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IMPACT OF AFFORESTATION ON STORM FLOWS

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SYNOPSIS

Effect of afforestation on storm flows for a catchment situated between the lower Himalayan and Shivalik ranges has been investigated. The catchment is shoe-shaped and encompasses an area of 3076 sq.kms. It is drained by river Ramganga and its tributaries. The area has been treated with eucalyptus and pine plantation. A least squares regression is suggested to estimate daily storm flow volumes from daily rainfall events after analysing the data for six sub basins for the five years period prior to the afforestation and for the five years of post treatment period for events larger than 10mm of mean daily rainfall. The results from the study indicate a decrease of 11% to 36% in the daily storm flow volumes for the post treatment in the five sub basins. However, there is no significant change in one of the sub basins. The flow duration curves are also presented for the catchment. The decrease in mean daily peak flow which is available for 10% of time is by 15% and the mean daily flow has decreased by 37%.

INTRODUCTION

The stormflow estimates are required to plan reservoir capacities and to predict flows further downstream to design flood control structures. Since forests occupy a large percentage of upland areas, it becomes imperative to know the inter-relationship between forests and stormflow volumes. It is essential to quantify the impact of forest management practices upon streamflow from forested watersheds.

The effect of changing the forest cover on storm runoff is a controversial subject. In one of the earlier studies, the peak discharges were not affected by clearcutting a 13 Hectare watershed (Hoover, 1944; Hewlett & Hibbert,1961) whereas Anderson and Hobba (1959) concluded that logging had increased peak streamflow volumes in numerous large watersheds in western Oregon. In a clearcutting experiment in a 44 Hectare watershed at Coweeta Hydrological Laboratory, Hewlett & Helvey (1970) found that stromflow volumes increased by 11 percent. They recorded a 7 percent increase in peak discharge but concluded that their data was inconclusive. A commercial clearcut in a 30 Hectare watershed in Fernow Experimental Forest in West Virginia produced a 24 percent increase in peakflow volumes (Reinhart,1964). Similarly clearcutting a 15.6 Hectare watershed a Hubbard Brook, New Hampshire produced results comparable to those from Coweeta and Fernow (Hornbeck, 1973). However, most subsequent studies have not detected statistically significant increase in peakflow after clearcut logging without soil disturbance (Rothacher, 1973; Harr and McCorson, 1979; Harr, 1986) whereas stormflow volumes increases upto 170 percent have been reported by Nakano (1967), Partridge and Sopper (1973), Zeimer (1981), Verry et al(1983) Lyons and Beschta (1983), Troendle and King (1985).

These studies were carried out on small experimental watersheds for complete or partial forest removal and the results cannot be generalised. Moreover no such estimates are available for Indian catchments and for afforestation of watersheds where changes in stormflow may be minute and spread over a long period of time, as the forest stand gains maturity gradually in contrast to logging where changes may occur instantaneously.

THE STUDY CATCHMENT

The study catchment encompasses an area of 3076 sq.kms and is located between latitude of 29-30'N to 30-06'N and 78-35'E to 79-34'E longitude(Fig.1). It is located between the lower Himalayan and Shivalik ranges. The catchment is shoe-shaped and is drained by the river Ramganga and its tributaries. The river traverses a course of 146 kilometres before entering the plains at Kalagarh. The river channel originates at an elevation of 1760 metres above the mean sea level and the elevation of outfall at Kalagarh is 255.0 metres above the mean sea level. Bed slope varies from 1 in 40 in the upper reaches, to 1 in 100 in the lower reaches.

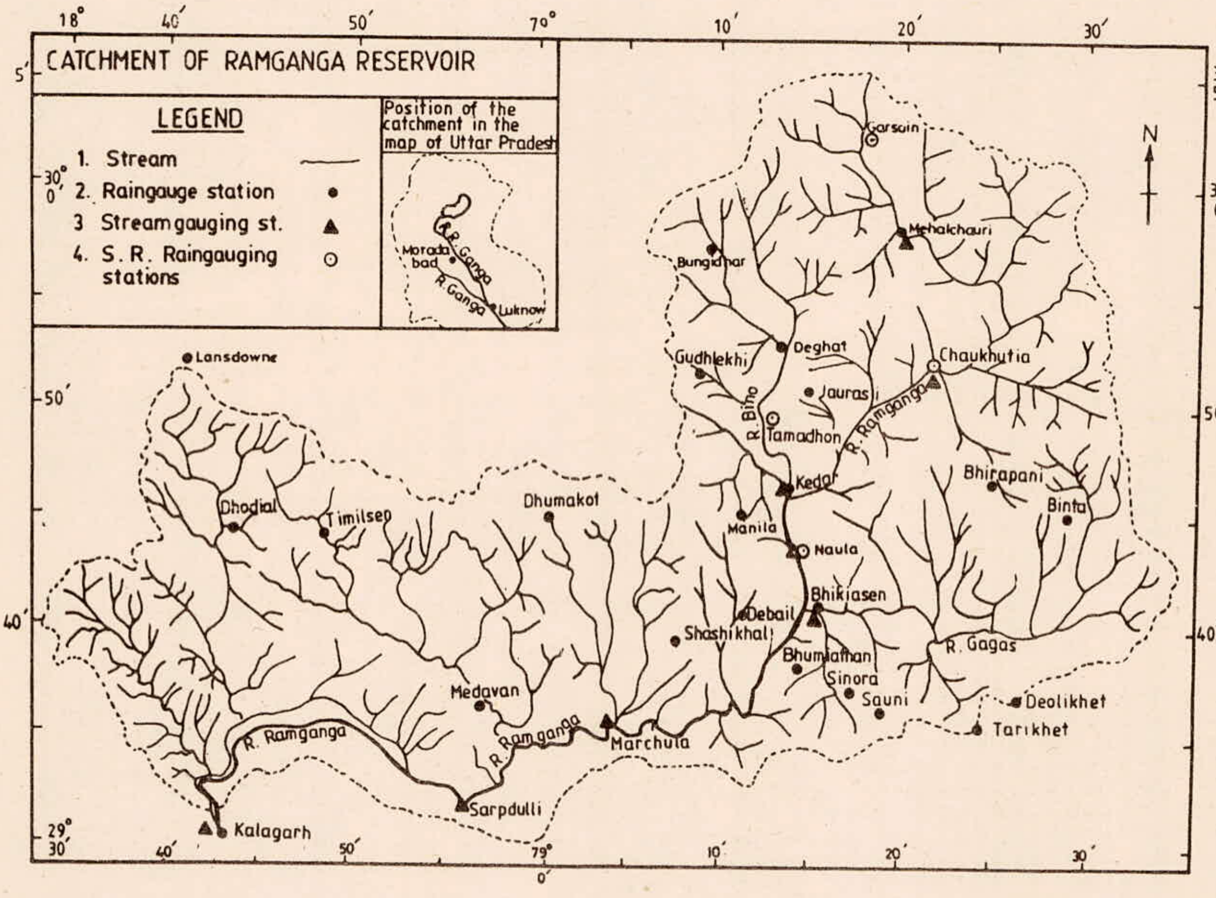

FIG.1. CATCHMENT OF RIVER RAMGANGA

The catchment is divided into six subcatchments according to the location of streamgaging stations. These subcatchments are drained by the river Ramganga upto Mehalchauri, Chaukhutia; by the river Bino upto Kedar; by the river Ramganga upto Naula; by the river Gagas upto Bhikiasen and by the river Ramganga upto Kalagarh.

The catchment area is fully covered by a network of thirtyone non-recording raingages. Runoff observations are available from clock-type stage recorders.

The climate of the study area is Himalayan subtropical with mean annual temperature of 30 degree centigrade and mean minimum temperature of 18 degree centrigrade. The mean annual precipitation is 1020mm and 80% of it occurs in the form of rainfall during the months of June to September. The area lies below snowline and maximum elevation of the catchment is 3112 metres above the mean sea level. The slopes are steep with comparatively flat areas near the river banks where cropping is done in summer season.

The area is covered by tropical forests of eucalyptus and pine type. The area has been undergoing extensive afforestation since 1962. During the study period of 1970 to 1983, the forest cover increased from 43.6% to 53.7%.

FLOW DURATION ANALYSIS

The flow duration curve for the pretreatment and post treatment is presented in fig 2.

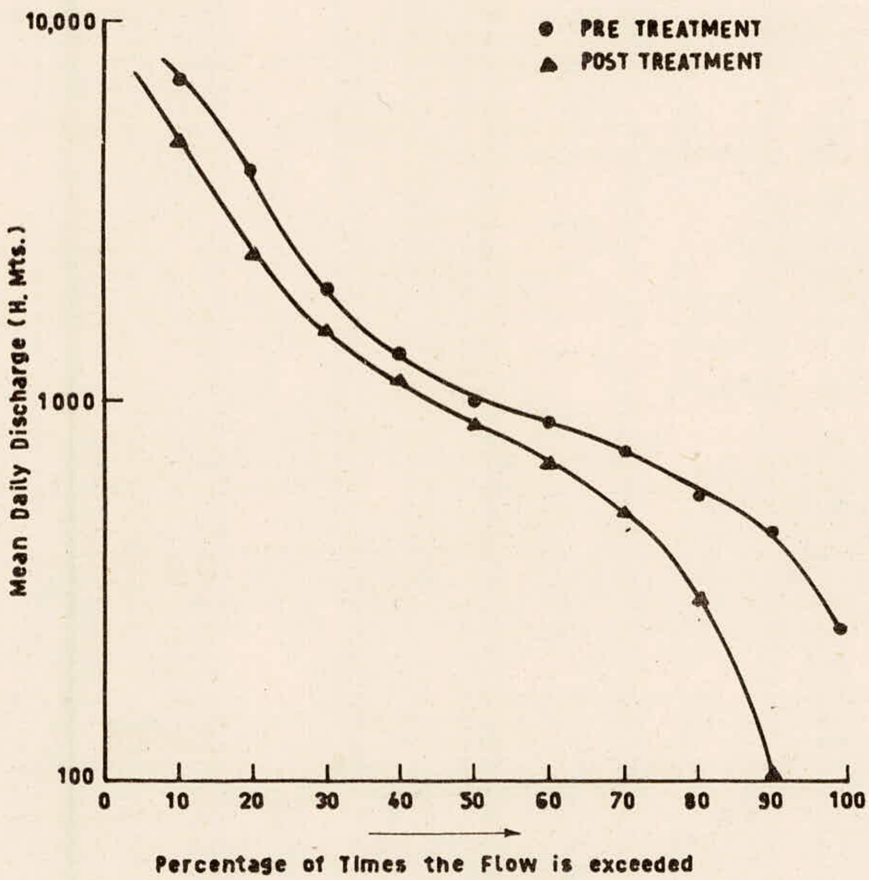

Fig. 2. FLOW DURATION CURVE — PRETREATMENT AND POST TREATMENT PERIOD.

The flow duration curves were prepared for the daily flows at Kalagarh from a computer algorithm after arranging the dataset into descending order of magnitude and dividing into 5000 class intervals. The value of discharge for a particular class interval corresponding to percent of times the flow is exceeded is then computed by linear interpolation. The discharge statistics and the percentage change in flow regime with treatment is presented in Table 1.

PREDICTION MODEL FOR STORM FLOW VOLUMES

For the estimation of the impact of afforestation on storm flow volumes a power fuction model has been fitted to the available data for precipitation and runoff volumes for the five years of pretreatment and post treatment periods. The regression model satisfactorily explains the variance in the given dataset although no physical modelling of the underlying phenomena is involved (HEC,1970). The model adopted is:-

$$R = a\,(P)^{b}$$

where

R = Daily stormflow volume in mm.
P = Mean daily precipitation in mm.
a, b = Regression constants.

All storm producing events with more than 10mm of daily precipitation in the monsoon season, occuring after a continuous spell of rainfall for atleast one weak, were selected for analysis; postulating thereby that the soil moisture requirements have been met with and the precipitation is directly contributing towards streamflow generation after interception storage has been fulfilled. The mean daily precipitation estimates were computed using thiessen weights for the point rainfall observations available within the catchment. The parameters a, b were estimated by least squares regression and details of regression statistics are given in Table 2.

MODEL PERFORMANCE

The model fitted to the data set for the pretreatment and post treatment period is shown in Table 3. The mean daily precipitation amounts alongwith observed and predicted stormflow volumes is also shown in Table 3. The percentage decrease in the stormflow volumes with afforestation is also included in it.

DISCUSSION OF RESULTS

The results from the study corroborate the hypothesis that forests provide additional storage in root zone to reduce the stromflow volumes and because of enhanced transpiration and interception losses.

The results from the flow duration curve analysis indicate an overall decrease of 33.0 percent in the mean daily stromflow volumes. There is a decrease of 38.61 percent in the (Q_{10}) volumes whereas the decrease in (Q_{50}) is about 12.0 percent as shown in Table 1.

The results from the model are similar to those obtained by Hewlett et al (1977) by R-Index method but the mode of analysis involves lesser number of parameters estimation. Analysis of observations before and after treatment indicates a decrease of 11 percent to 36 percent in the daily stormflow volumes for the post treatment period in five of the subbasins. However, there is no significant change in one of the subcatchments, known as Chaukhutia.

Reduction in stormflow volumes is because of the fact that forests are considered to be strong evaporators and affect redistribution of flow pattern by releasing the streamflow gradually during lean season thereby contributing to the reduction of stormflow volumes.

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Table 1 - Change in flow regime with afforestation

Item	Discharge Hac. Mtrs. Mean	S.D.	Percentage of times the flow is exceeded									
			10	20	30	40	50	60	70	80	90	99
Pre-treatment period (1969-72)	28.64	10.58	7946	4029	1987	1353	1004	897	742	566	356	250
Posttreatment period (1981-84)	18.91	2.85	4877	2446	1548	1154	883	692	515	302	87	1.087
Percent decrease in flow	33.95	-	38.61	39.28	22.10	14.78	12.02	22.86	30.65	46.65	75.5	99.5

Table 2 - Model parameters for stormflow volumes for pretreatment and post treatment period.

Catchment / Item		Mehal	Chauk	Kedar	Naula	Bhikiasen	Kalagarh
Pre-treatment							
Length of record		1971-75	1970-74	1970-74	1970-74	1970-74	1969-73
No. of events		122	134	121	112	71	110
Regression constants	a	0.4176	0.3281	-0.1909	-0.3229	-0.1080	-0.6847
	b	0.4910	0.4572	0.5852	0.9131	0.4520	0.9977
Co-eff.of corr.		0.3907	0.3337	0.2462	0.4435	0.2885	0.5521
Co-eff.of det.		0.1527	0.1113	0.0606	0.1967	0.0833	0.3048
Posttreatment							
Length of record		1979-83	1979-83	1979-83	1979-83	1979-83	1980-84
No. of events		122	129	100	88	64	106
Regression constants	a	0.3067	0.2977	-0.5182	-0.1457	-0.6450	-0.4579
	b	0.5270	0.4604	0.9004	0.7243	0.7903	0.7468
Co-eff.of corr.		0.4100	0.3099	0.4549	0.4037	0.3790	0.4003
Co-eff.of det.		0.1681	0.0960	0.2069	0.1629	0.1436	0.1603

Table 3 - Change in stormflow volumes with afforestation

Catchment / Item	Mehal	Chauk	Kedar	Naula	Bhikiasen	Kalagarh
Pre-treatment						
Rainfall(mm)	26.750	24.740	25.920	22.640	20.323	32.312
Runoff observed	14.840	9.862	6.458	9.818	3.045	8.772
Runoff predicted	14.840	9.862	6.458	9.818	3.045	8.772
Model fitted	$2.6157\ P^{0.4910}$	$2.1286\ P^{0.4572}$	$0.6443\ P^{0.5852}$	$0.4754\ P^{0.913}$	$0.7798\ P^{0.4570}$	$0.2069\ P^{0.9977}$
Posttreatment						
Rainfall(mm)	25.050	24.460	20.880	20.780	17.466	28.286
Runoff observed	12.058	9.870	5.718	7.320	2.192	5.566
Runoff predicted	12.058	9.870	5.718	7.320	2.192	5.566
Model fitted	$2.0262\ P^{0.5270}$	$1.9847\ P^{0.4604}$	$0.3032\ P^{0.9004}$	$0.7149\ P^{0.7243}$	$0.2264\ P^{0.7930}$	$0.3884\ P^{0.7468}$
Percent decrease in runoff	18.74	-	11.45	25.44	28.02	36.54