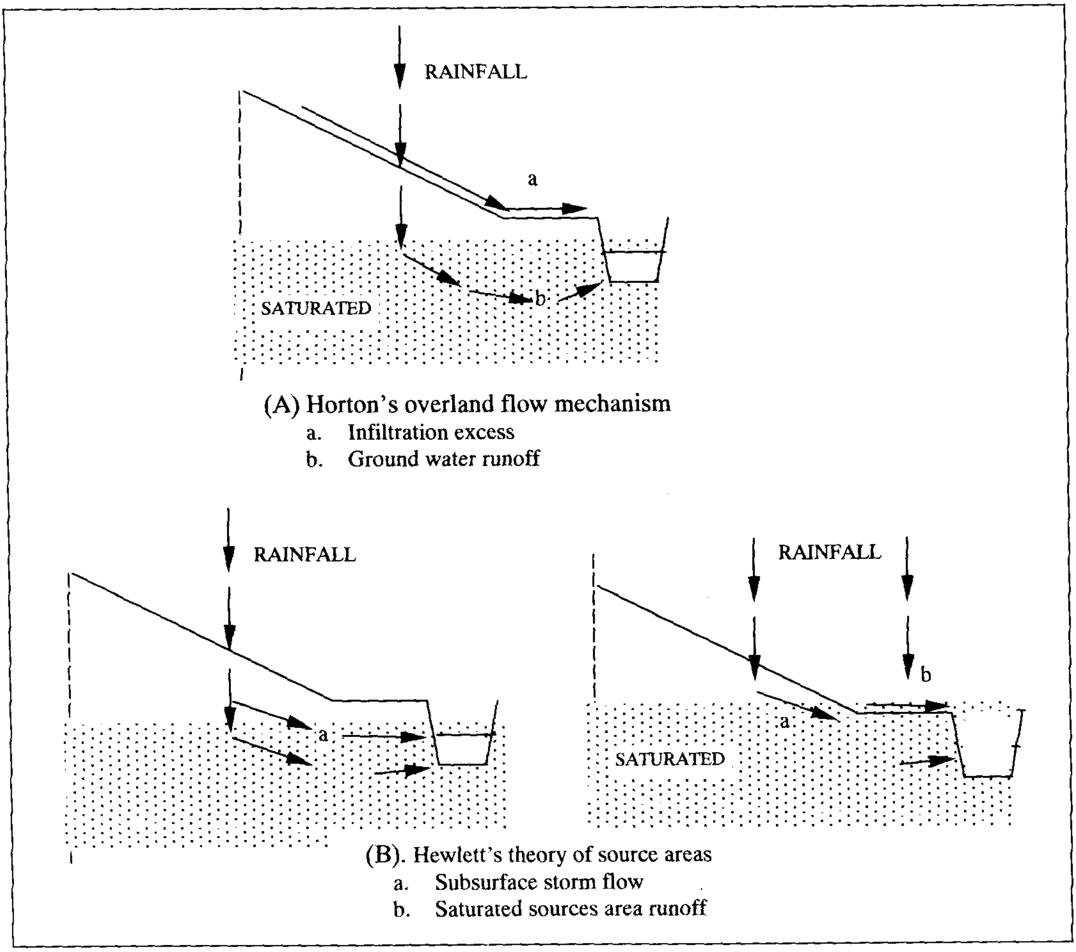

Fig. 5. Runoff process in Western Ghats

forested watershed serves as a storage reservoir and releases water slowly as compared to cultivated watersheds.

In the case of cultivated watersheds almost 50% of the rainfall leaves the watershed as runoff, whereas in case of the dense forested watershed about 30% of the rainfall leaves the watershed as runoff. The results lead to the conclusion that the impermeable layer within the soil profile is likely to impede the vertical movement of water into the soil and produce the lateral flow (Fig. 5). The amount of runoff produced by dense forested watershed is less as compared to the cultivated watershed and this is in agreement with the fundamental concept. The high canopy cover and humus content of dense forest reduced the runoff generated from the watershed.

CONCLUSION

From the above results it can be concluded that the impermeable layer within the soil profile impedes vertical movement of water into the soil and produces the lateral flow. This lateral interflow reaches the valley portion of the watershed where it saturates the soil. After some time this area becomes super saturated and acts like impervious surface producing 100 percent surface runoff. This area is responsible for the sharp peak of the runoff hygrographs. Thus land use has no significant effect on water yield from the selected small agricultural watersheds of Western Ghats, since land use is not the lone factor which influences the runoff production from these watersheds. Direct runoff is generating from source areas and Hortanian overland flow is a rare Phenomenon in these watersheds of Western Ghat region.

ACKNOWLEDGEMENTS

The authors thank Prof. John Thomas, Dean, Kelappaji College of Agricultural Engineering & Technology and Dr. M. Baba, Director, Centre for Earth Science Studies for the facilities extended during the conduct of the study.

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