National Symposium on Hydrology
Dec.16-18.1987, N.I.H., Roorkee

EFFECT OF AFFORESTATION ON RUNOFF FROM A FORESTED MOUNTAINOUS CATCHMENT

A M Kalra*   Satish Kumar*   B P Parida**

ABSTRACT

The effect of afforestation on runoff has been studied and discussed for many years but till todate there is no single index to quantify the effect of gradually varying forest cover for prediction of yield for management of water resources in our country because of variable response of forested watersheds. To study the effect of afforestation on runoff a study was conducted in a lower Himalayan forested catchment where afforestation and other soil conservation measures are in progress. The analysis by flow duration curve for pretreatment and post treatment period reveals decreasing trend in flow regime by 22.4%. The peak flows have decreased by 18.1% with minor increases in mean and low flows (1.3 and 0.3 respectively). The decrease in peak runoff has been further confirmed by analysing the rainfall-runoff events for the same period by statistical analysis which registered a decrease in runoff volumes by 12.43%.

INTRODUCTION

Forests form an integral component of the eco-system. Growth in population together with various developmental activities have persuaded the human race to encroach upon the forest territories causing thereby a considerable amount of deforestation over the years. One of the earlier studies of Bates and Henry (1928) conducted on experimental plots at Wagon Wheel Gap, U.S.A. demonstrating positive influence of forests on the resultant yield from the watershed has encouraged all concerned including the hydrologists (Hursh, 1948; Chow,1964; Storey et al, 1964; Hibbert, 1967; Lee, 1980; Cassells et al, 1982; Lohani,1985; Sikka,1985) to take up further studies for quantitatively evaluating the effect of deforestation on hydrologic variables. While most of these studies were limited to small experimental watersheds, very little effort seems to have gone in respect of evaluating the effect of deforestation as well as afforestation over natural particularly the mountainous watersheds, on the hydrologic variables.

* Asstt. Prof. in Civil Engg.,Punjab Engg. College,Chandigarh
** Scientist 'E', National Institute of Hydrology, Roorkee.

Owing to operation of large number of water resource projects and mining activities on the upland and mountaineous areas which are usually covered with forests, invokes a need for afforestation as an alternative to maintain the ecological balance. An attempt has therefore been made to study the effect of afforestation on the runoff from a forested mountainous Indian catchment quantitatively, such that the results could be used in scientific management of water resources in such an area.

METHODOLOGY

The effect of forest cover on runoff is to decrease the overland flow because of increased interception loss. The flow is subsurface dominant and emerges as channel flow near the outfall. The runoff from a catchment occurs after the conjunctive equilibrium between evaporation and infiltration has been achieved; both being characteristics of plant cover type. The runoff trends have been investigated in respect of flows occuring due to storms as well as yield under varying degree of forest cover in the following paragraphs by fitting a regression model to storm flow data and confirming the effects obtained from the analysis by use of flow duration curves for pretreatment and post treatment periods.

THE STUDY CATCHMENT

The Mehalchauri catchment is a sub-catchment of River Ramganga form its source to discharge measuring site at Mahalchauri and is located between lower Himalayan and Shivalik ranges in Northern India. The River Ramganga originates in high hills at an elevation of 2000 mts above MSL and flows south in well confined river channel with a mean slope of 1 in 40, covering a distance of 18.4 kms upto Mehalchauri. The details of the catchment are given in Table 1.

The catchment receives about 1580 mm of rainfall, 80% of which occurs in the form of heavy showevers from south west monsoons from mide June to middle of September and remaining occurs during the winter months. The area lies below snowline. The daily precipitation estimates are available for Garsain and Chaukhuntia since January, 1970. Subsequently rainfall records are available at Mehalchauri after January 1974. The runoff estimates are available at Mehalchauri from 1971 onwards from self recording gage recorders in the form of continuous hydrographs. The gaging sites are shown in Figure 1. The trends in precipitation and runoff are shown in Figure 2.

The catchment is covered by dense tropical forests of euclyptus and pine type. The forest cover was changed from 51.15% in 1970 to 61.77% in 1983 by extensive afforestation and other soil conservation measures like terracing, contour bunding etc. to stabilise the soil on slopes which are of the order of 30 degrees or more with alluvial deposites near the channel banks.

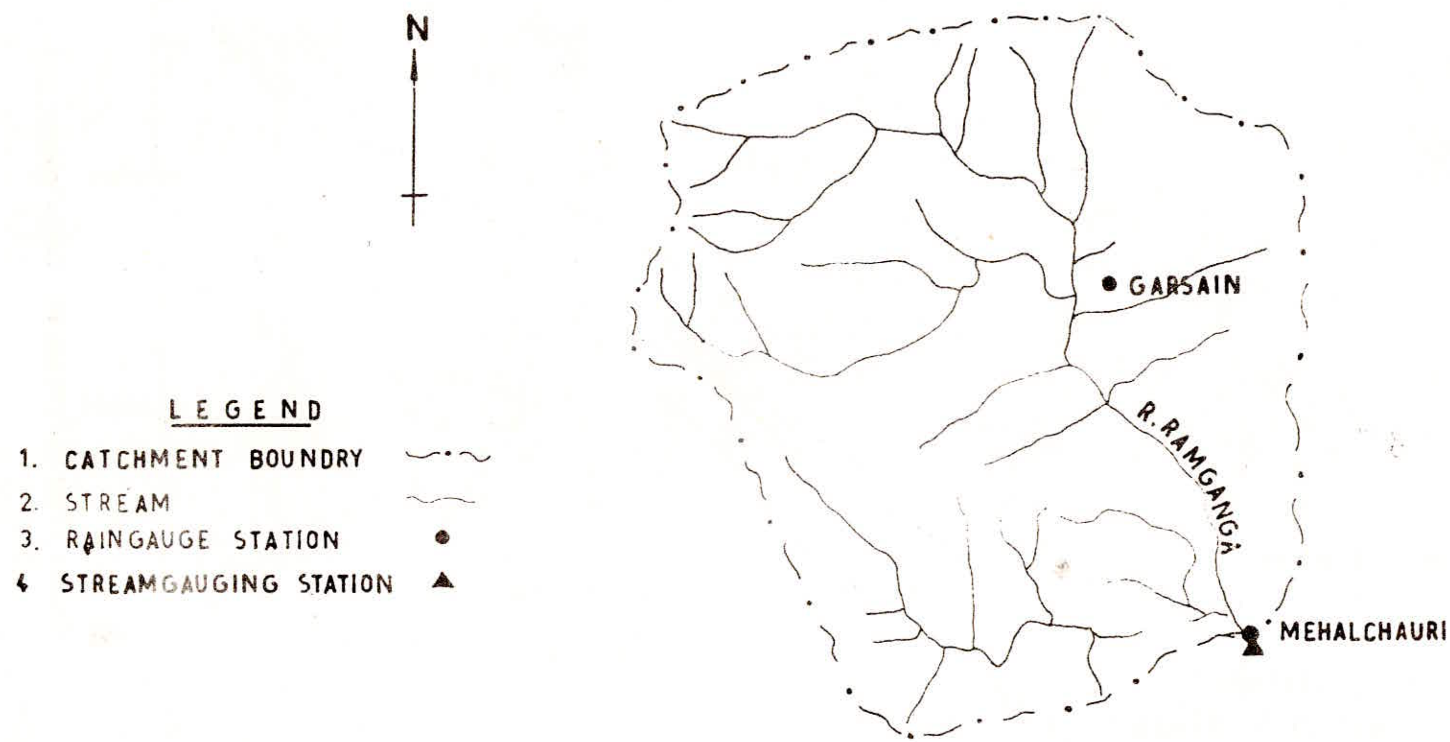

FIG.1. DETAILS OF STUDY CATCHMENT.

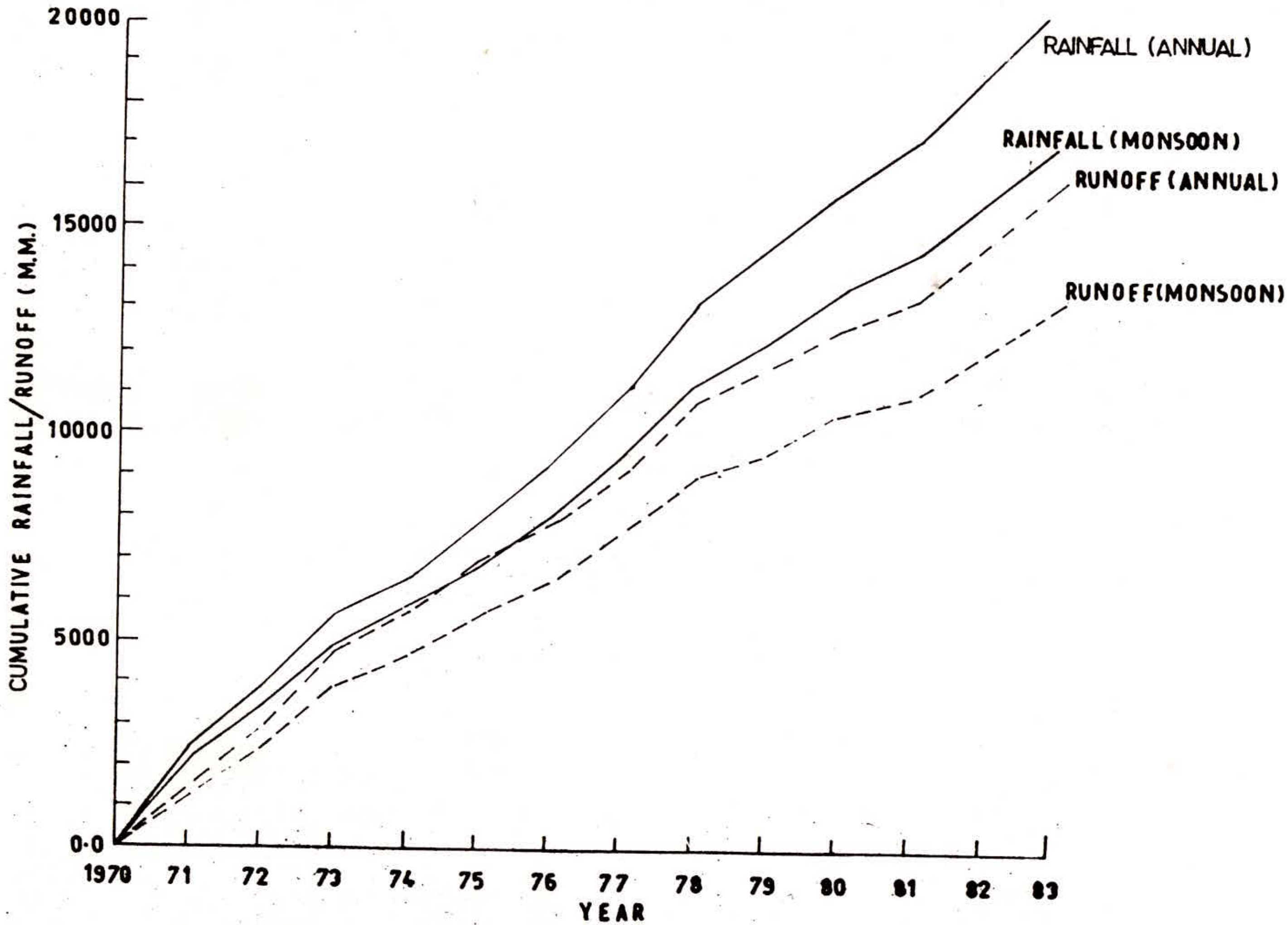

FIG.2- CUMULATIVE RAINFALL AND RUNOFF PLOT FOR MEHALCHAURI

Table 1 - Physiographic Details of catchment

Sl. No.	Item	
1.	Location Latitude	$29^{o}57'$ - $30^{o}06'$N
	Longitude	$79^{o}11'$ - $79^{o}20'$E
2.	Area (Sq.Kms) 'A'	157.47
3.	Elevation (above M.S.L) on gauging site	1296.0 mets.
4.	Main Stream Length (Kms) L'	18.4
5.	Main Stream Slope	1 in 40
6.	Shape Factor (L^2/A)	2.149
7.	Form Factor (A/L^2)	0.465
8.	Elongation Ratio ($1.128(\frac{A^{0.5}}{L})$)	0.769
9.	Initial Forest Cover (%)	51.15
10.	Degree of Treatment (%)	10.62
11.	Mean Annual Precipitation (mm)	1582
12.	Mean Runoff (mm)	1235

INFLUENCE OF FORESTS ON PEAK FLOWS

For estimation and quantification of the possible effect of afforestation on peak flow model of the type.

$$R = a(P)^{b} \qquad \text{..... (1)}$$

has been adopted.

where, R = Daily Storm flow in mm
P = Mean Daily Precipitation in mm
a,b = Regression parameters.

For the analysis purpose pretreatment (1971-75) and post treatment (1979-83) data have been fitted through the model as in Eqn.(1) by selecting all storm producing events from 10 mm of precipitation upwards in the monsoon season after a spell of continuous rainfall for atleast one week; postulating thereby that soil moisture requirements have been metwith and precipitation is directly contributing towards storm flow generation after interception storage has been fulfilled. Details of the regression analysis have been presented in Table 2.

Table 2 - Model Parameters for Storm Flows During Pre and Post Treatment Period

Item	Pre Treatment	Post Treatment
1. Length of Record	5 years (1971 - 1975)	5 years (1979 - 1983)
2. No.of Events selected	122	121
3. Regression Statistics		
a	0.6157	2.0262
b	0.4910	0.5270
Corelation Coefficient	0.39	0.41
Coefficient of Determination	0.15	0.17

The change in storm flow response is shown in Figure 3. From the correlation so obtained, the runoff estimate for various precipitation estimates are given in Table 3 for quantification of decrease in runoff with increasing forest cover.

Table 3 - Change of Storm Flows During Pre and Post Treatment Period

Precipitation (mm)	10	20	30	50	80
	Storm Flows (mm)				
1. Pre treatment	8.10	11.38	13.90	17.85	22.50
2. Post treatment	6.82	9.82	12.16	15.92	20.40
3. Percentage change in storm flow	-15.80	-13.70	-12.51	-10.81	- 9.33
4. Mean Percentage Change in stormflow		-12.43			

INFLUENCE OF FOREST COVER ON YIELD

To assess the change in flow regime because of forest cover changes, flow duration curves have been prepared for pre treatment and post treatment periods from the available records suggested by Foster (1934) and Barrow (1943) which also takes care of the impact of land use changes.

Table 4 - Change in flow regime

	Mean flow in Hect-met.	Percentage of times flow equalled or exceeded 10	20	30	40	50	60	70	80	90	99
1. Pre Treatment	64.6	285.5	138.1	73.6	50.2	39.7	33.9	30.3	29.6	25.4	17.7
2. Post Treatment	50.1	264.4	134.9	71.4	51.2	40.8	35.1	31.9	29.1	25.7	14.3
3. % Change	-22.4	-21.1	-3.2	-2.2	1.0	1.1	1.2	1.6	-0.5	0.3	-3.4

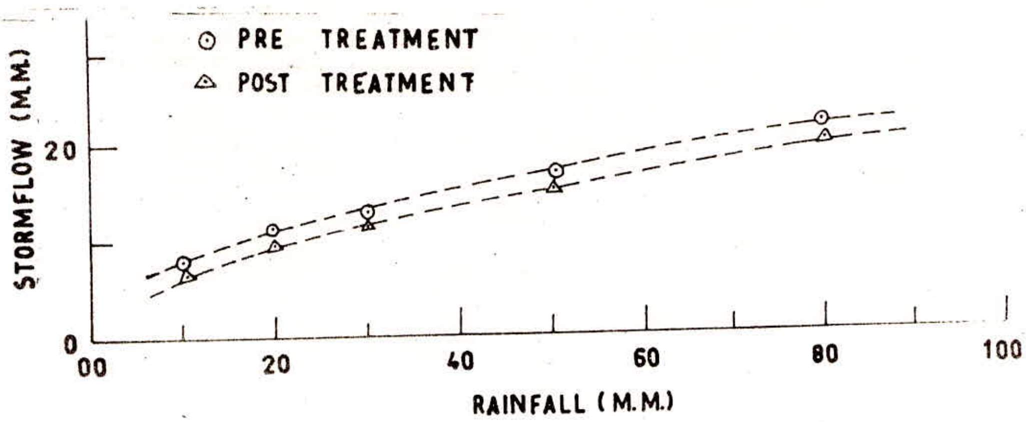

FIG. 3. REDUCTION IN STORMFLOW AT MEHALCHAURI.

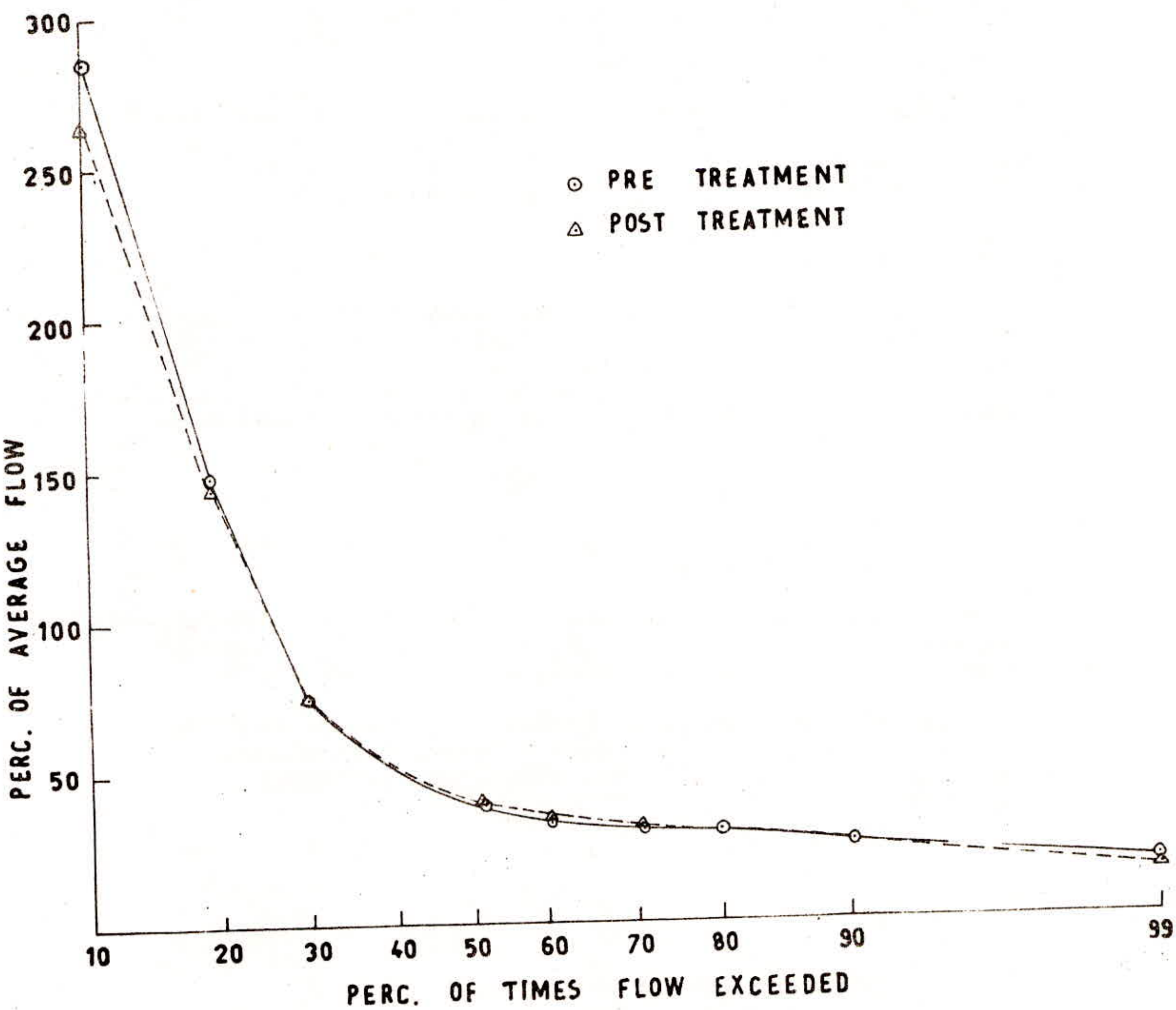

FIG.4- FLOW DURATION CURVE FOR MEHALCHAURI

In the present study to eliminate the differences in mean annual runoff per unit area of catchment the discharge units have been expressed as percentage of mean flow. This technique also eliminates the effect of higher or lower than average flows during the recorded period. Moreover the selection of class intervals is an important factor to have an accurate flow duration curve. A computer algorithm was prepared so as to classify the data into 5000 class intervals and values at desired percentages interpolated from them. A normal probability scale has been used for the abscissa representing the percentage of times the flow equalled or exceeded and an arithmatic scale for the ordinate representing the discharge as shown in Figure 4. The change in flow regime has been tabulated in Table 4.

CONCLUSIONS

The computed stormflow reduction of 12.43% means that forests reduce the peak flows since more water is available for evaporation and infiltration because of increased retention time of water droplets on tree leaves and in the undergrowth in forests. The greatest reduction in stormflow (15.80%) is seen to have been associated with lowest precipitation amounts (10 mm) with a mean of 12.43%. Further it is seen to be decreasing with increasing precipitation amounts. These findings are also confirmed from the results obtained by flow duration curve analysis where the decrease in peak flows (Q_{10}) is 21.1%.

Similarly there is an overall decrease in the daily yield from 64.6 hectare metres to 40.1 hectare metres. However the magnitude of mean flow has been seen to have increased by 1.1% with small increase in low flow (Q_{90}) by 0.3%.

The findings from the study are indicative of a change in flow regime because of afforestation establishing the fact that forests are strong evaporators. The decrease in yield can be attributed to increased forest cover. However, there is an increase of mean daily flow and considerable decrease in peakflow affecting thereby a redistribution of flow pattern. Thus more water is available for use during lean season which is conserved by forest cover from stormflow in the form of natural storage.

REFERENCES

1. Barrows, H.K. (1943), Water power engg., McGraw Hill Book Co. N.York, pp.791.

2. Bates, C.G. and Henry, A.J. (1928), Forests and streamflow experiments at Wagon Wheel gap - Colorado, U.S. Weather Bureau monthly weather Review, Suppl No.030, pp.79.

3. Bosch, J.M. and Hewlett, J.D. (1928), A review of catchment exps. to determine the effect of vegetation changes on water yield and evapotranspiration, Jn. of Hydrology (55), pp. 2-23.

4. Cassells, D., L.S. Hamilton and S.R. Saplaco (1982), 'Understanding the Role of Forests in Watershed Protection', Honolulu, East West Centre Environment and Policy Institute Working Paper.

5. Chow, V.T. (1964), 'Hand book of Applied Hydrology', McGraw Hill Book Company, New York.

6. Foster, H.A. (1924), Theoretical frequency curves and their application to engg. Problems, Trans A.S.C.E (87), pp.142-203.

7. Hibbert A.R. (1967), Forest treatment effects on water yield, International Symposium on forest Hydrology, Porgamon press, N.York, pp.527-543.

8. Hursh, C.R. (1948), 'Local climate in the Copper Basin of Tennessee as Modified by the removal of vegetation Circular 774', Washington D.C., U.S. Department of Agriculture.

9. Lee, R. (1980), 'Forest Hydrology', Columbia University Press, New York.

10. Lohani, V.K. (1985), Forest influences on hydrological parameters, National Institute of Hydrology, Roorkee, SR-5, pp.62.

11. Sikka, A.K. (1985), 'Status of Hydrological studies in forested catchments', National Institute of Hydrology, Roorkee, SR-6, pp.53.

12. Storey, H.C., R.L.Hobba and J.M.Rosa (1964), 'Hydrology of forest lands and rangelands', In Handbook of Applied Hydrology (Ed.Van Te Chow).