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# STATISTICAL ANALYSIS OF RAINFALL IN BELGAUM DISTRICT, KARNATAKA


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ABSTRACT

Belgaum district in Karnataka has been experiencing drought continuously for the past few years. To study the phenomenon of low rainfall in the district, statistical analysis of monthly and annual rainfall data of raingauge stations located in the district and neighbouring Bijapur and Dharwar observatories has been carried out. Besides studying the cross correlation of rainfall in monsoon months and serial correlation, other techniques like linear regression and polynomial regression have also been applied to identify the presence of any trend.

There was no relation between the rainfall in each of the monsoon months and the monsoon total, and among the rainfall of the monsoon months. Also, the serial correlation was poor indicating the absence of any persistence in the series. Linear regression of rainfall data for Belgaum observatory on split sample data has indicated a falling trend in recent years.

A comparison of the Malaprabha catchment rainfall and flow data showed good agreement. There was no decreasing trend in the Malaprabha catchment rainfall. Polynomial regression of the rainfall series has indicated some trend in the rainfall series of Khanapur, Hukeri and Bijapur.

## 1.0 INTRODUCTION

Belgaum district in Karnataka is one of the districts hard hit by drought in the State. The river flows and reservoir levels have been reported to be diminishing in the last few years. The reservoir at Naviluteerth on Malaprabha has not been able to fill up to the F.R.L. during the last few years.

The Belgaum district has experienced severe drought conditions during 1982-83 which has recurred during 1983-84, 1984-85 and is continuing in 1985-86. Based on rainfall data received upto 15th July, 1985, the Government of Karnataka(1985) has declared eight out of ten talukas in the district as drought affected. Four of these talukas were reported to be under severe drought and two under mild drought. The cropped area in the district was reduced to about 67% of the normal area.

To understand the phenomenon of low rainfall in the district a climatological study of the rainfall of Belgaum district and neighbouring area has been undertaken. The study is particularly aimed at identification of the presence of any trend or persistence.

## 2.0 REVIEW

Studies for identifying the trend and periodicities in the rainfall series have been carried out by several authors for more than 30 years. Reynolds(1953) and Gregory(1956) had studied the regional variation of rainfall in Britain. Around the same time Pramanik and Jagannathan (1953) found systematic variations in the annual rainfall over certain parts of India.

Namias(1968) had studied the trends in rainfall of Central Park Observatory, New York and related them to general circulation aberrations. Mitchel (1968) had also studied the trends in rainfall of Central Park Observatory using power spectrum analysis.

Koteswaram and Alvi(1969), Bhargava and Bansal(1973) had studied the secular trends and periodicities in the monsoon and annual rainfall of selected stations in India and had noted the presence of quasi-biennial oscillations. Winstanley(1973) while dealing with the aridity in the Sahel zone has established a 200 and 700 year harmonic cycle in the behaviour of rainfall and has included Bikaner and Jodhpur also in this cycle. Jagannathan and Bhalme(1973) showed that rainfall in India during the monsoon season(June-Sept.) has oscillations corresponding to the sunspot cycle.

Parthasarathy and Dhar(1974 and 1975) have examined the trends and periodicities in the sub-divisional rainfall of India extending over 60 years by using techniques like Mann-Kendal rank statistic, low pass filter and power spectrum analysis. Pareek et al.(1976) and Ramasastri(1979) have used similar techniques for studying the trends of seasonal and annual rainfall in Sutlej catchment and West Rajasthan respectively. Parthasarthy and Dhar(1974) have noticed the presence of persistence in the rainfall series of south interior Karnataka sub-division.

## 3.0 PROBLEM DEFINITION

Climatic fluctuation is a complex and vaguely comprehended phenomenon. In general, prediction of climate is possible if:

(i) a climatic variable is statistically auto-predictable from knowledge of its own past history,

(ii) a climatic variable is statistically correlated with one or more environmental variables that in turn are statistically and physically auto-predictable.

One of the methods to examine climatic shifts is the statistical analysis of the past behaviour of the sample. In statistical analysis, the time series is assumed to be composed of two components; the deterministic component like trend, cycle, persistence and the non-deterministic component namely randomness. Though it was recognised that auto-prediction of annual rainfall from its own time series was not possible because of the randomness associated with the process, efforts were made by various investigators to make long range forecasts of seasonal and annual precipitation through lag correlation in time and space Yevjevich(1964) has shown the time series of the past century to fit a stochastic model of a stationary, normally distributed random variable at a wide variety of locations.

As indicated in the review at 2.0, further studies by several authors in India and other countries on seasonal and annual rainfall have indicated immense potential of statistical analysis in the identification of trends and persistence. WMO(1969) has recommended a number of statistical techniques for climatological analysis. Using some of these methods, the monthly, seasonal and annual rainfall of raingauge stations located in the Belgaum district and that of two neighbouring observatories has been analysed to study presence of any trend and persistence in the rainfall series of this area.

## 3.1 Description of the Study Area

Belgaum district is the northern most district in Karnataka bordering Maharashtra. There are ten talukas in the district namely Athani, Bailhongal, Belgaum, Chikodi, Gokak, Hukeri, Khanapur, Raibag, Ramdurg and Saundatti.

The district is bounded on the west by the western ghats. The area is more or less undulating one. The elevation of the hills extends to more than 1000 m a.s.l. Of the total geographical area of 1346348 ha, 192776 ha is under forest, and 627328 ha which is nearly 50% of the geographical area is normally under crops.

The Belgaum district is semi-arid in parts of Athni, Raibag, Gokak, Bailhongal taluks and Ramdurg and Saundatti Taluks. Climate in rest of the district ranges from subhumid to humid towards west.

Nearly 95 percent of the annual rainfall is received during the period April to October, because of South-west monsoon. Most of the remaining rainfall is received during November and December under the influence of Northeast monsoon. The normal monthly and annual rainfall (India Meteorological Department, 1962) of raingauge stations located in the district is given in Table 1. The location of the raingauge stations is shown in Index map at figure 1.

The district has two major river systems Ghataprabha and Malaprabha which are tributaries of river Krishna. The other rivers Hiranyakesi and Markandeya are tributaries to Ghataprabha. There are two dams, on Ghataprabha at Hidkal and on Malaprabha at Naviluteerth. Their locations are shown in figure 2.

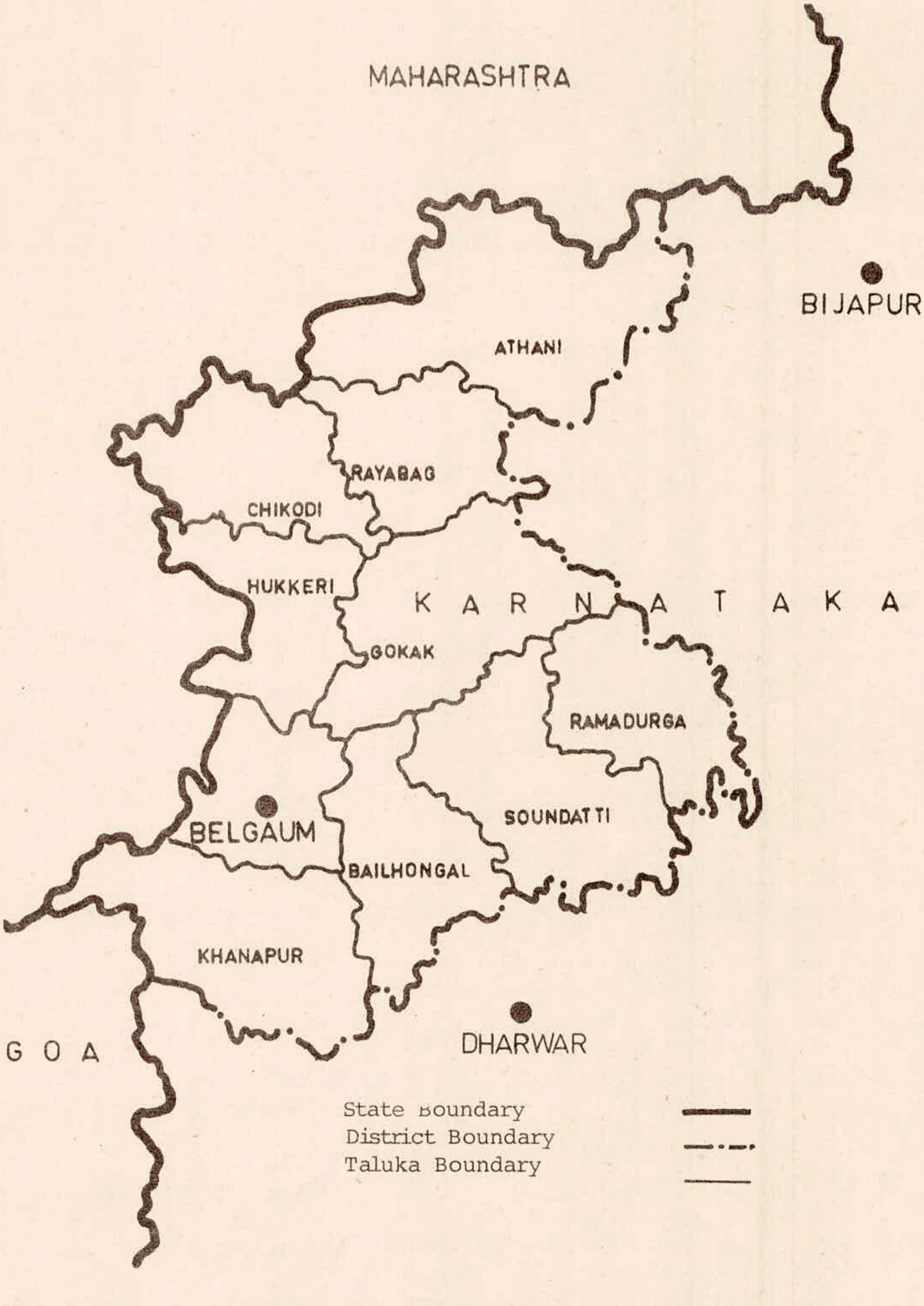



FIG. 1: INDEX MAP OF BELGAUM DISTRICT

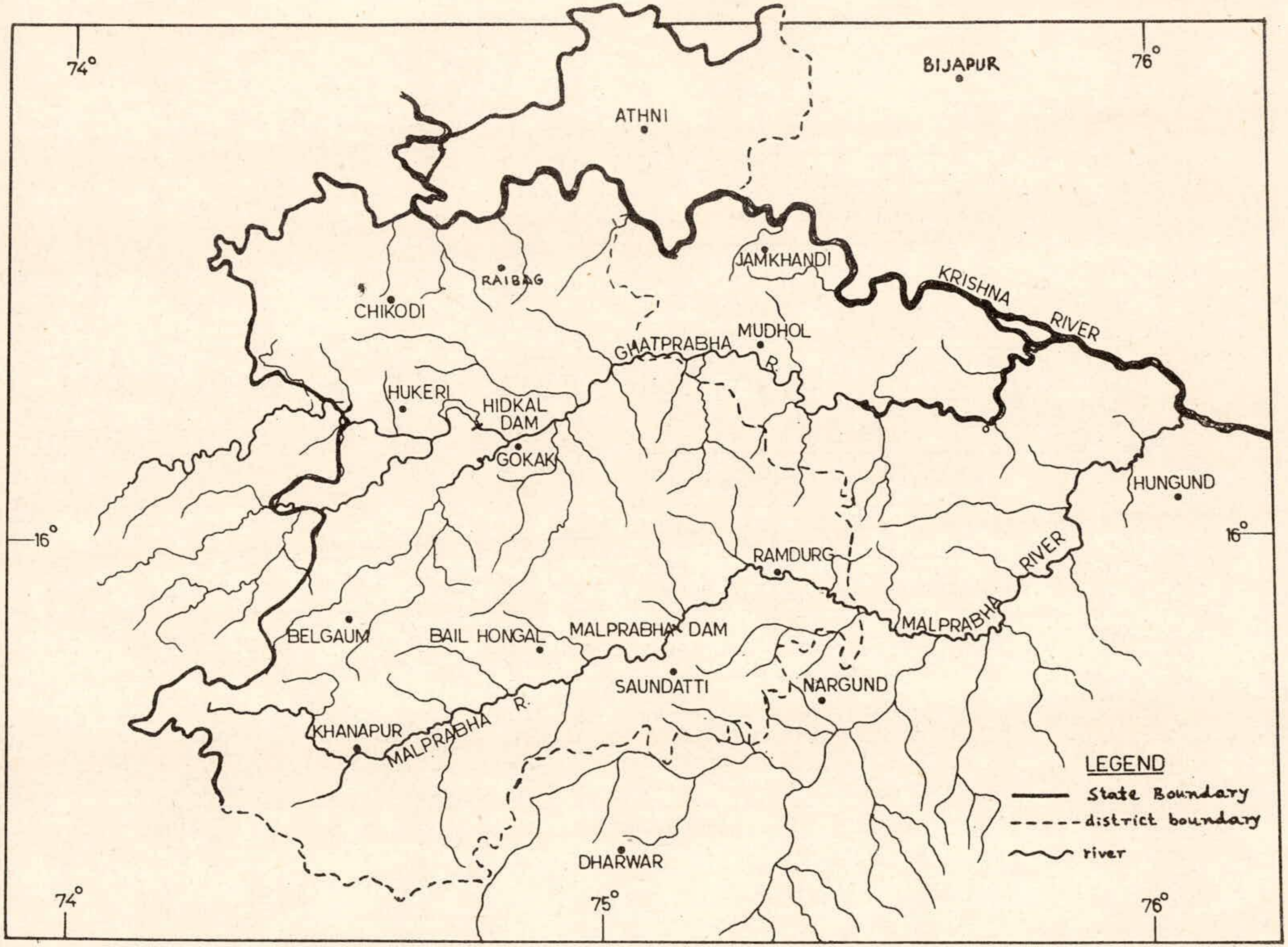



FIG. 2 - MAP SHOWING RIVER SYSTEMS IN BELGAUM DISTRICT

Table 1: Normal monthly and annual rainfall 1901-1950)* in mm.

| Station | Jan | Feb. | March | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BELGAUM | 3.6 | 1.3 | 9,9 | 43.2 | 66.5 | 190.7 | 459.0 | 247.1 | 118.9 | 111.0 | 40.6 | 11.4 | 1303.2 |
| KHANAPUR | 1.3 | 0.8 | 5.1 | 28.7 | 53.3 | 285.0 | 693.9 | 345.9 | 119.9 | 102.9 | 37.1 | 9.7 | 1683.6 |
| HONGAL | 1.3 | 1.8 | 8.4 | 36.8 | 62.7 | 100.3 | 136.4 | 87.1 | 110.7 | 114.3 | 40.6 | 8.4 | 708.8 |
| SAUNDATTI | 2.8 | 3.3 | 7.4 | 36.1 | 62.7 | 62.5 | 86.9 | 71.4 | 112.0 | 106.7 | 51.1 | 7.4 | 610.4 |
| RAMDURG | 2.3 | 2.5 | 10.9 | 29.0 | 51.1 | 70.9 | 73.7 | 70.6 | 120.4 | 83.1 | 38.3 | 9.7 | 572.5 |
| GOKAK | 3.6 | 1.3 | 5.6 | 30.0 | 57.1 | 68.8 | 75.9 | 63.0 | 95.3 | 109.5 | 44.2 | 9.7 | 564.0 |
| ATHNI | 4.6 | 1.3 | 5.6 | 26.7 | 53.1 | 72.9 | 75.2 | 137.9 | 93.0 | 33.3 | 8.9 | 587.9 | |
| CHIKODI | 2.5 | 1.0 | 6.9 | 34.0 | 51.8 | 80.8 | 127.3 | 86.4 | 94.5 | 98.8 | 38.9 | 9.9 | 632.8 |
| HUKERI | 1.8 | 2.5 | 8.4 | 32.8 | 66.5 | 82.5 | 129.8 | 82.8 | 103.9 | 109.2 | 43.7 | 11.7 | 675.6 |
| BIJAPUR | 5.8 | 2.3 | 7.1 | 19.6 | 29.5 | 76.2 | 58.7 | 65.8 | 141.5 | 76.7 | 30.7 | 6.6 | 520.5 |
| DHARWAR | 2.0 | 1.5 | 8.9 | 48.3 | 74.4 | 95.3 | 174.0 | 121.4 | 102.4 | 125.2 | 48.0 | 1.9 | 813.3 |

* Normal Monthly and Annual Rainfall and Rainy Days
India Meteorological Department, 1962.

## 4.0 METHODOLOGY

The average monthly and annual rainfall for the Belgaum district and the catchment of Malaprabha upto Naviluteerth has been computed by Thiessen polygon method. The average for Ghataprabha upto Hidkal could not be computed due to gaps in the data of Chandgad, a raingauge in the Kolhapur district of Maharashtra which has influence over the catchment.

The statistical parameters mean, standard deviation and coefficient of skewness for rainfall data have been computed for each of the twelve months and also for monsoon(June-Sept.), non-monsoon(Oct.-May) Water year(June-May) and annual(Jan.-Dec.) periods. Also, the decade means and progressive means for 10,20,30,...years have been computed to identify the periods of low rainfall epoch.

### 4.1 Study of Monsoon Pattern

To study the dependance of the total monsoon rainfall on the rainfall of each monsoon month, and the relationship of the rainfall of each of the monsoon months with one another, cross correlation using the equation(1) has been worked out.

$$r = \frac{\left[ \frac{1}{N} \sum_{i=1}^{N} x_i \, y_i - \frac{1}{N^2} \left( \sum_{i=1}^{N} x_i \right)^2 \right]^{1/2}}{\left[ \frac{1}{N} \sum_{i=1}^{N} x_i^2 - \frac{1}{N^2} \left( \sum_{i=1}^{N} x_i \right)^2 \right]^{1/2} \left[ \frac{1}{N} \sum_{i=1}^{N} y_i^2 - \frac{1}{N^2} \left( \sum_{i=1}^{N} y_i \right)^2 \right]^{1/2}} \quad \ldots(1)$$

Where N is the length of the series and

$x_i$ and $y_i$ are two arrays of data. Cross correlation has also been worked out to see the dependence of non-monsoon rainfall on the previous monsoon rainfall

## 4.2 Test of Randomness

In the present study, the series are examined in the first instance for randomness as it often happens that for nonrandom climatological series there is likelihood of presence of some form of trend. It is also interesting to know whether rainfall in a particular month is related to the rainfall which occured in the previous months/years. This aspect has been studied by computing the serial correlation coefficient of the time series considering the monthly rainfall as sample data using the following equation.

$$r_k = \frac{\frac{1}{N-K}\sum_{i=1}^{N-K} x_i\, x_{i+k} - \frac{1}{(N-K)^2}\left(\sum_{i=1}^{N-K} x_i\right)\left(\sum_{i=1}^{N-K} x_{i+K}\right)}{\left[\frac{1}{N-K}\sum_{i=1}^{N-K} x_i^2 - \frac{1}{(N-K)^2}\left(\sum_{i=1}^{N-K} x_i\right)^2\right]^{1/2}\left[\frac{1}{N-K}\sum_{i=1}^{N-K} x_{i+K}^2 - \frac{1}{(N-K)^2}\left(\sum_{i=1}^{N-K} x_{i+k}\right)^2\right]^{1/2}} \quad \ldots(2)$$

Where

N is length of the series

$x_i$ and $x_{i+k}$ are two sets of data and

K is lag

This analysis has been carried out for K values of 3,5,15, and 20.

## 4.3 Test for Trend

To identify the existence of any trend or persistence in the rainfall series, the following tests have been carried out

(i) Comparison of decade means with mean of whole period.

(ii) Linear regression and

(iii) Polynomial regression.

4.3.1 Comparison of decade means and mean of whole period:

The decade means were compared with the mean of the whole period of the respective rainfall series, to identify low or high rainfall trend in a particular decade. A test of 'null' hypothesis of randomness (WMO, 1966) has been applied to determine whether the differences of the means are no larger than would be compatible with the hypothesis.

$$T_k = \frac{\bar{X}k - \bar{X}}{S} \qquad \ldots(3)$$

where $\bar{x}_k$ is the mean of any k observations

$\bar{x}$ is the mean of the whole period

and s is the standard deviation of the whole period series.

$$\text{The statistic } t_k = \left[\frac{K(N-2)}{N-K-KT_k^2}\right]^{1/2} T_k \qquad \ldots(4)$$

is distributed as Student's t with (N-2) degrees of freedom which could be used to test the significance of non-randomness.

4.3.2 Linear regression

Linear regression of the form y=mx + c has been attempted for the rainfall series. The regression coefficient m indicates the presence of a rising or falling trend. The coefficient was tested using the Student's t test.

4.3.3 Polynomial regression

Polynomial regression relationship of 1st and 2nd order has been also fitted to the rainfall series for examining the possibility of trend in the rainfall series. The regression coefficients were tested with the F values for the test of significance.

## 5.0 DATA

Monthly and annual rainfall data of ten raingauge stations in the Belgaum district and two observatories in the neighbouring Bijapur and Dharwar districts for the period 1901-50 has been taken from the monthly and annual rainfall data published by India Meteorological Department(1970). Data for the period 1951 -80 has been obtained from the I.M.D.and from 1981 to 1984 it has been collected from the office of the Chief Engineer, Public Works Dept.(Irrigation), Govt. of Karnataka at Belgaum. Data for Dharwar was available only upto 1978. Inspite of the best efforts, data of Saundatti raingauge was not available for the period 1957-58 and 1960-65. As such no analysis could be done for Saundatti.

## 6.0 APPLICATION

The statistical techniques described earlier have been applied to the monthly,seasonal and annual rainfall data of raingauge stations in Belgaum, its district average and also catchment average rainfall of Malaprabha river upto Naviluteerth. To visualise graphically, the presence of any trend, plots of annual rainfall of all the raingauge stations in the district; and the average annual rainfall of Belgaum district and of catchment of Malaprabha upto Naviluteerth have been made. They are shown in figures 3(a) to 3(l). The 3 year and 5 year moving averages of annual rainfall of the respective raingauges are also shown on the corresponding graphs.

The statistical parameters, mean, standard deviation, coefficient of variation and coefficient of skewness of the monthly, seasonal(monsoon and non-monsoon), annual and water year rainfall are given in tables 2(a) to 2(l) for the raingauge stations, Belgaum district average and Malaprabha catchment average.

The values of serial correlation are given in table 3 for lag values of 5, 10, 15 and 20. The cross correlation matrices of monsoon rainfall are given in table 4(a) to 4(j).

### 6.1 Trend Analysis

The decade means of each raingauge station; and district and catchment average have been compared with the mean of the whole period of the respective rainfall series. In case of Dharwar, the mean of the last period was only of eight years i.e.1971-78. These are given in table 5. A graph of the decade means is presented at figure 4. The progressive decadal means are shown in table 6.

The rainfall trend at Khanapur and in the catchment of Malaprabha has been further examined by comparison with the observed discharges at Khanapur and estimated inflows into Malaprabha reservoir at Naviluteerth. The plots of rainfall and flows at these two sites are given in figures 5 and 6.

Linear regression analysis has been carried out on the monthly and annual rainfall series of the raingauge stations and average of Belgaum district and Malaprabha catchment. The linear correlation and regression coefficients along with its t value are given in table 7(a) to 7(l). In view of the shift in the trend of rainfall series of Khanapur and Belgaum, regression analysis has been carried out on split samples also.

Polynomial regression of 1st and 2nd order has been fitted to the data series of monthly, monsoon total, non-monsoon total, annual and water year rainfall. The results are presented in tables 8 to 12 respectively. The analysis has also been carried out in respect of 3 year and 5 year moving average series of monthly and annual rainfall. The results for annual rainfall are presented in tables13 and 14.

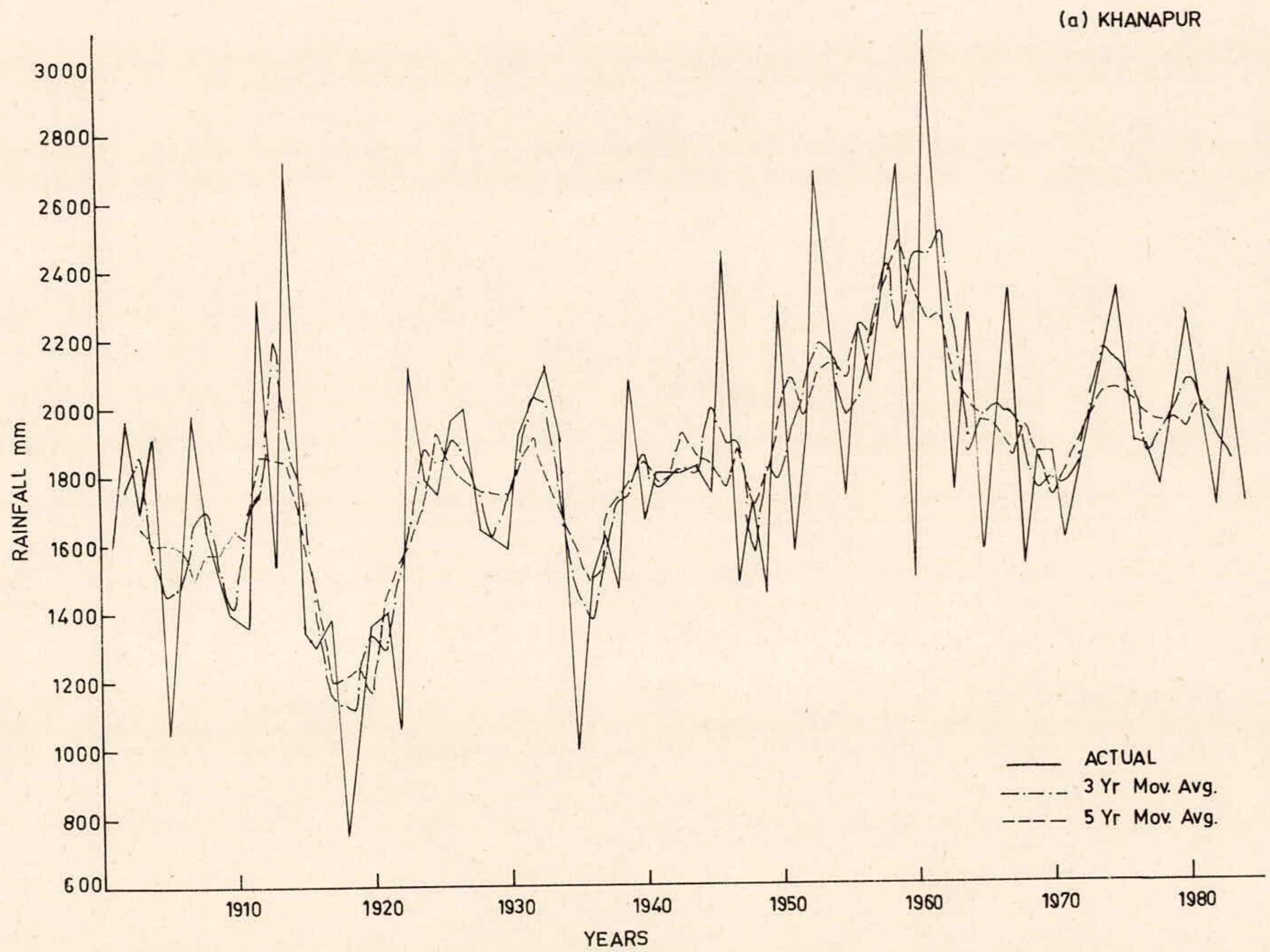
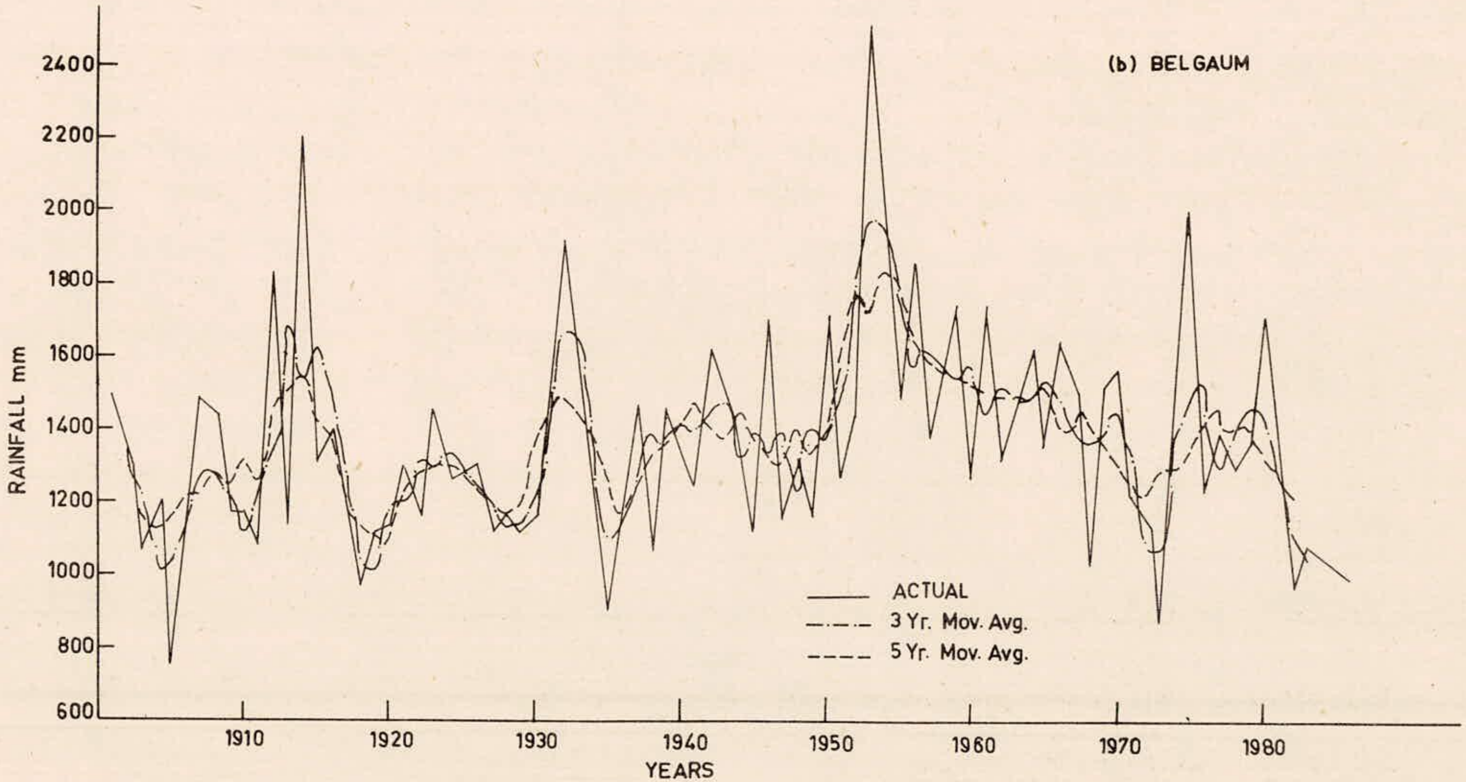



Figure 3 Annual rainfall time series and its 3 and 5 years moving averages.

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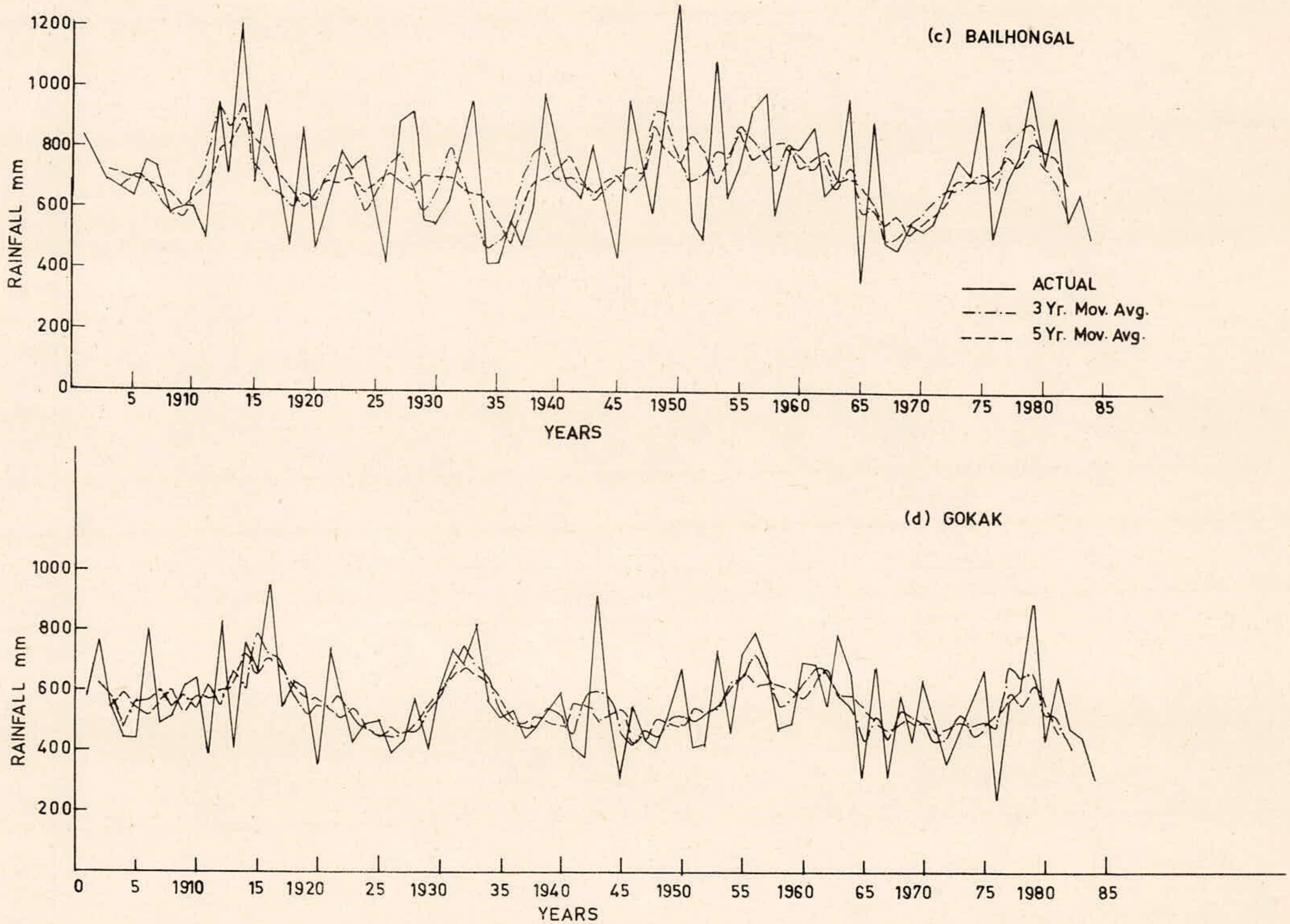


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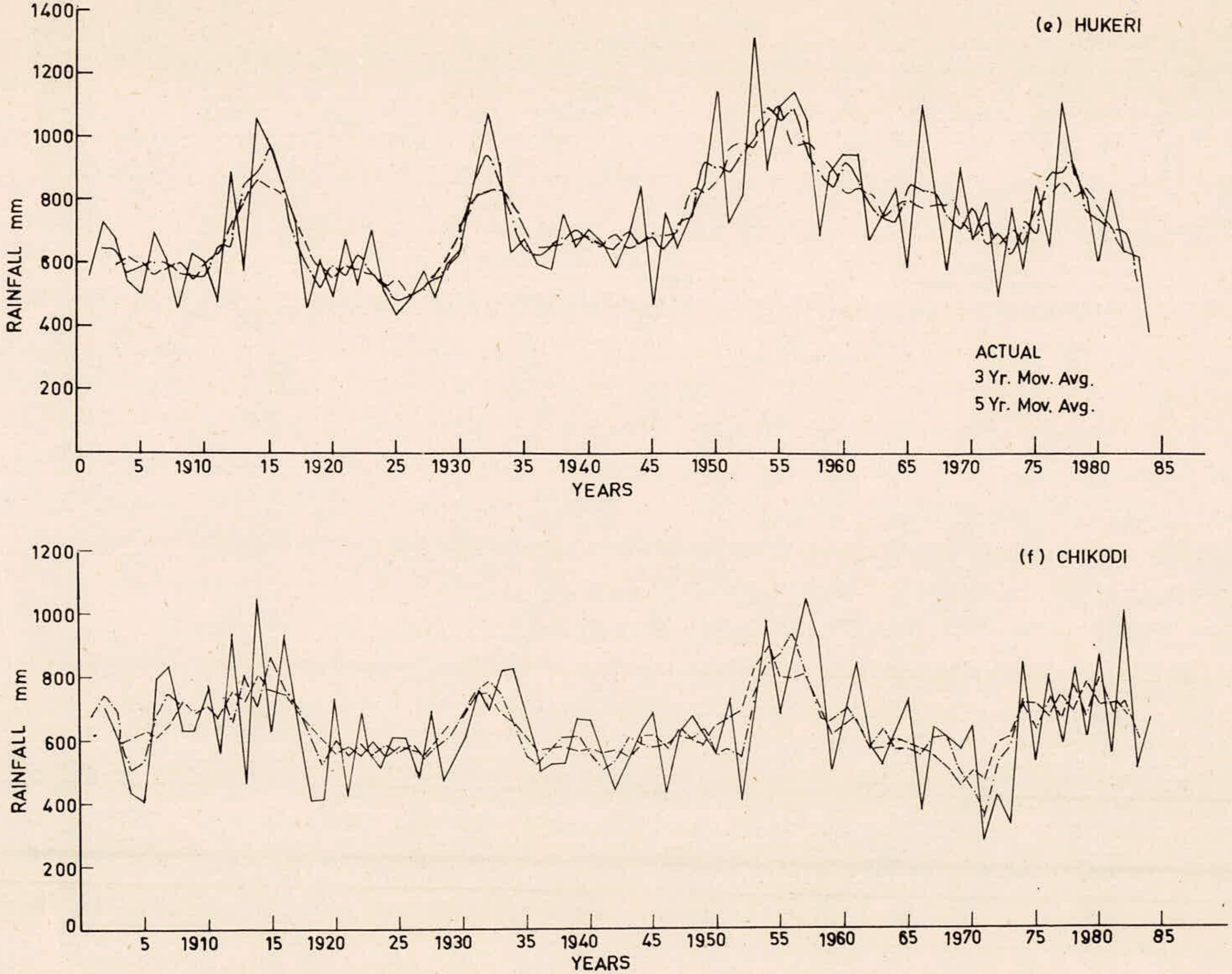


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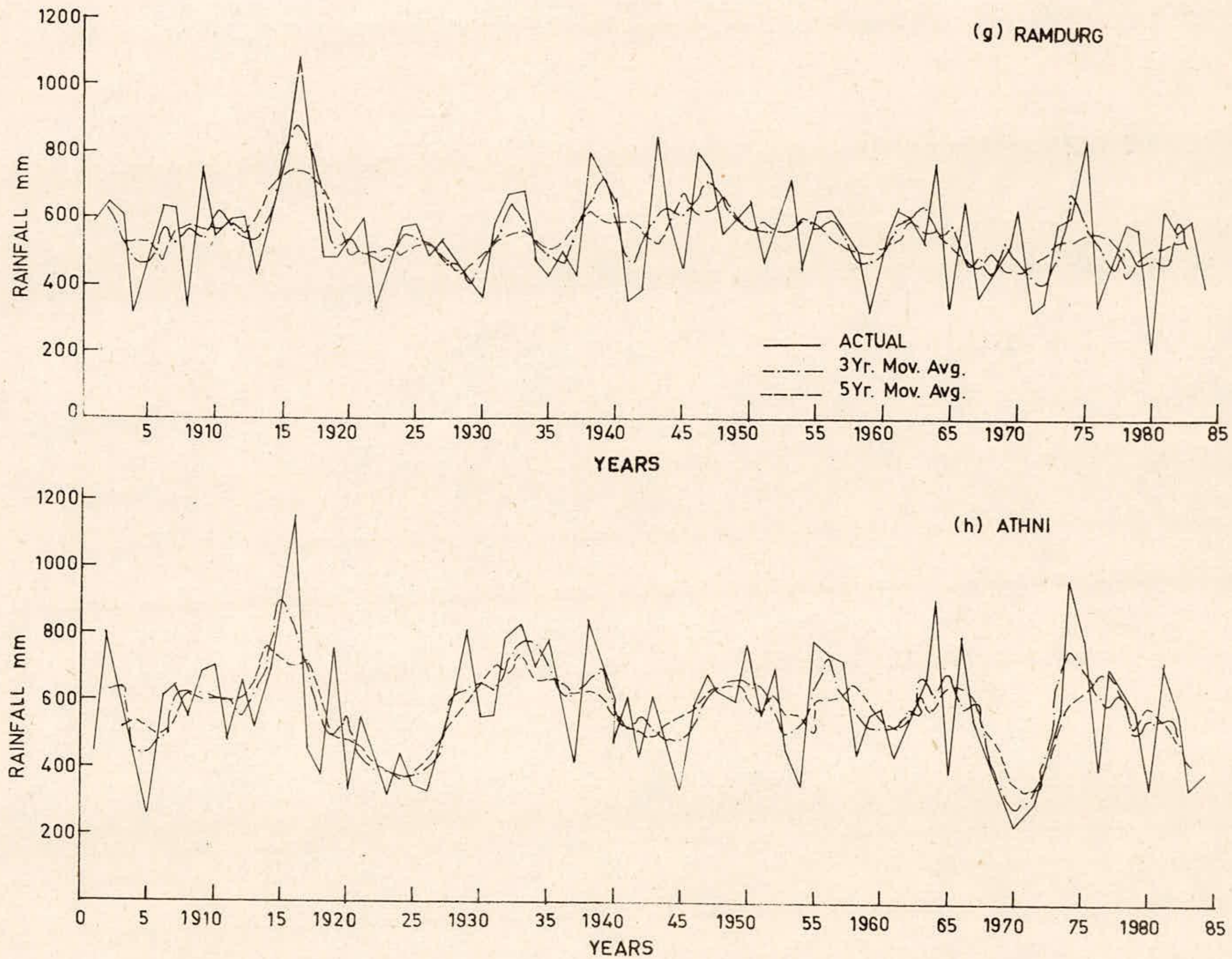


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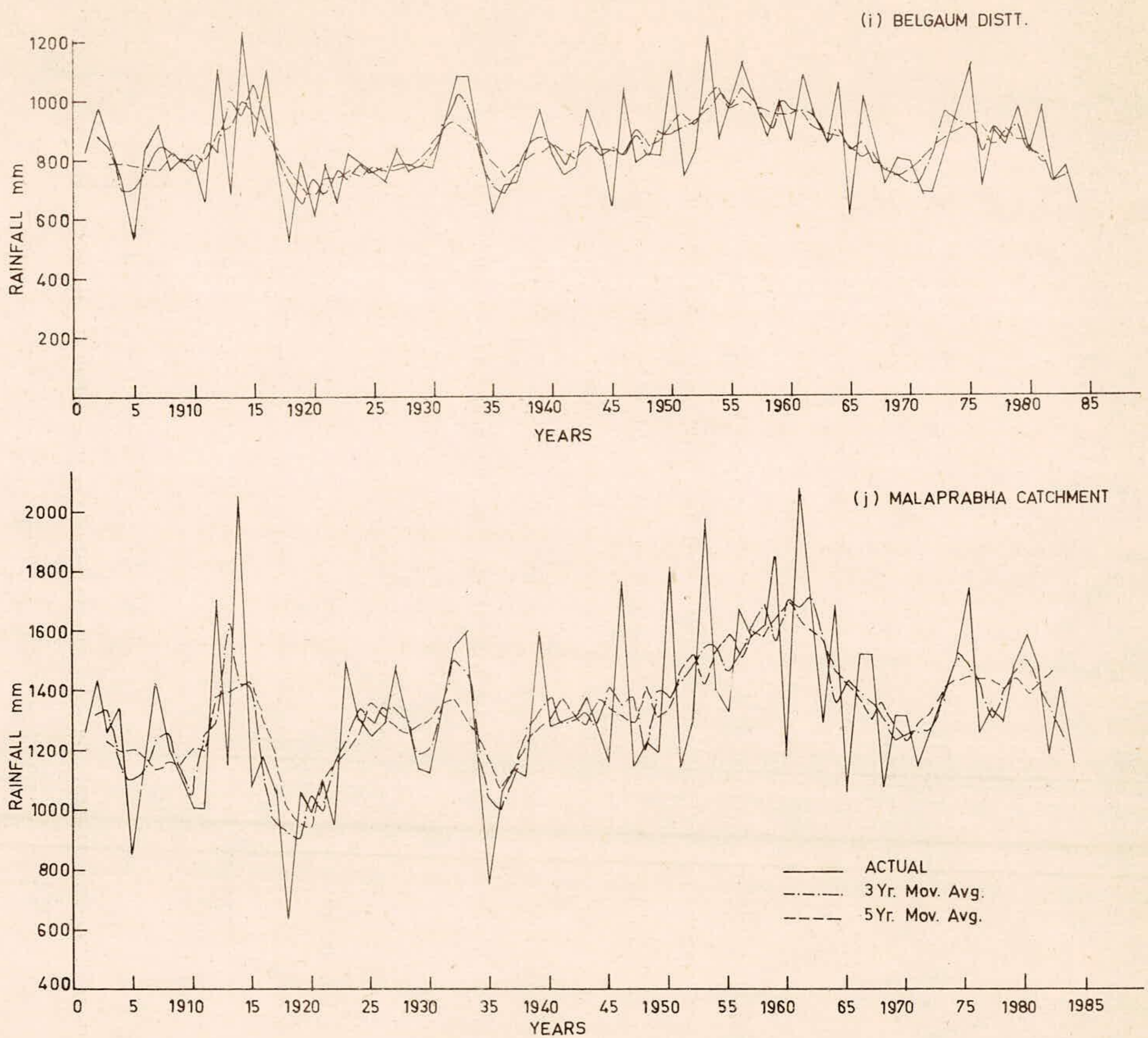


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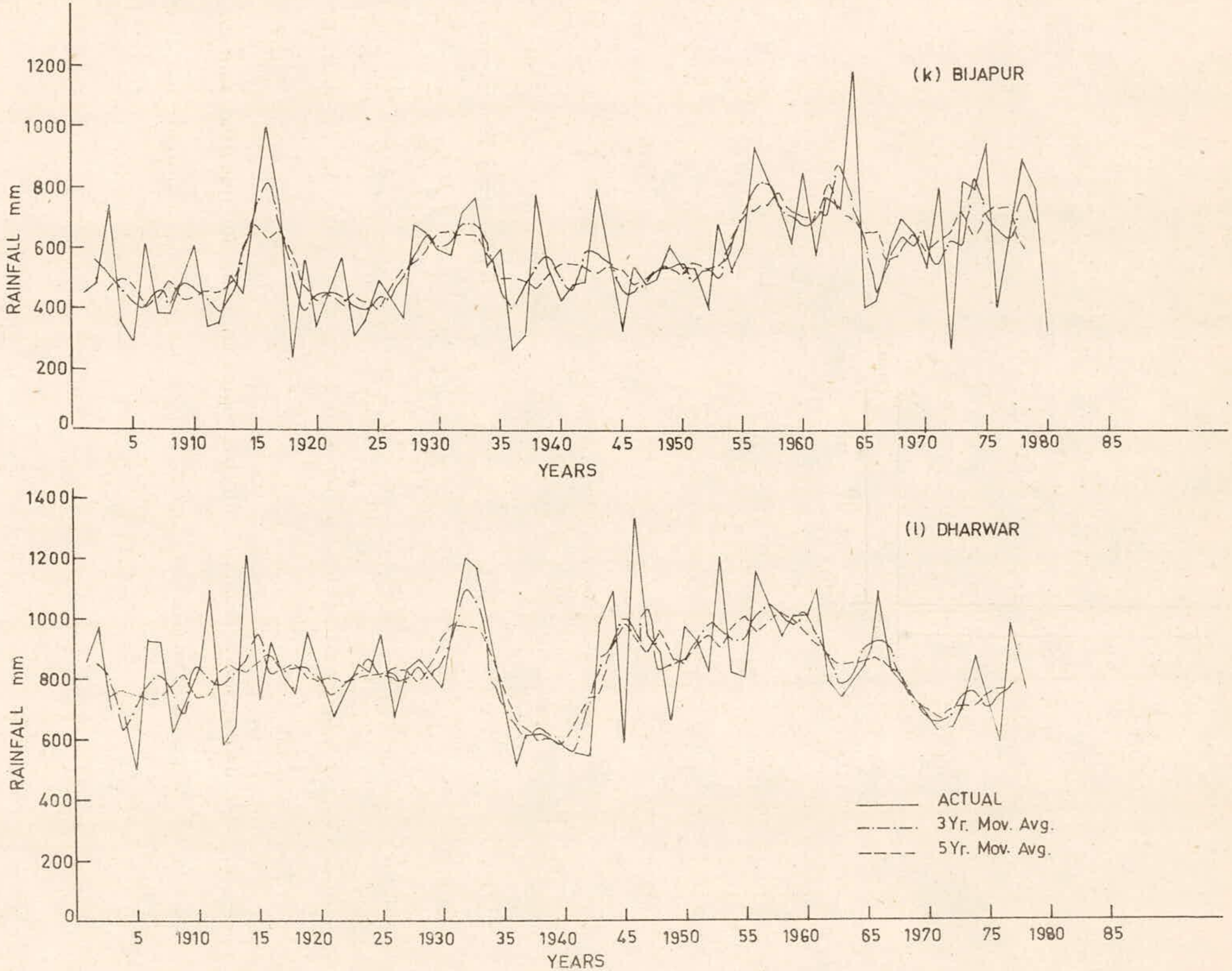


Figure 3 Annual rainfall time series and its 3 and 5 years moving averages.

Table 2(a) Statistical Parameters of rainfall at Khanapur

(Based on Data of 1901-84)

| Month/ Season | Mean mm | Standard Deviation mm | Coeff.of Variation % | Coefficient of Skewness |
|---|---|---|---|---|
| January | 1.2 | 4.2 | 350 | 4.0 |
| February | 0.8 | 2.9 | 363 | 4.0 |
| March | 4.9 | 10.3 | 210 | 2.9 |
| April | 28.8 | 27.2 | 94 | 1.1 |
| March | 65.1 | 65.6 | 100 | 2.2 |
| June | 321.7 | 167.5 | 52 | 0.8 |
| July | 731.7 | 318.8 | 44 | 0.5 |
| August | 380.9 | 201.1 | 53 | 1.2 |
| September | 123.7 | 63.5 | 51 | 0.4 |
| October | 114.8 | 75.1 | 67 | 0.9 |
| November | 38.3 | 46.0 | 120 | 2.2 |
| December | 6.9 | 25.4 | 368 | 7.6 |
| Monsoon (Jun-Oct) | 1669.8 | 399.0 | 24 | 0.2 |
| Non-monsoon (Nov-May) | 144.7 | 85.0 | 59 | 0.9 |
| Annual (Jan-Dec) | 1824.5 | 413.2 | 23 | 0.4 |
| Water-Year (June-May) | 1814.5 | 401.0 | 22 | 0.3 |

Table 2(b) Statistical Parameters of rainfal at Belgaum(obsy)(Based on data of 1901-84)

| Month / Season | Mean mm | Standard Deviation mm | Coeff. of Var. % | Coeff. of Skewness |
|---|---|---|---|---|
| January | 2.2 | 7.9 | 359 | 5.3 |
| February | 2.4 | 8.1 | 338 | 4.3 |
| March | 9.5 | 17.2 | 181 | 3.3 |
| April | 46.8 | 38.9 | 83 | 1.0 |
| May | 82.4 | 72.9 | 88 | 1.8 |
| June | 204.8 | 111.5 | 54 | 1.5 |
| July | 457.6 | 194.2 | 42 | 0.8 |
| August | 259.2 | 144.7 | 56 | 1.2 |
| September | 122.5 | 66.4 | 54 | 0.8 |
| October | 121.8 | 106.4 | 87 | 2.9 |
| November | 39.6 | 47.3 | 119 | 2.2 |
| December | 8.8 | 24.5 | 278 | 5.6 |
| Monsoon (June-Oct) | 1165.9 | 296.5 | 25 | 1.4 |
| Non-Monsoon (Nov-May) | 188.5 | 100.5 | 53 | 0.9 |
| Annual (Jan-Dec) | 1357.5 | 304.5 | 22 | 1.0 |
| Water Year (June-May) | 1354.4 | 319.5 | 24 | 1.0 |

Table 2(c) Statistical Parameters of rainfall at Bailhongal(Based on data of 1901-84)

| Month/ Season | Mean mm | Standard Deviation mm | Coefficient of Var. % | Coefficient of Skewness |
|---|---|---|---|---|
| January | 1.0 | 3.8 | 380 | 4.06 |
| February | 1.5 | 4.9 | 327 | 4.50 |
| March | 6.8 | 12.5 | 184 | 2.44 |
| April | 35.1 | 31.3 | 89 | 1.30 |
| May | 72.1 | 56.8 | 79 | 1.23 |
| June | 142.7 | 253.5 | 178 | 4.70 |
| July | 136.7 | 72.0 | 53 | 0.84 |
| August | 86.2 | 70.5 | 82 | 1.99 |
| September | 109.1 | 75.9 | 70 | 1.28 |
| October | 116.9 | 74.7 | 64 | 0.89 |
| November | 36.6 | 41.8 | 114 | 1.52 |
| December | 6.8 | 17.6 | 259 | 4.95 |
| Monsoon (June-Oct) | 591.6 | 286.1 | 48 | 2.79 |
| Non-Monsoon (Nov-May) | 156.9 | 81.7 | 52 | 0.56 |
| Annual (Jan-Dec) | 707.3 | 183.3 | 26 | 0.57 |
| Water Year (June-May) | 748.5 | 307.8 | 41 | 2.5 |

Table 2(d) Statistical Parameters of rainfall at Gokak(Based on data of 1901-84)

| Month/ Season | Mean mm | Standard Deviation mm | Coefficient of Var. % | Coefficient of Skewness |
|---|---|---|---|---|
| January | 2.5 | 8.1 | 324 | 4.13 |
| February | 1.7 | 7.4 | 435 | 7.53 |
| March | 6.9 | 14.2 | 206 | 3.00 |
| April | 30.5 | 32.0 | 105 | 1.88 |
| May | 64.8 | 52.7 | 81 | 1.23 |
| June | 64.3 | 45.2 | 70 | 1.37 |
| July | 75.9 | 46.5 | 61 | 1.09 |
| August | 58.7 | 53.5 | 91 | 1.8 |
| September | 101.7 | 66.7 | 66 | 0.83 |
| October | 106.3 | 75.4 | 71 | 0.79 |
| November | 38.9 | 46.9 | 121 | 1.54 |
| December | 7.6 | 16.9 | 222 | 3.25 |
| Monsoon (Jun-Oct) | 406.5 | 114.0 | 28 | 0.54 |
| Non-monsoon (Nov-May) | 149.5 | 84.0 | 56 | 0.82 |
| Annual(Jan-Dec) | 559.8 | 150.4 | 27 | 0.44 |
| Water Year (Jun-May) | 556.0 | 142.0 | 26 | 0.29 |

Table 2(e) Statistical Parameters of rainfall at Hukeri(Based on Data of 1901-84)

| Month | Mean mm | Standard Deviation mm | Coefficient of Var. % | Coefficient of Skewness |
|---|---|---|---|---|
| January | 1.1 | 4.4 | 400 | 35.3 |
| February | 1.9 | 6.1 | 321 | 15.4 |
| March | 8.7 | 14.2 | 163 | 8.3 |
| April | 35.3 | 31.8 | 90 | 7.1 |
| May | 81.3 | 67.4 | 83 | 5.3 |
| June | 90.2 | 57.6 | 64 | 6.5 |
| July | 145.4 | 77.3 | 53 | 3.2 |
| August | 88.3 | 59.4 | 67 | 6.7 |
| September | 108.0 | 68.6 | 64 | 3.7 |
| October | 117.4 | 75.7 | 64 | 5.0 |
| November | 43.3 | 55.0 | 127 | 5.3 |
| December | 9.1 | 26.3 | 289 | 28.0 |
| Monsoon (Jun-Oct) | 549.3 | 155.5 | 78 | 5.2 |
| Non-Monsoon (Nov-May) | 177.8 | 110.3 | 62 | 3.8 |
| Annual (Jan-Dec) | 729.4 | 193.2 | 26 | 3.3 |
| Water Year (Jan-May) | 727.1 | 202.9 | 28 | 3.2 |

Table 2(f) Statistical Parameters of rainfall at Chikodi(Based on data of 1901-84)

| Month/ Season | Mean mm | Standard Deviation mm | Coefficient of Var. % | Coefficient of Skewness |
|---|---|---|---|---|
| January | 1.6 | 6.1 | 381 | 4.9 |
| February | 1.0 | 3.7 | 370 | 5.1 |
| March | 6.5 | 12.2 | 187 | 2.6 |
| April | 29.4 | 29.4 | 100 | 1.4 |
| May | 59.2 | 47.7 | 81 | 1.1 |
| June | 79.7 | 56.1 | 70 | 1.8 |
| July | 129.8 | 61.0 | 47 | 0.3 |
| August | 89.9 | 58.8 | 65 | 1.5 |
| September | 96.8 | 66.3 | 68 | 1.1 |
| October | 100.2 | 68.0 | 68 | 0.7 |
| November | 36.8 | 44.0 | 120 | 1.8 |
| December | 8.2 | 22.2 | 270 | 3.5 |
| Monsoon (Jun-Oct) | 496.0 | 140.0 | 28 | 0.39 |
| Non-Monsoon (Nov-May) | 140.0 | 80.0 | 57 | 0.65 |
| Annual(Jan-Dec) | 638.9 | 163.3 | 26 | 0.38 |
| Water Year (Jun-May) | 636.0 | 160.0 | 25 | 0.13 |

Table 2(g) Statistical Parameters of rainfall at Ramdurg(Based on data of 1901-84)

| Month/Season | Mean mm | Standard Deviation mm | Coeff. of Var. % | Coeff. of Skew. |
|---|---|---|---|---|
| January | 1.8 | 5.9 | 328 | 4.0 |
| February | 1.9 | 5.8 | 305 | 4.4 |
| March | 8.1 | 16.6 | 205 | 3.0 |
| April | 28.1 | 26.4 | 94 | 1.7 |
| May | 55.4 | 44.9 | 81 | 1.0 |
| June | 67.8 | 43.6 | 64 | 0.9 |
| July | 70.9 | 41.1 | 58 | 1.3 |
| August | 63.8 | 64.7 | 101 | 2.7 |
| September | 118.9 | 73.1 | 61 | 0.7 |
| October | 91.1 | 61.8 | 68 | 0.7 |
| November | 38.6 | 59.2 | 153 | 2.8 |
| December | 7.5 | 19.8 | 264 | 4.0 |
| Monsoon(Jun-Oct) | 412.7 | 120.9 | 29 | 0.4 |
| Non-Monsoon (Nov-May) | 139.0 | 87.5 | 63 | 1.0 |
| Annual(Jan-Dec) | 553.9 | 148.1 | 27 | 0.4 |
| Water Year(June-May) | 551.7 | 146.5 | 27 | 0.5 |

Table 2(h) Statistical Parameters of Rainfall at Athni(Based on data of 1901-84)

| Month/Season | Mean mm | Standard Deviation mm | Coeff. Of.Var. % | Coeff. of Skew. |
|---|---|---|---|---|
| January | 3.0 | 9.5 | 317 | 4.1 |
| February | 1.0 | 4.3 | 430 | 6.6 |
| March | 6.0 | 12.2 | 203 | 2.5 |
| April | 23.7 | 28.6 | 121 | 2.1 |
| May | 52.9 | 45.7 | 86 | 0.8 |
| June | 73.2 | 47.7 | 65 | 0.9 |
| July | 73.6 | 550 | 75 | 1.5 |
| August | 64.2 | 62.6 | 98 | 1.8 |
| September | 137.9 | 90.3 | 65 | 0.9 |
| October | 95.5 | 82.2 | 86 | 1.1 |
| November | 32.8 | 47.9 | 146 | 2.1 |
| December | 8.4 | 23.1 | 275 | 4.4 |
| Monsoon(Jun-Oct) | 444.6 | 157.2 | 35 | 0.4 |
| Non-monsoon(Nov-May) | 126.0 | 76.7 | 61 | 0.6 |
| Annual(Jan-Dec) | 573.7 | 178.9 | 31 | 0.4 |
| Water Year(Jun-May) | 570.0 | 174.3 | 31 | 0.3 |

Table 2(i) Statistical Parameter of Rainfall of Belgaum District(Based on data of 1901-84)

| Month /Season | Mean mm | Standard Deviation mm | Coeff. of Var. | Coeff of Skewness |
|---|---|---|---|---|
| January | 1.9 | 4.8 | 253 | 3.5 |
| February | 1.4 | 3.4 | 243 | 3.3 |
| March | 6.7 | 9.0 | 134 | 2.5 |
| April | 31.0 | 21.0 | 68 | 1.0 |
| May | 63.7 | 42.9 | 67 | 1.2 |
| June | 127.3 | 56.6 | 44 | 1.2 |
| July | 221.1 | 83.1 | 38 | 0.6 |
| August | 132.7 | 67.0 | 50 | 1.4 |
| September | 115.1 | 55.9 | 49 | 0.7 |
| October | 105.8 | 62.4 | 59 | 0.7 |
| November | 37.8 | 43.0 | 113 | 2.0 |
| December | 7.6 | 19.4 | 255 | 5.5 |
| Monsoon(Jun-Oct) | 702.1 | 136.4 | 19 | 0.48 |
| Non-Monsoon(Nov-May) | 147.9 | 68.8 | 47 | 0.51 |
| Annual(Jan-Dec) | 849.5 | 149.6 | 18 | 0.46 |
| Water-Year(Jun-May) | 850.1 | 151.6 | 118 | 0.37 |

Table 2(j) Statistical Parameters of Rainfall of Malaprabha Catchment
(Based on data of 1901-84)

| Month/Season | Mean mm | Standard Deviation mm | Coeff. of Var. % | Coeff of Skewness |
|---|---|---|---|---|
| January | 1.2 | 3.4 | 28 | 3.3 |
| February | 1.3 | 3.2 | 25 | 2.9 |
| March | 5.9 | 10.0 | 17 | 2.8 |
| April | 32.3 | 24.1 | 75 | 1.0 |
| May | 69.1 | 56.2 | 81 | 1.7 |
| June | 237.0 | 140.0 | 59 | 1.9 |
| July | 468.7 | 197.1 | 42 | 0.5 |
| August | 251.8 | 130.0 | 51 | 1.2 |
| September | 117.8 | 55.1 | 47 | 0.7 |
| October | 114.1 | 68.9 | 60 | 0.9 |
| November | 38.0 | 42.0 | 110 | 1.8 |
| December | 6.9 | 21.5 | 32 | 7.1 |
| Monsoon(Jun-Oct) | 1189.3 | 272.0 | 23 | 0.33 |
| Non-Monsoon(Nov-May) | 152.6 | 75.1 | 49 | 0.58 |
| Annual (Jan-Dec) | 1333.3 | 272.6 | 20 | 0.5 |
| Water-Year (June-May) | 1341.9 | 283.7 | 21 | 0.42 |

Table 2(k) Statistical Parameters of Rainfall at Bijapur(obsy)( Based on data of 1901-80)

| Month/Season | Mean mm | Standard Deviation mm | Coeff. of Var. % | Coeff. of Skewness |
|---|---|---|---|---|
| January | 3.7 | 12.9 | 349 | 4.8 |
| February | 2.8 | 7.8 | 278 | 3.8 |
| March | 6.1 | 11.0 | 180 | 2.4 |
| April | 22.1 | 25.1 | 114 | 2.2 |
| May | 36.0 | 33.6 | 93 | 0.9 |
| June | 79.0 | 51.5 | 65 | 0.7 |
| July | 73.9 | 63.5 | 86 | 1.7 |
| August | 73.9 | 62.3 | 84 | 0.7 |
| September | 147.5 | 90.4 | 61 | 1.1 |
| October | 95.1 | 77.7 | 82 | 0.8 |
| November | 30.3 | 51.5 | 170 | 3.4 |
| December | 6.0 | 13.0 | 217 | 3.7 |
| Monsoon(Jun-Oct) | 469.0 | 175.0 | 37 | 0.6 |
| Non-Monsoon(Nov-May) | 106.0 | 73.0 | 69 | 1.0 |
| Annual(Jan-Dec) | 576.7 | 193.0 | 33 | 0.5 |
| Water Year(Jun-May) | 575.0 | 196.0 | 34 | 0.4 |

Table 2(1) Statistical Parameters of Rainfall at Dharwar(obsy) (Based on data of 1901-78)

| Month/Season | Mean mm | Standard Deviation mm | Coeff. of Var. % | Coeff. of Skewness |
|---|---|---|---|---|
| January | 1.3 | 5.9 | 220 | 6.7 |
| February | 1.3 | 5.8 | 224 | 6.8 |
| March | 7.1 | 15.1 | 470 | 2.7 |
| April | 49.5 | 34.9 | 70 | 0.6 |
| May | 79.9 | 52.5 | 66 | 0.8 |
| June | 105.4 | 57.3 | 54 | 1.3 |
| July | 177.5 | 84.6 | 48 | 1.1 |
| August | 115.2 | 68.8 | 60 | 1.2 |
| September | 111.1 | 73.2 | 66 | 1.5 |
| October | 124.0 | 77.2 | 62 | 1.2 |
| November | 46.1 | 58.0 | 126 | 1.8 |
| December | 10.1 | 30.5 | 302 | 6.3 |
| Monsoon(Jun-Oct) | 633.3 | 159.2 | 25 | 0.9 |
| Non-Monsoon(Nov-May) | 192.8 | 92.5 | 48 | 0.6 |
| Annual(Jan-Dec) | 827.4 | 184.3 | 22 | 0.5 |
| Water Year(Jun-May) | 826.1 | 195.8 | 24 | 0.5 |

Table 3 Serial Correlation Coefficient of rainfall series

| Station | Lag Value 3 | 5 | 15 | 20 |
|---|---|---|---|---|
| Khanapur | -0.04 | 0.04 | -0.02 | 0.01 |
| Belgaum | -0.05 | 0.06 | -0.02 | 0.03 |
| Bailhongal | 0.0 | 0.02 | -0.01 | -0.02 |
| Gokak | - 0.03 | 0.03 | -0.02 | 0.03 |
| Hukeri | 0.00 | 0.02 | 0.02 | 0.00 |
| Chikodi | 0.03 | 0.01 | -0.01 | 0.00 |
| Ramdurg | 0.01 | -0.01 | 0.02 | 0.02 |
| Raibag* | -0.05 | 0.04 | 0.02 | - |
| Athni | -0.02 | 0.03 | 0.10 | 0.0 |
| Belgaum Dist. | -0.05 | 0.04 | 0.00 | 0.00 |
| Malaprabha | -0.03 | 0.03 | -0.03 | 0.00 |
| Bijapur** | 0.01 | 0.03 | -0.01 | 0.01 |
| Dharwar*** | 0.00 | 0.05 | -0.01 | -0.01 |

* Based on 612 monthly values

** Based on 960 monthly values.

*** Based on 936 monthly values

Table 4(a) Correlation Matrix for Khanapur

| | June | July | Aug. | Sept. | Oct. | Monsoon Total |
|---|---|---|---|---|---|---|
| June | 1.00 | -0.01 | -0.19 | -0.03 | -0.05 | 0.12 |
| July | | 1.00 | -0.12 | -0.08 | 0.04 | 0.16 |
| Aug. | | | 1.00 | -0.15 | -0.09 | 0.14 |
| Sept. | | | | 1.00 | -0.01 | 0.22 |
| Oct. | | | | | 1.00 | 0.20 |
| Non-Monsoon | | | | | | -0.08 |

Table 4(b) Correlation Matrix for Belgaum(obsy)

| | June | July | Aug | Sept | Oct. | Monsoon total |
|---|---|---|---|---|---|---|
| June | 1.00 | -0.15 | -0.14 | 0.08 | 0.24 | 0.08 |
| July | | 1.00 | -0.02 | -0.08 | -0.14 | 0.12 |
| Aug. | | | 1.00 | -0.10 | -0.15 | 0.08 |
| Sept | | | | 1.00 | 0.03 | 0.10 |
| Oct. | | | | | 1.00 | 0.11 |
| Non-Monsoon | | | | | | 0.06 |

Table 4(c) Correlation Matrix for Bailhongal

| | June | July | Aug. | Sept. | Oct. | Monsoon total |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.05 | -0.16 | -0.04 | 0.09 | -0.10 |
| July | | 1.00 | 0.01 | 0.06 | -0.15 | -0.08 |
| Aug. | | | 1.00 | 0.00 | 0.16 | -0.08 |
| Sept. | | | | 1.00 | 0.06 | -0.07 |
| Oct. | | | | | 1.00 | -0.09 |
| Non-Monsoon | | | | | | 0.13 |

Table 4(d) Correlation Matrix for Gokak

| | June | July | Aug | Sept. | Oct. | Monsoon total |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.24 | -0.17 | 0.09 | -0.11 | -0.13 |
| July | | 1.00 | -0.14 | 0.15 | -0.01 | -0.11 |
| Aug. | | | 1.00 | 0.22 | 0.07 | -0.09 |
| Sept. | | | | 1.00 | 0.14 | -0.09 |
| Oct. | | | | | 1.00 | -0.09 |
| Non-Monsoon | | | | | | 0.00 |

Table 4(e) Correlation Matrix for Hukeri

| | June | July | Aug. | Sept. | Oct. | Monsoon Total |
|---|---|---|---|---|---|---|
| June | 1.00 | -0.06 | -0.11 | 0.00 | 0.05 | -0.09 |
| July | | 1.00 | -0.03 | -0.05 | 0.21 | -0.06 |
| Aug. | | | 1.00 | -0.02 | -0.01 | -0.05 |
| Sept. | | | | 1.00 | 0.01 | -0.03 |
| Oct. | | | | | 1.00 | -0.05 |
| Non-monsoon | | | | | | 0.14 |

Table 4(f) Correlation Matrix for Chikodi

| | June | July | Aug. | Sept. | Oct. | Monsoon Total |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.01 | -0.06 | 0.11 | -0.01 | -0.16 |
| July | | 1.00 | -0.01 | -0.03 | -0.02 | -0.17 |
| Aug. | | | 1.00 | 0.04 | 0.06 | --0.19 |
| Sept. | | | | 1.00 | 0.04 | -0.19 |
| Oct. | | | | | 1.00 | -0.24 |
| Non-monsoon | | | | | | -0.01 |

Table 4(g) Correlation Matrix for Ramdurg

| | June | July | Aug. | Sept. | Oct. | Monsoon Total |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.15 | 0.14 | 0.06 | -0.20 | -0.22 |
| July | | 1.00 | -0.12 | -0.02 | -0.11 | -0.30 |
| Aug. | | | 1.00 | 0.04 | -0.03 | -0.28 |
| Sept. | | | | 1.00 | 0.06 | -0.27 |
| Oct. | | | | | 1.00 | -0.24 |
| Non-Monsoon | | | | | | -0.03 |

Table 4(h) Correlation Matrix for Athni

| | June | July | Aug | Sept | Oct. | Monsoon |
|---|---|---|---|---|---|---|
| June | 1.00 | -0.06 | -0.06 | -0.04 | -0.13 | -0.13 |
| July | | 1.00 | 0.00 | -0.05 | 0.04 | -0.14 |
| August | | | 1.00 | 0.11 | 0.06 | -0.13 |
| Sept. | | | | 1.00 | 0.08 | -0.13 |
| Oct. | | | | | 1.00 | -0.11 |
| Non-Monsoon | | | | | | -0.01 |

Table 4(i) Correlation Matrix for Bijapur

| | June | July | Aug. | Sept. | Oct. | Monsoon |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.02 | -0.09 | 0.04 | -0.10 | 0.03 |
| July | | 1.00 | 0.14 | -0.05 | 0.00 | 0.04 |
| Aug. | | | 1.00 | -0.03 | 0.07 | 0.06 |
| Sep . | | | | 1.00 | 0.00 | 0.04 |
| Oct. | | | | | 1.00 | 0.07 |
| Non-monsoon | | | | | | 0.08 |

Table 4(j) Correlation Matrix for Dharwar

| | June | July | Aug. | Sept. | Oct. | Monsoon |
|---|---|---|---|---|---|---|
| June | 1.00 | 0.31 | -0.15 | -0.01 | 0.01 | 0.04 |
| July | | 1.00 | -0.03 | 0.20 | 0.08 | 0.07 |
| Aug. | | | 1.00 | 0.07 | 0.21 | 0.07 |
| Sept. | | | | 1.00 | -0.15 | 0.08 |
| Oct. | | | | | 1.00 | 0.05 |
| Non-Monsoon | | | | | | 0.15 |

Table 5: Decadal Mean & $T_k$ values of Annual Rainfall Series

| Station | 1901-10 | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971-80 |
|---|---|---|---|---|---|---|---|---|
| Khanapur | 1614.1 (-.51) | 1536.0 (-.70) | 1695.1 (-.31) | 1732.9 ( -.22) | 1841.8 (.04) | 2084.5 (.63 ) | 2104.9 (.68) | 1966.6 (.34) |
| Belgaum | 1218.8 (-.46) | 1310.9 (-.15) | 1231.8 (.41) | 1372.4 (.05) | 1383.0 ( .08) | 1643.7** ( .94) | 1469.1 (.37) | 1336.3 (-.07) |
| Bailhongal | 686.9 (-.11) | 739.2 (.17) | 686.5 (-.11) | 666.8 (-.22) | 762.2 (.30) | 756.5 (.27) | 647.2 -.33) | 730.3 (.13) |
| Hukeri | 601.0 (-.66) | 716.3 (-.07) | 568.3 (-.83) | 748.1 (.10) | 743.8 (.07) | 959.0 (1.20)* | 781.5 (.27) | 758.9 (.15) |
| Gokak | 582.7 (.15) | 613.7 (.36) | 516.2 (-.29) | 592.5 (.22) | 515.0 (-.30) | 592.8 (.22) | 563.9 (.03) | 533.1 (-.18) |
| Chikodi | 658.8 (.12) | 685.8 (.29) | 596.4 (-.26) | 632.6 (-.04) | 588.7 (-.31) | 738.0 (.61) | 552.7 (.53) | 632.5 (.04) |
| Ramdurg | 552.5 -(.01) | 637.1 (.56) | 481.5 (-.49) | 596.1 (.28) | 595.8 (.28) | 538.9 (-.06) | 544.6 (-.06) | 485.4 (-.46) |
| Athni | 572.6 -(.006) | 630.7 (.32) | 480.9 (-52) | 674.0 (.56) | 579.1 (.03) | 591.1 (.10) | 522.4 (-.29) | 565.7 -(.04) |
| Belgaon Dist. | 808.6 (-.27) | 844.8 (-.03) | 773.3 (-.51) | 857.3 (.05) | 852.7 (.02) | 952.8 (.69) | 874.4 (.17) | 857.9 (.06) |
| Malaprabha | 1206.3 (-.47) | 1191.0 (-.52) | 1244.2 (-.33) | 1273.5 (-.22) | 1362.0 (.11) | 1512.6 (.66) | 1471.1 (.51) | 1414.0 (.30) |
| Bijapur | 479.5 ( -.50) | 529.8 (-.24) | 496.4 (-.42) | 559.5 (-.09) | 536.5 (-.21) | 676.5 (.52) | 661.1 (.44) | 674.7 (.50) |
| Dharwar | 766.6 (-.33) | 853.3 (.14) | 806.5 (-.11) | 784.7 (-.23) | 855.9 (.15) | 970.5 (.23) | 832.4 (.02) | 730.0 (-.52) |

* Value significant at 5 % level of significance.

** Value significant at 10 % level of significance.

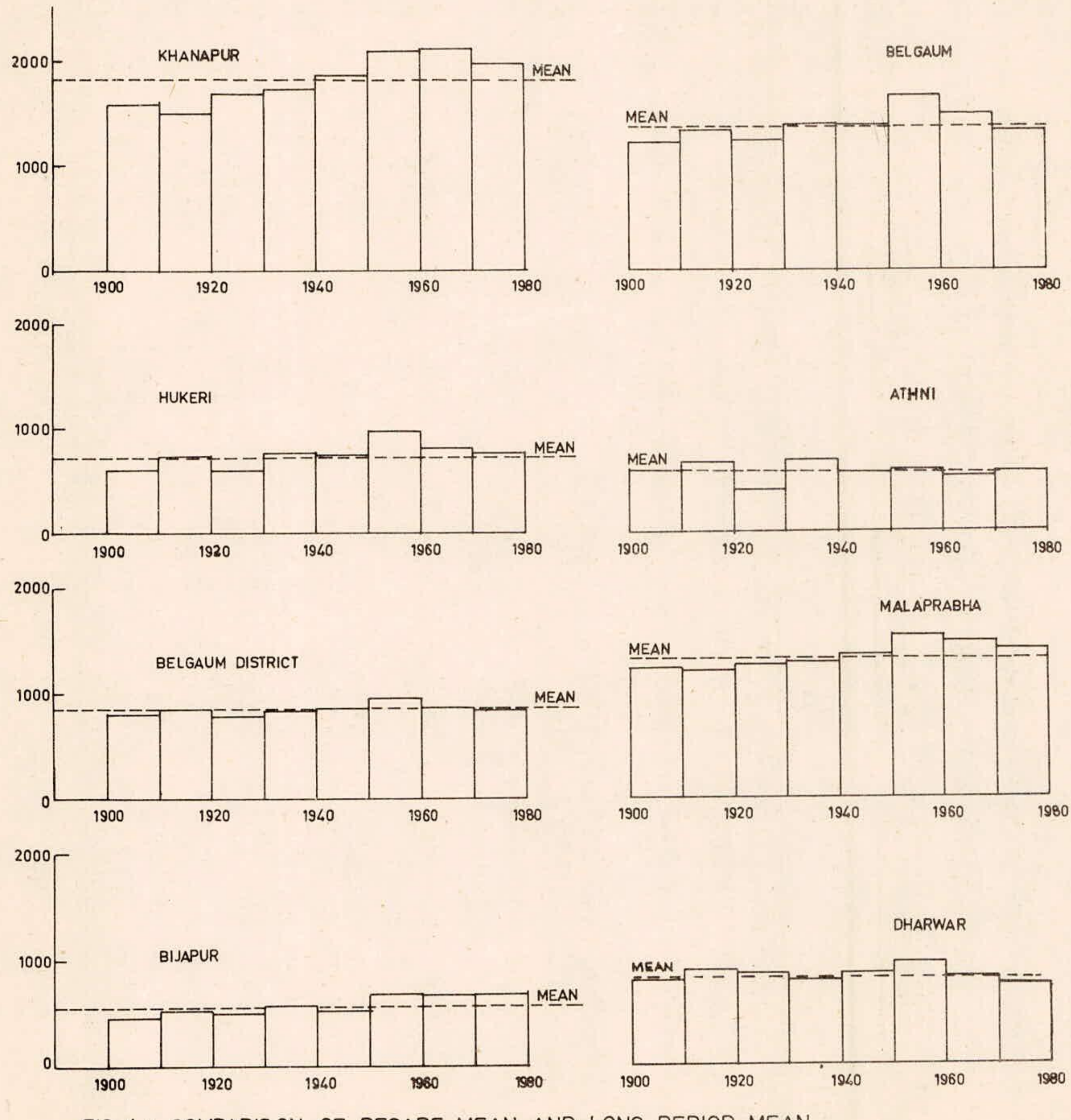


FIG. 4 :- COMPARISON OF DECADE MEAN AND LONG PERIOD MEAN

Table 6 : Progressive decade means of Annual rainfall series

| Station | 1901 to 1910 | 1901 to 1920 | 1901 to 1930 | 1901 to 1940 | 1901 to 1950 | 1901 to 1960- | 1901 to 1970 | 1901 to 1980 | 1901 to 1984 |
|---|---|---|---|---|---|---|---|---|---|
| Khanapur | 1614.1 | 1575.1 | 1615.1 | 1644.5 | 1683.9 | 1750.7 | 1801.3 | 1822.0 | 1824.5 |
| Belgaum | 1218.2 | 1264.8 | 1253.8 | 1283.5 | 1303.4 | 1360.1 | 1375.6 | 1370.7 | 1357.5 |
| Bailhongal | 686.9 | 713.1 | 704.2 | 694.9 | 708.3 | 716.4 | 706.5 | 709.4 | 707.3 |
| Hukeri | 600.9 | 658.6 | 628.5 | 658.4 | 675.5 | 722.7 | 731.1 | 734.6 | 729.4 |
| Gokak | 582.7 | 598.2 | 570.9 | 576.3 | 564.0 | 568.8 | 568.1 | 563.7 | 559.8 |
| Chikodi | 658.8 | 672.3 | 647.0 | 643.4 | 632.5 | 650.0 | 636.1 | 635.7 | 638.9 |
| Ramdurg | 552.5 | 594.8 | 557.0 | 566.8 | 572.6 | 567.0 | 563.8 | 554.0 | 553.9 |
| Athni | 572.6 | 601.7 | 561.4 | 589.5 | 587.4 | 588.1 | 578.7 | 577.1 | 573.7 |
| Belgaum Dist. | 808.6 | 826.7 | 808.9 | 821.0 | 827.3 | 848.3 | 852.0 | 852.7 | 849.5 |
| Malaprabha | 1206.3 | 1198.6 | 1213.8 | 1228.6 | 1255.4 | 1298.3 | 1323.0 | 1334.3 | 1333.3 |
| Bijapur (obsy) | 479.5 | 504.6 | 501.9 | 516.3 | 520.3 | 546.4 | 562.8 | 576.7 | - |
| Dharwar (obsy) | 766.6 | 809.9 | 808.8 | 802.8 | 813.4 | 839.6 | 838.5 | 806.7* | - |

* Mean based on data upto 1978 only.

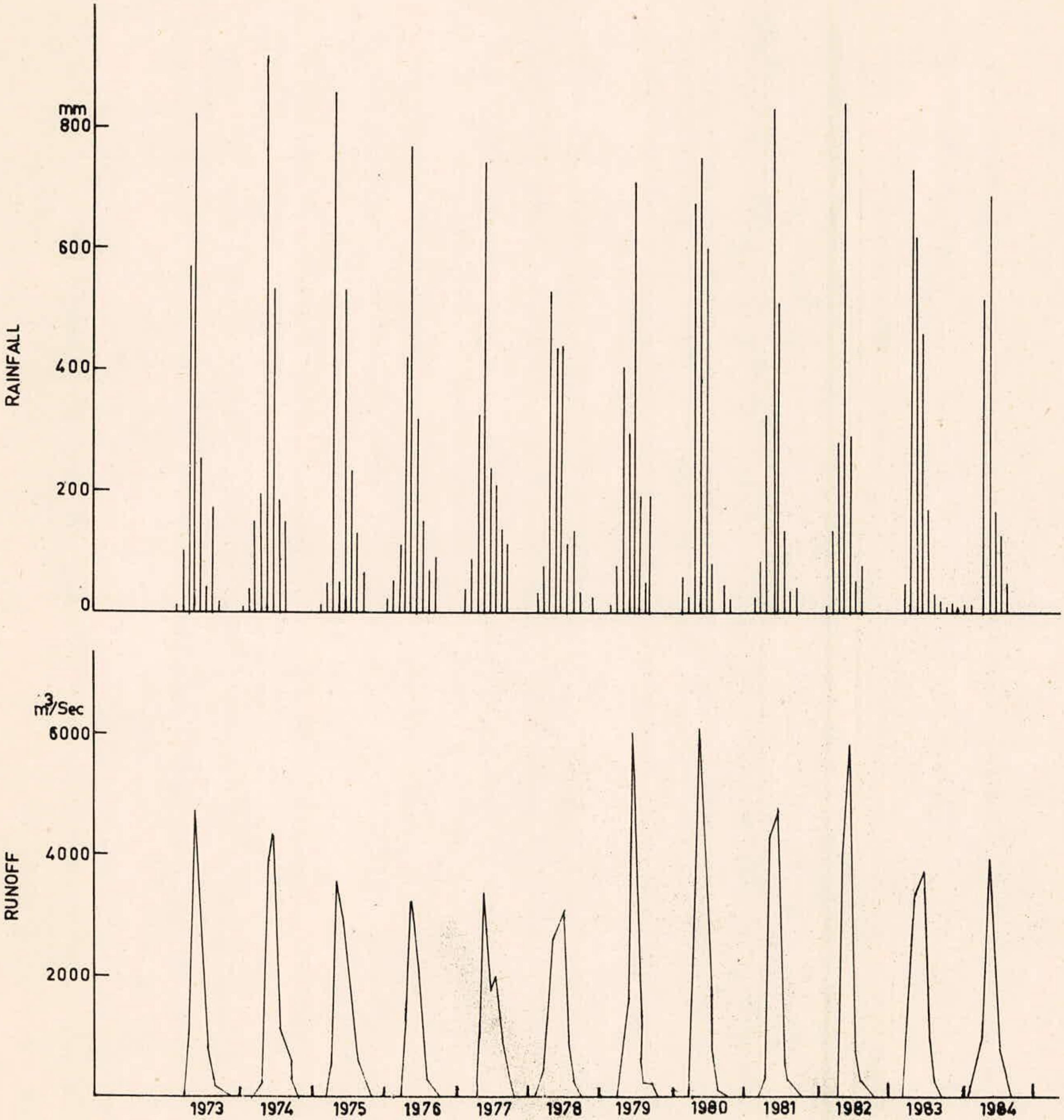


FIGURE 5 :- RAINFALL AND FLOWS AT KHANAPUR GAUGE & DISCHARGE SITE (C.A. :326 $km^2$)

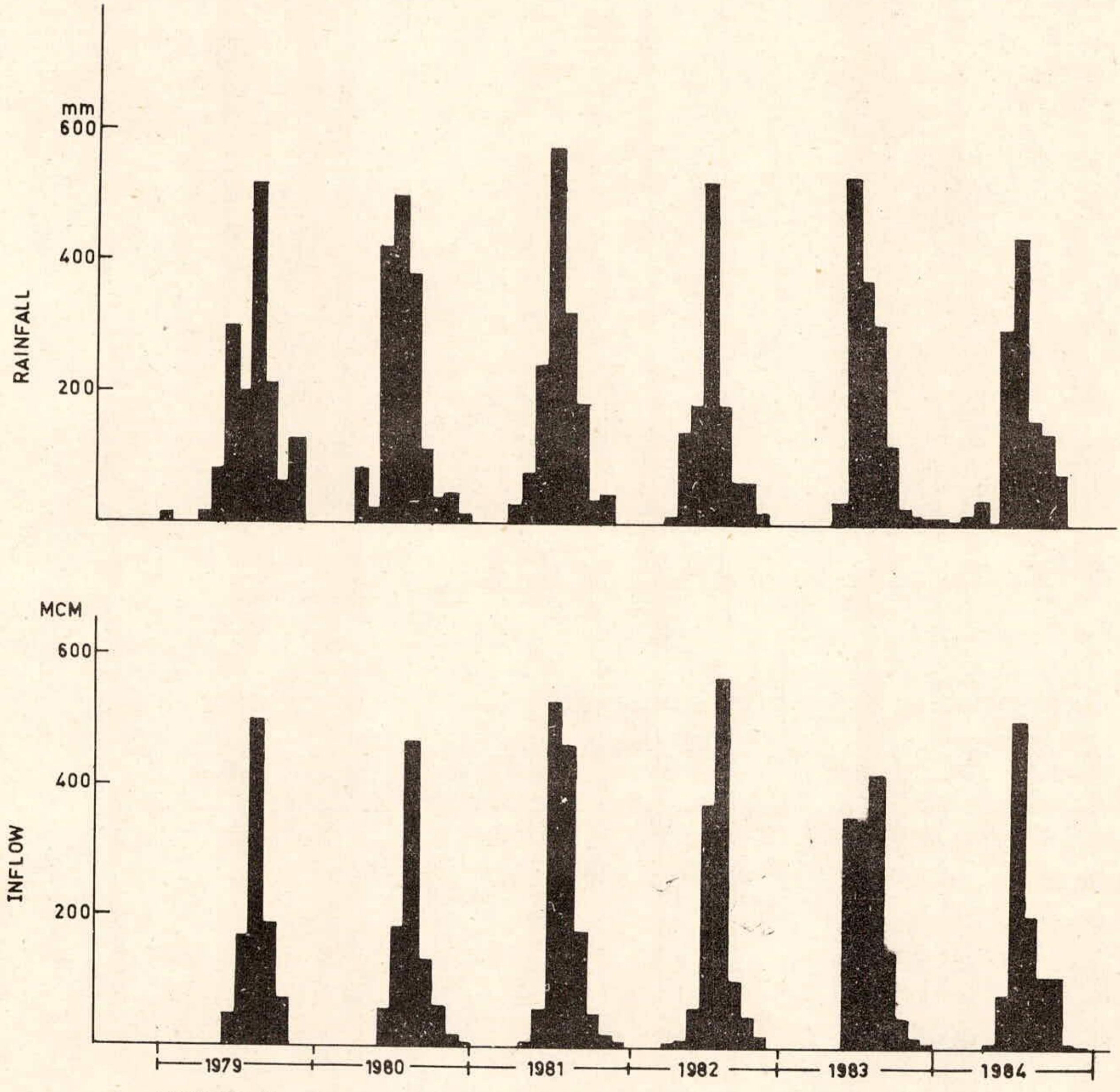

FIGURE 6 – RAINFALL AND FLOWS OF MALAPRABHA RIVER CATCHMENT UPTO NAVILUTEERTH

Table 7(a)(i) Linear Regression Coefficients of Khanapur Rainfall for the period 1901-84 for the period 1901-84

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.012 | 1.15 | 0.00 | 0.11 |
| February | 0.070 | 1.20 | -0.01 | -0.64 |
| March | 0.018 | 5.20 | -0.01 | -0.17 |
| April | 0.066 | 31.88 | -0.07 | -0.60 |
| May | 0.178 | 44.71 | 0.48 | 1.64 |
| June | 0.274 | 241.64 | 1.88 | 2.58** |
| July | 0.137 | 655.9 | 1.78 | 1.25 |
| August | 0.182 | 317.24 | 1.50 | 1.67 |
| September | 0.191 | 102.60 | 0.50 | 1.76 |
| October | 0.058 | 104.29 | 0.18 | 0.52 |
| November | 0.084 | 31.56 | 0.16 | 0.76 |
| December | 0.222 | 16.78 | -0.23 | -2.07** |
| Annual | 0.386 | 1546.54 | 6.54 | 3.79* |

Table 7(a)(ii) Linear Regression Coefficients of Khanapur Rainfall for the period 1901-60

| Month | Correlation Coeffcient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.240 | 2.35 | -0.04 | -1.88 |
| February | 0.129 | 1.59 | -0.02 | -0.99 |
| March | 0.108 | 3.44 | 0.07 | 0.83 |
| April | 0.045 | 28.49 | 0.07 | 0.35 |
| May | 0.133 | 45.41 | 0.37 | 1.02 |
| June | .179 | 259.27 | 1.45 | 1.39 |
| July | 0.217 | 599.60 | 3.68 | 1.69 |
| August | 0.107 | 321.88 | 1.17 | 0.82 |
| September | 0.118 | 103.47 | 0.43 | 0.91 |
| October | 0. 341 | 69.38 | 1.60 | 2.76 |
| November | 0.019 | 36.31 | -0.04 | -0.15 |
| December | 0.250 | 21.30 | -0.42 | -1.97 |
| Annual | 0.369 | 1484.38 | 8.73 | 3.03* |

* Significance at 1 % level of significance ** Significant at 5 % level

Table 7(a) (iii) Linear Regression Coefficients of Khanapur Rainfall for the period 1961-84

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.361 | -2.14 | 0.31 | 1.82 |
| February | 0.307 | -0.38 | 0.09 | 1.51 |
| March | 0.087 | -2.01 | 0.09 | 0.41 |
| April | 0.010 | 23.40 | 0.03 | 0.05 |
| May | 0.273 | 131.7 | -3.64 | -1.33 |
| June | 0.608 | 134.2 | 18.60 | 3.60* |
| July | 0.465 | 1085.47 | -24.34 | -2.46** |
| August | 0.169 | 505.10 | -5.25 | -0.80 |
| September | 0.110 | 153.14 | -0.94 | -0.52 |
| October | 0.474 | 139.61 | -3.49 | -2.52** |
| November | 0.046 | 41.12 | 0.41 | 0.215 |
| December | 0.133 | 5.23 | -0.15 | -0.63 |
| Annual | 0.341 | 2225.08 | -17.32 | -1.7 |

*Significant at 1% level of significance
** Significant at 5% level of significance

Table 7(b)(i): Linear Regression of Belgaum for the period 1901-84

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | .257 | 5.72 | -0.08 | -2.41 |
| February | .130 | .56 | 0.04 | 1.19 |
| March | .009 | 9.21 | 0.01 | 0.08 |
| April | .130 | 38.01 | 0.21 | 1.19 |
| May | .239 | 52.08 | 0.71 | 2.23** |
| June | .142 | 177.25 | 0.65 | 1.30 |
| July | 0.34 | 469.04 | 0.27 | -0.31 |
| August | .028 | 252.10 | 0.17 | 0.26 |
| September | .082 | 113.05 | 0.22 | 0.74 |
| October | .077 | 107.48 | 0.34 | 0.70 |
| November | .001 | 39.69 | 0.00 | -0.008 |
| December | .172 | 16.11 | -0.17 | -1.58 |
| Annual | .146 | 1280.27 | 1.82 | 1.33 |

Table 7(b)(ii) Linear Regression of Belgaum Rainfall for the period 1901-52

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.186 | 6.61 | -0.12 | -1.34 |
| February | 0.026 | 1.56 | -0.01 | -0.18 |
| March | 0.122 | 5.60 | 0.15 | 0.87 |
| April | 0.168 | 32.42 | 0.46 | 1.21 |
| May | 0.150 | 52.06 | 0.54 | 1.07 |
| June | 0.027 | 195.86 | -0.15 | -0.19 |
| July | 0.097 | 423.65 | -1.30 | 0.69 |
| August | 0.005 | 247.29 | 0.05 | 0.04 |
| September | 0.072 | 125.46 | -0.32 | -0.51 |
| October | -0.232 | 80.67 | 1.23 | -1.69 |
| November | 0.026 | 42.42 | -0.09 | -0.18 |
| December | 0.159 | 19.08 | -0.31 | -1.14 |
| Annual | 0.153 | 1232.69 | 2.74 | 1.09 |

Table 7b(iii) Linear Regression of Belgaum for the period 1953-84

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | .092 | 0.31 | -0.01 | -0.507 |
| February | .011 | 4.25 | -0.01 | -0.038 |
| March | .271 | 16.24 | -0.42 | -1.542 |
| April | .021 | 51.97 | -0.08 | -0.114 |
| May | .225 | 143.83 | -2.16 | -1.263 |
| June | .133 | 192.31 | 2.03 | 0.733 |
| July | .515 | 622.39 | -10.04 | -3.29* |
| August | .341 | 370.37 | -5.69 | -1.99 |
| September | .145 | 114.66 | 1.01 | 0.80 |
| October | .405 | 234.52 | -5.99 | -2.42** |
| November | .168 | 26.03 | 0.77 | 0.93 |
| December | .067 | 6.82 | -0.09 | -0.37 |
| Annual | .573 | 1784.08 | -20.7 | -3.83* |

* Significant at 1% level of significance **Significant at 5% level

Table 7(c) Linear Regression Coefficients of Bailhongal Rainfall

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.124 | 1.81 | -0.02 | -1.12 |
| February | 0.041 | 1.81 | -0.01 | -0.37 |
| March | 0.112 | 9.24 | -0.06 | -1.02 |
| April | 0.087 | 39.81 | -0.11 | -0.79 |
| May | 0.125 | 59.79 | 0.29 | 1.14 |
| June | 0.304 | 277.13 | -3.16 | -2.89* |
| July | 0.012 | 133.22 | 0.03 | 0.11 |
| August | 0.065 | 78.16 | 0.19 | 0.59 |
| September | 0.015 | 107.14 | 0.05 | 0.14 |
| October | 0.008 | 115.77 | 0.03 | 0.08 |
| November | 0.080 | 42.43 | -0.14 | -0.73 |
| December | 0.185 | 12.41 | -0.13 | -1.70 |
| Annual | Could not be computed because of square root of negative value. | | | |

Table 7(d) Linear Regression Coefficients of Gokak Rainfall

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.133 | 4.35 | -0.04 | -1.22 |
| February | 0.116 | 0.19 | 0.04 | 1.06 |
| March | 0.083 | 4.84 | 0.05 | 0.76 |
| April | 0.015 | 31.31 | -0.02 | -0.13 |
| May | 0.076 | 57.75 | 0.17 | 0.70 |
| June | 0.105 | 72.54 | -0.19 | -0.96 |
| July | 0.046 | 79.68 | -0.09 | -0.42 |
| August | 0.115 | 69.40 | -0.25 | -1.05 |
| September | 0.091 | 91.09 | 0.25 | 0.83 |
| October | 0.085 | 117.45 | -0.26 | -0.78 |
| November | 0.147 | 50.93 | -0.28 | -1.35 |
| December | 0.168 | 12.57 | -0.12 | -1.54 |
| Annual | 0.125 | 592.42 | -0.77 | -1.14 |

* Significant at 1 % level of significance.

Table 7(e) Linear Regression Coefficients of Hukeri Rainfall(1901-84)

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.168 | 2.38 | -0.03 | -1.54 |
| February | 0.051 | 2.41 | -0.01 | -0.47 |
| March | 0.039 | 7.73 | 0.02 | 0.35 |
| April | 0.089 | 30.32 | 0.12 | 0.81 |
| May | 0.213 | 56.25 | 0.59 | 1.98 |
| June | 0.129 | 77.30 | 0.30 | 1.18 |
| July | 0.157 | 124.19 | 0.50 | 1.44 |
| August | 0.125 | 75.42 | 0.30 | 1.14 |
| September | 0.102 | 95.77 | 0.29 | 0.93 |
| October | 0.115 | 102.23 | 0.36 | 1.05 |
| November | 0.038 | 39.60 | 0.09 | 0.35 |
| December | 0.242 | 20.14 | -0.26 | -2.26 |
| Annual | 0.281 | 634.65 | 2.23 | 2.65* |

* Significant at 5 % level of significance.

Table 7(f) Linear Regression Coefficients of Chikodi Rainfall for the period (1901-84)

| Month | Correlation Coefficient | Constant | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.096 | 2.63 | -0.02 | -0.87 |
| February | 0.054 | 1.32 | -0.01 | -0.49 |
| March | 0.017 | 6.13 | 0.01 | 0.15 |
| April | 0.192 | 39.21 | -0.23 | -1.77 |
| May | 0.162 | 45.73 | 0.32 | 1.49 |
| June | 0.009 | 78.77 | 0.02 | 0.09 |
| July | 0.041 | 134.15 | -0.10 | -0.37 |
| August | 0.105 | 79.15 | 0.25 | 0.96 |
| September | 0.037 | 92.45 | 0.10 | 0.34 |
| October | 0.119 | 114.22 | -0.33 | -1.08 |
| November | 0.051 | 40.73 | -0.09 | -0.46 |
| December | 0.166 | 14.61 | -0.15 | -1.52 |
| Annual | 0.035 | 648.84 | -0.23 | -0.32 |

Table 7(g) Linear Regression Coefficients of Rainfall at Ramdurg for the period (1901-84)

| Month | Correlation Coefficient | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | .036 | 2.20 | -0.01 | -0.33 |
| February | .181 | 3.78 | -0.04 | -1.67 |
| March | .107 | 11.19 | -0.07 | -0.98 |
| April | .140 | 34.52 | -0.15 | -1.28 |
| May | .076 | 42.5 | 0.14 | 0.69 |
| June | .005 | 68.25 | -0.01 | -0.05 |
| July | .149 | 81.62 | -0.25 | -1.37 |
| August | .089 | 73.91 | -0.24 | -0.81 |
| September | .053 | 112.18 | 0.116 | 0.48 |
| October | .097 | 80.71 | 0.25 | 0.88 |
| November | .147 | 53.76 | -0.36 | -1.34 |
| December | .228 | 15.40 | -0.19 | -2.12 |
| Annual | .130 | 587.58 | -0.79 | -1.19 |

* Significant at 5 % level of Significance

Table 7(h) Linear Regression Coefficients of Rainfall of Athni for the period (1901-84)

| Month | Correlation Coefficients | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.172 | 5.89 | -0.07 | -1.58 |
| February | 0.056 | 1.43 | -0.01 | -0.51 |
| March | 0.106 | 3.68 | 0.05 | 0.97 |
| April | 0.193 | 33.32 | -0.23 | -1.78 |
| May | 0.019 | 51.46 | 0.03 | 0.17 |
| June | 0.031 | 70.71 | 0.06 | 0.28 |
| July | 0.110 | 84.12 | -0.25 | -1.00 |
| August | 0.157 | 81.43 | -0.40 | -1.44 |
| September | .012 | 139.77 | -0.04 | -0.10 |
| October | .076 | 84.64 | 0.26 | 0.69 |
| November | .012 | 31.87 | 0.02 | 0.105 |
| December | .072 | 11.23 | -0.07 | -0.65 |
| Annual | .079 | 598.44 | -0.58 | -0.72 |

Table 7(i) Linear Regression Coefficients of Rainfall at Belgaum District for the period(1901-84)

| Month | Correlation Coefficient | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.175 | 3.32 | -0.03 | -1.61 |
| February | 0.035 | 1.67 | 0.00 | -0.32 |
| March | 0.003 | 6.71 | 0.00 | 0.025 |
| April | 0.109 | 35.01 | -0.09 | -0.99 |
| May | 0.160 | 51.75 | 0.28 | 1.47 |
| June | 0.011 | 126.18 | 0.03 | 0.10 |
| July | 0.040 | 215.32 | 0.14 | 0.37 |
| August | 0.051 | 126.76 | 0.14 | 0.46 |
| September | 0.067 | 108.68 | 0.15 | 0.60 |
| October | 0.021 | 103.56 | 0.05 | 0.19 |
| November | 0.057 | 42.06 | -0.10 | -0.51 |
| December | 0.195 | 14.24 | -0.16 | -1.80 |
| Annual | 0.123 | 817.36 | 0.76 | 1.13 |

Table 7(j) Linear Regression Coefficients of Rainfall of Malaprabha Catchment for the period 1901-84.

| Month | Correlation Coefficient | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | .093 | 1.78 | -0.01 | -0.84 |
| February | .043 | 1.49 | -0.01 | -0.39 |
| March | .062 | 6.99 | -0.03 | -0.56 |
| April | .074 | 35.38 | -0.07 | -0.67 |
| May | .185 | 50.94 | 0.43 | 1.71 |
| June | .010 | 239.38 | -0.06 | -0.09 |
| July | .117 | 428.57 | 0.94 | 1.07 |
| August | .162 | 215.08 | 0.86 | 1.49 |
| September | .126 | 105.67 | 0.29 | 1.15 |
| October | .045 | 108.73 | 0.13 | 0.41 |
| November | .008 | 37.43 | 0.01 | 0.07 |
| December | .213 | 14.90 | -0.19 | -1.98 |
| Annual | .319 | 1182.0 | 3.56 | 3.04* |

* Significant at 1 % level of significance

Table 7(k) Linear Regression Coefficients of Rainfall of Bijapur(obsy)

for the period (1901-80)

| Month | Correlation Coefficient | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | 0.141 | 6.90 | -0.08 | -1.26 |
| February | 0.105 | 1.37 | 0.04 | 0.93 |
| March | 0.020 | 6.55 | -0.01 | -0.18 |
| April | 0.134 | 16.30 | 0.14 | 1.19 |
| May | 0.228 | 22.64 | 0.33 | 2.07** |
| June | 0.052 | 74.29 | 0.12 | 0.46 |
| July | 0.221 | 49.43 | 0.60 | 2.00** |
| August | 0.181 | 54.24 | 0.49 | 1.62 |
| September | 0.103 | 131.40 | 0.40 | 0.91 |
| October | 0.306 | 53.75 | 1.02 | 2.83 * |
| November | 0.018 | 28.73 | 0.04 | 0.16 |
| December | 0.135 | 9.08 | -0.08 | -1.20 |
| Annual | 0.363 | 454.69 | 3.01 | 3.44* |

**Significant at 5% level of significance.
* Significant at 1 % level of Significance.

Table 7(I) Linear Regression Coefficients of Rainfall at Dharwar(obsy)

for the period 1901-78

| Month | Correlation Coefficient | Intercept | Regression Coefficient | t value |
|---|---|---|---|---|
| January | .083 | 2.17 | -0.02 | -0.73 |
| February | .036 | 1.69 | -0.01 | -0.31 |
| March | .048 | 8.45 | -0.03 | -0.42 |
| April | .127 | 41.87 | 0.20 | 1.12 |
| May | .047 | 75.67 | 0.11 | 0.41 |
| June | .098 | 95.67 | 0.25 | 0.86 |
| July | .035 | 172.32 | 0.13 | 0.31 |
| August | .116 | 129.13 | -0.35 | -1.02 |
| September | .123 | 95.39 | 0.40 | 1.08 |
| October | .023 | 127.13 | -0.08 | -0.20 |
| November | .005 | 45.71 | 0.01 | 0.04 |
| December | .183 | 19.87 | -0.25 | -1.62 |
| Annual | .042 | 814.0 | 0.34 | 0.36 |

Table 8: Polynomial regression coefficients of monthly rainfall time series

| Station | No. of Obser-vations | Degree | Inter-cept | Ist Reg. Coeff. | 2nd Reg. Coeff. $10^{-5}$ | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 1008 | 2 | 123.32 | 0.078 | .02 | 1.43 |
| Belgaum | 1008 | 1 | 107.59 | 0.0117 | - | 0.46 |
| Bailhongal | 1008 | 1 | 72.89 | 0.02 | - | 3.43 |
| Gokak | 1008 | 2 | 48.98 | -.0048 | 7.0 | 0.28 |
| Hukeri | 1008 | 2 | 45.50 | 0.5 | 0.4 | 3.25 |
| Chikodi | 1008 | 1 | 53.70 | -0.0009 | - | 0.02 |
| Ramdurg | 1008 | 2 | 46.43 | 0.0078 | 5.0 | 0.41 |
| Raibag | 612 | 1 | 43.06 | 0.0006 | - | 0.0 |
| Athni | 1008 | 1 | 49.54 | -0.0037 | - | 0.27 |
| Belgaum Distt. | 1008 | 2 | 67.71 | 0.038 | 6.0 | 0.12 |
| Malaprabha | 1008 | 2 | 104.59 | 0.009 | 1.4 | 0.49 |
| Bijapur | 960 | 2 | 38.55 | 0.015 | 3.0 | 4.05 + |
| Dharwar | 936 | 1 | 67.45 | 0.003 | - | 0.14 |

+ Significant of 5 percent level of Significance

Table 9: **Polynomial regression** coefficients of Monsoon total rainfall time series

| Station | No. of observations | Degree | Intercept | Ist Reg. Coeff. | 2nd Reg. Coeff. | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 84 | 2 | 1335.1 | 11.88 | -0.07 | 6.39 + |
| Belgaum | 84 | 1 | 1118.9 | 1.10 | -- | 0.68 |
| Bailhongal | 84 | 1 | 713.4 | -2.86 | -- | 5.21 + |
| Gokak | 84 | 2 | 439.6 | -1.206 | 0.007 | 0.62 |
| Hukeri | 84 | 2 | 399.0 | 7.03 | -0.06 | 5.53 + |
| Chikodi | 84 | 1 | 498.74 | -0.05 | - | 0.01 |
| Ramdurg | 84 | 1 | 416.66 | -0.09 | - | 0.03 |
| Raibag | 51 | 1 | 399.0 | -0.009 | -- | 0.0 |
| Athni | 84 | 1 | 460.67 | -0.37 | - | 0.28 |
| Belgaum Distt. | 84 | 2 | 671.64 | 1.12 | -0.007 | 0.37 |
| Malaprabha | 84 | 2 | 1108.09 | 1.41 | 0.008 | 1.60 |
| Bijapur | 80 | 2 | 377.16 | 1.59 | $.6\times10^{-5}$ | 5.34 + |
| Dharwar | 78 | 2 | 564.76 | 4.46 | -0.05 | 0.95 |

+ Significant of 5 percent level of Significance

Table 10: Polynomial regression of Non-monsoon total rainfall time series

| Station | No.of observation | Degree | Intercept | Ist Reg. Coeff | 2nd Reg. Coeff | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 84 | 2 | 140.33 | -0.18 | 0.005 | 0.25 |
| Belgaum | 84 | 2 | 125.24 | 3.04 | -0.02 | 2.12 |
| Bailhongal | 84 | 1 | 163.96 | -0.16 | - | 0.20 |
| Gokak | 84 | 1 | 157.32 | -0.17 | - | 0.22 |
| Hukeri | 84 | 1 | 156.0 | 0.49 | - | 0.98 |
| Chikodi | 84 | 1 | 148.52 | 0.189 | - | 0.27 |
| Ramdurg | 84 | 1 | 167.40 | -0.66 | - | 2.93 |
| Raibag | 51 | 1 | 130.0 | -0.46 | - | 0.49 |
| Athni | 84 | 2 | 136.02 | -0.15 | -0.001 | 0.32 |
| Belgaum Distt. | 84 | 1 | 152.81 | -0.11 | - | 0.14 |
| Malaprabha | 84 | 1 | 194.75 | -0.04 | - | 0.01 |
| Bijapur | 80 | 2 | 82.22 | 1.12 | $4.1\times10^{-5}$ | 0.58 |
| Dharwar | 78 | 1 | 194.75 | -0.04 | - | 0.01 |

Table 11: Polynomial regression coefficients of Annual rainfall time series

| Station | No. of observation | Degree | Intercept | Ist Reg. Coeff | 2nd Reg, Coeff | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 84 | 2 | 1481.31 | 11.08 | -0.05 | 7.35 + |
| Belgaum | 84 | 1 | 1280.27 | 1.81 | - | 1.78 |
| Bailhongal | 84 | 1 | 706.7 | 0.01 | - | 0.0 |
| Gokak | 84 | 2 | 593.84 | -0.86 | 0.001 | 0.64 |
| Hukeri | 84 | 2 | 539.4 | 8.8 | -0.07 | 5.78 + |
| Chikodi | 84 | 1 | 648.84 | -0.23 | - | 0.10 |
| Ramdurg | 84 | 2 | 560.93 | 1.06 | -0.02 | 0.96 |
| Raibag | 51 | 1 | 519.50 | -0.08 | - | 0.0 |
| Athni | 84 | 1 | 598.45 | -0.58 | - | 0.52 |
| Belgaum Distt. | 84 | 2 | 781.33 | 3.27 | -0.03 | 1.09 |
| Malaprabha | 84 | 2 | 1131.31 | 7.09 | -0.04 | 4.9 + |
| Bijapur | 80 | 2 | 464.83 | 2.27 | 0.009 | 5.87 + |
| Dharwar | 78 | 1 | 813.98 | 0.339 | - | 0.13 |

+ Significant at 1 percent level of Significance

Table 12: Polynomial regression coefficients of Water year rainfall time series

| Station | No. of observation | Deg. | Intercept | Ist Reg. Coeff | 2nd Reg. Coeff | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 84 | 2 | 1475.4 | 11.69 | -0.06 | 6.84 + |
| Belgaum | 84 | 1 | 1277.7 | 1.80 | - | 1.58 |
| Bailhongal | 84 | 1 | 877.4 | -3.03 | - | 5.03 ++ |
| Gokak | 84 | 2 | 572.4 | 0.32 | -0.01 | 0.73 |
| Hukeri | 84 | 2 | 520.9 | 9.97 | -0.09 | 5.99 + |
| Chikodi | 84 | 1 | 647.3 | -0.24 | - | 0.11 |
| Ramdurg | 84 | 2 | 546.9 | 1.83 | -0.03 | 1.17 |
| Raibag | 51 | 1 | 530.0 | -0.47 | - | 0.14 |
| Athni | 84 | 1 | 598.5 | -0.65 | - | 0.70 |
| Belgaum Distt. | 84 | 1 | 833.3 | 0.39 | - | 0.33 |
| Malaprabha | 84 | 2 | 1248.3 | 2.08 | 0.002 | 1.59 |
| Bijapur | 80 | 2 | 459.4 | 2.72 | 0.002 | 5.36 + |
| Dharwar | 78 | 1 | 814.4 | 0.29 | - | 0.09 |

+ Significant at 5 percent level of Significance

+ Significant at 1 percent level of Significance

Table 13: Polynomial regression coefficients of 3 years moving average series of annual rainfall

| Station | No. of observations | Deg. | Intercept | Ist Reg. Coeff | 2nd Reg. Coeff | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 82 | 2 | 1493.2 | 9.98 | -0.03 | 7.35 + |
| Belgaum | 82 | 2 | 1147.2 | 10.65 | -0.09 | 2.71 |
| Bailhongal | 82 | 2 | 710.8 | -0.49 | 0.008 | 0.06 |
| Gokak | 82 | 2 | 605.5 | -1.95 | 0.01 | 0.41 |
| Hukeri | 82 | 2 | 538.5 | 8.3 | -0.06 | 6.35 + |
| Chikodi | 82 | 1 | 650.4 | -0.28 | - | 0.14 |
| Ramdurg | 82 | 2 | 560.3 | 1.12 | -0.02 | 0.85 |
| Raibag | 49 | 1 | 502.0 | 0.92 | - | 0.37 |
| Athni | 82 | 1 | 588.8 | -0.24 | - | 0.08 |
| Belgaum Distt. | 82 | 2 | 792.7 | 2,21 | -0.01 | 1.24 |
| Malaprabha | 82 | 2 | 1143.7 | 5.94 | -0.02 | 5.19 + |
| Bijapur | 78 | 2 | 477.7 | 1.02 | 0.02 | 6.85 + |
| Dharwar | 76 | 1 | 815.5 | 0.28 | - | 0,08 |

+ Significant at 1 percent level of Signifiance

Table 14: Polynomial regression coefficients of 5 year moving average series of annual rainfall

| Station | No.of obser-vation | Deg. | Intercept | Ist Reg. Coeff | 2nd Reg. Coeff | F Value |
|---|---|---|---|---|---|---|
| Khanapur | 80 | 2 | 1512.5 | 8.14 | -0.009 | 7.64 + |
| **Belgaum** | 80 | 2 | 1169.0 | 8.57 | -0.06 | 2,84 |
| Bailhongal | 80 | 2 | 710.6 | -0.47 | 0.008 | 0.04 |
| Gokak | 80 | 2 | 605.3 | -1.93 | 0.01 | 0.41 |
| Hukeri | 80 | 2 | 564.0 | 6.5 | -0.04 | 6.42 + |
| Chikodi | 80 | 2 | 678.0 | -2.08 | 0.02 | 0.34 |
| Ramdurg | 80 | 2 | 552.2 | 1.91 | -0.03 | 1.26 |
| Raibag | 47 | 1 | 501.0 | 0.97 | - | 0.36 |
| Athni | 80 | 1 | 593.1 | -0.39 | - | 0.21 |
| Belgaum Distt. | 80 | 2 | 795.4 | 1.95 | -0.01 | 1.27 |
| Malaprabha | 80 | 2 | 1155.7 | 4.8 | -0.007 | 5.47 + |
| Biajpur | 76 | 2 | 473.2 | 1.46 | 0.02 | 5.62 + |
| Dharwar | 74 | 1 | 803.3 | 0.75 | - | 0.56 |

+ Significant at 1 percent level of Significance

## 7.0 RESULTS

The graphical analysis of the annual rainfall series and their respective three year and five year moving average series did not indicate the presence of any trend for any raingauge station excepting Khanapur, Belgaum and Hukeri. Khanapur and Belgaum show a rising trend until 1961 and 1953 respectively. Since these are located in the catchment of Malaprabha, this trend is also reflected in the Malaprabha catchment rainfall series. While Khanapur does not indicate any falling trend after 1961, Belgaum shows a falling trend after 1953. At Hukeri also, there is falling trend in the rainfall after 1956. The average rainfall of Belgaum district does not show any trend.

### 7.1 Rainfall Characteristics

From tables 2(a) to 2(l) it may be seen that the monsoon season from June to October contributed nearly 80 to 90% of the annual rainfall, July being the principal rainy month. The coefficient of variation of rainfall during the non-monsoon months and season is more than that of the monsoon months' and season's rainfall. Rainfall during the monsoon months is less skewed as compared to rainfall during the non-monsoon months. With the exception of Belgaum, Bailhongal and Hukeri, the seasonal, water year and annual rainfall of all other raingauge stations, Belgaum district average and Malaprabha catchment average is nearly normally distributed as indicated by the coefficient of skewness during these periods. The coefficient of skewness of seasonal, water year and annual rainfall of Hukeri is high.

The correlation of the rainfall of monsoon months among themselves and with the monsoon total rainfall is insignificant indicating the general independent nature of rainfall occurrence. The monsoon and non-monsoon rainfall also showed similar behaviour.

## 7.2 Persistence

The serial correlation coefficient(table 3) was nearly zero at all lag values for all the rainfall series thereby showing the absence of any significant persistence in the rainfall series of the region.

## 7.3 Rainfall trends in time

From the decadal means of annual rainfall and the progressive means presented in tables 5 and 6, it may be seen that rainfall during 1901 to 1910 and after 1980 was generally low. The rainfall was high during the decades 1951-60, 1961-70 and 1971-80. From the figure 5, it may be also observed that the decadal means are very close to the long period mean. Excepting for Belgaum and Hukeri during the period 1951-60, the $T_k$ values given in table 5 for each decade are not significant for any other raingauge or district and catchment average.

## 7.4 Linear Trend

In general, the monthly rainfall series do not indicate presence of any linear trend. Linear regression analysis on split samples, however, revealed a significant rising trend in June months' rainfall at Khanapur and falling trend in the July month's rainfall at Belgaum in the last 25 to 30 years. The effect of the rising trend in June at Khanapur is also noticed in the catchment rainfall series(1962-84) of Malaprabha However, the decreasing trend in July noticed for Belgaum is not significant in the Malaprabha series.

### 7.4.1 Trend in annual series

Linear regression analysis of the annual rainfall series has revealed significant rising or falling trend at Khanapur, Belgaum, Hukeri and Bijapur. While a rising trend has been noticed in the annual rainfall series at Khanapur and Bijapur a falling trend is noticed in the series of Belgaum(1953-84) and Hukeri(1901-84)

### 7.4.2 Trends in the district and catchment average series

The presence of the rising trend noticed in the monthly or annual rainfall series of Khanapur and the falling trend noticed in the monthly and annual rainfall series of Belgaum and Hukeri is not reflected in the monthly or annual rainfall series of the district averages of Belgaum district because of the relatively small influence each of these gauges have in the determination of the district averages and the nullifying effect introduced by the rising and falling trends. As such the Belgaum district averages do not show any linear trend either in the monthly or the annual rainfall series.

## 7.5 Non-linear Trend

The continuous monthly rainfall series of Bailhongal, Bijapur and Hukeri reveal some trend as indicated by the polynomial regression coefficients in table 8. While the trend at Hukeri and Bijapur is non-linear(2nd order), the trend at Bailhongal is linear(1st order). The non-linear trend at Bijapur is significant at the 5 % level of significance while the trend indicated at Bailhongal and Hukeri is not significant.

### 7.5.1 Non-linear trend of seasonal and annual series

In addition to Bailhongal, Hukeri and Bijapur, the monsoon and water year rainfall, the polynomial regression analysis also indicate the presence of non-linear trend at Khanapur. While the trend at Bailhongal is linear(1st order) and significant at the 5 % level of significance the trend at the other three stations is non-linear and is significant at the 1% level of significance.

The non-monsoon rainfall series do not show any trend and the polynomial regression of the annual series show that the trend is present at only Khanapur, Hukeri and Bijapur and this is significant at the 1 % level of significance.

### 7.5.2 Non-linear trend of district and catchment average rainfall series

For reasons explained earlier in section 7.4.2, the polynomial regression of the district averages of Belgaum do not indicate the presence of any form of trend in either monthly, seasonal or annual rainfall series.

Monsoon, annual and water year series of Malaprabha catchment, however, reveal some trend of which only the trend in the annual rainfall series is significant at 1 % level of significance.

## 7.6 Regression of Moving Average Series

Linear and polynomial regression of the 3 year and 5 year moving average rainfall series of the raingauge stations, district and catchment average rainfall has indicated the same trends as was obtained from similar analysis with the actual rainfall series. Significant trends are noticed in the 3 year and 5 year moving average series of Khanapur, Hukeri, Bijapur and Malaprabha catchment.

## 8.0 CONCLUSIONS

From the results of the analysis, it could be broadly concluded that

(i) There is significant rising trend in the rainfall at Khanapur during the period 1901 to 1961 and at Bijapur for 1901 to 1980.

(ii) There is a falling trend in the rainfall at Belgaum and Hukeri especially for period 1953-1984.

(iii) Because of averaging of point values the trends noticed in the series of Khanapur, Belgaum and Hukeri are evened out in the average rainfall series of Belgaum district which did not indicate presence of any trend.

(iv) The flow data at Khanapur and the inflow into the reservoir on Malaprabha are in good agreement with general pattern of rainfall. The trend noticed at Khanapur is also reflected in the rainfall series of Malaprabha catchment.

The trends noticed in this study in the rainfall series for Khanapur, Belgaum, Hukeri and Bijapur raingauges may be part of a long term cycle. This however, needs further examination by studying the behaviour of rainfall series of the stations in the contiguous region. The effect of changes in land use over the years on rainfall pattern in the region would also, have to be considered in this connection.

## REFERENCES


1. Bhargava,B.N. and R.K.Bansal,(1969)"A quasi-biennial oscillation in precipitation at some Indian stations". Indian Journal of Meteorology and Geophysics, Vol.20, No.2, pp.127-128.

2. Government of Karnataka(1985),"Drought Prone Areas Programme, Belgaum district". Annual Plan 1985-86 and 1986-87.

3. Gregory, G(1956),"Regional variations in the trends of annual rainfall over the British Isles". Geography journal, Vol.122, Part III, pp.346-353.

4. India Meteorological Department(1962),"Normal Monthly and Annual Rainfall and Rainy days", Memoirs No.XXXI Part III.

5. India Meteorological Department (1970),"Monthly and Annual Rainfall and Number of Rainy days 1901-50", Vol.IV-A.

6. Jagannathan, P. and H.N.Bhalme(1973),"Changes in the pattern of distribution of monsoon rainfall over India associated with sunspot". Proceedings of the Symposium on Physical and Dynamic Climatology, Leningrad, USSR(Aug.16-20, 1971). WMO.

7. Jagannathan, P. and B.Parthasarathy(1973),"Trends and periodicities of rainfall over India". Monthly Weather Review, Vol.101, No.4, pp.371-375.

8. Koteswaram, P. and S.M.A.Alvi(1969),"Secular trends and periodicities in rainfall at West Coast stations in India". Current science Vol.38, No.10, pp.229-231.

9. Mitchell,J.M.(1968),"Some remarks on the statistical predictability of drought and related climatic anomalies", Proceedings of the Conference on the Drought in Northeastern United States (15-17 May 1967) pp 129-159.

10. Namias, J.(1968),"Further studies of drought over North-eastern United States". Proceedings of conference on the drought in the North-eastern United States (15-17 May 1967), pp.57-94.

11. Pareek,R.S., S.K.Dube and S.D.S.Abbi(1976),"A statistical study of the annual rainfall in the Sutlej catchment and annual runoff at Bhakra dam site". Indian Journal of Meteorology, Hydrology and Geophysics, Vol.27, No.3, pp.309-315.

12. Parthasarathy,B.and O.N.Dhar,(1974),"Secular variations of regional rainfall over India". Quart.journal Roy.Met.Soc.Vol.100, No.424,pp.245-257.

13. Parthasarathy, B. and O.N.Dhar,(1975),"Trend analysis of annual Indian rainfall", Hydrological Sciences Bulletin, Vol.XX,2-6, pp.257-260.

14. Pramanik,S.K. and P.Jagannathan,(1953),"Climatic Changes in India(1)-Rainfall". Indian Journal of Meteorology and Geophysics, Vol.4,No.4, pp.291-309.

15. Ramasastri,K.S.,(1979),"On the desertification and trends of rainfall in West Rajasthan", Proc. of the International Symposium on Hydrological aspects of droughts, pp.27-37.

16. Reynolds,G.(1953),"Rainfall at Bidston 1887-1951" Quart Jour.Roy. Met.Soc.Vol.79, No.390,pp.137-149.

17. Winstanley,D.(1973),"Recent rainfall trends in Africa and the Middle East and India". Nature, Vol.243, No.5407,pp.464-465.

18. World Meteorological Organisations(1966),"Climatic Change", Technical Note 79.

19. Yevjevich,V.M.(1964),"Fluctuations of wet and dry years, Part II, Analysis by Serial Correlation", Colorado State University Hydrology papers No.4.