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Some aspects of daily rainfall distribution over a high range river basin in central Kerala

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सार — मध्य केरल के चालकुडी नदी बेसिन के बारह क्षेत्रों की प्रतिदिन की वर्षा वितरण का अध्ययन किया गया है । सामान्यीकृत वर्षा वक्र (एन.आर.सी.) तैयार किया गया है और प्रतिदिन की वर्षा वितरण के विभिन्न प्राचल बनाए गए हैं । सामान्यीकृत वर्षा वक्र के आधार पर वर्षा की प्रत्येक 10% मात्रा के अनुसार वर्षा के दिनों की संख्या और माध्य वर्षा प्रबलता की गणना की गई है । यह पाया गया है कि विभिन्नता का गुणांक (सी.वी.) दैनिक वर्षा वितरण का अत्यन्त महत्वपूर्ण प्राचल है जो सामान्यीकृत वर्षा वक्र के स्वरूप का निर्धारण करता है । विभिन्नता गुणांक मानों के वितरण की आवृति यह दर्शाती है कि 100% से 120% के स्तर पर विभिन्नता गुणांक अधिक है । वर्षा विहीन दिनों और उल्लेखनीय वर्षा वाले दिनों के वर्षा में योगदान का परिकलन किया गया है । मौसमी वर्षा की लगभग आधी वर्षा निम्न प्रबलता की है जो कि कुल वर्षा की 80% है तथापि शेष 20% वर्षा उच्च प्रबलता के कारण बाढ़, भूक्षरण आदि के दृष्टिकोण से पर्याप्त उल्लेखनीय है ।

ABSTRACT. The daily rainfall distribution of twelve stations in the Chalakudy river basin of central Kerala is studied. Normalised rainfall curve (NRC) is constructed and various parameters of the daily rainfall distribution are derived. The number of rainy days and mean rain intensities at each 10% rain amounts are calculated from the NRC. It has been found that the coefficient of variaiton (CV) is the most important parameter of the daily rainfall distribution which determines the shape of NRC. Frequency distribution of CV values reveals that the CV is highest in the range of 100-120%. Rainfall contributions by non-rainy days and significant rainfall days are calculated. About half of the seasonal rainfall which contributes 80% of the total rainfall are of low intensity. However, the remaining 20% due to higher intensity rainfall are of considerable significance for floods, erosion, etc.

Key words — Coefficient of variation, Significant rainfall, Non-rainy days

1. Introduction

Rainfall is an important parameter in both hydrology and meteorology. For local water management, maintenance of forestry and horticulture, planning and execution of various launch campaigns, a critical study of the rainfall characteristics of the place is required. The study is more important as far as mountainous river basins are considered.

There are various methods available for analysing daily rainfall data. One method of analysing the daily rainfall data is the investigation of the association between the cumulated percentage of rain amount (X) and cumulated percentage of number of rainy days (Y) after arranging the rainfall data in ascending or descending order of rain amount. This provides various kind of information about the nature of rainfall distribution.

Rai Sircar (1955) made a study of southwest (SW) monsoon rainfall for a group of stations around Delhi, Calcutta, Bangalore and Tiruchirapalli by constructing the NRC. A detailed study of NRCs for 15 Indian stations was made by Ananthakrishnan and Soman (1989). Soman and Krishnakumar (1990) extended the work for 365 stations in the entire Indian sub-continent. Daily rainfall distribution of Thiruvananthapuram has been studied by Satheeshkumar (1993). Jayasree and Anil Kumar (1995) presented a similar study for fewer stations in the Chalakudy river basin.

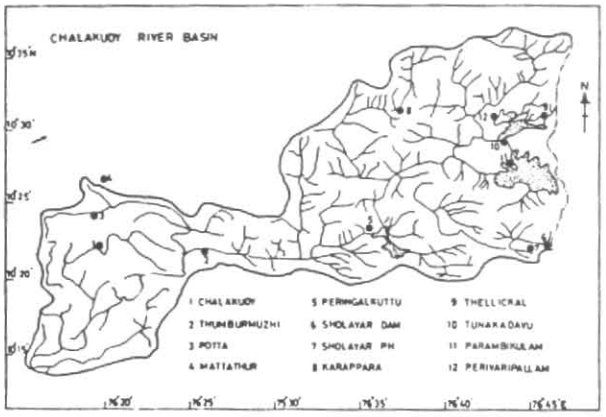

Fig. 1. Station location map

In the present paper, results for twelve stations of the Chalakudy river basin of central Kerala are presented. River basin, which extends along 76°15′-76°55′E longitude and 10°10′ - 10°35′N latitude, originates from Anamalai hills of Western Ghats has a total length of 134 km and drainage area 1706 sq km.

2. Data and methodology

Daily rainfall data from twelve stations distributed uniformly within Chalakudy river basin for a period of 20 years (1972-91) were collected from Irrigation Department. Fig.1 gives the station location map. The data are being analysed and the normalised rainfall curve (NRC) which depicts the relationship between X and Y is constructed using the following equation:

$$X = Y \exp \{- b (1 - Y)^c\}; \; c \leq 1 \qquad (1)$$

where b and c being empirical constants. Parameters b and c can be evaluated by utilising the pair of values (X^*, 0.5), (0.5, Y^*) for the NRC. X^* and Y^* are the percentage of rain amount which is cumulated in 50% of number of rain days and percentage number of days which account for 50% cumulated rain amount respectively. Actual rain intensity (I) at any point (X, Y) is related to the slope of the NRC at that point by the relation

$$I = r dX/dY \qquad (2)$$

where, $r = R/N$, R being the total rainfall depth and N is the number of rain days and

$$dX/dY = \{1 + bcY (1-Y)^{c-1}\} \exp [- b (1 - Y)^c] \quad (3)$$

TABLE 1

Number of rain days and mean rain intensity

Cumulated ratio of rain amount	Number of rain days	Mean rain intensity
0.0 - 0.1	NY_1	r/Y_1
0.1 - 0.2	$N(Y_2-Y_1)$	$r/(Y_2-Y_1)$
0.2 - 0.3	$N(Y_3-Y_2)$	$r/(Y_3-Y_2)$
0.3 - 0.4	$N(Y_4-Y_3)$	$r/(Y_4-Y_3)$
0.4 - 0.5	$N(Y_5-Y_4)$	$r/(Y_5-Y_4)$
0.5 - 0.6	$N(Y_6-Y_5)$	$r/(Y_6-Y_5)$
0.6 - 0.7	$N(Y_7-Y_6)$	$r/(Y_7-Y_6)$
0.7 - 0.8	$N(Y_8-Y_7)$	$r/(Y_8-Y_7)$
0.8 - 0.9	$N(Y_9-Y_8)$	$r/(Y_9-Y_8)$
0.9 - 1.0	$N(Y_{10}-Y_9)$	$r/(Y_{10}-Y_9)$

Note : Y_1, Y_2 ... Y_{10} are the ratios of cumulated number of rain days corresponding to the ratio of cumulated rain amounts 0, 0.1, 0.2 ... 1.0 respectively.

Using Eqns. (2) & (3), the rain intensity at specified points along the NRC can be calculated. Eqn. (1) has been employed to study the various parameters of daily rainfall distribution. The point where slope becomes 45° corresponds to mean rain intensity per rainy day. Number of rain days and mean rain intensities at each of the 10% rain amounts were calculated by the method given in Table 1.

Coefficients of variation and mean rain amount per rain day were calculated for all the stations for all the months, seasons and year as a whole.

The rainfall contribution by non-rainy days (days with amounts < 2.5 mm) to the total amount and days of significant rainfall with amounts in excess of 'r' were calculated and their contribution to the total amount were found out. Also the contributions of 25, 50, 75 and 90% rain amounts as a percentage of number of rainy days were calculated for all the twelve stations. Computations of distributions of rain amounts for 25, 50, 75 and 90% of rain days were also carried out.

3. Results and discussion

Earlier studies have shown that the coefficient of variation (CV) of daily rain amounts is a

TABLE 2

Frequency distribution of CV values of 204 rainfall series

S. No.	CV (%)	Frequency		
		Monthly	Seasonal	Annual
1.	60.1-70.0	1	1	0
2.	70.1-80.0	2	0	0
3.	80.1-90.0	13	1	0
4.	90.1-100.0	22	7	2
5.	100.1-110.0	33	13	4
6.	110.1-120.0	31	15	6
7.	120.1-130.0	21	4	0
8.	130.1-140.0	10	5	0
9.	140.1-150.0	5	1	0
10.	150.1-160.0	3	0	0
11.	160.1-170.0	1	0	0
12.	170.1-180.0	0	0	0
13.	180.1-190.0	2	0	0
14.	190.1-200.0	0	1	0

significant parameter of daily rainfall distribution, which uniquely determines the shape of the NRC. For low values of coefficient of variation 'c' approaches unity and the equation $X = Y \exp \{- b (1 - Y)^c\}$ with only one empirical constant 'b' gives fairly good representation of the NRC. Percentage of rain amount (X^*) which is cumulated in 50% of number of rain days and percentage number of days (Y^*) which account for 50% cumulated rain amount are important parameters of the distribution which are uniquely linked with CV of the distribution.

The present study shows that the CV for all the stations varies from 60-200% for all the months, seasons and year (Table 2). Highest variability occurs during January-February months, whereas lowest variability is seen during southwest (SW) monsoon season. We can see that maximum variability occurs in the range 110-120%. One station Potta has no variation in the month of February (There was no rain in Potta in the month of February during 1972-91). Table 3 shows that the station Thumburmuzhi has the lowest coefficient of variation (93), whereas Thunakadavu and Parambikulam have the highest coefficients of variation (119 each).

TABLE 3

Number of rain days (n), rainy days (n'), coefficient of variations (CV) and mean rain intensities (r)

S. No.	Station name	n	n'	CV (%)	r (mm/day)
1.	Chalakudy	143.3	124.0	113	20.928
2.	Thumburmuzhi	143.3	135.9	93	29.237
3.	Potta	119.8	111.3	100	23.914
4.	Mattathur	127.8	115.0	108	24.716
5.	Peringalkuttu	139.7	134.7	105	27.805
6.	Sholayar dam	147.3	139.2	102	27.802
7.	Sholayar P.H.	150.4	137.1	103	25.997
8.	Karappara	135.4	122.6	117	26.945
9.	Thellikal	108.6	89.4	115	13.986
10.	Parambikulam	120.2	100.3	119	14.328
11.	Thunakadavu	118.4	93.4	119	12.066
12.	Perivaripallam	113.5	92.3	118	12.607

It is seen that larger CV is associated with stations of smaller number of rain days and higher rain amount. Both Parambikulam and Thunakadavu have the same CV, and hence NRC's of these two stations will have similarity between them and hence can be represented by a single curve. Out of all the stations taken into consideration only one station, Thumburmuzhi, with low coefficient of variation has 'c' exceeding unity which shows that it is not a good representation for that station. Table 4 gives the values of X^*, Y^* and empirical constants obtained from the NRC. Fig. 2 gives the NRC's for the two stations with lowest and highest CV.

We can see that the actual rain intensity varies from 12-30 mm/day annually. Monthwise variation is from 6-40 mm/day. Rain intensity is highest for Thumburmuzhi and least for Thunakadavu. During southwest monsoon season mean daily rainfall per rainy day (days with amount > 2.5 mm) varies from 15-35 mm/day, whereas the variation is about 14-27 mm/day during post-monsoon period. Highest intensity is observed during monsoon months and least during winter and summer months.

Table 5 gives the mean rain intensities at specified points on the NRC calculated using Eqns. (2) & (3) and shows that the high intensity rainfall was clustered

TABLE 4

Constants of the equation representing NRC during SW monsoon rainfall and annual rainfall

S. No.	Station name	SW monsoon rainfall				Annual rainfall			
		x^*	y^*	b	c	x^*	y^*	b	c
1.	Chalakudy	0.19	0.80	0.73	0.79	0.13	0.83	1.14	0.93
2.	Thumburmuzhi	0.23	'c' approaches unity			0.27	0.73	0.40	0.51
3.	Potta	0.18	0.80	0.82	0.87	0.17	0.85	0.71	0.59
4.	Mattathur	0.23	0.76	0.74	0.89	0.17	0.83	0.77	0.70
5.	Peringalkuttu	0.17	0.81	0.86	0.87	0.36	0.73	0.40	0.51
6.	Sholayar dam	0.23	0.79	0.87	0.86	0.12	0.82	0.57	0.87
7.	Sholayar P.H.	0.18	0.79	0.85	0.94	0.20	0.80	0.66	0.73
8.	Karappara	0.14	0.84	0.99	0.79	0.15	0.83	0.95	0.83
9.	Thellical	0.21	0.80	0.59	0.66	0.20	0.80	0.66	0.73
10.	Parambikulam	0.31	0.78	0.81	0.95	0.19	0.80	0.73	0.78
11.	Thunakadavu	0.11	0.84	0.63	0.56	0.12	0.80	0.58	0.65
12.	Perivaripallam	0.21	0.80	0.60	0.67	0.21	0.80	0.62	0.69

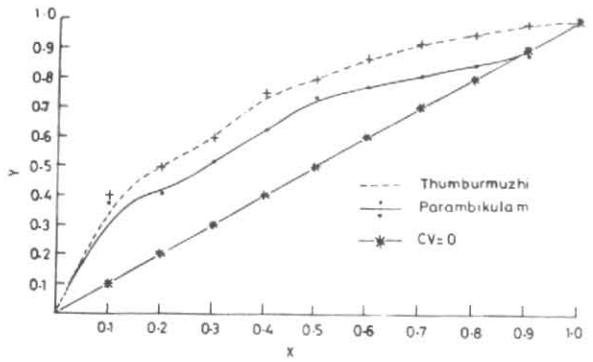

Fig. 2. Normalised rainfall curves for Thumburmuzhi and Parambikulam

around the upper end of normalized rainfall curve for all the stations. In the case of series with large CV, slope approaches zero faster at the upper end of NRC indicating high intensities of rainfall. The computed rain intensities at 50% of cumulated seasonal rainfall amount vary from 9 mm/day to a maximum of 58 mm/day. Calculated values of rain intensities in the interval Y = 90 to 99.9% for all the stations show that there are heavy rainfalls reaching 200 mm/day with maximum observed during January and February months and minimum during SW monsoon season. Rain intensities at 99.9% of the NRC is maximum for Peringalkuttu and least for Parambikulam. But during SW monsoon season the highest is for Karappara and the least for Parambikulam. So the heavy rainfall regime represented by the upper end of the normalised rainfall curve for the last 1% of the cumulated time interval is of particular interest in connection with the situations such as flooding, erosion etc.

Tables 6 (a & b) gives the number of rainy days and mean rain intensities at each of the 10% rain amounts for the selected five stations for SW monsoon and annual rainfall. This kind of information gives the expected number of days of rainfall and the associated ntensities which is needed for the estimation of run-off, planning of hydro-electric projects etc.

The rainfall contribution by non-rainy days taken as a percentage to the total amount shows that it is highest during October-February period (about 4%) and least during monsoon period (2-3%). Non-rainy days are about 3-22% of the total number of rain days which contribute nearly 1-4% of the total amount. Highest non-rainy day contributions are observed for Thunakadavu and Parambikulam and least for Thumburmuzhi. Days of significant rainfall, which constitute 30-40% of the total number of rain days, contribute about 55-75% of the total rain during a month or a season. Contribution is least for Parambikulam (54%) and highest for Thumburmuzhi (74%). Highest contribution is observed during SW monsoon period and least during pre-monsoon months with some local and seasonal variations. Contribution of 25, 50, 75 and 90% rain amounts as a percentage of number of rain days were calculated which gave about 62, 80, 93 and 98% respectively. Half of the seasonal rain is contributed by about 80% of rain days from falls of low intensity. A good percentage of this

TABLE 5

Rain intensities at specific points on the NRC for SW monsoon season and annual series

S. No.	Station name	$x = 0$	$y = 0.2$	$y = 0.5$	$y = 0.8$	$y = y^*$	$y = 0.9$	$y = 0.99$	$y = 0.995$	$y = 0.999$
1.	Chalakudy	11.1	12.8	20.3	31.1	31.1	37.8	56.4	62.3	78.6
		6.6	10.0	17.7	33.6	31.7	38.9	50.4	52.4	56.5
2.	Thumburmuzhi				constant 'c' approaches unity					
		17.5	21.4	30.1	33.5	36.2	41.6	56.3	61.1	74.4
3.	Potta	11.2	14.9	22.7	35.6	35.6	42.8	58.1	62.0	71.4
		11.8	14.0	19.1	33.7	30.0	39.2	84.8	107.2	189.0
4.	Mattathur	13.0	16.8	24.7	36.0	37.1	43.5	55.6	58.3	65.0
		11.5	12.8	32.7	34.8	32.7	41.6	74.0	86.7	126.8
5.	Peringalkuttu	13.6	18.4	28.1	45.2	44.8	54.1	73.7	78.6	90.4
		18.6	20.3	23.9	32.0	32.7	38.4	79.2	102.1	196.7
6.	Sholayar dam	14.6	18.5	20.5	28.6	32.9	46.6	54.7	88.7	99.8
		20.5	24.6	29.6	32.9	42.3	56.6	65.9	79.0	94.9
7.	Sholayar P.H.	13.2	18.1	28.2	42.8	43.6	51.0	61.9	63.7	67.3
		13.4	16.4	22.5	33.8	33.8	41.6	67.6	79.7	106.8
8.	Karappara	12.1	16.6	26.8	51.1	46.5	59.3	95.0	106.2	136.8
		9.5	13.0	20.8	37.1	35.0	43.7	64.9	70.9	86.4
9.	Thellical	8.0	9.4	12.4	18.2	18.2	22.5	40.1	47.6	73.1
		7.2	8.8	12.1	18.6	18.6	22.4	36.3	41.4	57.4
10.	Parambikulam	6.4	9.3	13.2	19.6	20.1	23.3	28.0	30.7	36.0
		6.9	8.7	12.5	19.2	19.2	23.3	35.1	38.9	49.4
11.	Thunakadavu	6.6	7.7	10.0	16.5	13.7	19.5	43.2	55.5	102.7
		6.7	7.9	10.3	15.1	15.1	18.7	33.7	40.2	62.6
12.	Perivaripallam	6.9	8.4	10.8	15.9	15.9	19.7	34.4	40.6	60.9
		6.8	8.1	10.9	16.1	16.1	19.9	33.9	39.6	57.9

may be lost by evaporation from surface. The remaining 50% rainfall contributed by rainfall of higher intensity in about 20% of rain days is of major importance for recharge of surface water resources, in producing floods, causing soil erosion etc. Computation of the contribution of rain amounts for 25, 50, 75 and 90% rain days was also carried out for all the months, seasons and years. Throughout the year about 3-4% were contributed by 25% rain days, 12-16% rainfall by 50% rain days, 38-42% by 75% rain days and 65-70% in 90% of rain days., *i.e*, the average contribution by the last 10% of cumulated rain days to the total rainfall which varies from 30-35%.

4. Conclusion

The present study reveals that a great deal of information about the rainfall behaviour can be obtained from NRC of a station. CV is the most important parameter of the daily rainfall distribution which uniquely determines the shape of NRC. There is no universal NRC that can represent all the rainfall regimes. Mean rain amount per rain day varies from 12-30 mm/day. Computed rain intensities at 50% of cumulated seasonal rainfall amount vary from about 9-58 mm/day. About half of the seasonal rainfall which contributes 80% of total amount are of low intensity. Higher intensity rainfall is only about 20%, concentrated at the upper extremity of NRC. But it is of considerable significance in floods, erosion etc. Non-rainy days are about 3-22% of total number of rain days and it contributes only 1-4% of the total amount. Average contribution by last 10% cumulated rain days is about 25-30%, which is of major importance for the recharge of surface water resources. In the entire region of study, days of significant rainfall are about 30-40% and contribute 55-75% of the total amount. These results are expected to provide the baseline information pertaining to rainfall characteristics of the watershed.

TABLE 6(a)

Number of rainy days and rain intensities at each 10% rain amounts for the southwest monsoon rainfall series

Class interval	Chalakudy		Thumburmuzhi		Peringalkuttu		Thunakadavu		Parambikulam	
	RD*	RI*	RD	RI	RD	RI	RD	RI	RD	RI
0.0-0.1	29.50	6.09	24.70	11.49	34.05	8.39	18.55	4.13	21.55	4.89
0.1-0.2	14.35	13.61	13.25	21.44	13.45	21.26	12.40	6.20	12.65	8.30
0.2-0.3	9.25	21.04	12.35	22.98	10.75	26.57	7.40	10.35	6.15	17.07
0.3-0.4	7.60	25.71	6.20	45.95	8.10	35.44	11.15	6.89	5.45	19.20
0.4-0.5	6.75	28.92	2.65	107.23	5.85	49.07	2.50	31.04	4.80	21.95
0.5-0.6	4.20	46.22	6.20	45.95	4.50	63.78	1.25	62.07	3.40	30.72
0.6-0.7	4.20	46.22	7.05	40.20	4.50	63.78	3.75	20.69	3.40	30.72
0.7-0.8	3.35	57.84	4.40	64.33	2.70	106.31	1.85	41.39	3.40	30.72
0.8-0.9	3.35	57.84	3.55	80.42	9.60	79.73	1.85	41.39	2.78	38.43
0.9-1.0	1.70	115.69	7.90	35.74	1.80	159.49	1.25	62.07	4.80	21.94

*RD - rainy days; RI - rain intensity

TABLE 6(b)

Number of rainy days and rain intensities at each 10% rain amounts for the annual rainfall series

Class interval	Chalakudy		Thumburmuzhi		Peringalkuttu		Thunakadavu		Parambikulam	
	RD*	RI*	RD	RI	RD	RI	RD	RI	RD	RI
0.0-0.1	54.6	5.5	46.2	9.0	36.4	10.7	26.2	5.5	31.1	5.5
0.1-0.2	19.8	15.1	12.3	34.3	17.5	22.2	19.2	7.4	19.1	9.0
0.2-0.3	12.4	24.2	13.6	30.8	17.5	22.2	11.8	12.0	13.1	13.3
0.3-0.4	8.7	34.5	13.6	30.8	16.2	24.0	9.4	15.3	10.1	17.1
0.4-0.5	7.5	40.3	13.6	30.8	10.8	36.0	8.2	17.6	7.0	24.4
0.5-0.6	7.5	40.3	6.8	61.7	13.5	28.8	6.2	23.2	8.1	21.4
0.6-0.7	3.7	80.6	6.8	61.7	6.8	57.7	4.4	32.5	3.0	57.0
0.7-0.8	5.0	60.4	5.4	77.2	6.8	57.7	3.8	38.2	3.0	57.0
0.8-0.9	2.5	120.9	4.1	102.8	6.8	57.7	2.6	56.6	4.0	42.7
0.9-1.0	2.5	120.9	13.6	30.8	2.7	144.2	1.9	76.5	2.0	85.6

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References

Ananthakrishnan, R. and Soman, M.K., 1989. "Statistical distribution of daily rainfall and its association with the coefficient of variation of rainfall series"., *Inter. J. Climatol.*, **9**, pp. 485-490.

Jayasree, V. and Anil Kumar K.G., 1995, "A study on the daily rainfall distribution over a river basin", Paper presented for TROPMET' 95, NRSA, Hyderabad.

Rai Sircar, N.C., 1955, "Some aspects of monsoon rainfall in India", *Indian J. Meteorol. Geophys.*, **6**, pp. 217-224.

Satheesh Kumar, C., 1993, "Non-linear models for predicting rainfall depth in Kerala, Proc. 6th Kerala Science Congress, pp. 321-324.

Soman, M.K. and Krishnakumar K., 1990. "Some aspects of daily rainfall distribution over India during the southwest monsoon season", *Inter. J. Climatol.*, **10**, pp. 299-311.