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Study of normal rainfall of Satara district

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ABSTRACT. Issue of districtwise Farmers' Weather Bulletin in its present form, is too general to be of any specific use to the farmer. It was felt that attempts should be made to improve the Farmers' Weather Bulletins and a beginning in this direction is made with a detailed study of rainfall characteristics over Madhya Maharashtra. It is often seen that there is wide variation in the intensity and distribution of rainfall even within the same district. A study of such rainfall characteristics of Satara district in south Madhya Maharashtra has been taken up. A rough line of delineation running north-south across the district is suggested which distinguishes the rainfall distribution in the talukas to the west and the talukas to the east.

1. Introduction

Of the many services rendered by the India Meteorological Department, service to agriculture is very important in view of the fact that India is basically an agricultural country. India Meteorological Department initiated an experimental programme of issuing Farmers' Weather Bulletins in 1930, but these forecasts are too general to be of any specific use to the farmer. In an area of highly variable rainfall, the farmer needs an accurate rainfall forecast for the different parts of the district. In order to achieve this, background information giving details of rainfall characteristics of the different parts of the district is absolutely necessary.

It is well known that variability of rainfall is very high in Madhya Maharashtra during the chief rainy months, *i.e.*, July and August. This sub-division has been selected for the study. It is observed that there is a wide variation in the intensity and distribution of rainfall from one station to another even within the same district. The District Gazetteers also show that the cropping pattern differs accordingly from one part of the district to another. Thus it was realised that the study of rainfall should begin from the taluka level in a district. Satara district in south Madhya Maharashtra has been selected initially for the study. This study will aid the forecaster in issuing more meaningful bulletins with a fair degree of confidence in respect of specified areas of a district, if possible even upto the taluka level. Basically this will involve a detailed study of rainfall distribution over the district. As a first step in this direction normal rainfall of the district has been analysed and presented in this paper. In this series subsequent papers will be attempts to go into the details of the actual distribution of rainfall in the district pertaining to specific synoptic situations.

2. Physical features of Satara district

Satara district at the western limit of the Deccan tableland lies between 16°15′ N & 18°10′ N and 73°45′ E & 75°00′ E, with an area of 6474 sq. km. The district has a compact shape, with an east-west stretch of about 145 km and north-south about 121 km. Residual hill ranges and intermediate valleys, all well developed on a tableland surface, form the main element of landscape in the Satara district. On the west it has the Sahyadrian scarp with its major peaks usually flat topped and intervening saddles. The Mahadeo range, which is the next major well developed range begins as an offshoot of the Sahyadries in the northwestern part of the district. Eastwards it runs as a main range and sends off several minor ranges southeastwards and southwards. The Sahyadrian ranges and its minor hill chains on the plateau surface, and the Mahadeo range and its minor ranges, enclose between them the major river system of Satara. In this district, there are four distinct river basins. The *Krishna* draining the major portion to the south, *Yerla* also draining to the south, the mideast portions, the *Man* draining the eastern parts to join the *Bhima* river outside the limits of the districts and the *Nira* draining the northern belt of the district. Fig. 1 is the contour map of Satara district.

3. Data

Satara district consists of Khandala, Wai, Mahabaleshwar, Medha, Satara, Koregaon, Patan, Karad, Vaduj, Dahiwadi and Phaltan talukas

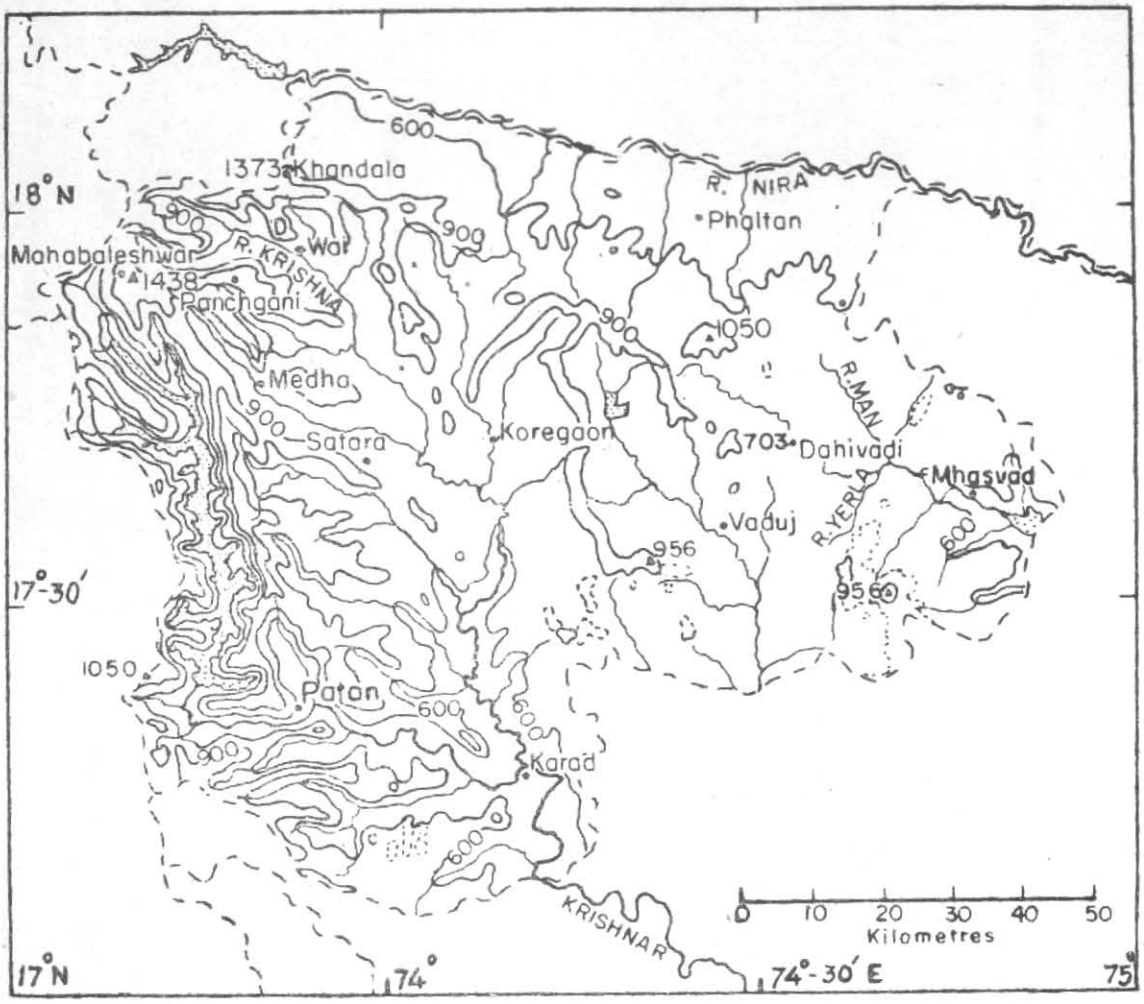

Fig. 1. Contour map of Satara district

Fig. 2. Map showing the month of maximum rainfall and line of delineation

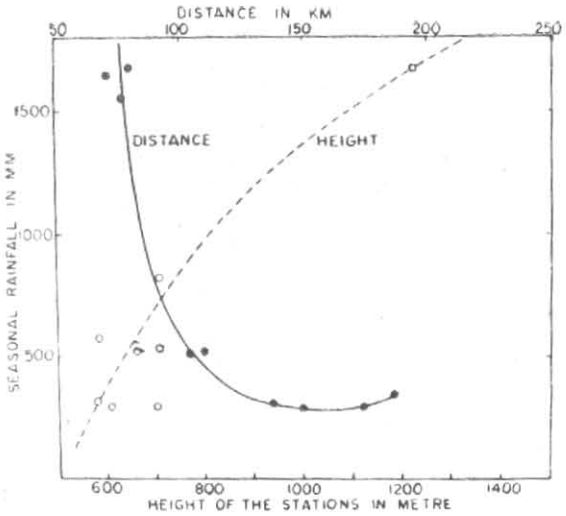

Fig. 3

TABLE 1

Location of the nine stations in the Satara district

Station (Taluka)	Lat. (°N)	Long. (°E)	Altitude (m)	Period
Mahabaleshwar (,,)	17° 56′	73° 40′	1382	1901-50
Wai (,,)	17° 56′	73° 54′	704	1901-50
Satara (,,)	17° 41′	73° 59′	707	1901-50
Koregaon (,,)	17° 42′	74° 10′	663	1901-50
Karad (,,)	17° 17′	74° 11′	581	1901-50
Phaltan (,,)	17° 59′	74° 26′	581	1901-50
Vaduj (,,)	17° 36′	74° 27′	—	1901-50
Dahiwadi (,,)	17° 42′	74° 33′	703	1901-50
Mhaswad (Dahiwadi)	17° 38′	74° 47′	607	1901-50

Monthly rainfall data for 14 stations in the eleven talukas published by India Meteorological Department have been utilised in this study for discussion on annual, seasonal and monthly rainfall. Fig. 1 gives the location of the stations. The daily accumulated normals of rainfall for the available nine stations, namely, Mahabaleshwar, Wai, Satara, Koregaon, Karad, Mhaswad, Phaltan, Vaduj and Dahiwadi have been used in the study of the various aspects of pentad and daily rainfall in the district. Though Mahabaleshwar is a hill station at a height of 1382 metres above mean sea level with an annual rainfall of 6226 mm, which is one order higher than the rainfall in the other stations in the district, it has been included in this study only to the extent it helps in explaining the rainfall distribution in the other parts of the district. Table 1 gives the geographical co-ordinates of these stations in the district along with their height above mean sea level.

4. Analysis and Results

The study has been divided into three parts, namely, study of seasonal and monthly rainfall, study of pentad rainfall and the study of daily rainfall.

4.1. *Monthly rainfall*

The annual, seasonal and monthly rainfall for the 14 stations in the district are given in Table 2. On examination of annual rainfall in the district it is seen that annual rainfall varies from 2480 mm at Patan to 463 mm at Dahiwadi excluding Mahabaleshwar which gets annual rainfall of 6226 mm. In general the contribution of seasonal rainfall to annual rainfall is slightly more on the western side than the eastern side though all the stations get 60 % more than of the annual rainfall during monsoon season. Thus this study is confined to the monsoon months June to September only. Moreover all the stations in the district do not get maximum rainfall in the same month. Some stations in July while the others show a maximum in September. Fig. 2 shows the month of maximum rainfall in the different stations. The month of maximum number of rainy days also shows similar features. Fig. 3 shows the variation of seasonal rainfall with distance from the sea and also with height above mean sea level. Thus a simple examination of the normal monthly rainfall data suggests that the rainfall distribution in the district is not uniform.

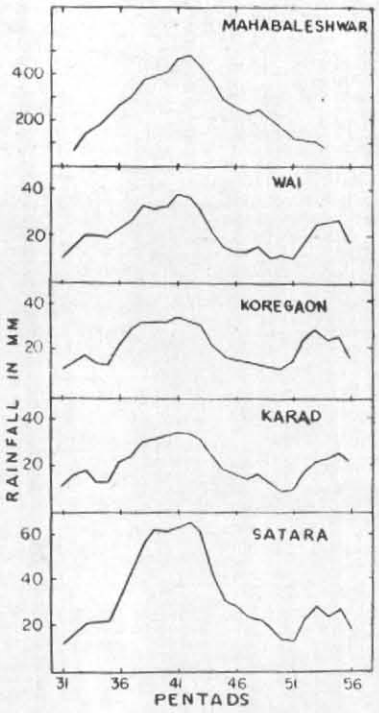

Fig. 4. Pentad rainfall

4.2. *Pentad rainfall*

In order to understand the rainfall distribution in the district, pentad rainfall normals were calculated for each of the standard pentad as given in Table 3 for the 9 available stations and are plotted in Figs. 4 and 5. The following conclusions can be drawn :

(*i*) Rainfall gradually increases from 1 June which corresponds to 31st standard pentad in all stations and the trend is maintained till the 32nd pentad in case of Mhaswad, Phaltan and till the 33rd pentad for Vaduj, Wai, Koregaon, Karad and Satara. The rainfall decreases in the case of Dahiwadi.

TABLE 2

Average monsoon rainfall and number of rainy days* (Satara district)

Station	June		July		August		September		Total rainfall		Seasonal annual percentage
	Av. rainfall (mm)	No. of rainy days	Av. rainfall (mm)	No. of rainy days	Av. rainfall (mm)	No. of rainy days	Av. rainfall (mm)	No. of rainy days	Seasonal	Annual	
Mahabaleshwar	939.8	21.2	2546.1	30.0	1764.3	29.6	685.8	22.3	5936.0	6226.3	95
Panchgani	274.3	12.4	697.2	24.6	408.4	22.6	293.9	12.7	1673.8	1865.3	90
Medha	260.5	11.2	724.1	23.6	409.5	19.5	158.8	9.9	1552.9	1723.9	90
Wai	112.5	7.3	209.3	14.1	105.2	8.7	114.5	6.6	541.5	710.4	76
Patan	251.2	11.9	813.9	24.2	417.8	20.5	155.1	9.8	1638.0	2480.0	66
Satara	134.4	6.5	370.4	10.5	196.9	7.6	125.0	7.1	826.7	1025.7	80
Koregaon	98.3	7.5	198.6	14.7	108.2	10.1	122.2	7.3	527.3	706.3	75
Khandala	78.8	5.7	106.4	7.7	59.4	4.9	103.0	5.5	347.6	501.6	69
Karad	96.3	6.8	195.8	14.4	117.3	11.4	99.1	6.9	508.5	713.1	71
Pusesavli	84.8	6.6	147.9	11.6	86.3	8.4	122.8	7.4	441.9	635.8	70
Phaltan	87.9	5.5	51.3	4.7	50.3	3.9	127.0	7.3	316.5	473.0	67
Vaduj	85.9	5.7	75.1	7.4	55.0	4.6	133.4	7.1	349.4	512.6	68
Dahiwadi	76.5	5.6	54.2	4.8	46.2	3.6	123.0	7.0	299.9	463.2	65
Mhaswad	73.1	5.0	46.5	3.7	45.2	3.5	134.3	6.8	299.1	472.3	63

*Based on data from 1901-1950

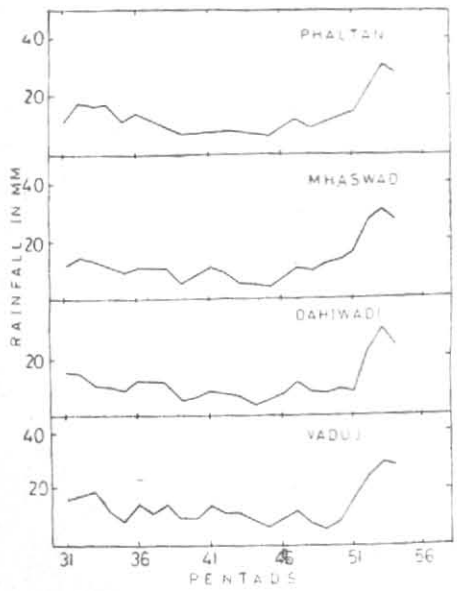

Fig. 5. Pentad rainfall

TABLE 3

Standard pentads

Pentad	Period	Pentad	Period
31	31 May-4 Jun	44	4-8 Aug
32	5-9 Jun	45	9-13 Aug
33	10-14 Jun	46	14-18 Aug
34	15-19 Jun	47	19-23 Aug
35	20-24 Jun	48	24-28 Aug
36	25-29 Jun	49	29 Aug-2 Sep
37	30 Jun 4 Jul	50	3-7 Sep
38	5-9 Jul	51	8-12 Sep
39	10-14 Jul	52	13-17 Sep
40	15-19 Jul	53	18-22 Sep
41	20-24 Jul	54	23-27 Sep
42	25-29 Jul	55	28 Sep-2 Oct
43	30 Jul-3 Aug		

(*ii*) Thereafter there is a decreasing trend in the pentad rainfall in all the stations except Mahabaleshwar where it continues to increase uninterruptedly from 1 June.

(*iii*) Pentad rainfall increases from 36th pentad for all the stations. The increasing tendency persists in the case of Wai, Satara, Koregaon and Karad in the subsequent pentads, whereas in the case of Phaltan, Mhaswad and Vaduj it starts decreasing again from 37th pentad. In Dahiwadi pentad rainfall is found to be steady from 36th pentad.

(*iv*) Pentad rainfall continues to increase upto 41st pentad for Wai, Koregaon, Karad and Satara and then starts decreasing from 42nd pentad upto 50th pentad, whereas in case of Phaltan, Mhaswad and Vaduj the rainfall continues to decrease upto 45th pentad and increases at a small rate upto 51st pentad. In Dahiwadi rainfall increases from 45th pentad.

(*v*) From 42nd pentad though the rainfall decreases in all the stations, still the pentad rainfall at Wai, Karad, Koregaon and Satara is nearly three to four times the rainfall at Phaltan, Mhaswad, Vaduj and Dahiwadi.

(*vi*) There is a sudden increase in the rainfall activity over the entire district from 52nd pentad which corresponds to the 2nd week of the September and reaches a maximum during 53rd pentad in Vaduj and Dahiwadi and during 54th/55th pentad for all the other stations in the district.

(*vii*) During 37th-41st pentad the rainfall pattern in the stations like Wai, Koregaon, Satara, Karad and that in Phaltan, Mhaswad, Vaduj and Dahiwadi are quite opposite to each other.

(*viii*) During the pentads 49-51 the rainfall activity in the entire district is minimum.

(*ix*) Rainfall distribution in Mahabaleshwar is also similar to that of Wai, Karad, Koregaon and Satara, with increasing trend upto 41st pentad and a decrease from 42nd pentad though the 2nd maximum in September is not seen. Ananthakrishnan (1971) has opined that pentad rainfall decreases from the beginning to the end of June in the interior Peninsula. But from this study it is seen that though Satara is an interior district, the western part of the district still behaves like a coastal station with increasing rainfall during June while the eastern part has characteristics similar to the interior Peninsula.

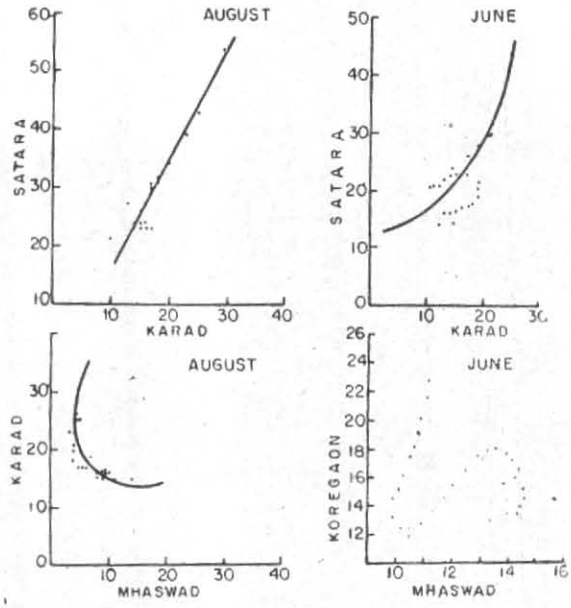

Fig. 6. Scatter diagrams

4.3. *Daily rainfall*

With this preliminary idea of inhomogeniety of rainfall as indicated by the analysis of monthly and pentad rainfall, an attempt was made to study the normal daily rainfall in the district for all the 9 available stations, namely, Mahabaleshwar, Wai, Satara, Koregaon, Karad, Phaltan, Mhaswad, Vaduj and Dahiwadi during the monsoon period June-September. Five-day moving averages were calculated to see whether there is any correlation between the daily rainfall at the nine stations. To study the correlation between the stations, each pair of rainfall values corresponding to the nine stations were plotted to find out the approximate form of relationship between the variates. The scatter diagrams drawn can be grouped into four categories, namely, having positive linear correlation, positive non-linear correlation, negative non-linear correlation and no correlation. One example of each type is given in Fig. 6. Karl Pearson's coefficient of correlation given by :

$$r = \frac{\mu_{11}}{\sigma_x \sigma_y}$$

where, r = coefficient of correlation

μ_{11} = covariance between x and y

σ_x = standard deviation of x

σ_y = standard deviation of y

was calculated for each of the pair of stations which have positive linear correlation. They are given in Table 4 for the four months from June-September. On careful examination of these tables, the following conclusions can be drawn :

TABLE 4

Nature of relationship between daily normal rainfall at the various stations in the Satara district

	Mahabaleshwar (1)	Wai (2)	Satara (3)	Koregaon (4)	Karad (5)	Phaltan (6)	Mhaswad (7)	Vaduj (8)	Dahiwadi (9)
					June				
Wai		1	PC	PC	X	X	X	X	NC
Satara		PC	1	PL $r=0.755$	PC	X	NC	X	NC
Koregaon		PC	PL $r=0.755$	1	PL $r=0.948$	X	X	X	X
Karad		X	PC	PL $r=0.948$	1	X	X	PL $r=0.489$	X
Phaltan		X	X	X	X	1	PL $r=0.717$	PL $r=0.623$	X
Mhaswad		X	NC	X	X	PL $r=0.717$	1	PL $r=0.817$	PL $r=0.689$
Vaduj		X	X	X	PL $r=0.489$	PL $r=0.623$	PL $r=0.817$	1	PL $r=0.503$
Dahiwadi		NC	NC	X	X	X	PL $r=0.689$	PL $r=0.503$	1
					July				
Mahabaleshwar	1	PL $r=0.963$	PL $r=0.848$	PL $r=0.853$	PL $r=0.942$	X	X	X	X
Wai	PL $r=0.963$	1	PL $r=0.748$	PL $r=0.871$	PL $r=0.904$	X	X	X	X
Satara	PL $r=0.848$	PL $r=0.748$	1	PL $r=0.685$	PL $r=0.937$	NC	NC	NC	NC
Koregaon	PL $r=0.853$	PL $r=0.871$	PL $r=0.685$	1	PL $r=0.784$	X	NC	X	X
Karad	PL $r=0.942$	PL $r=0.904$	PL $r=0.937$	PL $r=0.784$	1	NC	NC	X	NC
Phaltan	X	X	NC	X	NC	1	PL $r=0.717$	PL $r=0.720$	PL $r=0.860$
Mhaswad	X	X	NC	NC	NC	PL $r=0.717$	1	PL $r=0.809$	PL $r=0.896$
Vaduj	X	X	NC	X	X	PL $r=0.720$	PL $r=0.809$	1	PL $r=0.923$
Dahiwadi	X	X	NC	X	NC	PL $r=0.860$	PL $r=0.896$	PL $r=0.923$	1
					August				
Mahabaleshwar	1	PL $r=0.946$	PL $r=0.976$	PL $r=0.974$	PL $r=0.988$	NC	X	X	NC
Wai	PL $r=0.946$	1	PC	PL $r=0.948$	PL $r=0.959$	NC	NC	X	NC
Satara	PL $r=0.976$	PC	1	PL $r=0.990$	PL $r=0.982$	NC	NC	X	NC
Koregaon	PL $r=0.974$	PL $r=0.948$	PL $r=0.990$	1	PL $r=0.970$	X	NC	X	NC
Karad	PL $r=0.988$	PL $r=0.959$	PL $r=0.982$	PL $r=0.970$	1	NC	NC	X	NC
Phaltan	NC	NC	NC	X	NC	1	PL $r=0.937$	PL $r=0.545$	PL $r=0.887$
Mahaswad	X	NC	NC	NC	NC	PL $r=0.937$	1	PL $r=0.460$	PL $r=0.910$
Vaduj	X	X	X	X	X	PL $r=0.545$	PL $r=0.460$	1	PL $r=0.583$
Dahiwadi	NC	NC	NC	NC	NC	PL $r=0.887$	PL $r=0.910$	PL $r=0.583$	1

TABLE 4 (*contd*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					September				
Wai		1	PL r=0.939	PL r=0.872	PL r=0.986	PL r=0.959	PL r=0.907	PL r=0.845	PL r=0.935
Satara		PL r=0.939	1	PL r=0.755	PL r=0.950	PL r=0.955	PL r=0.965	PL r=0.847	PL r=0.939
Koregaon		PL r=0.872	PL r=0.755	1	PL r=0.944	PL r=0.956	PL r=0.993	PL r=0.921	PL r=0.955
Karad		PL r=0.986	PL r=0.950	PL r=0.944	1	PL r=0.983	PL r=0.950	PL r=0.904	PL r=0.965
Phaltan		PL r=0.959	PL r=0.955	PL r=0.956	PL r=0.983	1	PL r=0.961	PL r=0.913	PL r=0.981
Mhaswad		PL r=0.907	PL r=0.965	PL r=0.993	PL r=0.950	PL r=0.961	1	PL r=0.929	PL r=0.957
Vaduj		PL r=0.845	PL r=0.847	PL r=0.921	PL r=0.904	PL r=0.913	PL r=0.929	1	PL r=0.943
Dahiwadi		PL r=0.935	PL r=0.939	PL r=0.955	PL r=0.965	PL r=0.981	PL r=0.957	PL r=0.943	1

r=Karl Pearson's coefficient of correlation, X=No correlation, 1= Positive linear, perfect, PL=Positive linear, PC=Positive non-linear, NC=Negative non-linear.

(*i*) During the months June, July and August Wai, Koregaon, Karad and Satara are positively correlated and the linear correlations are significant at 1 per cent level while with Phaltan, Mhaswad, Vaduj and Dahiwadi they are generally either negatively correlated or not correlated at all. The negative correlation is not linear also.

(*ii*) Phaltan, Mhaswad, Vaduj and Dahiwadi have positive linear correlation during June to August except in the case of Dahiwadi which is not correlated with Phaltan in the month of June.

(*iii*) During September all the nine stations are positively correlated and the correlation coefficients are significant at 1 per cent level.

(*iv*) Mahabaleshwar also has positive correlation with Wai, Karad, Satara and Koregaon during July and August. This finding can be interpreted in terms of the common rain producing mechanism in Mahabaleshwar, Wai, Karad, Satara and Koregaon, *i.e.*, strong westerly winds which produce enormous rainfall over Mahabaleshwar. Hence under favourable conditions of heavy rainfall in Mahabaleshwar one can expect that this effect may extend upto a certain distance from the Ghats in Satara district during July and August. In the month of September the entire district gets rainfall due to some other mechanism different from the above.

5. Conclusions

The above study of the normal rainfall of Satara district suggests that the entire district consisting of Mahabaleshwar, Wai, Medha, Satara, Koregaon, Patan, Karad, Phaltan, Dahiwadi, Vaduj and Khandala talukas is not homogeneous with respect to rainfall during the months June, July and August. The rainfall pattern in the western part of the district consisting of Khandala, Mahabaleshwar, Wai, Medha, Satara, Patan, Karad and Koregaon talukas is similar to the rainfall distribution in Mahabaleshwar whereas the eastern parts consisting of Phaltan, Dahiwadi, Vaduj and Mhaswad behave differently. Hence a single common districtwise forecast for Satara will never be appropriate for agricultural operations. One can imagine a line delineating the western and the eastern parts of the district running north-south across Koregaon more or less parallel to Western Ghats. Talukas to the west of this line can be expected to receive good rainfall under conditions favourable for good rainfall activity in the Ghats whereas under the same conditions the eastern parts of the district may receive poor rainfall. This line of demarcation is shown in Fig. 2 and the forecaster may use it for predicting the intensity and spatial distribution of rainfall in the different areas of Satara district.

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