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GENERATION OF MULTISTATION DAILY RAINFALL DATA FOR YIELD STUDIES IN BEAS CATCHMENT

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ABSTRACT

For the development of water resources the evaluation of water potential is necessary. The historical streamflow data constitutes just one sample from past which is unlikely to repeat in future. The synthetic generation of stream flow data provides a number of alternative samples for periods longer than that for historical data, thus making it possible to carry-out water availability studies in a more rational manner.

The present paper describes a study using a multisite rainfall generation procedures for 3 stations. The procedure has been suitably modified and used to generate alternative sequences of daily rainfall data for monsoon period for 12 rain-gauge stations of the Beas basin. The statistical parameters of generated data for same length as historical data i.e. 11 years, compares well with those for historical data. The statistical parameters of generated data clearly indicate the efficacy of the methodology for rainfall generation.

INTRODUCTION

Prediction of water yield gives information in advance, on the amount of water which may be avilable at particular site. Such information is invaluable in guiding the planning of operations of reservoir and reservoir system. For yield studies the streamflow data is one of the hydrological inputs. In hilly areas the stream flow data is poor due to difficult terrain and inaccessible areas. The stream flow is also affected by catchment characteristics. Therefore in such cases generating the sequences of rainfall makes a better alternative for developing stream flow sequences for a period longer than historic stream flow data.

The river Beas is a principal tributary of river Sutlej in Indus basin. The river Beas originates in upper Himalayas from Beas Kund near Rohtang pass at a height of about 3960 m and flows in the east westerly direction till it emerges in the plain at Pong dam site. The total length of the lower Beas upto confluence with Sutlej is about 395 km and length upto Pong dam is 230 km. The total catchment area upto Pong dam is 12560 sq.km. out of which about 775 sq.km. is under permanent snow. A Pandoh diversion dam is also situated on the river Beas at about 140 km. upstream of the Pong dam. The total catchment area of river Beas upto Pandoh dam is 5276 sq.km. The catchment area consist scientifically managed forest, cultivated land and uncultivated weathered rock.

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There are 24 raingauge stations in the catchment at which the data of varying length from 1901 to 1970 is available. Only following twelve stations were taken for generating the rainfall sequences in the catchment. The four groups each having three stations were made on the basis of mean annual rainfall and height above m.s.l. for multistation generation. The data of 11 years from 1955 to 1965 has lesser number of missing data. Therefore the data for this period was considered suitable as input for generating the longer sequences of rainfall and the four groups of 3 stations each were considered as follows:

Group 1:-	(A) Dehragopipur	(B) Palampur	(C) Dharamshala
Group 2:-	(A) Jhanjeli	(B) Panjan	(C) Banjor
Group 3:-	(A) Hamirpur	(B) Mandi	(C) Bhangrotu
Group 4:-	(A) Jogindar Nagar	(B) Kataula	(C) Kulu

MODEL DESCRIPTION

The rainfall in the catchment has been generated with the network of three raingauge stations. There are eight possible combinations (Kreager, 1971) of wet-dry states shown in Table -1. Markov Chain approach has been used to determine the transition probabilities from one state (wet or dry) to other state. The number of occurreces of A, B and C at time (t-1)days wet and A at (t-0)wet divided by the total number of occurences of A,B and C at (t-1) wet gives the observed frequency of a wet day at A following wet days at A, B and C. For the particular case No.8 as given in Table 1, the wet-dry sequences could be determined by leg-four model. In this way the transition probabilities for all the cases are known.

If station A has been generated wet then the rainfall at station A will be used to determine the probability level at station B. If A were dry, but station B is at time (t-1) were wet, then the magnitude of precipitation at station B will be used to determine the probability level to generate a wet or dry at station B. If both A and B were dry on (t-0) and (t-1) respectively and C is wet at (t-1) days then the magnitude of precipitation at station C will be used to select the probability level for generating wet or dry day at station B.

If both stations A and B generated wet, then only one rainfall amount from either station A or station B will be used to determine the probability level for station C. If A is wet and B is dry, the rainfall amount at station A will be used to determine the probability at station C. If A is dry and B is wet the rainfall amount at station B will be used to determine the probability level at station C. If both station A and station B are dry but station C at (t-1)days is wet the rainfall amount at station C at previous day will be used to determine the probability level at station C. Therefore the transition probabilities for stations A, B and C for all cases were calculated as shown in Table 2, by using suitable computer program (Obeysekera,1978).

Historic cumulative frequency curve and additional cumulative frequency curves shown in Fig.1, 2a and 2b were developed for generation of amount of rainfall. Following multiple regression relationships were used to generate the transformed values of rainfall at station B & C.

$$\text{Station B} = a + b\,(\text{station A}) + \varepsilon$$

$$\text{station C} = a_1 + b1\,(\text{station B}) + c1\,(\text{station C}) + \varepsilon$$

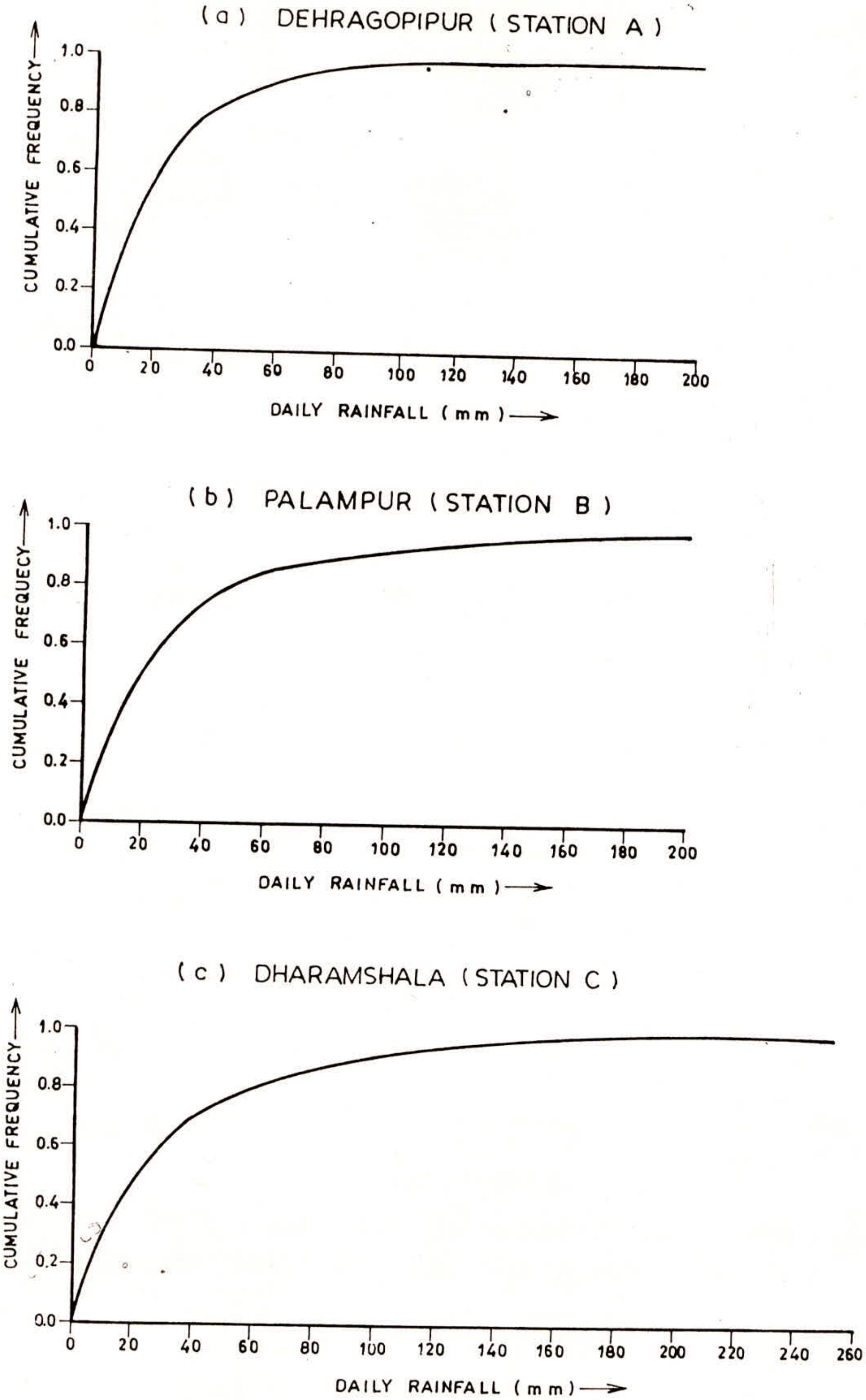

FIG.1. HISTORIC CUMULATIVE FREQUENCY DISTRIBUTION.

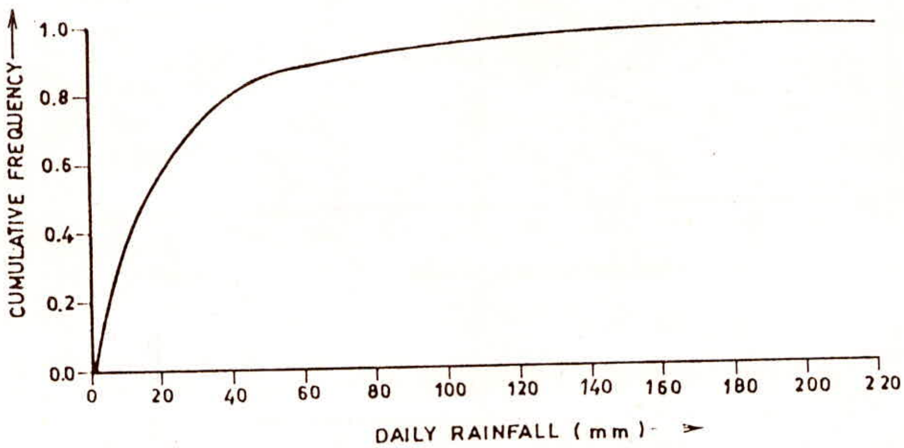

FIG.2(a).CONDITIONAL CUMULATIVE FREQUENCY AT PALAMPUR WITH NO RAIN AT DEHRAGOPIPUR.

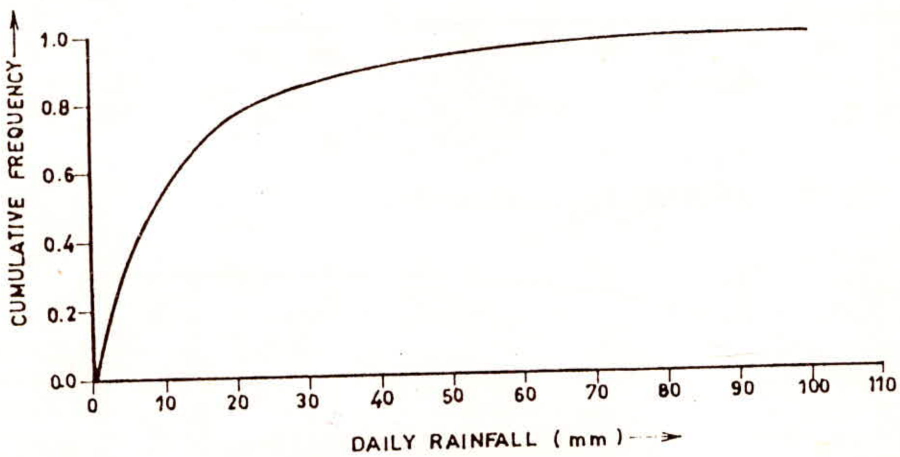

FIG.2(b).CONDITIONAL CUMULATIVE FREQUENCY AT DHARAMSHALA WITH NO RAIN AT DEHRAGOPIPUR AND PALAMPUR.

·where,

station A, station B and station C are the transformed amount of rainfall and

a, a_1, are the intercept

b, b_1 & c_1, are the regression coefficients

and ϵ, is the normally distributed random component with observed variance.

MODEL APPLICATION FOR GENERATION OF DAILY RAINFALL DATA

The raingauge station Dehragopipur(1), Palampur(2) and Dharamshala (3) were placed in a group on the basis of mean annual rainfall and height above mean sea level. The monsoon period was found from 20 June to 17 September by plotting the 5 day average of daily historic rainfall from 1955 to 1965. The historic rainfall for this period was examined and the three levels of rain were made as follows:

Level of rain	Interval of rain (mm)
1	0-10
2	10-30
3	30 and above

The computer programme developed by Kreager (1971) and also used by Obeysekara(1978) was suitably modified and was applied to generate the magnitude of rainfall. For any station it would be achieved through sampling from historic cumulative frequency (Fig.1, 2a, 2b) if the correlation coefficient for regression relationships by which the actual generation is to be done is insignificant w.r.t. a predetermined level. The regression coefficient for transformed value of station B and station C are shown in Table 3 and 4 respectively. In this way generation of daily rainfall from cumulative frequency curve was possible. The rainfall relationship will be obtained by using the 10 daily rainfall relationship developed for observed data of monsoon period and yield studies for the catchment will be done.

DISCUSSION OF RESULTS

The statistical parameters (mean, stdandard deviation and skewness) of the generated daily rainfall data at three stations Dehragopipur(1), Palampur(2) and Dharamshala(3) of group 1 were calculated and were compared with those of observed data for same period(Table 5). There is slight variation between the observed and generated statistical parame ters. The above statistical parameters were also computed for generated mean seasonal value and were found to compare well with those of obser ved data (Table 6). Similarly data was generated for other groups and statistics was compared. The above values have been generated by consi dering that three raingauge stations of a group are correlated and there is no significant correlation among stations of different groups. Further improvement in the methodology could include consideration of correlation among different groups as well.

CONCLUSIONS

The good reproduction of statistics of observed rainfall by generated data clearly indicates the efficacy of the methodology for rainfall generation for longer period. This approach could be used for generating longer period rainfall data for each of the raingauge stations in the basin for estimation of average rainfall and corresponding flows, providing longer flow series for yield estimation.

Table-1 Wet-Dry States for Raingauge Station A

Case	Station B (t-1)	Station C (t-1)	Station A (t-1)	Station A (t-0)
1	Wet	Wet	Wet	Wet or dry
2	Wet	Wet	Dry	Wet or dry
3	Wet	Dry	Wet	Wet or dry
4	Wet	Dry	Dry	Wet or dry
5	Dry	Wet	Wet	Wet or dry
6	Dry	Wet	Dry	Wet or dry
7	Dry	Dry	Wet	Wet or dry
8	Dry	Dry	Dry	Wet or dry

Table-2 Transition Probabilities of Station A, B and C

Case	Level of rain	Transition Probabilities		
		Station A (Dehragopipur)	Station B (Palampur)	Station C (Dharamshala)
1	1	0.533	0.810	0.947
	2	0.597	0.880	0.958
	3	0.663	0.965	0.990
2	1	0.600	1.000	0.696
	2	1.000	0.818	0.882
	3	0.000	1.000	0.667
3	1	0.500	0.650	0.841
	2	0.667	0.568	0.863
	3	0.500	0.802	0.950
4	1	0.364	0.600	0.838
	2	0.500	0.200	0.488
	3	1.000	0.333	0.568
5	1	0.264	0.765	0.950
	2	0.500	0.846	0.955
	3	0.418	1.000	1.000
6	1	0.217	0.632	0.286
	2	0.308	0.619	0.700
	3	0.500	1.000	0.000
7	1	0.353	0.378	0.647
	2	0.333	0.350	0.813
	3	0.667	0.200	0.769
8	1	0.177	0.271	0.177

Table 3

Linear Regression Relations Developed from Transformed Rainfall at Station A and B

Cases	Level of Rain	a	b	Correlation	Variance
	1	- 0.645	- 0.072	0.220	0.224
1	2	- 0.919	0.374	0.786	0.035
	3	0.727	- 1.440	0.219	13.604
	1	- 2.783	0.565	0.698	0.447
2	2	- 1.173	0.471	0.844	0.029
	3	-51.434	34.896	1.000	0.000
	1	- 1.976	- 0.083	0.029	15.138
5	2	- 1.357	0.403	0.213	0.821
	3	- 1.215	0.157	0.037	4.661
	1	- 1.905	0.139	0.354	0.578
6	2	- 1.228	0.483	0.878	0.297
	3	13.094	- 7.526	0.624	32.200

Table 4

Linear Regression Relation Developed from Transformed Daily Rainfall at Station A, B ad C.

Case	Level of Rain	a'	b'	c'	Correlation	Variance
1	1	0.282	-0.098	0.447	0.488	0.671
	2	1.033	-0.326	0.556	0.493	0.590
	3	0.169	0.002	0.407	0.367	0.773
2	1	-0.812	0.044	-	0.004	0.770
	2	-0.589	0.123	-	0.009	0.573
	3	-3.873	1.251	-	1.000	0.000
3	1	-0.334	-	0.222	0.045	0.663
	2	-0.228	-	0.525	0.026	0.649
	3	-0.818	-	0.679	0.138	0.666
5	1	0.110	-0.104	0.752	0.750	0.459
	2	0.660	-0.100	0.171	0.000	0.978
	3	0.006	-0.240	1.142	0.376	0.327
6	1	-2.613	1.118	-	0.000	0.000
	2	1.472	-0.486	-	0.099	0.305
	3	0.000	0.000	-	0.000	0.000
7	1	-0.254	-	0.343	0.058	0.753
	2	-0.900	-	1.790	0.204	0.871
	3	-0.250	-	0.416	0.701	0.782

Table 5

Statistics of 11 Years Observed and Generated Sequences

Year	Station No.	Observed Sequence			Generated Sequence		
		Mean (mm)	Std.Dev (mm)	Skew-ness	Mean (mm)	Std.Dev. (mm)	Skewness
	1	9.970	23.461	4.178	6.51	14.91	3.700
1	2	21.611	28.514	2.054	15.12	33.06	3.540
	3	29.741	40.803	2.446	21.42	33.640	2.120
	1	11.059	25.178	3.026	9.02	19.36	4.410
2	2	17.539	25.993	2.366	18.00	28.96	2.020
	3	22.550	30.304	2.312	28.81	39.90	2.200
	1	11.628	21.348	2.664	10.54	19.46	2.950
3	2	23.986	35.980	1.728	21.18	37.20	2.740
	3	22.407	36.797	2.815	28.49	42.40	2.210
	1	11.134	21.401	2.413	15.45	28.44	3.450
4	2	20.776	34.125	2.645	22.73	46.17	2.960
	3	42.083	60.511	2.246	20.85	43.28	4.060
	1	10.840	15.729	1.681	8.68	12.88	1.660
5	2	21.948	33.880	2.337	12.99	20.87	2.39
	3	35.580	50.793	2.379	23.70	30.84	1.830
	1	10.088	15.483	1.865	10.68	21.37	3.810
6	2	17.068	27.158	2.162	18.57	37.59	2.86
	3	22.160	27.874	1.315	18.95	27.30	2.090
	1	10.564	17.640	1.852	10.63	20.49	2.770
7	2	28.488	38.862	2.092	17.35	34.99	3.620
	3	31.856	41.862	2.445	19.53	27.17	1.660
	1	90.707	18.797	2.537	6.85	14.18	2.800
8	2	19.416	34.212	2.977	14.57	24.10	2.240
	3	16.561	29.208	3.910	20.15	35.85	20.80
	1	9.322	15.843	2.273	5.061	11.58	3.400
9	2	22.166	38.827	2.357	11.95	20.31	3.05
	3	26.422	36.432	2.103	22.92	40.79	4.54
	1	9.949	22.166	5.206	13.01	28.32	2.960
10	2	15.102	23.099	3.637	17.50	30.12	3.40
	3	24.546	28.913	1.553	34.03	47.04	2.33
	1	6.256	14.493	2.554	7.97	14.59	2.46
11	2	7.941	17.487	3.695	17.15	34.22	3.99
	3	11.116	23.435	3.585	34.03	51.38	2.33

Table 5

Statistics of 11 Years Observed and Generated Sequences

Year	Station No.	Observed Sequence Mean (mm)	Std.Dev (mm)	Skew-ness	Generated Sequence Mean (mm)	Std.Dev. (mm)	Skewness
1	1	9.970	23.461	4.178	6.51	14.91	3.700
	2	21.611	28.514	2.054	15.12	33.06	3.540
	3	29.741	40.803	2.446	21.42	33.640	2.120
2	1	11.059	25.178	3.026	9.02	19.36	4.410
	2	17.539	25.993	2.366	18.00	28.96	2.020
	3	22.550	30.304	2.312	28.81	39.90	2.200
3	1	11.628	21.348	2.664	10.54	19.46	2.950
	2	23.986	35.980	1.728	21.18	37.20	2.740
	3	22.407	36.797	2.815	28.49	42.40	2.210
4	1	11.134	21.401	2.413	15.45	28.44	3.450
	2	20.776	34.125	2.645	22.73	46.17	2.960
	3	42.083	60.511	2.246	20.85	43.28	4.060
5	1	10.840	15.729	1.681	8.68	12.88	1.660
	2	21.948	33.880	2.337	12.99	20.87	2.39
	3	35.580	50.793	2.379	23.70	30.84	1.830
6	1	10.088	15.483	1.865	10.68	21.37	3.810
	2	17.068	27.158	2.162	18.57	37.59	2.86
	3	22.160	27.874	1.315	18.95	27.30	2.090
7	1	10.564	17.640	1.852	10.63	20.49	2.770
	2	28.488	38.862	2.092	17.35	34.99	3.620
	3	31.856	41.862	2.445	19.53	27.17	1.660
8	1	90.707	18.797	2.537	6.85	14.18	2.800
	2	19.416	34.212	2.977	14.57	24.10	2.240
	3	16.561	29.208	3.910	20.15	35.85	20.80
9	1	9.322	15.843	2.273	5.061	11.58	3.400
	2	22.166	38.827	2.357	11.95	20.31	3.05
	3	26.422	36.432	2.103	22.92	40.79	4.54
10	1	9.949	22.166	5.206	13.01	28.32	2.960
	2	15.102	23.099	3.637	17.50	30.12	3.40
	3	24.546	28.913	1.553	34.03	47.04	2.33
11	1	6.256	14.493	2.554	7.97	14.59	2.46
	2	7.941	17.487	3.695	17.15	34.22	3.99
	3	11.116	23.435	3.585	34.03	51.38	2.33

Table 6

Statistics of 11 Years Seasonal Observed and Generated Sequences

Station No.	Observed Mean (mm)	Std.Dev. (mm)	Skewness	Generated Mean (mm)	Std.Dev. (mm)	Skewness
1	901.28	126.05	-2.145	854.43	270.62	0.557
2.	1767.59	478.43	-0.739	1531.23	291.88	0.177
3.	2331.93	780.01	0.259	2263.82	504.61	0.747

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