

A study of heavy rainfall in and around Jaipur

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सारांश— सामाजिक जीवन के विभिन्न पहलुओं पर पड़ने वाले प्रभाव को ध्यान में रखते हुए किसी शहर में भारी वर्षा का अध्ययन काफी महत्वपूर्ण है। जयपुर भारत के अर्ध-शुष्क क्षेत्र में स्थित है। इसलिए जयपुर पर भारी वर्षा के अध्ययन का महत्व और बढ़ जाता है। इस शोध-पत्र में जयपुर की वर्षा के आंकड़ों का विश्लेषण करके जयपुर पर भारी वर्षा के विभिन्न पहलुओं तथा राजस्थान राज्य में 70 वर्ष से भी अधिक अवधि के वर्षा मापों को प्रस्तुत किया गया है। इन भारी वर्षाओं के लिए उत्तरदायी सिनाप्टिक लक्षणों को विभिन्न किस्मों में वर्गीकृत किया गया है।

ABSTRACT. Study of heavy rainfall in a city assumes great importance on account of its impact on various aspects of social life. Jaipur is situated in a semi-arid region of India. Study of heavy rainfall over Jaipur is, therefore, of added significance. The various aspects of heavy rainfall over Jaipur, by analysing the rainfall data of Jaipur and State raingauges in Rajasthan, extending over a period of 70 years (1901-70) are presented. Synoptic features responsible for the occurrence of these heavy spells are classified into various types.

1. Introduction

Study of heavy rainfall in a city is important on account of its impact in terms of traffic dislocation, loss of life and property, man-power loss and health problems created in its wake (Berggren 1975).

A synoptic-climatological study of heavy rainfall situations would assist in the forecasting techniques also. In the present study, Jaipur, the capital city of Rajasthan has been chosen as the variability of rainfall is large, the coefficient being about 47 per cent (Rao 1958).

2. Earlier work

Rao (1958) critically examined the rainfall over east and west Rajasthan upto 1954 and found no significant change in the rainfall pattern. Jagannathan and Raghavendra (1966) estimated the contribution of different operating factors for the single month of August 1917, inferred that depressions accounted for about 50 per cent of that month's rainfall and went on to conclude that the same conclusion can be applied in general to a very heavy rainfall year as well.

Rao (1970) from a study for the period 1966-69, monsoon season, found that the cause of heavy rainfall over northwest India was predominantly low pressure areas.

3. The present study

In the present study, the various aspects of heavy rainfall in Jaipur such as the areal extent, the centre

of maximum rain storm etc on the occasions of heavy and very heavy rainfall have been analysed. Also the synoptic features responsible for spells of heavy rainfall over Jaipur are classified and presented. For this purpose, all available rainfall data extending over a period of 70 years, including those of State raingauges of Rajasthan were extracted from available records and analysed. The antecedent synoptic situations were carefully studied, noted and grouped.

4. Location of Jaipur

Jaipur is located on a small plain surrounded by small rugged hillocks, the summits of which are crowned with forts at all important points. The north and the west are bounded by broken chain of hills and offshoot of Aravali mountains beyond which lies the Rajputana desert. A class I observatory was functioning at Natanika Bagh, Jaipur (26 deg. 55' N, 75 deg. 50' E) and it was amalgamated with the observatory at Sanganer Aerodrome (26 deg. 49' N, 75 deg. 40' E) from 1 June 1953.

5. Discussion of results

In Jaipur, heavy and very heavy rainfall have occurred during the period from June to October. The number of heavy rainfall days, the amount of heavy rainfall; the number of very heavy rainfall days and the amount of very heavy rainfall in each of the months June-October from 1901 to 1970 have been presented in Table 1.

TABLE 1
Heavy/very heavy rainy days and amounts during
the period 1901-1970

Month	Heavy R/F		Very heavy R/F		Average/ Day (cm)
	Days	R/F (cm)	Days	R/F (cm)	
Jun	5	38.46	0	0	7.69
Jul	24	202.54	2	27.75	8.86
Aug	29	241.73	6	88.36	9.43
Sep	6	45.85	1	18.74	9.23
Oct	3	29.67	0	0	9.89
Total	67	558.25	9	134.85	9.15

From Table 1, it is seen that during the period of 70 years under study :

- (i) The total number of days of heavy and very heavy rain is 76.
- (ii) Heavy rain occurs once a year and very heavy rain occurs once in eight years.
- (iii) The mean amount of heavy rainfall in a day was 7.69 cm in June, 8.86 cm in July, 9.43 cm in August, 9.23 cm in September and 9.89 cm in October; the mean being 9.15 cm on any one heavy rainfall day.
- (iv) A heavy rainfall day occurs once in 14 years in June, once in about 3 years in July, once in about 2 years in August, once in 10 years in September and once in about 23 years in October.
- (v) The number of days (70 years) of heavy and very heavy rainfall is maximum in August (35 days) followed by July (25 days), September (7 days), June (5 days) and October (3 days).

Above table provides one significant clue as to whether one may normally expect heavy rainfall to occur in a given year.

It was also desired to examine whether the day-to-day rainfall in a given month can also provide an additional clue as to whether one may expect heavy rainfall to occur in that month. With this end in view, Tables 2 (a-e) were drawn up. These are self-explanatory. One significant fact that emerges from the tables is that the average amount of rainfall on a rainy day (ignoring the contribution of heavy rainfall days) as against that in a non-heavy rainfall year is nearly twice in June and October (2.37 cm as against 1.05 in June, 2.43 as against 1.31 in October) and nearly 1½ times in July (1.56 cm as against 1.31 cm). Thus together with the knowledge of the yearly frequency of heavy rainfall, the observance of the day-to-day rainfall would indicate the likelihood of the occurrence of heavy rainfall in a given month.

6. Location of centre of maximum rainstorm

While heavy rainfall occurs in Jaipur, the heaviest rainfall on that day need not necessarily be in Jaipur, but it may occur proximate to Jaipur. For this purpose, on days of heavy rainfall in Jaipur during the period from 1901 to 1970, the rainfall amounts of all the available stations in Jaipur in Rajasthan State and neighbourhood were collected, plotted and analysed.

From this, the position and amount of rainfall of maximum value could be easily located.

Table 3 gives the date, the H.R. amount (J) in Jaipur, the amount (M) in the maximum rainstorm centre close to Jaipur, the ratio of M/J and the distance and direction of maximum rainstorm centre. It is seen from this table that on days of heavy and very heavy rainfall :

- (i) The rainstorm of maximum value occurs at Jaipur itself on 40, 32, 35, 29 and 67 per cent occasions in June-October months respectively.
- (ii) SSE direction of Jaipur is the most preferred direction for occurrence of rainstorm of maximum value.
- (iii) The probable distance of centre of maximum rainstorm, when it does not occur over Jaipur itself, is 10-125 km away from Jaipur.
- (iv) Monthwise, the most probable directions of occurrence of maximum rainstorms are SSW and WNW in July and SSE in August and September.
- (v) The probable distance of maximum rainstorm, when not occurring over Jaipur itself, lies between 100 & 125 km in July and between 75 & 125 km in August.

7. Areal extent of heavy rainfall

On occasions of heavy/very heavy rainfall in Jaipur, the rainfall reported by stations in Rajasthan and neighbourhood were plotted and isohyets of 6.5 cm were drawn. The areal extent of isohyets were determined and the radius of equivalent circular area was found out. The results have been presented in the last column of Table 3.

The average equivalent radius of the extent of heavy rainfall monthwise for June-October are 25, 35, 36, 23 and 38 km, the highest values being 37, 115, 117, 69 and 58 km respectively. No significant correlation could be found between the extent of heavy rainfall and its amount over Jaipur.

8. Contribution of significant rainspells

Rainfall on a heavy rainfall day may not be evenly distributed over the entire 24-hour period. Autographic charts (available since 1946) of Jaipur were studied to determine the period and duration of significant spells (whose intensity is 12 mm per hour or more) of rainfall contributing to heavy/very heavy rain over the station. Examination of contribution of significant spells to the total rainfall on a heavy/very heavy rainfall day indicated that :

- (i) Significant spells contributed to the total rainfall to the extent of 81, 68, 59, 88 and 94 per cent monthwise from June to October, the mean contribution being 78 per cent in any month.
- (ii) The average duration of a significant spell was 100, 96, 88, 60 and 80 minutes monthwise from June-October, the mean duration being about 85 minutes in any month.

TABLE 2
Average rainfall in June-October 1901-1970

Item	All yrs			All yrs			All yrs		
	All yrs	Heavy R/F yrs	Non-heavy R/F yrs	All yrs	Heavy R/F yrs	Non-heavy R/F yrs	All yrs	Heavy R/F yrs	Non-heavy R/F yrs
	(a) June			(b) July			(c) August		
Average No. of rainy days in a yr	3.34	5.75	3.20	10.03	11.71	13.88	10.36	13.10	8.41
Average rainfall in month (cm)	4.67	20.27	3.37	18.96	26.60	15.69	21.45	31.83	13.40
Average rainfall/rainy day (cm)	1.40	3.53	1.05	1.89	2.27	1.13	2.07	2.51	1.5
Av. R/F per rainy day excluding heavy R/F days (cm)	—	2.37	—	—	1.56	—	—	1.80	—
	(d) September			(e) October					
Average No. of rainy days in a yr	5.23	10.71	4.62	0.84	3.33	0.73			
Average rainfall in month (cm)	9.39	23.77	7.79	1.59	15.56	0.96			
Av. rainfall/rainy day (cm)	1.79	2.22	1.69	1.88	4.67	1.31			
Av. R/F per rainy day excluding heavy R/F days (cm)	—	1.50	—	—	2.43	—			

TABLE 3

Maximum rainstorm centre and the areal extent of heavy rainfall

S. No.	Date	Rainfall over Jaipur (J) (cm)	Rainfall in Max. rainstorm centre (M) (cm)	M/J	Max. rainstorm centre		Areal extent of heavy rainfall (km ²)	Equivalent radius (km)
					Dist- ance (km)	Dir. (°)		
June								
1	30 Jun 1913	7.06	7.06	1	Over Jaipur		218	8.34
2	16 Jun 1920	8.71	16.00	1.84	128	238°	1519	21.99
3	24 Jun 1920	6.65	12.70	1.91	116	064	4120	36.21
4	22 Jun 1933	7.49	9.25	1.23	069	342	4300	36.99
5	15 Jun 1951	8.55	8.55	1	Jaipur		1042	18.22
July								
1	20 Jul 1907	8.71	13.43	1.54	006	210	113	6.0
2	26 Jul 1908	7.87	8.20	1.04	012	195	1191	19.48
3	4 Jul 1909	7.92	9.91	1.25	115	068	7545	49.02
4	12 Jul 1912	11.30	20.7	1.83	124	110	18248	76.23
5	19 Jul 1912	9.57	14.93	1.56	120	356	1846	24.25
6	12 Jul 1919	9.29	21.74	2.34	062	093	17315	74.26
7	17 Jul 1920	7.41	7.41	1	Jaipur		145	6.8
8	27 Jul 1920	12.90	20.32	1.58	030	339	8488	51.99
9	28 Jul 1920	10.61	10.61	1	Jaipur		843.86	16.39
10	27 Jul 1921	6.52	6.52	1	Jaipur		50	3.99
11	28 Jul 1922	7.18	12.70	1.77	080	271	54000	131.14
12	24 Jul 1929	12.14	30.69	2.53	116	273	21305	82.37
13	18 Jul 1931	6.98	7.70	1.14	012	034	2055.55	25.59
14	19 Jul 1940	6.75	6.75	1	Jaipur		314	10.0
15	19 Jul 1945	14.83	20.83	1.40	128	238	8399	51.72
16	24 Jul 1948	6.52	6.52	1	Jaipur		73.5	5.0
17	18 Jul 1950	8.35	8.35	1	Jaipur		854	16.49
18	25 Jul 1950	7.92	12.09	1.53	273	162	1787	23.86
19	16 Jul 1954	6.80	12.25	1.80	075	300	14415	87.75
20	3 Jul 1956	6.60	6.60	1	Jaipur		78.5	5.0
21	21 Jul 1956	8.48	8.48	1	Jaipur		913	17.1
22	23 Jul 1957	10.59	29.91	1.61	157	301	41547	115.0
23	8 Jul 1962	8.43	11.14	1.32	037	162	1219	19.7
24	26 Jul 1969	12.13	12.68	1.02	162	185	11049	59.32
25	11 Jul 1970	7.74	15.90	2.05	21	212	238	8.71

TABLE 3 (contd.)

S.No.	Date	Rainfall over Jaipur (J) (cm)	Rainfall in max. rainstorm centre (M) (cm)	M/J	Max. rainstorm centre		Areal extent of heavy rainfall (km ²)	Equivalent radius (km)
					Dis- tance (km)	Dir. (°)		
August								
1	7 Aug 1901	8.05	14.27	1.77	062	093	9928	56.23
2	8 Aug 1903	13.10	15.87	1.21	238	158	43005	117.0
3	24 Aug 1904	8.07	28.93	3.58	105	047	23779	87.0
4	25 Aug 1908	7.72	19.05	2.53	167	210	452	12.0
5	29 Aug 1909	7.14	7.14	1	Jaipur		113	6.0
6	26 Aug 1909	9.90	10.24	1.03	122	052	1201	19.56
7	11 Aug 1912	10.41	12.82	1.23	083	182	9213	54.17
8	12 Aug 1912	9.11	12.70	1.39	038	160	5381	41.40
9	11 Aug 1916	7.62	22.86	3.00	185	078	298	9.74
10	13 Aug 1921	10.13	10.13	1	Jaipur		126	7.90
11	1 Aug 1924	8.55	11.43	1.34	009	031	1062	18.39
12	26 Aug 1924	7.03	7.03	1	Jaipur		425.4	11.64
13	30 Aug 1926	12.87	15.80	1.23	193	236	2313	27.14
14	11 Aug 1931	10.64	14.38	1.35	113	167	11694	61.03
15	6 Aug 1932	17.90	19.91	1.11	121	145	15785	70.90
16	25 Aug 1934	10.56	19.05	1.80	117	152	5411	41.51
17	3 Aug 1935	11.78	19.89	1.69	009	053	9928	56.23
18	21 Aug 1936	8.48	8.48	1	Jaipur		536	13.07
19	3 Aug 1940	8.43	8.43	1	Jaipur		280	9.42
20	22 Aug 1942	13.13	14.48	1.10	068	030	5351	41.28
21	27 Aug 1942	7.87	7.87	1	Jaipur		576	13.5
22	29 Aug 1944	8.20	8.20	1	Jaipur		685	14.77
23	6 Aug 1946	9.70	11.73	1.21	161	104	1191	19.47
24	16 Aug 1946	6.85	13.87	2.03	097	086	6224	44.52
25	10 Aug 1948	6.75	9.58	1.42	030	340	2274.20	26.91
26	23 Aug 1948	6.93	7.37	1.06	081	275	2045	25.52
27	6 Aug 1952	7.13	7.13	1	Jaipur		0	0
28	25 Aug 1953	6.73	6.73	1	Jaipur		18614	76.99
29	15 Aug 1959	6.80	21.50	3.10	035	152	16293	72.03
30	16 Aug 1959	18.84	18.84	1	Jaipur		16293	72.03
31	19 Aug 1960	8.00	12.29	1.54	080	071	11298	59.98
32	2 Aug 1961	6.66	6.66	1	Jaipur		0	0
33	30 Aug 1963	7.00	7.00	1	Jaipur		1964	25.01
34	27 Aug	12.52	13.99	1.12	013	195	16778	73.10
September								
1	19 Sep 1902	7.49	8.76	1.17	038	158	2313	27.14
2	17 Sep 1917	10.03	19.89	1.98	014	330	96.29	5.53
3	10 Sep 1924	18.84	21.84	1.17	010	032	15149	69.46
4	25 Sep 1933	7.01	14.73	2.10	106	168	31153	99.61
5	4 Sep 1943	7.56	7.56	1	Jaipur		78.5	5.0
6	12 Sep 1945	7.16	19.48	2.72	059	032	248	8.89
7	4 Sep 1957	6.60	6.60	1	Jaipur		425	11.63
October								
1	14 Oct 1924	11.43	11.43	1	—		10622	58.16
2	24 Oct 1928	11.15	26.03	2.33	155		10017	56.48
3	3 Oct 1956	7.09	7.09	1	Jaipur		0	0

TABLE 4
Antecedent synoptic situations

Type	No. of occasions in different months					Total
	Jun	Jul	Aug	Sep	Oct	
1	2	9	6	0	1	18
2	1	5	9	6	0	21
3	1	5	5	1	2	14
4	1	4	6	0	0	11
Total	5	23	26	7	3	64

TABLE 5

Month	Av. No. of rainy days (based on data, 1901-1970)	Av. No. of significant rainy days (based on data from 1946-1966)
Jun	3.34	2.38
Jul	10.03	7.67
Aug	10.36	8.70
Sep	5.23	4.33

- (iii) 25 per cent of heavy rainfall occurs in about 15, 24, 22, 7 and 11 minutes monthwise from June to October and in about 16 minutes is mean in any month.
- (iv) 50 per cent of heavy rainfall occurs in about 40, 37, 52, 20 and 25 minutes monthwise from June to October, the mean being 35 minutes in any month.
- (v) The longest significant spell on a heavy rainfall day lasts for (a) about 35 minutes accounting for about 43 per cent of rainfall in June, (b) 63 minutes accounting for about 67 per cent of rainfall in July, (c) 66 minutes accounting for about 54 per cent of rainfall in August & (d) 40 minutes accounting for about 63 per cent of rainfall in September.

Table 5 gives the average number of rainy days and significant rainy days in each of the months from June to October. While a rainy day is defined as a day during which a rainfall of 2.5 mm or more has occurred, a significant rainy day is one during which at least one significant spell has occurred. It is obvious from Table 5, that the number of significant rainy days is less than the number of rainy days in a given month. The percentage of average number of significant rainy days to rainy days is about 71 per cent in

June, 76 per cent in July, 84 per cent in August, 83 per cent in September and 97 per cent in October.

9. Significant synoptic situations

Type I — Inflow of Arabian Sea current

This may be favoured by formation and/or intensification of a well-defined depression over west Punjab; or increased pressure gradient over west Rajasthan; or formation of a ridge axis along 76 deg. E. There have been occasions when a depression over Gujarat causes inflow of Arabian Sea current. This inflow of Arabian Sea current at lower levels is, at times, followed by the formation of a cyclonic circulation at 700 mb level.

Type II — Formation of low pressure area over the Gangetic plains

Formation of a low pressure area over the Gangetic plains around Allahabad, Varanasi, Patna or Gaya with its cyclonic circulation extending upto 700 mb helps bring about the confluence of westerlies and easterlies over Jaipur, causing heavy rainfall there.

Type III — Formation of a depression over the Head Bay or its movement inland in adjacent land areas

The exact mechanism by which the formation of depression over the Head Bay brings about heavy rainfall over Jaipur is not very clear.

Type IV — Proximity of axis of the monsoon trough to Jaipur

Position of the axis of monsoon trough close (within a degree or so) to Jaipur together with a diffluence at 300 mb level over Jaipur and adjoining areas is another typical synoptic situation causing heavy rain.

Table 4 gives the number of occasions of heavy rainfall under various synoptic situations listed above. It is seen that 24 per cent of heavy rainfall occasions are due to synoptic situation Type I, 28 per cent to Type II, 18 per cent to Type III and 14 per cent due to Type IV. The remaining 16 per cent are due to different situations which could not be classified into any single type.

10. Conclusions

(i) About 80 per cent of heavy/very heavy rainfall days occur in July and August & average rainfall on a heavy/very heavy rainfall day is about 9 cm.

(ii) Each rainy day in June and October in a heavy rainfall year receives nearly double the amount of that in a non-heavy rainfall year.

(iii) Significant spells of rain last, at an average, for 85 minutes and contribute 80 per cent to the total

rainfall. 82 per cent of rainy days are significant rainy days.

(iv) The most probable position of maximum rain-storm, when not occurring over Jaipur, is nearly 100 km to the southsoutheast of Jaipur.

(v) Heavy/very heavy rainfall over Jaipur occurs mostly due to increased inflow of moist air from the Arabian Sea caused due to formation and/or intensification of a well-marked depression over west Punjab or over Gujarat, or due to proximity of the axis of monsoon trough which favours confluence of easterlies and westerlies over Jaipur.

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