The density of reporting network necessary for a proper appraisal of the occurrence of rainfall in selected localities in the Bombay and Hyderabad States

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1. Introduction

In a previous paper (Rai Sircar and Hariharan 1954), the results of a study of the minimum network of raingauge stations necessary for a proper appraisal of the character of rainfall in four areas in India, *viz.*, Calcutta, Delhi, Bangalore and Tiruchirapally were described. In that paper, it was shown how such studies throw some useful light in regard to our criteria for the assessment of rainfall forecasts for small areas such as those included in the Farmers' Weather Bulletins. In view of the encouraging results obtained as a result of that study, it was decided to extend it for selected areas in the Bombay and Hyderabad States. The results of the study are described in this paper.

2. Localities and data

The four localities chosen for the present study are Ahmedabad, Ahmednagar, Bijapur and Nizamabad. For each station, an area within a radius of 50 miles around the station was considered. The rainfall data examined refer to the five-year period, 1941-1945, and comprise of all available records of state raingauge stations published by the respective State Governments. As in the previous paper, the precipitation character of all the four areas has been examined with reference to rainy days (days with rainfall of 10 cents or more) and days of any precipitation (one cent or more). The study also includes an examination of the character of the raininess in the area around the stations on days on which the meteorological observatories at the

respective stations did not record any precipitation and also of the rainfall distribution in the area on days on which the meteorological observatories reported 10 cents or more of rain. The relationship between the areal coverage of rainfall and intensity has also been studied.

(1) Ahmedabad area

The Ahmedabad area gets most of its annual rainfall during the four monsoon months June to September; as such, the rainfall data for this period only have been chosen for the study. There are 25 stations within an area of 50 miles round Ahmedabad with rainfall data for the period 1941-1945. The locations of the stations and the normal number of rainy days (*Mem. India met. Dep.*, 1949) for each station during the monsoon season are shown in Fig. 1. It maybe seen that the area within 50 miles of Ahmedabad is one of almost uniform rainfall.

Ahmedabad itself had rainfall of 10 cents or more on 30 per cent of the days of the monsoon period. If we get reports from five stations in the area (Ahmedabad plus one station from each quadrant), and consider the occurrence of rainfall at any one of them, the number of rainy days comes to 47 per cent. Similarly, if reports from 10, 15, 20, 25 stations are obtained, it is seen that the percentage of days of occurrence of rain at any one of the group increases to 54,58,61 and 63 per cents. The number of stations used to define the area and the percentage days of rain in the area are plotted in Fig. 2. The full curve relates to rainfall of 10 cents or more and the

dotted curve refers to rainfall of one cent or more, *i.e.*, any measurable precipitation. The curves indicate that as we consider data of a large number of stations, the frequency of rainy days in the area increases rapidly from 30 per cent for one station to 54 per cent for a group of ten. Thereafter, the increase is less rapid so much so that even if we consider one station in a group of 25, the number of rainy days is only 63 per cent. This would suggest that for Ahmedabad area the net-work of about 25 rain-recording stations should give a fairly good indication of the occurrence or non-occurrence of rain, and that, therefore, the existing network is fairly adequate for a critical study of the rainfall features of the locality. It may be noted that whereas we could conclude on the basis of reports from Ahmedabad alone that only 30 per cent of the days of the monsoon season are rainy, in reality nearly twice as many days are rainy if one takes into consideration the occurrence of rain at some point or other in an area 50 miles round the station; and as much as 76 per cent of the days are rainy, if any precipitation is taken into consideration.

The results of the study of the character of raininess in the Ahmedabad area on days on which the meteorological observatory there did not record any precipitation are shown in Table 1. It gives the number of occasions when 1, 2, 3 .... etc stations in the area had precipitation amounting to 10 cents or more when Ahmedabad was dry. It is seen that on one occasion every other rain record-ing station in the area had rain of 10 cents or more when Ahmedabad itself was dry. Five or more stations got rain on 28 of the dry days for Ahmedabad, and ten or more stations had rain on 9 occasions. Comparing with similar data for Calcutta given in the previous paper, it will be seen that Ahmedabad is not as bad in this respect as Calcutta. This would appear to be due to the fact that rainfall occurs in the Ahmedabad area only in association with well defined synoptic situations, whereas Cal-cutta receives rain even due to purely local causes.

The distribution of rainfall in the neigh-bourhood when Ahmedabad itself recorded 10 cents or more of rain but many of the re-maining stations did not get any precipita-tion has also been studied. The results are given in Table 2. It is seen that 50 per cent or more of the stations did not record any precipitation on seventeen of the rainy days for Ahmedabad. It is important to bear such facts in mind in issuing precipitation forecasts for small areas like a district and particu-larly in the verification of such forecasts when we are receiving reports from only one meteorological observatory in that district.

The relation, if any, that exists between the areal coverage and intensity of rainfall has been indicated in Fig. 3. For this purpose, the average amounts of rain per reporting station, when 1, 2, 3 etc stations reported rain were worked out. It is seen that there is fairly good relationship between the number of stations reporting rain and the ave-rage amount of rain per reporting sta-tion. But the increase in intensity with the increase in the number of stations is not very well-marked when the number of stations in-creases from 1 to 20. In this case, the average amount of rain per station increases only from $0 \cdot 1$ to $0 \cdot 4''$. But when the reporting stations increase beyond 20, the increase in intensity also becomes more marked, the intensity being $1 \cdot 7''$ per station when all the stations record rain. This shows that wide-spread rainfall in the Ahmedabad area is associated with synoptic situations capable of giving large amounts of rainfall such as depressions, storms etc.

(2) *Ahmednagar area*

There are only fourteen rain-recording sta-tions with data for the five-year period 1941-1945 within an area of 50 miles around the Ahmednagar observatory. Their locations and the normal number of rainy days at each of these are shown in Fig. 4. It is seen that the rainfall in the area is fairly uniform. The curve showing the percentage number of days when at least one station within a group of 1, 5, 10 etc stations reported rain is shown in Fig. 5. The percentage number of days goes on increasing rapidly with increase in the number of stations and it is clear from the
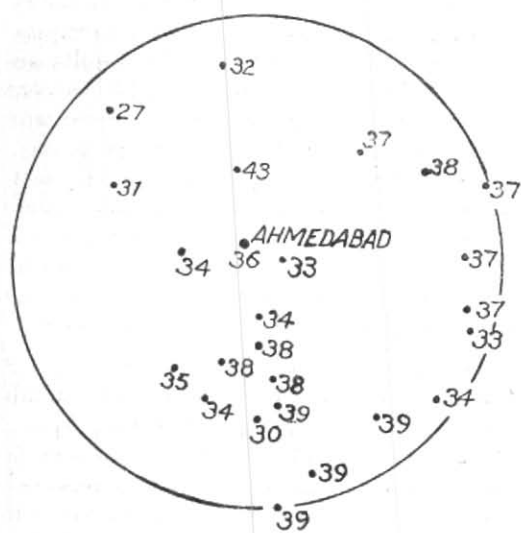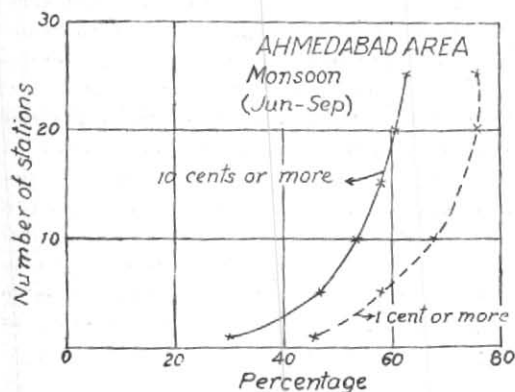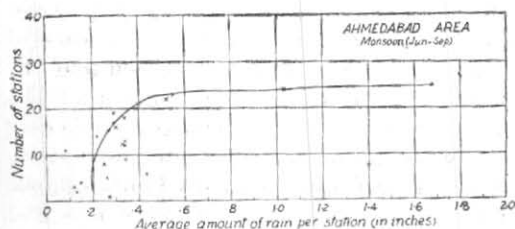
Fig. 1

Fig. 2

Fig. 3

TABLE 1

No. of occasions when 1, 2, 3 etc stations in the
Ahmedabad area reported rain of 10 cents or more
when Ahmedabad had no precipitation

No. of stations with rain	No. of occasions in 5 monsoon seasons, 1941-1945
1	38
2	14
3	18
4	10
5	7
6	4
7	5
8	2
8	1
10	2
11	2
12	3
13	1
24	1

TABLE 2

No. of occasions when 1, 2, 3 etc stations in the area
reported no precipitation when Ahmedabad had
10 cents or more of rain

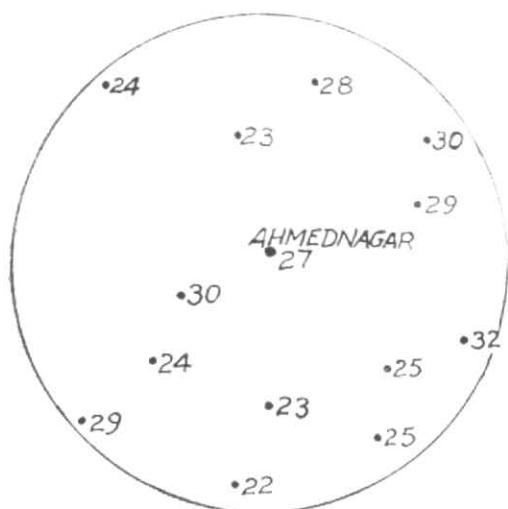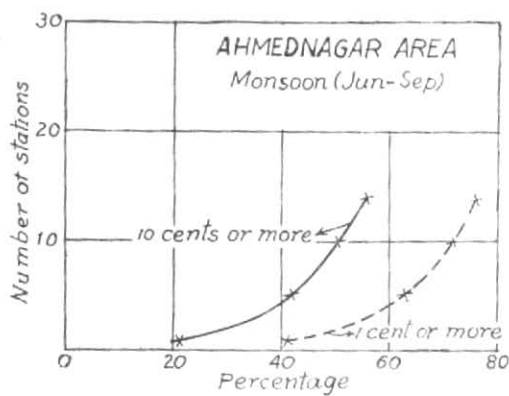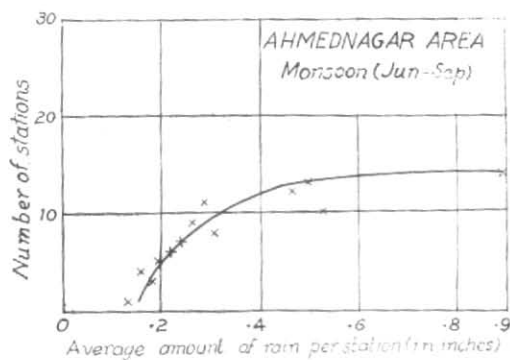| No. of stations without rain	No. of occasions in 5 monsoon seasons, 1941-1945
1	31
2	27
3	11
4	8
5	8
6	8
7	5
8	2
9	4
10	1
11	—
12	3
13	3
14	1
15	2
16	1
17	2
18	—
19	—
20	2
21	—
22	1
23	1
24	1

Fig. 4

Fig. 5

Fig. 6

TABLE 3

No. of occasions when 1, 2, 3 etc stations in the Ahmednagar area reported rain of 10 cents or more when Ahmednagar did not get any precipitation

No. of stations with rainy days	No. of occasions
1	71
2	24
3	20
4	11
5	4
6	2
7	1
8	----
9	3
10	—

TABLE 4

No. of occasions when 1, 2, 3 etc stations in the area had no precipitation when Ahmednagar had rain of 10 cents or more

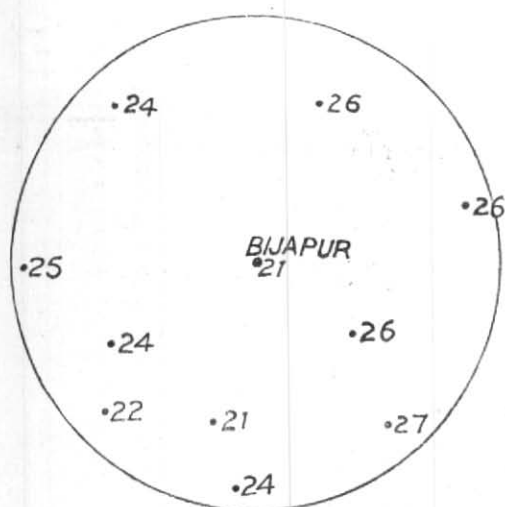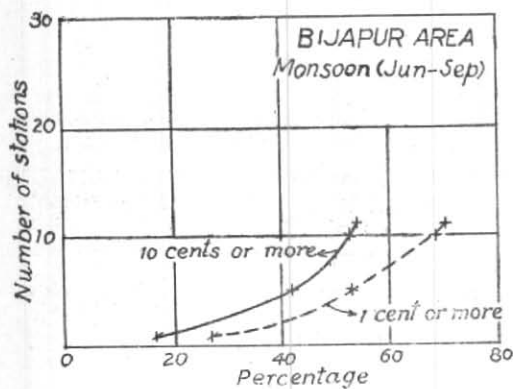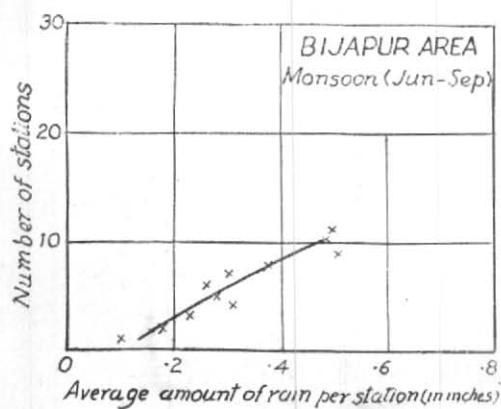| No. of stations without rain	No. of occasions
1	18
2	14
3	6
4	9
5	9
6	9
7	9
8	3
9	3
10	4
11	2
12	3
13	4

Fig. 7

Fig. 8

Fig. 9

TABLE 5

No. of occasions when 1, 2, 3 etc stations in the
Bijapur area reported rain of 10 cents or more
when Bijapur did not get any precipitation

No. of stations with rain	No. of occasions
1	75
2	34
3	25
4	19
5	8
6	4
7	1
8	3
9	—
10	—
11	—

TABLE 6

No. of occasions when 1, 2, 3 etc stations in the Bijapur
area had no precipitation when Bijapur had
10 cents or more of rain

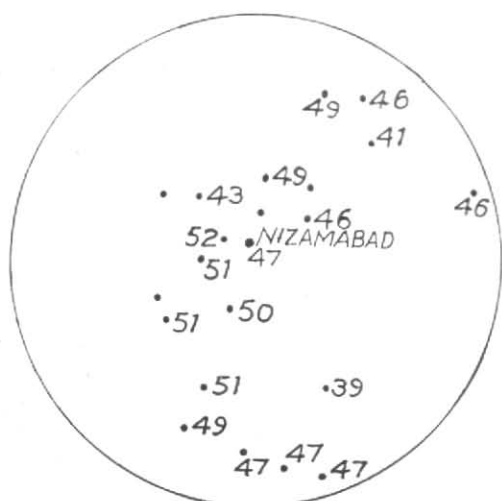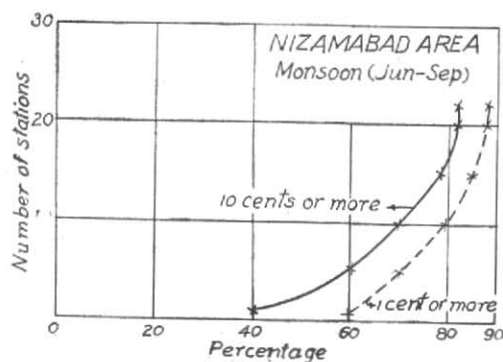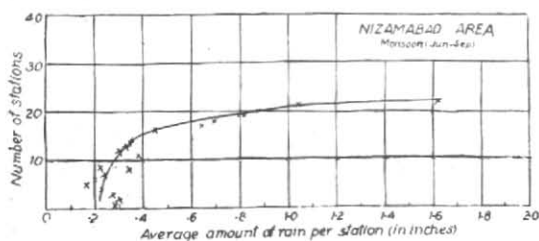| No. of stations without rain	No. of occasions
1	17
2	16
3	8
4	8
5	6
6	9
7	7
8	8
9	5
10	4

Fig. 10

TABLE 7

No. of occasions when 1, 2, 3 etc stations in the Nizamabad area reported rain of 10 cents or more when Nizamabad itself had no precipitation

No. of stations with rain	No. of occasions
1	50
2	28
3	23
4	17
5	5
6	9
7	6
8	1
9	1
10	3
11	1
12	1

Fig. 11

TABLE 8

No. of occasions when 1, 2, 3 etc stations in the Nizamabad area reported no precipitation when Nizamabad had 10 cents or more of rain

No. of stations without rain	No. of occasions
1	26
2	36
3	24
4	26
5	17
6	13
7	10
8	9
9	8
10	9
11	4
12	8
13	5
14	10
15	6
16	5
17	2
18	2
19	2

Fig. 12

curve that the existing net-work of rain-recording stations in the area is very inadequate for a correct appraisal of the precipitation coverage during the monsoon season. It is remarkable that whereas the number of rainy days at Ahmednagar alone during the monsoon season is 21 per cent, the percentage increases to 56, when we consider the incidence of rain at one station out of the fourteen. It would appear from the trend of the curve that if we had 25 or 30 rain-recording stations in the area, the percentage number of days of rain would be considerably greater. This indicates that the records of the Ahmednagar observatory or even the present returns are not representative of the true character of rainfall in the area.

Table 3 (p. 132) gives the number of occasions when 1, 2, 3 . . . . stations in the area had rainfall of 10 cents or more during the monsoon season when Ahmednagar itself did not have any precipitation. It is seen that of the 14 stations for which records are available, the maximum number that received 10 cents or more of rain when Ahmednagar was dry, was 9 and there were three such occasions. An examination (vide Table 4) of the rainfall distribution in the area when Ahmednagar had 10 cents or more shows that all the remaining 13 stations were dry on four occasions and 5 or more stations were dry on as many as 46 occasions.

The curve in Fig. 6 (p. 132) represents the average amount of rain per station corresponding to the different number of stations recording rain. For 5 stations reporting rain, the average amount per station is about 0·2″ whereas for 11 stations also it is only about 0·3″. When all the 14 stations have rain the average intensity is 0·9″· Owing to the limited number of rain-recording stations available in the area, it is not possible to say what will be the intensity if more rain-recording stations were available and all of them have rain. It would however appear that the rate of increase in intensity with the widespreadness of the rain is more in the case of Ahmednagar than in the case of the Ahmedabad area.

(3) Bijapur area

There are only 11 stations within a radius of 50 miles of Bijapur with rainfall data. The locations of these stations and the normal number of rainy days for each of them during the monsoon season, are shown in Fig. 7. It may be seen that the distribution of rainy days over the area is fairly uniform.

The rainfall frequency curves are shown in Fig. 8. Whereas only 17 per cent of the days are rainy if we take into account Bijapur alone, the percentage is nearly 3 times when occurrence of rain at any one of the 11 stations is taken into consideration. For any precipitation, the percentage number of days for Bijapur is 27 whereas it is 70 for any one of the 11 stations. It appears from the curve that if we had more rain-recording stations in the area, it is quite likely that on more than 80 per cent of the days one or the other of these stations would record rain. The frequency of occurrence of rainfall in the Bijapur area is, therefore, not as rare as is commonly supposed, although the distribution of rain is often highly localised as is clear from this study. It may also be seen that the existing network of rain-recording stations in the Bijapur area is very inadequate for a critical appraisal of the rainfall distribution in the area.

The occasions when 1, 2, 3 . . . . etc stations in the area reported 10 cents or more of rain but Bijapur itself did not record any measurable amount is shown in Table 5. The maximum number of stations (out of the available eleven) that recorded rain on such days is 8 and there were three such occasions. Nearly a third or more of the available number of stations had rain on as many as 35 occasions. An examination (vide Table 6) of the occurrence of rainfall in the area on days on which Bijapur had 10 cents or more of rain shows that on four occasions none of the remaining stations had any precipitation. On 39 occasions, 5 stations or more in the area did not record any rainfall. This again emphasizes the fact that the rainfall data of a single station, Bijapur, does not properly indicate the rain giving character of the synoptic situation on a large number of days.

Fig. 9 (p. 133) shows the relation between the average amount of rain per station per day and the corresponding number of stations reporting rain. It shows that there is appreciable increase in average amount as the number of stations receiving rain increases. The average amount is only $0 \cdot 1''$ when one station reports rain but nearly 5 times when ten stations receive rain.

(4) Nizamabad area

There are 22 rain-recording stations within an area of 50 miles of Nizamabad with data for the period 1941-1945. The locations of these stations and the normal number of rainy days at each one of them during the monsoon season are shown in Fig. 10. The number of rainy days in the area is seen to be fairly uniform.

The curve of the percentage frequency of rainy days for various number of stations used to define the area is given in Fig. 11. It would appear from the curve that about 25 stations would be fairly adequate for a proper appraisal of the incidence of rainfall in the Nizamabad area. Whereas the number of days of rain for Nizamabad alone is only 40 per cent, it is more than 80 percent when the incidence of rain at any one of the 22 stations is considered. If any precipitation is considered, it appears as if as many as 88 per cent of the days of the monsoon season are rainy in the Nizamabad area, although the percentage days of precipitation for Nizamabad is only 60.

The number of occasions when one or more of the stations in the Nizamabad area recorded rain when Nizamabad itself was dry is given in Table 7. It is seen that the maximum number of stations that recorded rain when Nizamabad had no precipitation at all is 12 and the number of such occasions is only one. It is seen that generally speaking, the occasions when 8 or more stations in the area get rain when Nizamabad is dry, are very rare. The rainfall distribution in the area shows (vide Table 8) that on occasions when Nizamabad got ten cents or more of rain, the maximum number of stations having no precipitation is 19 out of 22. The number of occasions when 15 or more stations were dry is 17. More than half the number of stations were dry on 40 occasions.

Fig. 12 represents the average amount of rain per station per rainy day for various number of stations reporting rain. It is seen that generally increase in intensity is not appreciable when the number of stations recording rain increases from 1 to 15. But there is appreciable increase in intensity when more than 15 stations in the area receive rain. Thus when rainfall in the area is widespread it is also heavy, but when it is local or scattered, there is not much increase in intensity.

3. Conclusion

This study of the rainfall distribution in the neighbourhood of four selected localities in the Bombay and Hyderabad States confirms the results arrived at in the previous paper that an adequate appraisal of the rainfall features on a particular day of even a small area within 50 miles of a station is not often possible on the basis of the rainfall report from that station alone. As long as we receive telegraphic report of rainfall from the existing network of observatory stations only, there can be a large number of occasions when even marked shower activity in the area between two synoptic stations may stand the chance of going unnoticed by the weather forecaster. On such occasions, telegraphic reports of rainfall from a wider network would be helpful in the assessment of the distribution of rainfall and in the attempts to prepare subsequently detailed forecasts for such small areas as are required in the Farmers' Bulletins.

4. Acknowledgements

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	1954	Indian J. Met. Geophys., 5, 3, p. 219,