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An analysis of the Rainless Days of Delhi

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ABSTRACT. Defining a rainless day as one when no rain was recorded or the rainfall recorded was 3 cents or less, the occurrence of all the rainless days and rainless spells at Delhi during the period 1876-1931 have been listed. Relevant tables giving means, standard deviation and extreme number of rainless days for different months and the frequencies of rainless spells of different duration have been derived. The probability of a day falling in a rainless spell of specified duration has also been worked out.

1. Introduction

The normal annual rainfall at Delhi is 26·24 inches of which nearly 80 per cent is recorded during the period of three months from the middle of June to the middle of September. The remaining 20 per cent of the annual rainfall is spread over the rest of the year. The day to day variation of rainfall at Delhi also shows a large range, *viz.*, 0 to 19 inches in 24 hours or in other words nearly 75 per cent of the normal annual rainfall might be recorded in one day itself. There are a few occasions when nearly half of the year records continuously long and dry spell without any appreciable amount of rain on any day during the period. Thus it will be seen that the major part of the year consists of rainless spells and a study of the occurrence of rainless days and rainless spells at Delhi may be equally interesting as any study of the rainfall and rainy days. This will also facilitate in understanding the local climatology for short range forecasting and other purposes. An attempt has been made in this direction to analyse the incidence of 17,951 rainless days at Delhi during the period of 56 years from 1876-1931.

2. Data

Rainfall observations have been recorded at Delhi for over a century now (from 1845 to date), although the publication of data after proper scrutiny and checking were commenced much later in 1875. The Indian Daily Weather Report containing the daily rainfall, recorded at the observatory stations in India is available for a still shorter period. The data for the period 1876-1887 were extracted from the original registers with the Meteorological Office, Poona. Since the complete data were not available for 1875, that year was omitted. The length of the period for which the analysis was made, could not be extended to include the recent data on account of the fact that in 1931 the observatory site was changed to New Delhi, more than five miles away. The following extract describing the old observatory site (28° 41′ N, 77° 16′ E) gives a general idea of the exposure of the meteorological instruments.

"The observatory is situated in the middle of the city at the Civil Hospital almost overshadowed by the Jama Masjid to the south, but to the east a broad grassy esplanade extends between it and the fort and the river Jumna so that in this direction the situation is open. On the other three sides it is surrounded by buildings but not very closely and the building stands in a fair sized compound in which is built the thermometer shed to the east of the hospital".[1]

The rainless day for the purpose of this study was defined as a day when no rain was recorded or the rainfall recorded was three cents or less. This definition yields a different specification for a rainy day from the one adopted by the India Meteorological Department according to which a day when 10 cents or more of rain is recorded is a rainy day. By following this definition it may be mentioned that 521 days (4 per cent of the total number of occasions) when the rainfall recorded was

TABLE 1

Average, maximum and minimum number of rainless days in Delhi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average (days) ..	28.3	25.9	29.2	28.5	28.6	25.3	20.2	20.5	24.8	30.1	29.5	29.6	320.5
Standard deviation (days) ..	2.3	2.3	1.7	1.7	1.8	2.9	4.2	5.8	4.0	1.2	1.1	1.8	11.7
Maximum (days) ..	31	28	31	30	31	30	28	31	30	31	30	31	340
Frequency of above ..	10	17	16	18	8	1 (1919)	2 (1907, 1918)	3	4	30	41	26	1 (1918)
Minimum (days) ..	21	20	25	23	23	16	11	9	14	27	24	24	286
Years of occurrence ..	1895	1893	1893 1911	1877	1893	1895	1909	1887	1900	1877 1891 1911 1914	1911	1898	1894

between 4 and 9 cents were considered as rainy days and hence excluded from the analysis of rainless days. The number of days when the rainfall recorded varied from trace to 3 cents was 262, about 2 per cent of the total number of rainless days considered here.

3. Mean monthly number of rainless days

Table 1 gives the average monthly and annual number of rainless days together with its standard deviation during the period 1876-1931. The extreme values of maximum and minimum number of rainless days in each month together with the respective years have also been given. In the case of the maximum values, where on a large number of occasions the whole of the month was rainless, only their frequencies have been indicated in the table. The years of occurrence of the maximum values have been separately discussed later in the paper with specific reference to long spells of dry weather.

The southwest monsoon season from June to September is characterised by a small number of mean rainless days per month and large values for the standard deviation. The mean number of rainless days for each month shows a rapid decrease in June and a rapid increase in October. The onset and withdrawal of the monsoon towards the last week of June and September respectively are obviously responsible for this. A second minimum in the number of rainless days is observed in February on account of the winter rains. Considering the year as a whole, 90 per cent of the days are rainless, the monthly distribution varying from the maximum values in October and November to the minimum values in July and August.

The annual number of rainless days for each year during 1876-1931 is shown in Fig. 1. Their frequency distribution between specified limits is also given in Table 2. It will be seen that on 33 occasions

TABLE 2

Frequency of annual number of rainless days between 1876—1931

Number of rainless days	Frequency in 56 years
286—290	2
291—295	1
296—300	1
301—305	3
306—310	2
311—315	5
316—320	9
321—325	14
326—330	10
331—335	4
336—340	5

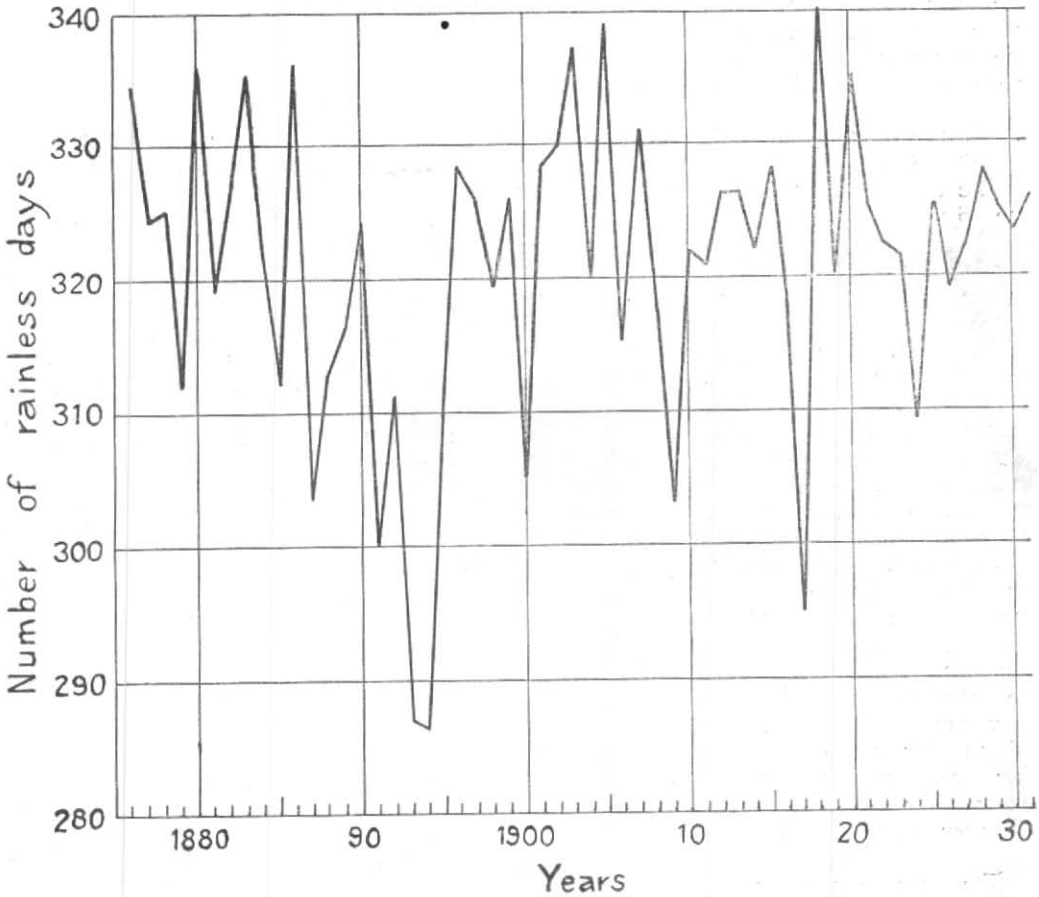

Fig. 1. Frequency of rainless days in each year at Delhi (1876-1931)

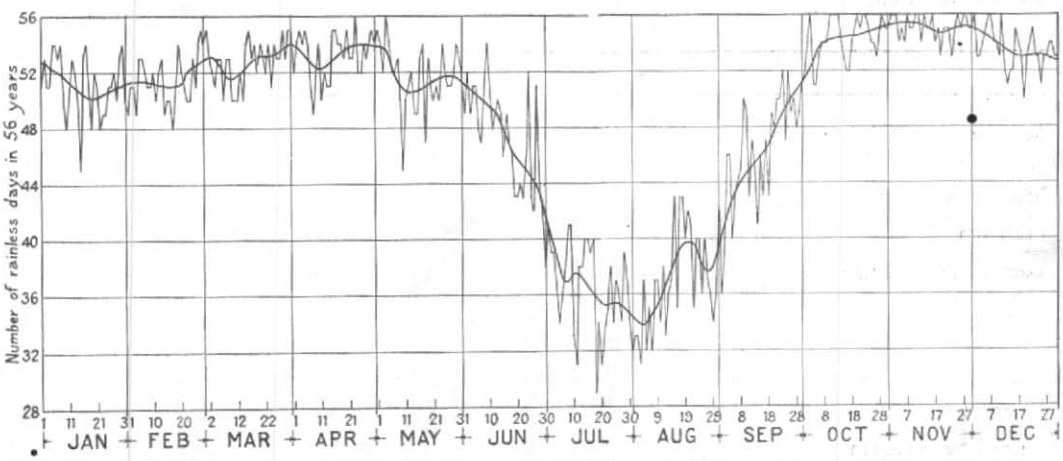

Fig. 2. Number of occasions on which each day of the year was rainless during period 1876-1931

the annual number of rainless days was more than 320.5 - the mean annual number ; the extremes of 340 and 286 rainless days were recorded in 1918 and 1894 respectively.

4. Mean number of rainless days in each day of the year

The total number of rainless days during the 56 years has been found for each of the 365 days of the year by tabulating the daily rainfall for each year suitably. These are shown in Fig. 2 together with a mean curve of the moving averages for a period of 11 days. The variation of the mean daily number of rainless days shows large fluctuations. The mean curve, however, brings out clearly the seasonal variation, *viz.*, a marked trough during the monsoon months, June to September and secondary minima in January and February due to rains associated with the passage of western disturbances. The number of rainless days on any day shown by this mean curve is the mean of the values for 11 days centred on that date and can be taken to indicate the number of rainless occasions that might be expected to fall on that date in one random period of 56 years. The wettest period of the year is the last week of July. The fair and dry weather with rainless days extends for 3 to 4 weeks from the end of October to the end of November.

The average number of occasions in 56 years in which the different days in the month were rainless are given in Table 3, together with its standard deviation for each month of the year. The maximum and minimum number of occasions on which any day of the month was rainless during the period of 56 years together with the particular dates are also shown in this Table. It is seen that there have been dates which were rainless throughout the 56 years in the months of April, May and October to December. Such dates were much more frequent in the months of October and November than in the other months. It is also observed that July is the month with least number of rainless days and 18th July was rainless in 29 years out of 56.

5. Frequency of spells of rainless days

The rainless days constituting the major part of the year occur in short and long spells—the duration varying from 1 to 165 days. Defining a rainless spell as a period of one or more consecutive rainless days, two Tables (4 and 5) showing the frequency distribution of all the 1368 rainless spells of different durations observed during the period have been worked out, for the specified limits in each month. In Table 4, the spells have been classified under each month on the basis of the date of commencement of the spell. Since the rainless spells often extend to more than one month, these

TABLE 3

The average number of occasions in 56 years when different days in the month were rainless together with standard deviation and extremes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean of daily no. of rainless days	51.2	51.4	52.7	53.2	51.7	47.3	36.4	37.0	46.3	54.3	55.1	53.5
Standard deviation	2.1	1.7	1.6	1.7	2.9	3.8	3.2	3.5	3.9	1.5	0.9	1.5
Maximum	54	55	55	56	56	54	41	43	52	56	56	56
Dates of the maximum	5,6, 8,17, 30	27	1,16, 28,30, 31	23	4	9	1,8, 9	15,17. 18	23,25	3,10, 11,12, 13,20, 22,23, 29	1,2, 3,7, 10,11, 13,16, 25,27, 28	1,6, 7,11
Minimum	45	48	50	49	45	38	29	31	36	51	53	50
Dates of the minimum	15	17	7,10, 11,12 14	8	10	30	18	3	1	4,5	19, 23	19

TABLE 4

Monthly frequencies of rainless spells for the period 1876-1931

(Classified according to date of commencement of the spell)

Duration of spell (days)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1- 5 ..	33	37	24	22	37	89	201	198	80	5	3	10	739
6- 30 ..	49	35	30	28	53	65	63	51	46	13	5	32	470
31- 60 ..	11	12	15	15	8	1	3	1	10	9	8	3	96
61- 90 ..	4	5	4	2	—	—	—	2	8	9	2	3	39
91-120 ..	1	1	—	—	—	—	—	—	8	3	1	—	14
121-150 ..	1	—	—	—	—	—	—	1	6	—	—	—	8
> 150 ..	—	—	—	—	—	—	—	—	2	—	—	—	2

TABLE 5

Weighted frequencies of rainless spells

Duration of spell (days)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1- 5 ..	32.6	37.1	24.3	21.5	37.5	86.5	200.6	197.4	79.5	9.0	3.0	10.0
6- 30 ..	51.3	34.8	30.9	27.5	46.3	72.5	65.9	45.9	49.7	16.5	6.3	22.9
31- 60 ..	5.3	10.9	14.4	15.4	13.2	5.3	1.4	2.2	5.3	7.7	7.9	6.9
61- 90 ..	2.5	3.3	4.8	4.4	2.2	0.6	—	0.4	2.0	6.8	7.3	5.0
91-120 ..	1.2	0.6	0.6	0.6	0.3	—	—	—	1.0	3.2	3.4	3.3
121-150 ..	1.0	0.3	0.3	0.2	0.3	—	—	0.1	0.8	1.8	1.5	1.8
> 150 ..	0.4	0.3	0.1	—	—	—	—	—	0.1	0.2	0.2	0.2

figures do not show the actual distribution of rainless days of the different spells in all the months. For instance, 6 spells of duration of 121-150 days have commenced in September obviously extending over the four successive months—October to January. But since there were no spells of duration of 121-150 days commencing in any of the months October to December, the table does not indicate a spell for this interval in these months. Hence in Table 5, the frequencies are given for each month in fractional proportion to the number of days of the spells in the respective month, *e.g.*, in the case of a spell of 100 days duration extending from 1 September to 9 December, the frequencies in the interval 91-120 days have been distributed as follows—

September $= 0.3$, October $= 0.3$,
November $= 0.3$ and December $= 0.1$.

The figure for any month under a class interval is the total of the fractional components of the different spells assigned as shown above. Considering the interval 121-150 days, it will be seen from Table 5 that, in September, there were $0.8 \times (120+150)/2$ or 108 rainless days under this category, while in October it is $1.8 \times (120+150)/2$ or 243 days and so on. The two tables, although they show identical values for the lower limits of classification, differ much in the case of upper limits when the spells extend to more than a month.

On an average, there are about 13 occasions of short dry spells—5 days or less—in a year. The corresponding number for spells of 6-30 days and 31-60 days are 8 and 2 respectively. It is also noteworthy that there were two spells lasting more than 150 days during the period of analysis. The frequency of the spells of short duration is largest in July and August whereas the long spells are confined to the two months October and November. A list of the 19 long spells of more than 100 days is given in

TABLE 6

List of very long dry spells for more than 100 days

S. No.	No. of days	Period		Abnormalities observed before the dry spell
		From	To	
1	165	27- 9-75	8- 3-76	September rain +465 per cent
2	153	14- 9-05	13- 2-06	Monsoon rain (Jun-Sep) —57 per cent
3	139	25- 8-07	10- 1-08	Monsoon rain (Jun-Sep) —65 per cent
4	136	18- 9-26	31- 1-27	
5	135	28- 9-97	9- 2-98	
6	124	30- 9-15	31- 1-16	Monsoon rain (Jun-Sep) —41 per cent
7	124	29- 1-22	1- 6-22	
8	123	12- 9-20	12- 1-21	August rain —32 per cent September rain —98 per cent
9	122	15- 9-99	14- 1-00	September rain —95 per cent Monsoon rain (Jun-Sep) —50 per cent
10	121	7- 9-18	5- 1-19	September rain —93 per cent Monsoon rain (Jun-Sep) —50 per cent
11	120	25- 9-89	22- 1-90	
12	119	13- 9-08	9- 1-09	August rain +217 per cent
13	117	15- 9-82	9- 1-83	
14	116	2- 9-01	26-12-01	
15	107	19- 1-25	5- 5-25	
16	102	30- 9-81	9- 1-82	September rain —85 per cent
17	102	1- 9-85	11-12-85	August rain +114 per cent
18	102	19- 9-87	29-12-87	August rain +114 per cent
19	101	7-10-16	15- 1-17	

Table 6. The long spells generally commence in September and continue up to December or January. In a few cases, however, the long spells set in much later in January. It will be seen that long spells of 30—60 days duration have been recorded even in the monsoon months. Another interesting feature to be noticed about the occurrence of these long spells is that in some of the cases these long rainless spells are preceded by abnormal rainfall—either large excess or large deficit, *e.g.*, in the case of long spell commencing on 27 September 1875 it may be mentioned that this was preceded by the heaviest rainfall of 27.4 inches in September on record. A preliminary examination of the synoptic situation, however, does not indicate any peculiar feature during such spells or preceding them.

Fig 3 shows all the long dry spells of duration more than 30 days for each year, the length of the spell being nearly proportional to the length of the thick lines in the figure.

6. Probability of a day falling in a rainless spell of specified duration

To obtain an idea of the relative probability for any day in the year occurring in a rainless spell of a specified duration; the average odds to one against a rainless day falling in a rainless spell has been worked

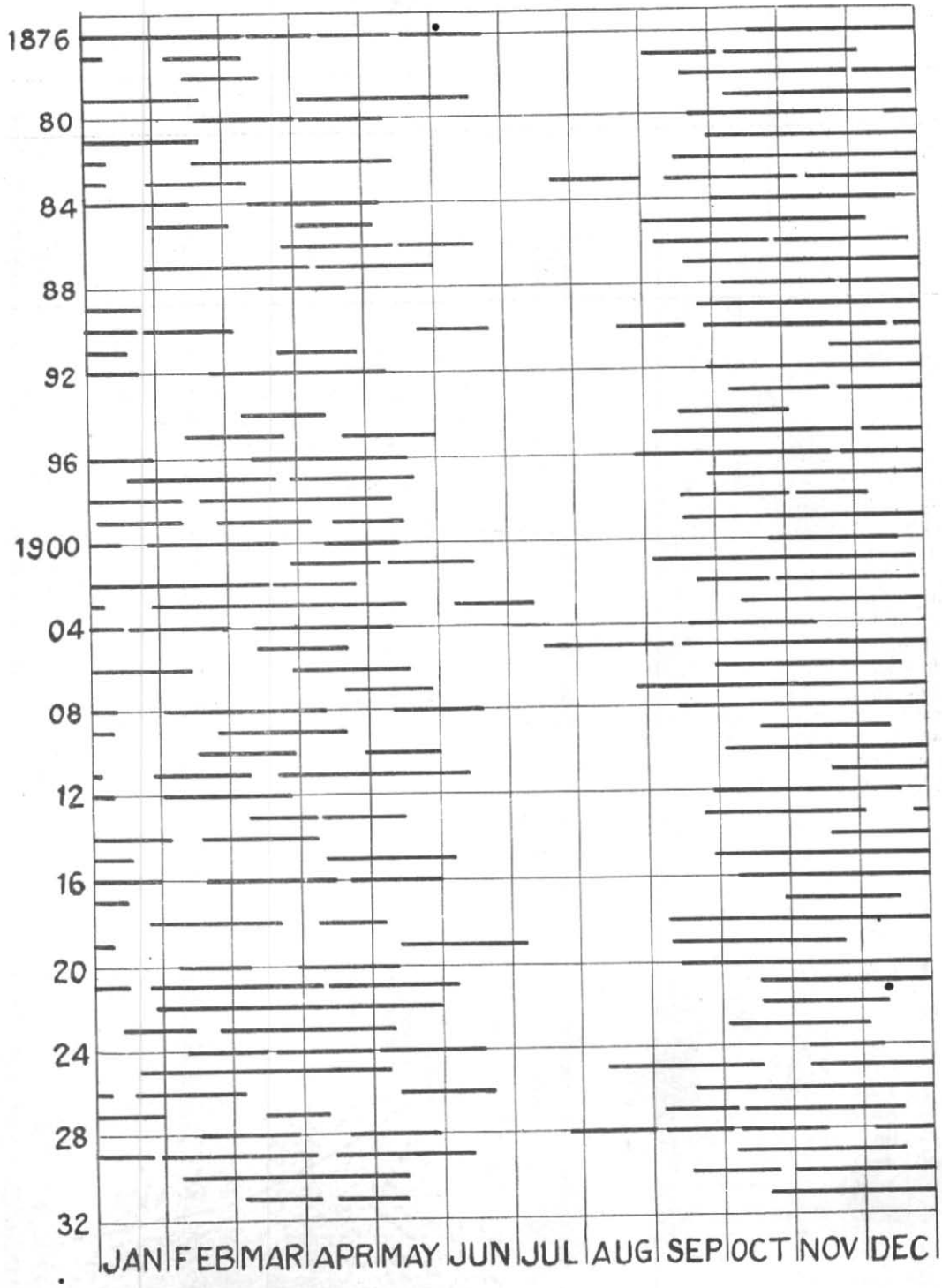

Fig. 3. Rainless spells of duration more than 30 days at Delhi during 1876-1931

TABLE 7

Average odds against a rainless day falling in a rainless spell of different durations

Duration of spell (days)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greater than 6	0.19	0.16	0.11	0.08	0.16	0.40	1.71	1.44	0.44	0.07	0.03	0.08
30	1.33	0.85	0.63	0.59	1.50	5.98	33.40	10.90	1.83	0.27	0.11	0.33
60	2.52	3.06	2.75	3.11	6.95	36.50	No record	43.30	4.07	0.71	0.52	0.80

out by using the formula[2]—

$$\left(b - \frac{N_p}{56}\right) / \frac{N_p}{56}$$

where N_p is the total number of rainless days in 56 years in spells of p or more consecutive days in a month of b days. Table 7 gives the average monthly odds to one against a rainless day occurring in spells of duration greater than 6, 30 and 60 days. The values are lowest in November for all the different lengths of spells. The two months October and December show similar features. In the case of spells longer than 30 days, the values show an increase in the month of January decreasing in February and March with a second maximum in the monsoon months. July and August show the highest values.

The rainless spell of weather is much more persistent in the winter season from October to February than in the hot weather period from March to May.

7. **Acknowledgement**

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