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VARIATION IN ANNUAL RAINFALL OF VIDARBHA DURING THE LAST CENTURY (1901–2000)

1.   The production of crop in India is very much dependent on rainfall even today as irrigation facility is limited to a small part of country. Thus, the rainfall has a great influence on economy of India. Therefore, extensive studies have been done by various scientist on All India rainfall and tried to show the trend and periodicity of rainfall.

On a regional basis, the transformation of natural land-cover by soil cultivation, large–scale irrigation, re-afforestation programmes and other conservation measures may measurably influence the climate. In industrialized regions, the extensive spread of air pollutant may add further climate influences (WMO, 1966). Thus, man is capable of altering the climate. In addition to this, India is a very big country with geographical variation. Therefore climate of India has spatial variation too. Hence a need to study rainfall characteristics of each sub-division in detail is felt very much.

The Vidarbha sub-division lies in the central part of India. Vidarbha mostly depends on rainfall for its agricultural production. In view of high importance of regional rainfall, a detailed study of century-long annual rainfall series of Vidarbha based on data of important rain gauge stations has been made and the results are presented.

2.   The validity of any statistical analysis depends primarily on the quality of the data used. The monthly rainfall data of departmental and part time observatory of IMD at Nagpur, Akola, Amraoti, Chandrapur, Gondia, Buldana, Bramhapuri, Pushad, Sironcha, Wardha and Yeotmal covering all districts of Vidarbha sub division for whole twentieth century *i.e.*, from 1901 to 2000 have been used for this analysis. The annual rainfall of each station has been calculated from monthly data. The missing values have been interpolated as per the ratio method by considering the nearby station or regional average. The average rainfall of Vidarbha region has been calculated by taking simple arithmetic mean of station rainfall. The rainfall data for period 1901 to 1950 has been collected from the publication of India Meteorological Department (IMD) and for the period 1951 to 2000 data has been collected from Regional Meteorological Centre, Nagpur.

3.1. *Statistical properties of Vidarbha rainfall* - The statistical parameters of Vidarbha annual and

TABLE 1

Statistics of large–scale deficient years of Vidarbha

S.No.	Year	Actual rainfall (mm)	Percentage departure from Normal	Standardized value	Rank
1.	1902	796.2	- 28.2	- 1.56	7
2.	1904	789.1	- 28.9	- 1.60	4
3.	1918	824.0	- 25.7	- 1.42	10
4.	1920	589.7	- 46.8	- 2.59	1
5.	1950	789.4	- 28.8	- 1.60	5
6.	1952	792.5	- 28.6	- 1.58	6
7.	1965	815.2	- 26.5	- 1.47	8
8.	1972	775.9	- 30.0	- 1.67	3
9.	1984	746.8	- 32.7	- 1.81	2
10.	1987	818.9	- 26.2	- 1.45	9
11.	1996	833.1	- 25.0	- 1.38	11

monsoon rainfall for the period 1901-2000 have been calculated. The mean summer monsoon rainfall of Vidarbha is 956.0 mm which is 86.2 % of the annual amount 1109.6 mm. The standard deviation of annual series is 200.4 mm and monsoon rainfall series is 177.1 mm. The coefficient of variation is 18.1 % for annual rainfall series and 18.5 % for monsoon rainfall series. The median value of annual rainfall series is 1099.2 mm and monsoon series is 951.0 mm.

The auto correlation for the series is -0.19 which is too low to suggest any persistence in the series.

The frequency distribution of the time series was tested for normality by using the Chi-square test, with equal probability class intervals. The Chi-square statistic 11.45 obtained is for seven degree of freedom and the same is not significant at the 5 % level value, 14.07. Hence Vidarbha annual rainfall series can be taken to be Gaussian. Statistical tests requiring normality of the distribution can be applied to this time series.

3.2. *Years of large scale deficient and excess rainfall* – In order to identify the years of large-scale deficient (Drought) and large–scale excess (Flood), the criteria of IMD and Mooley and Parthasarathy (1983,1984) have been used. The IMD criteria identify large- scale deficient and large-scale excess if percentage departure is 25% or more. Mooley and Parthasarathy defined standard deviate [$t_i = (R_i - R_m) / \sigma$] less than -1.28 as large-scale deficient and more than $+1.28$ as large–scale excess year. The large-scale deficient and excess years and their statistical details are shown in Tables 1 and 2 and also in Fig. 1.
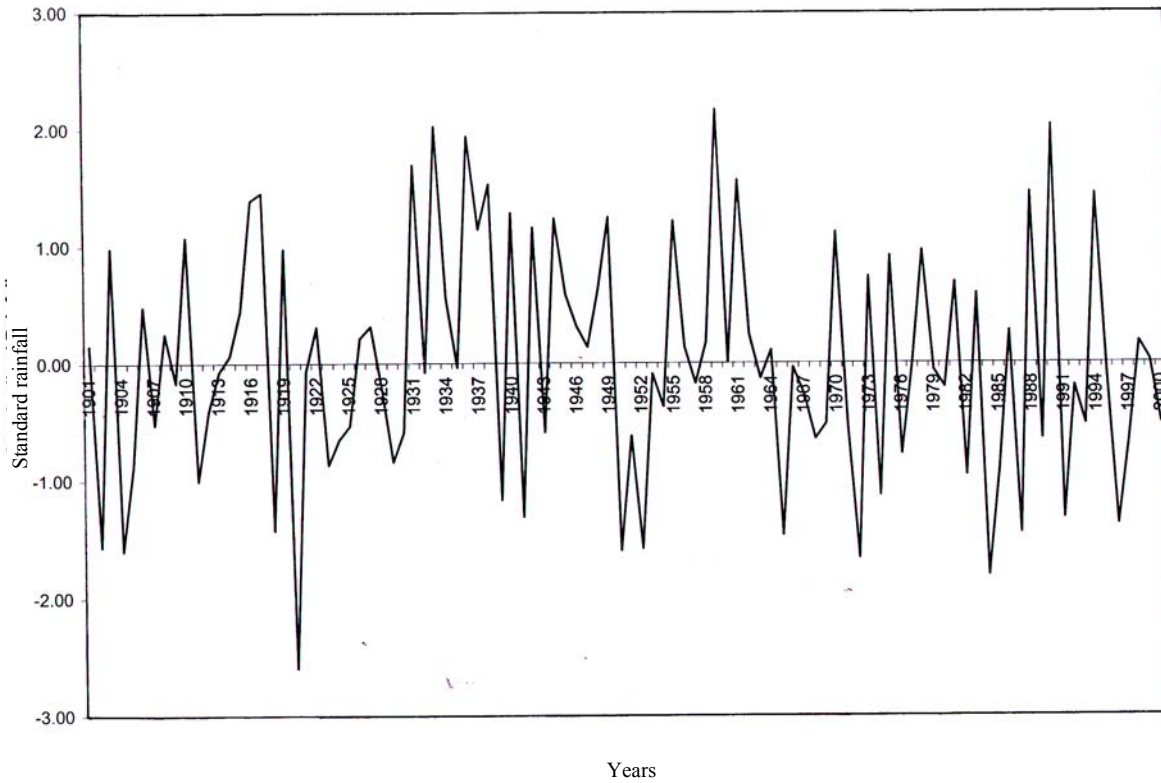
Years

Fig. 1. Standardized annual rainfall value of Vidarbha

It is seen from Table 1 that there are 11 large-scale deficient years. The year 1920 is most deficient with percentage departure of − 46.8 %. There is no two consecutive large-scale deficient years, however in 1902, 1904 ; 1918, 1920 and 1950, 1952 the existence of two years periodicity is indicated. There is no large-scale deficiency recorded during 1921-49 (29 years).

There are 11 large-scale excess years during the 20th century as shown in Table 2. The highest excess being 39.2% in 1959 and next to it being 36.7% in 1990. It is again noticed here that in the years 1931, 1933; 1936, 1938; 1959, 1961 and 1988, 1990 large-scale excess rainfall have been recorded with two years periodicity .

The large-scale deficient and excess years show the existence of QBO (Quasi Biennial Oscillation) which will be confirmed later on in the other tests .

3.3. *Mann-Kendall rank statistic* – The most likely alternative to randomness in a climatic time series is some form of trend, which need not be linear one. It is therefore advantageous to use test of randomness to check the trend.

TABLE 2

Statistics of large–scale excess years of Vidarbha

S.No.	Year	Actual rainfall (mm)	Percentage departure from Normal	Standardized value	Rank
1.	1916	1388.5	25.1	1.39	11
2.	1917	1401.6	26.3	1.46	9
3.	1931	1449.4	30.6	1.70	5
4.	1933	1515.3	36.6	2.02	3
5.	1936	1498.3	35.0	1.94	4
6.	1938	1416.3	27.6	1.53	7
7.	1959	1544.1	39.2	2.17	1
8.	1961	1423.1	28.2	1.56	6
9.	1988	1402.1	26.4	1.46	8
10.	1990	1516.8	36.7	2.03	2
11.	1994	1399.6	26.1	1.45	10

Mann − Kendall rank statistic has been suggested as a powerful test when most likely alternative to
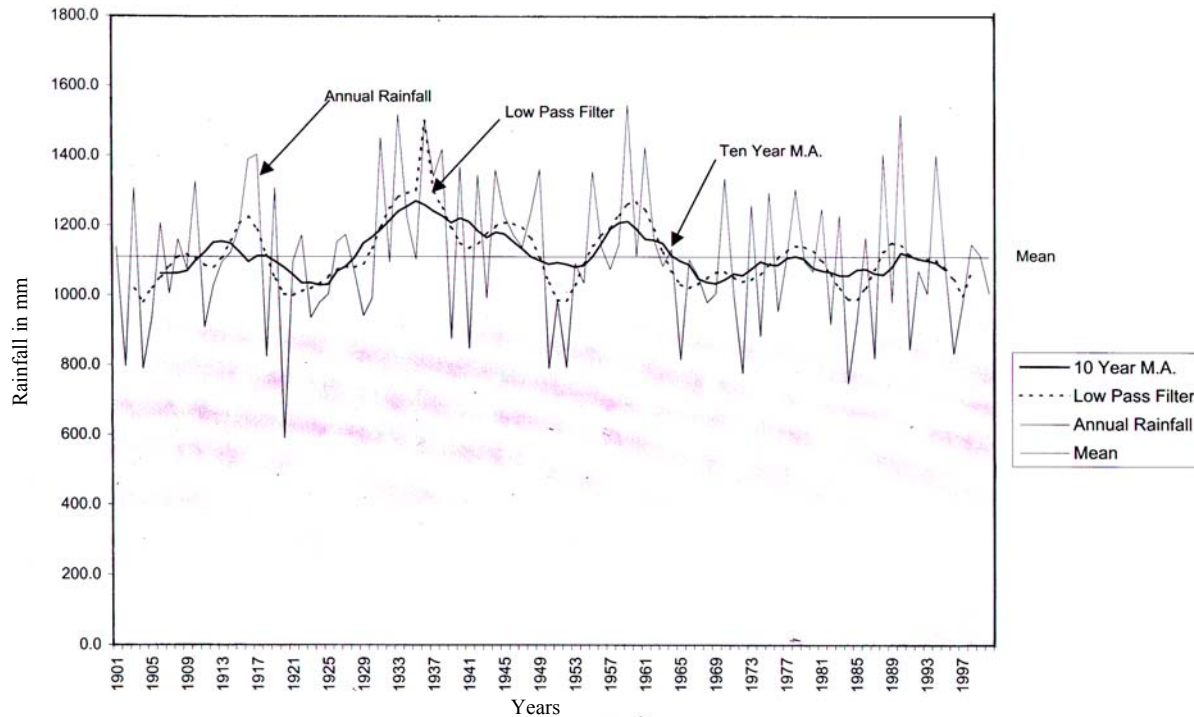
Fig. 2. Ten year moving average, Low pass filter and actual rainfall in Vidarbha

TABLE 3

Student's *t*-value

S.No.	First period		Second Period		Difference of Mean	% of change	Student's *t*-value
	Years	Mean	Years	Mean			
1.	1901-1925	1071.3	1926-1950	1186.3	+115.0	+10.73	-1.956
2.	1926-1950	1186.3	1951-1975	1102.4	-73.9	-6.23	+1.466
3.	1951-1975	1102.4	1976-2000	1078.5	-23.9	-2.16	+0.430

randomness is linear or non-linear trend. In this test the statistics τ is computed using the formula :

$$\tau = \left[4 \sum n_i / N(N-1) \right] - 1$$

Where n_i is the number of values larger than *i*th value in the series subsequent to its position in the time series. The value of τ will be tested for significance by the statistic $(\tau)_t$, which is given by

$$(\tau_t) = \pm t_g \left[(4N+10)/9N(N-1) \right]^{1/2}$$

Where t_g is the value of *t* at the probability point in the Gaussian distribution appropriate to the two tail test.

It is seen that Mann-Kendall statistic for annual rainfall of Vidarbha τ is –0.045 which lies within required limit at 95% significance level (τ_t) = ± 0.133. This means that the alternative of trend can not be substantiate in these data.

3.4. *Student's t-test* – In the present study Vidarbha annual rainfall series of the period 1901 to 2000 has been broken into four equal periods, 1901-25, 1926-50, 1951-75 and 1976-2000. The significance of the difference of mean between two periods was tested by Student's *t*-test.

Table 3 gives the statistics regarding the mean of two periods, their difference, percentage of change and Student's *t*-value.
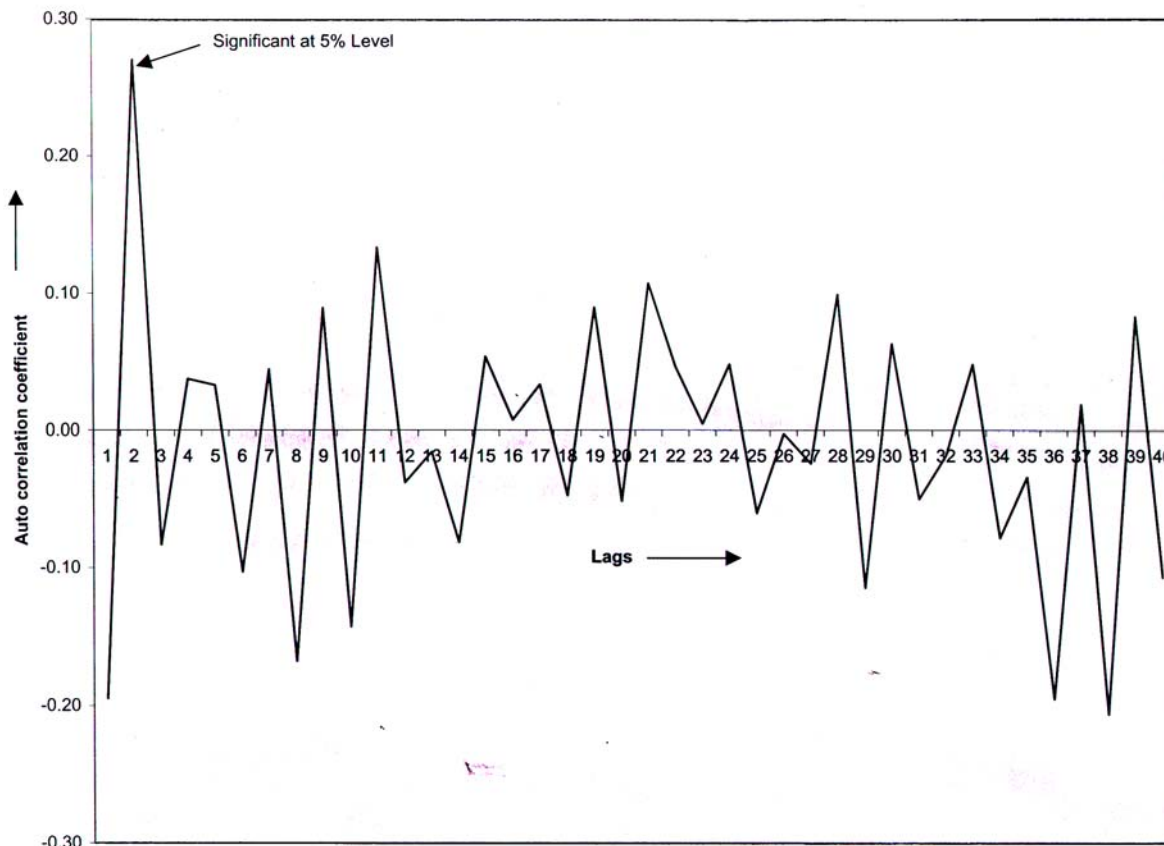
Fig. 3. Auto correlation coefficient

Student's *t*-values were tested at 95% significance level. All the Student's *t*-values calculated and shown in the Table 3 lies within 95% limit value 2.012. Thus, none of them was found significant. It indicates that the rainfall trend noticed in different periods are not statistically significant. However increasing trend noticed during the period 1926 to 1950 was very close to become significant.

3.5. *Ten–year moving average* - Statistical attempts to identify climatic trends frequently employ the calculation of a moving mean; a ten–year smoothing mean can be utilized to smooth out many of the short- term fluctuations. Fig. 2 shows the 10-yr moving average curve. It is observed in the 10-yr moving average curve that there is a gradual rise up to 1913 and afterwards the rainfall decreases slowly to the lowest value in the year 1924. From the year 1924 there is a rise in moving average curve to the highest value in the year 1935 and decreasing afterwards, the lowest being reached in 1953 after which it slowly increases to reach a high value in 1959. After 1959 there is a decrease upto year 1969. After 1968 the 10 years moving average curve is oscillating just below the mean most of the period.

However, simple moving average introduce apparent cycles even in the series that are wholly random and this effect is called "Slutzky-Yule Effect". In order to overcome this problem the Vidarbha rainfall series has been subjected to low-pass filter analysis.

3.6. *Low-pass filter* - To understand the nature of the fluctuation or trend if any the Vidarbha rainfall series has been subjected to a Binomial low-pass filter (WMO, 1966) .

$$S_i = 0.01\,R_{i\text{-}4} + 0.05\,R_{i\text{-}3} + 0.12\,R_{i\text{-}2} + 0.20\,R_{i\text{-}1} + 0.24\,R_i + 0.20\,R_{i+1} + 0.12\,R_{i+2} + 0.05\,R_{i+3} + 0.01\,R_{i+4}$$

The five term Binomial filter have been used to smooth the series. The smoothed rainfall S*i* is given by

$$S_i = 0.06\,R_{i\text{-}2} + 0.25\,R_{i\text{-}1} + 0.38\,R_i + 0.25\,R_{i+1} + 0.06\,R_{i+2}$$

No. of cases: 30
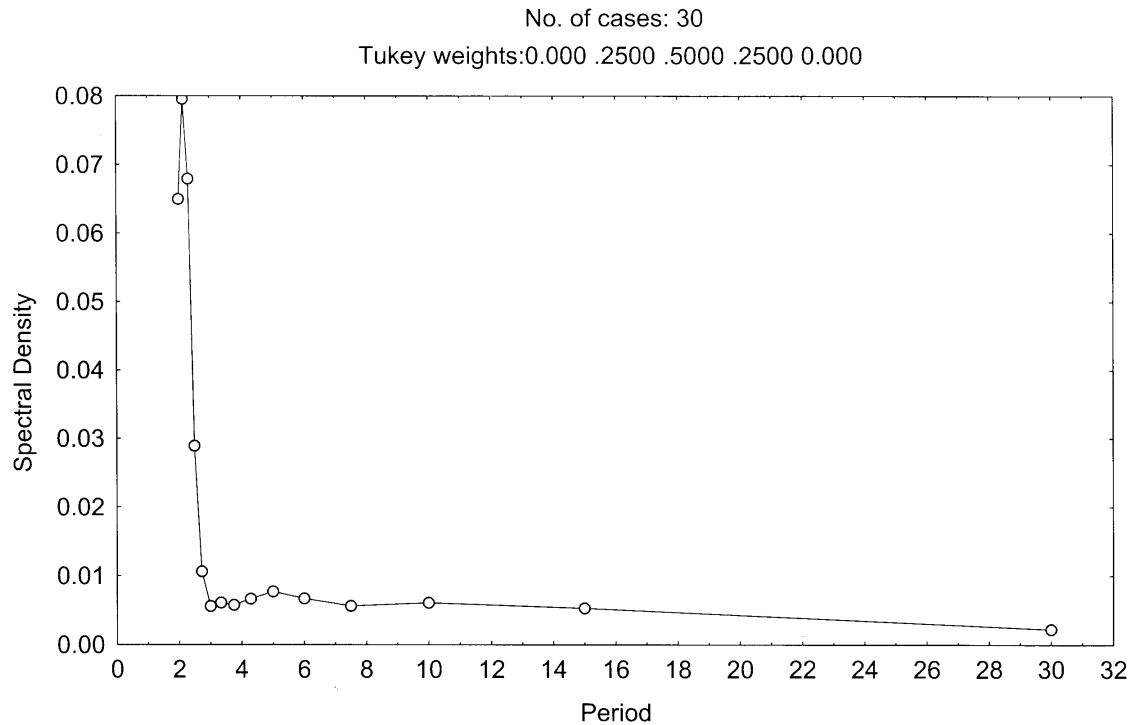Tukey weights:0.000 .2500 .5000 .2500 0.000

Fig. 4. Spectral analysis

The filtered low-pass curve and actual annual rainfall curve of Vidarbha are also shown in Fig. 2. It is observed from the figure that the low–pass filter curve is below normal rainfall line during the (*i*) 12 year period 1918 to 1929, and (*ii*) 25 year period 1964 to 1988 except for 2-3 years. Many large scale deficiency occurred during this period. The worst period being 1918 to 1929. The low-pass filter is above normal during the (*i*) 19 year period 1930 to 1948 and (*ii*) 9 yr period 1955 to 1963, where many large scale excess (floods) are noticed.

4. *Periodicities* - The Vidarbha annual rainfall series have been subjected to correlogram and spectrum analysis in order to see, if any, cycles are present in the series.

4.1. *Correlogram analysis* - The auto-correlation coefficients of annual rainfall of Vidarbha have been calculated upto 40 lags and the correlogram is shown in Fig. 3 to find out the cycle. The correlogram shows that the series is some what oscillatory in nature. A high correlation coefficient (CC) is noticed for lags 1, 2 , 36 and 38 , but CC is positive and significant at 5% level for lag 2 only. Thus Biennial oscillation has been found in the series.

4.2. *Spectrum analysis* - The time series of Vidarbha annual rainfall has been subjected to power spectrum analysis by following the method of Tuckey given in WMO Technical Note 79(1966). The spectrum results are shown in Fig. 4. There is a cycle of 2.14 yr significant at the 5% level. Thus Quasi-Biennial Oscillation (QBO) has developed in the series. Parthasarathy and Dhar (1974) have also observed similar periodicity in Vidarbha rainfall in their study for period 1901 to 1960.

5. The detailed statistical analysis of the Vidarbha annual rainfall during the period 1901-2000 enables us to draw the following conclusions:

(*i*) The average annual rainfall in Vidarbha is 1109.6 mm with a coefficient of variation of 18.1%. The rainfall series is Gaussian-distributed and does not indicate any persistence. The median rainfall value is 1099.2 mm.

(*ii*) The average summer monsoon rainfall of Vidarbha is 956.0 mm which is 86.2% of the annual rainfall. The coefficient of variation of monsoon rainfall is 18.5%.

(*iii*) The highest annual rainfall recorded is 1544.1mm (*i.e.*, 139.2% of the normal) in 1959 and the lowest annual rainfall recorded is 589.4 mm (*i.e.*, 53.2% of the normal) in 1920.

(*iv*) There are 11 large-scale deficient and 11 large-scale excess rainfall years in 100 years period.

(*v*) Student's *t*-test shows that increasing and decreasing trends noticed during various sub periods are not significant. However, the increasing trend observed during the period 1926 to 1950 was very close to become significant.

(*vi*) Only one significant cycle of 2.14 yr *i.e*., Quasi Biennial Oscillation is observed in 100-year period but is not consistently observed throughout the data record.

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