ANALYSIS OF TRENDS AND PERIODICITIES OF RAINFALL OF SOME DISTRICTS IN EAST RAJASTHAN

SATISH CHANDRA
DIRECTOR

STUDY GROUP

K S RAMASASTRI

VIBHA JAIN

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247667(UP)
INDIA

1987-88

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Rajasthan with a total geographical area of 342271 sq.km is the third largest State in the country. Since 1979 onwards many districts in East Rajasthan have been experienc - ing deficit rainfall year after year. To understand the phenomenon of the below normal rainfall for more than two years in succession in many districts, a statistical study of rainfall data from seven contiguous districts in East Rajasthan was undertaken. These districts were Alwar, Jhunjhu- nu, Sawai Madhopur, Bharatpur, Jaipur, Tonk and Kota.

Besides tests for randomness, trend analysis by linear and polynomial regression were attempted. The study indicated that rainfall in the non-monsoon season does not have any relationship with previous monsoon season rainfall. The serial correlation is nearly zero indicating lack of any persistence.

There is no curvilinear trend although some stations in each of the districts have shown some linear trend. How- ever, only few of these trends were statistically significant. The rainfall behaviour in the region needs to be studied in the broader perspective of man made changes brought in because of water resources development and introduction of irrigation in hitherto semi arid and arid areas.

1.0   INTRODUCTION

Rajasthan with a total geographical area of 342271 sq.km. is the third largest State in the country area wise. Meteorologically the State has been divided into two sub-divisions: East Rajasthan and West Rajasthan. The major river systems, Chambal, Banas, Sahibi, Mahi and Sabarmati originate from east Rajasthan. Thus, the rainfall and water resources of this region largely determine the agriculture, economy and well being of the State.

After a relatively good period of normal and above average rainfall from 1971 onwards, during the last nine years i.e. from 1979 onwards, the State has been going through a bad patch and many districts in East Rajasthan have been experiencing deficit rainfall year after year excepting 1983, when some districts had normal or above normal rainfall. The status of monsoon rainfall in the district headquarters of districts of East Rajasthan during the last five years (1983-87) is given in Table 1.

Table 1 : MONSOON (JUN-SEPT.) RAINFALL RECIEVED AT DISTRICT HEADQUARTERS

Sl.No.	Station	Normal	1983	1984	1985	1986	1987
1.	Ajmer	460.1	917.4	616.5	386.6	278.8	159.6
2.	Bhilwara	731.7	781.3	634.2	407.2	485.7	387.9
3.	Nagaur	264.7	346.0	194.0	263.2	101.0	145.7
4.	Tonk	615.9	747.6	421.5	274.3	436.0	265.0
5.	Alwar	562.1	798.0	557.8	767.1	190.8	223.0
6.	Bharatpur	596.9	899.4	464.0	612.6	251.7	347.7
7.	Dholpur	651.8	567.8	573.0	817.1	313.1	306.0
8.	Jaipur	527.6	715.6	379.5	445.4	445.5	293.7
9.	Jhunjhunu	327.7	326.3	319.0	406.0	166.0	191.2

10.	Sikar	423.9	606.3	269.0	363.2	259.3	158.6
11.	Bundi	711.1	722.0	953.2	397.0	878.7	357.8
12.	Jhalawar	1020.5	699.1	761.2	1041.7	1234.7	878.8
13.	Kota	728.2	430.4	600.6	535.0	811.2	367.2
14.	Sawai Madhopur	842.8	909.6	490.0	485.8	829.4	445.1
15.	Banswara	881.2	659.2	1284.7	421.0	1279.6	913.0
16.	Chittor-garh	960.4	682.3	640.0	483.6	723.6	570.7
17.	Dungarpur	687.8	702.8	900.6	280.4	466.1	491.9
18.	Udaipur	586.5	848.7	597.3	508.3	277.4	327.4

Source: Rajasthan Irrigation Department

To understand the phenomenon of low rainfall in some of the districts continuously for 2 to 4 years in succession, a statistical study of the long period rainfall data of the raingauges located in these districts has been undertaken to examine the presence of any trend or periodicity in the rainfall series of the east Rajasthan region. Seven contiguous districts bordering Haryana, Delhi, Uttar Pradesh and Madhya Pradesh have been selected for this purpose. The study area is marked in the index map of Rajasthan (Fig. 1).
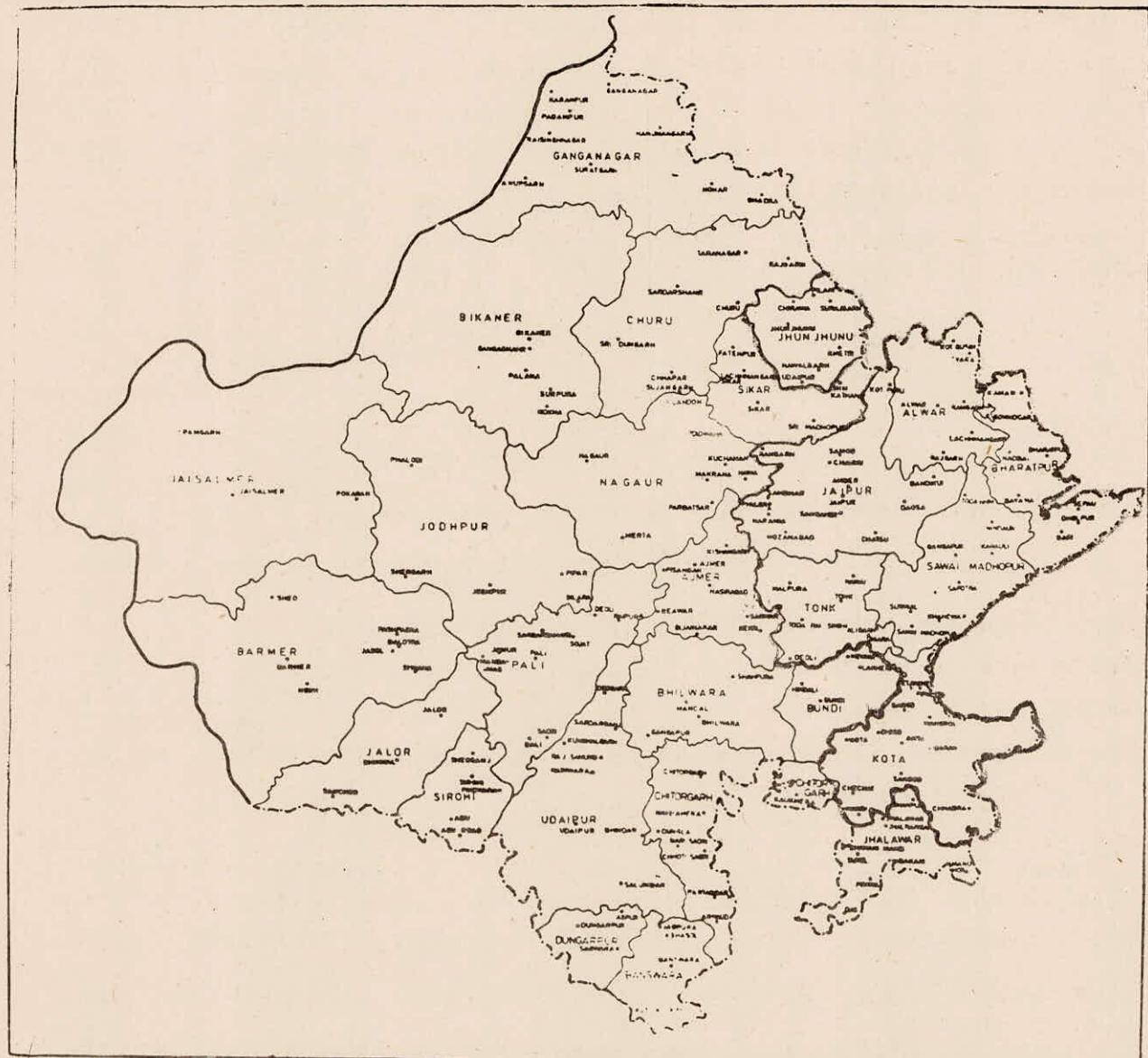
FIG.1 : INDEX MAP OF RAJASTHAN

2.0 REVIEW

Statistical analysis of rainfall data have been carried out by several workers during the last 35 years.

Namias (1968) and Mitchel (1968) studied the trends of rainfall of Central Park Observatory, New York using power spectrum analysis.

Koteswaram and Alvi (1969) and Bhargava and Bansal (1973) studied the secular trends and periodicities in the monsoon and annual rainfall of selected stations in India.

Winstanley (1973) while dealing with the aridity in the sahel zone established a 200 and 700 year harmonic cycle in behaviour of rainfall and included Bikaner and Jodhpur also in this cycle. To check the verasity of this Ramasastri (1979) studied the trends of seasonal and annual rainfall of west Rajasthan and did not notice any trend.

Dhar et al (1982) studied the trends and fluctuations of seasonal and annual rainfall of Tamil Nadu using the rainfall data of the 100 years period from 1877-1976. The analysis showed no significant increasing or decreasing tendency.

National Institute of Hydrology (1986-87) carried out statistical analysis of the monthly, seasonal and annual rainfall data of some raingauge stations in Belgaum district of Karnataka. The study indicated a rising trend upto 1954 and a falling trend in later years in the rainfall series of Belgaum. Though a rising trend was noticed upto 1962 at Khanapur, in the later years the values deviated around the long term mean. At other stations no trend whatsoever

was noticed.

Climatic changes in and around Rajasthan desert during the 20th Century were examined by Indian Institute of Tropical Meteorology (1986-87). Rainfall and temperature data during the period 1901-82 were examined in the light of change in land use pattern through irrigation. The results indicated a gradual decreasing trend in the mean annual surface temperature. The mean annual and south-west monsoon season rainfall series over most parts of the region indicated a conspicuous increasing trend.

Sharma(1986) carried out what was called a schematic study of twenty five monsoons in Rajasthan based on rainfall data during the period 1961-85. It was concluded that position of 12 districts, i.e. Nagaur, Sirohi, Ajmer, Jaipur, Sikar Jhunjhunu, Banswara, Alwar, Jalore, Dungarpur, Churu and Pali have improved whereas the position of the remaining 15 districts have shown negative trend. It is, therefore, a matter of great concern that areas of high precipitation, namely: Kota, Bundi, Jhalawar, Sawai Madhopur, Bhilwara, Chittorgarh and Udaipur are not receiving their normal rainfall. Although average monsoon rainfall has come down from 535 mm to 524 mm, i.e. by 2% during past 25 years but area wise position of deteriorating conditions reveals that 13% of area (three districts) has already deteriorated by recording less than 8% rainfall, 20% area (4 districts) is under active deterioration and 33% area (8 districts) has started deteriorating . The remaining 34% area (12 districts) has, however, been improving.

Ramanamurthy et al (1987) studied the long term variations in the rainfall over Upper Narmada catchment. Monthly, seasonal and annual areal rainfall of 38 stations in the upper Narmada catchment for the period 1901 to 1980 were analysed. To test the presence of increasing or decreasing trend, Mann-Kendall rank statistics, Crammer test and low pass filter were used. The analysis indicated an increasing trend from the beginning of the Century upto 1945 and thereafter stabilised around mean.

3.0   PROBLEM DEFINITION:

Climate is popularly thought of as some sort of average weather and its fluctuations. Climate can vary from year to year, fluctuate on time scales of several years, or change on longer time scales. Climatic fluctuation is a complex and vaguely comprehended phenomenon.

One of the methods to examine climatic shifts is the statistical analysis of the past behaviour of the set of parameters representing climate. Frequency distribution of rainfall, particularly in arid and semi-arid regions exhibit large departures from the Gaussian or normal distribution. All daily totals, many monthly and seasonal totals and some times even annual totals do not follow normal distribution. Another characteristic typical of the rainfall is the occurance of zero values. The simple climatological indices like mean and standard deviation are, therefore, inappropriate for rainfall data and can lead to erroneous conclusion.

In statistical analysis the time series is assumed to be composed of two components; the deterministic part like trend, cycle, persistence and the random component or noise. The noise is that part of climatic variability which arises from day to day weather variations. This noise is always present in a climatic statistic.

WMO (1969) has recommended a number of statistical techniques for climatological analysis. As indicated in the review several authors have attempted to identify the deterministic component of the rainfall time series by suppressing the noise or alternatively finding any pattern in the noise

occurrence by filtering the deterministic part.

An attempt is made in this study to identify the presence of trend or persistence in the rainfall series of the several rainguage stations located in east Rajasthan.

4.0 DESCRIPTION OF THE STUDY AREA

Climatically, Rajasthan has semi-arid climate in east and arid in the west. The south-west monsoon set over the State in the first week of July and starts receding by the second week of September. The State has a normal annual rainfall of 586.4 mm; East Rajasthan has 704.1 mm and West Rajasthan 311.4 mm. The coefficient of variability of annual rainfall ranges from 30 to 40% in the east to 60 to 80% in the west.

There are a total of 423 non-recording raingauges in 14 river basins and 98 more in the rest of the State, of which 31 are also equipped with self-recording raingauges.

5.0 DATA

The rainfall data of all the raingauge stations in the State is being published by the State Irrigation Department since the formation of Rajasthan State in 1956. The data for the earlier years was published by the respective princely States. The India Meteorological Department has published the monthly and annual rainfall data of raingauge stations in the State for the period 1901 to 1950 (India Meteorological Department, 1970). The State Irrigation Department has made available the daily rainfall data for other years for the period 1957 to 1985. Rainfall data for the period 1901 to 1950 has been taken from the I.M.D. publication (1970). For the period 1951 to 1956, the data has been collected from the rainfall volumes of Rajasthan available in the Hydrology Directorate of Central Water Commission.

For the present study, the rainfall data of raingauge stations located in the districts of Alwar, Jhunjhunu, Jaipur, Bharatpur, Sawai Madhopur, Tonk and Kota have been used. The details of raingauge stations and length of data are given in Table 2:

Table 2: RAINGAUGE STATIONS AND THE PERIOD OF RAINFALL DATA
USED IN THE ANALYSIS

Sl.No.	Name of Station	Period
	District Jhunjhunu	
1.	Jhunjhunu	1901 to 1985
2.	Chirawa	1901 to 1985
3.	Khetri	1901 to 1985
	District Alwar	
4.	Alwar	1901 to 1985
5.	Kisangarh	1901 to 1985

6.	Mandawar	1901 to 1985
7.	Lachmangarh	1901 to 1985
8.	Tijara	1901 to 1985
9.	Nimrana	1901 to 1985
10.	Govindgarh	1932 to 1985
11.	Kotkasim	1930 to 1985
12.	Ramgarh	1934 to 1985

District Kota

13.	Kota	1901 to 1985
14.	Baran	1901 to 1985
15.	Itawa	1901 to 1985
16.	Atru	1901 to 1985
17.	Sangod	1929 to 1985
18.	Mangrol	1929 to 1985
19.	Shahbad	1901 to 1985
20.	Kisanganj	1911 to 1985
21.	Chipabarod	1901 to 1985

District Tonk

22.	Tonk	1901 to 1985
23.	Malpura	1901 to 1985
24.	Niwai	1929 to 1985

District Jaipur

25.	Jaipur	1901 to 1985
26.	Dausa	1901 to 1985
27.	Lalsot	1901 to 1985
28.	Sanganer	1901 to 1985
29.	Kotputli	1901 to 1985
30.	Chatsu	1901 to 1985
31.	Baswa	1931 to 1985

District Sawai Madhopur

32.	Sawai Madhopur	1901 to 1985
33.	Hindaun	1901 to 1985
34.	Gangapur	1901 to 1985
35.	Sapotra	1901 to 1985
36.	Karauli	1901 to 1985
37.	Khandar	1930 to 1985

<u>District Bharatpur</u>

38.	Bharatpur	1901 to 1985
39.	Sepao	1929 to 1985
40.	Sirmathura	1929 to 1985
41.	Kamen	1901 to 1985
42.	Dholpur	1901 to 1985
43.	Baseri	1929 to 1985
44.	Rajakhera	1901 to 1985
45.	Bari	1929 to 1985
46.	Biana	1901 to 1985
47.	Nadbai	1908 to 1985

6.0 METHODOLOGY

Besides the monthly and annual rainfall series at the raingauge stations in each district, the average monthly and annual rainfall series for each district have also been computed using the arithmetic average.

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 periods of high or low rainfall epoch.

6.1 Monsoon and Non-monsoon Rainfall

To study the relationship, if any, of the non-monsoon seasonal rainfall with the previous monsoon season rainfall, correlation coefficient of the non-monsoon with previous monsoon season rainfall has been worked out.

Also, to study the relationship of the rainfall during each of the monsoon months among themselves and on the monsoon season total, cross correlation has been worked out between monsoon months' (June-Sept.) and monsoon total rainfall series.

6.2 Test for Randomness

Besides testing for non-radomness in the rainfall series, the dependance of rainfall in a particular month on the rainfall during the previous month or months in the same year or earlier years is determined by computing the serial correlation with different lag periods using the following equation:

$$
r_k = \frac{\frac{1}{N-K} \sum_{i=1}^{N-K} X_i X_{i+k} - \frac{1}{(N-k)^2} (\sum_{i=1}^{N-K} X_i)(\sum_{i=1}^{N-K} X_{i+k})}{[\frac{1}{N-K} \sum_{i=1}^{N-K} X_i^2 - \frac{1}{(N-K)^2} \sum_{i=1}^{N-K} X_i^2]^{1/2} [\frac{1}{N-K} \sum_{i=1}^{N-K} X_{i+k}^2 - \frac{1}{(n-k)^2} \sum_{i=1}^{N-k} X_{i+k}^2]^{1/2}}
$$

where, N is length of the series,

X_i and X_{i+k} are two sets of data, and

K is lag

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

6.3 Tests for Trend

The presence of linear or curvilinear trend in the rainfall series has been studied by the following tests:

(i)   Comparison of decade means with whole period means,

(ii)   Linear regression, and

(iii)   Polynomial regression.

6.3.1 Decadal means

Decadal means and progressive decadal means were computed for comparison with long term mean of the respective rainfall series. A test of 'null' hypothesis of randomness (WMO, 1966) has been applied to determine whether the difference of means are not larger than would be compatible with the null hypothesis:

$$T_k = \frac{\bar{X}_k - \bar{X}}{\sigma} \qquad \ldots (2)$$

where,

$\bar{X}_k$ is the mean of any k observations,

$\bar{X}$ is the mean of the whole period, and

σ is the standard deviation of the whole period series

The statistic $t_k = [\frac{K (N-2)}{N-K-K T_k^2}]^{1/2} T_k$ $\qquad \ldots (3)$

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

14

6.3.2 Regression

Linear and polynomial regression of Ist and IInd order has been fitted to the rainfall series for examining the possibility of trend in the rainfall series. The linear regression was tested using t test and the polynomial by F test.

7.0   RESULTS AND DISCUSSION

To identify the presence of any trend by visual interpretation, annual rainfall of all the raingauges are plotted. In figures 2 (a) to 2(g) the annual rainfall time series of one long term raingauge/observatory representing respective districts are shown. The rainfall series do not indicate any trend.

The statistical parameters, mean, standard deviation Coefficient of variation and coefficient of skewness of season (monsoon and non-monsoon), annual and water year are given in tables 3(a) to 3(d) for all the raingauge stations whose data are used in the analysis. The coefficient of variation in the monsoon months is high but less when compared to the non-monsoon months. The coefficient of skewness is high and positive indicating a large bias towards low rainfall values Coefficient of skewness of monsoon, annual and water year rainfall series, is, however, close to zero indicating a near normal distribution.

The correlation of rainfall of monsoon season with non-monsoon season and the monsoon months among themselves is insignificant indicating the independent nature of rainfall occurrence.

7.1   Serial Correlation

The values of serial correlation for lag 5, 10,15, and 20 are given in table 4. The serial correlation coefficient is nearly zero at all the lag values for all the rainfall series, thereby indicating the lack of any persistance in
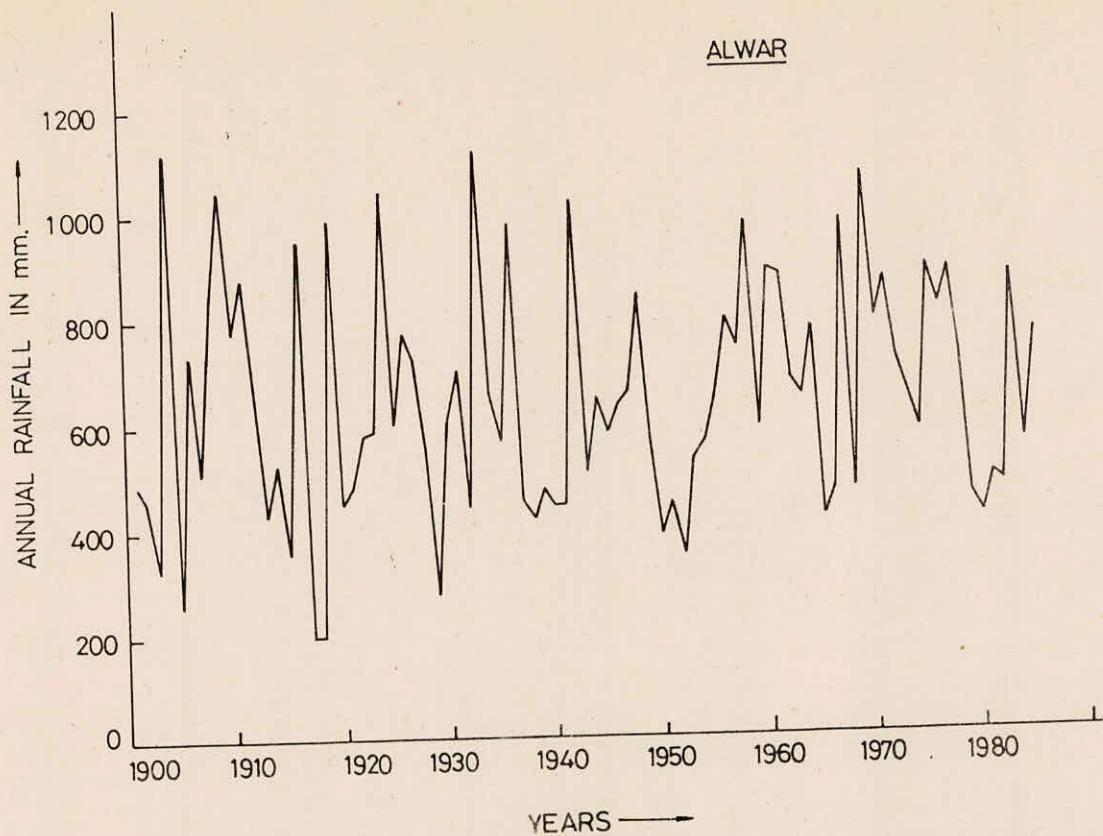
FIG.2(a) : ANNUAL RAINFALL TIME SERIES OF ALWAR
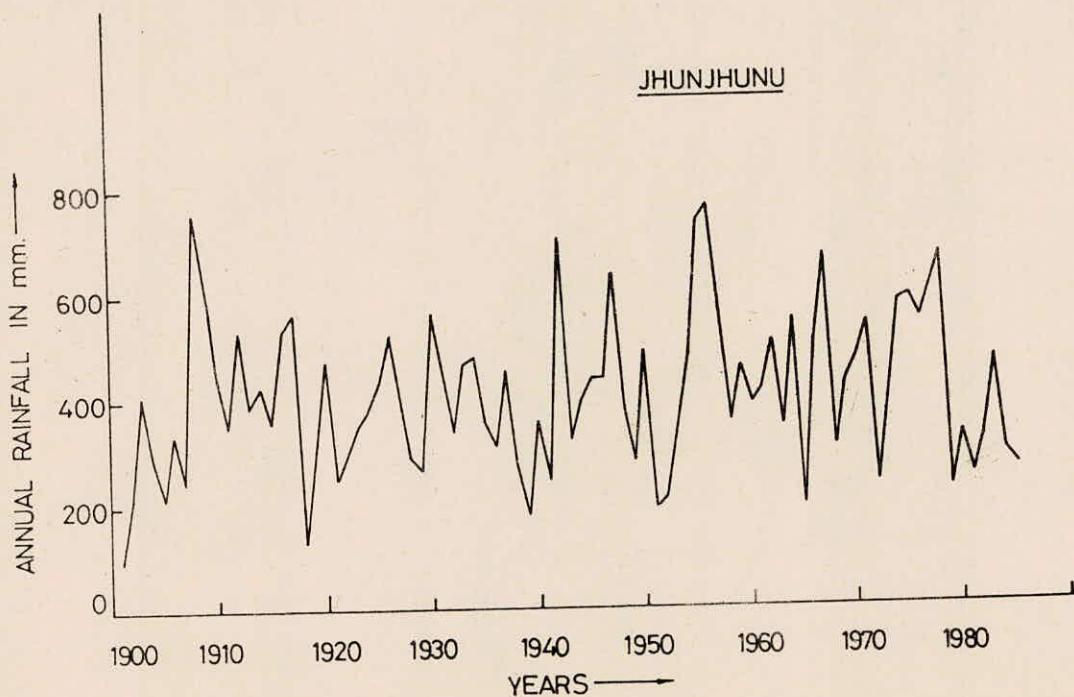
FIG.2(b) : ANNUAL RAINFALL TIME SERIES OF JHUNJHUNU
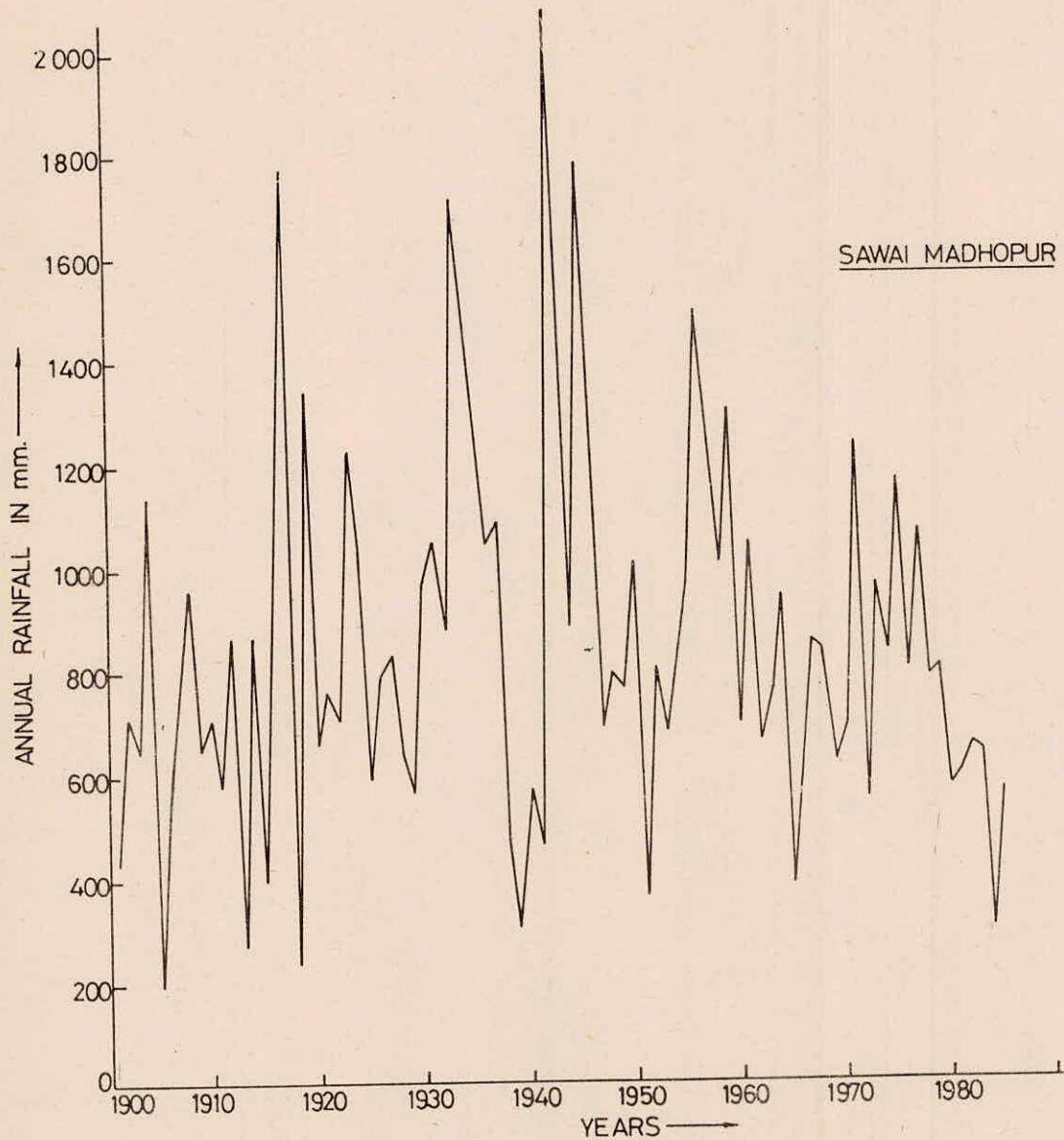
FIG 2(c) : ANNUAL RAINFALL TIME SERIES OF SAWAI MADHOPUR

BHARATPUR

ANNUAL RAINFALL IN m.m.

YEARS →
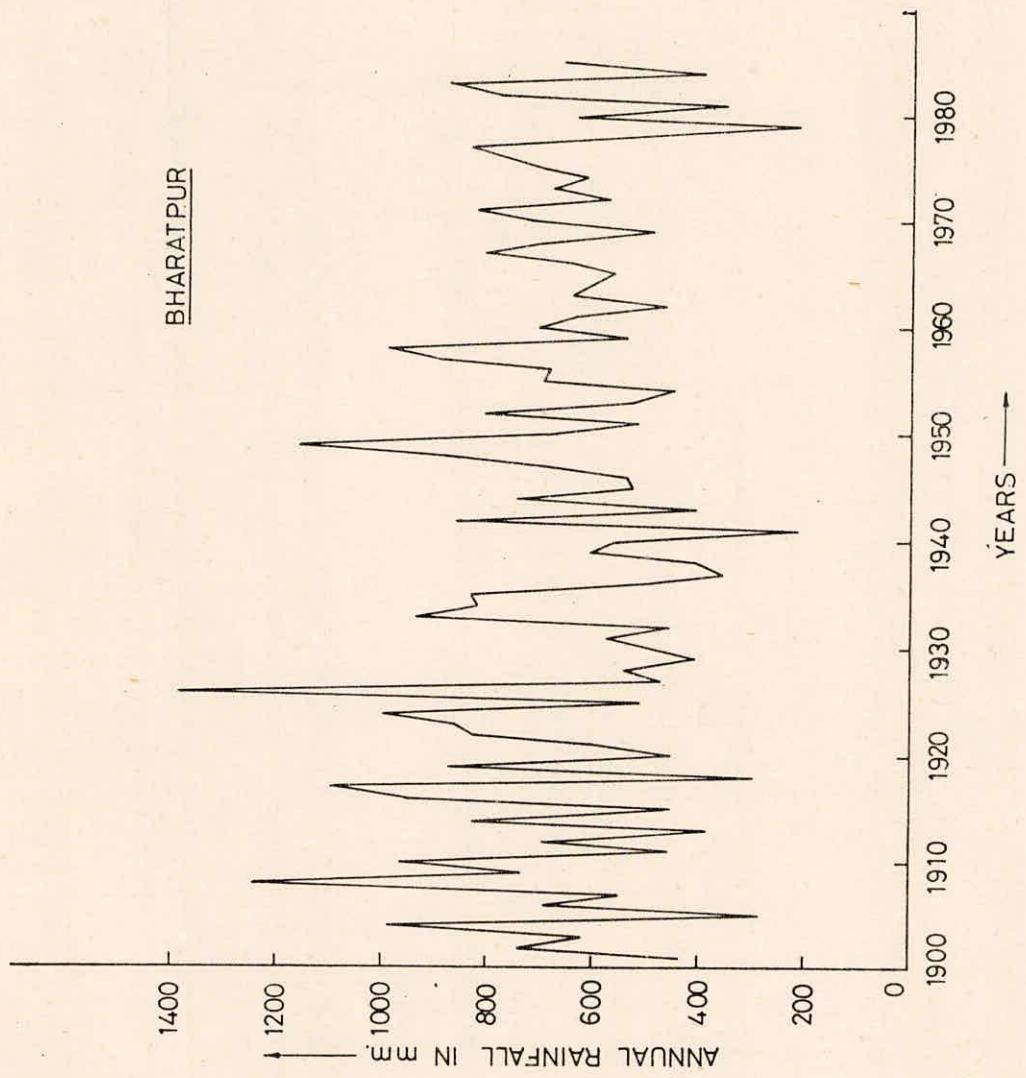
FIG 2(d) : ANNUAL RAINFALL TIME SERIES OF BHARATPUR

· 19
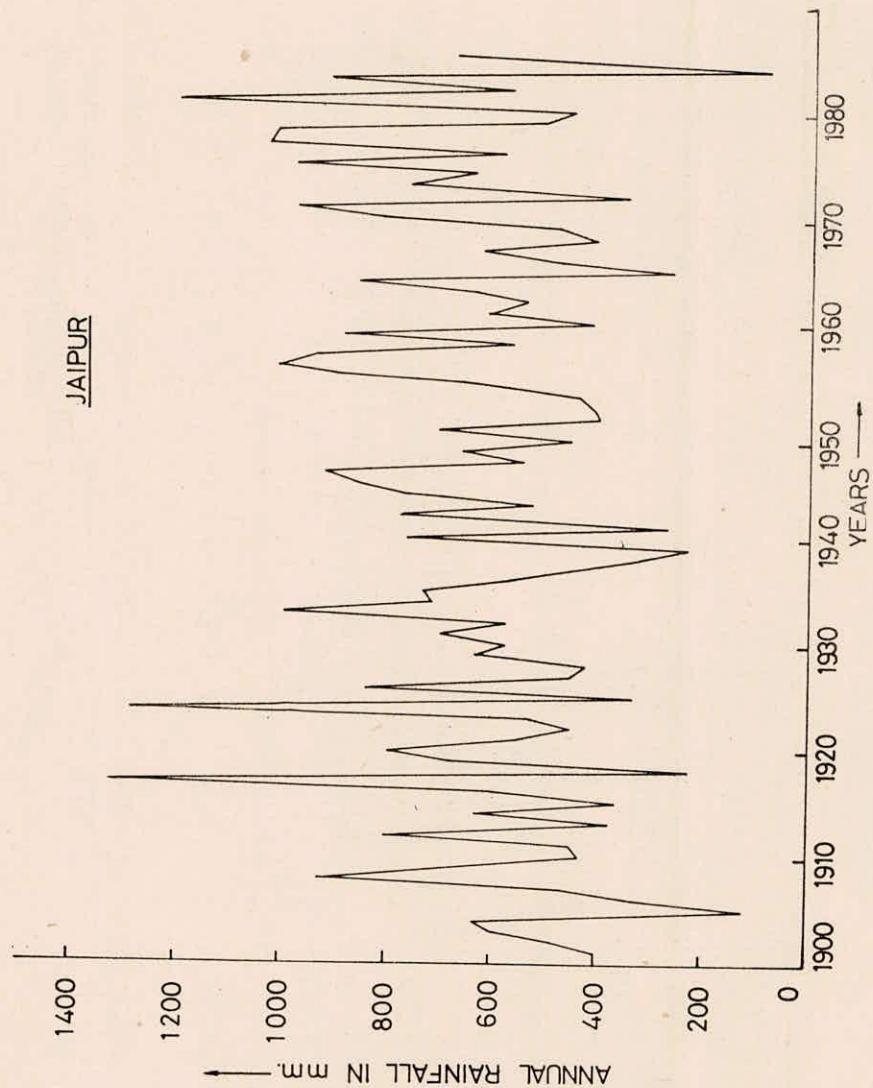
FIG. 2(e) : ANNUAL RAINFALL TIME SERIES OF JAIPUR

20
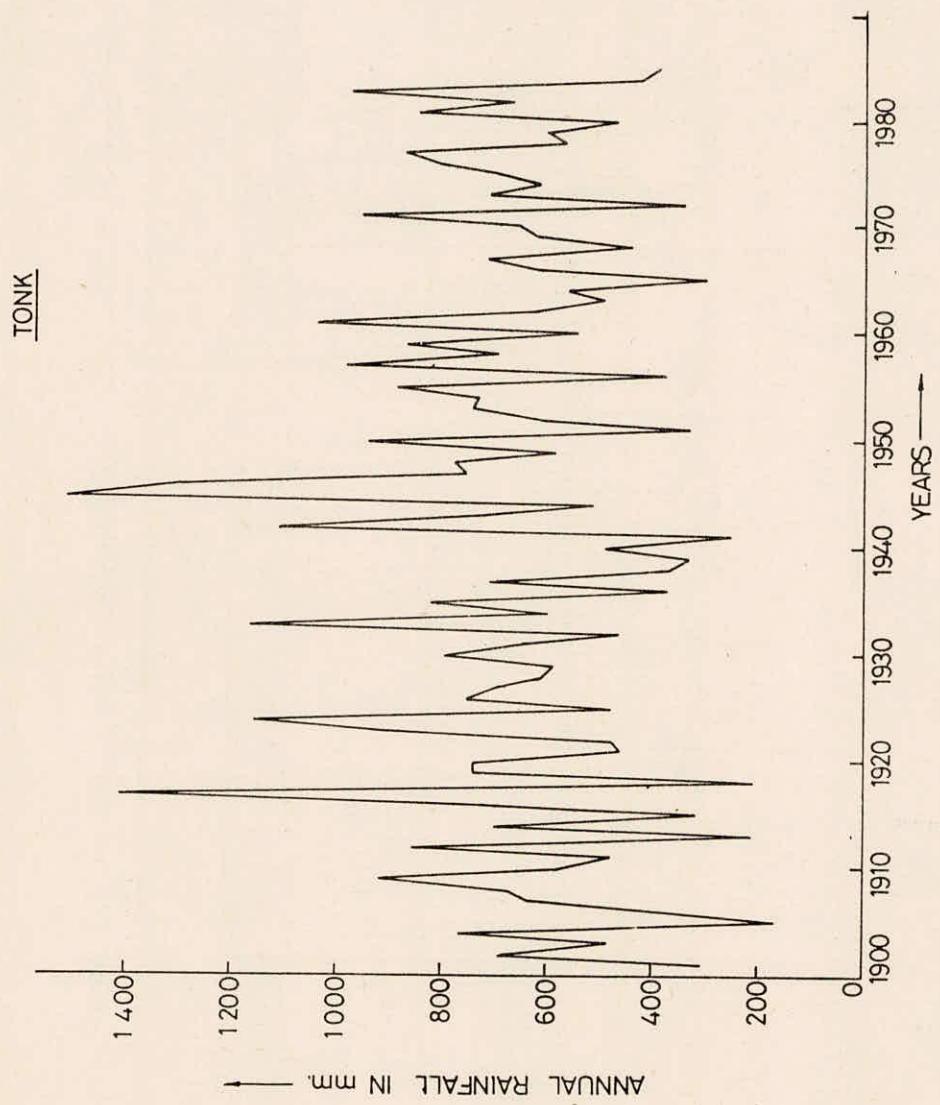
FIG. 2(f) : ANNUAL RAINFALL TIME SERIES OF TONK
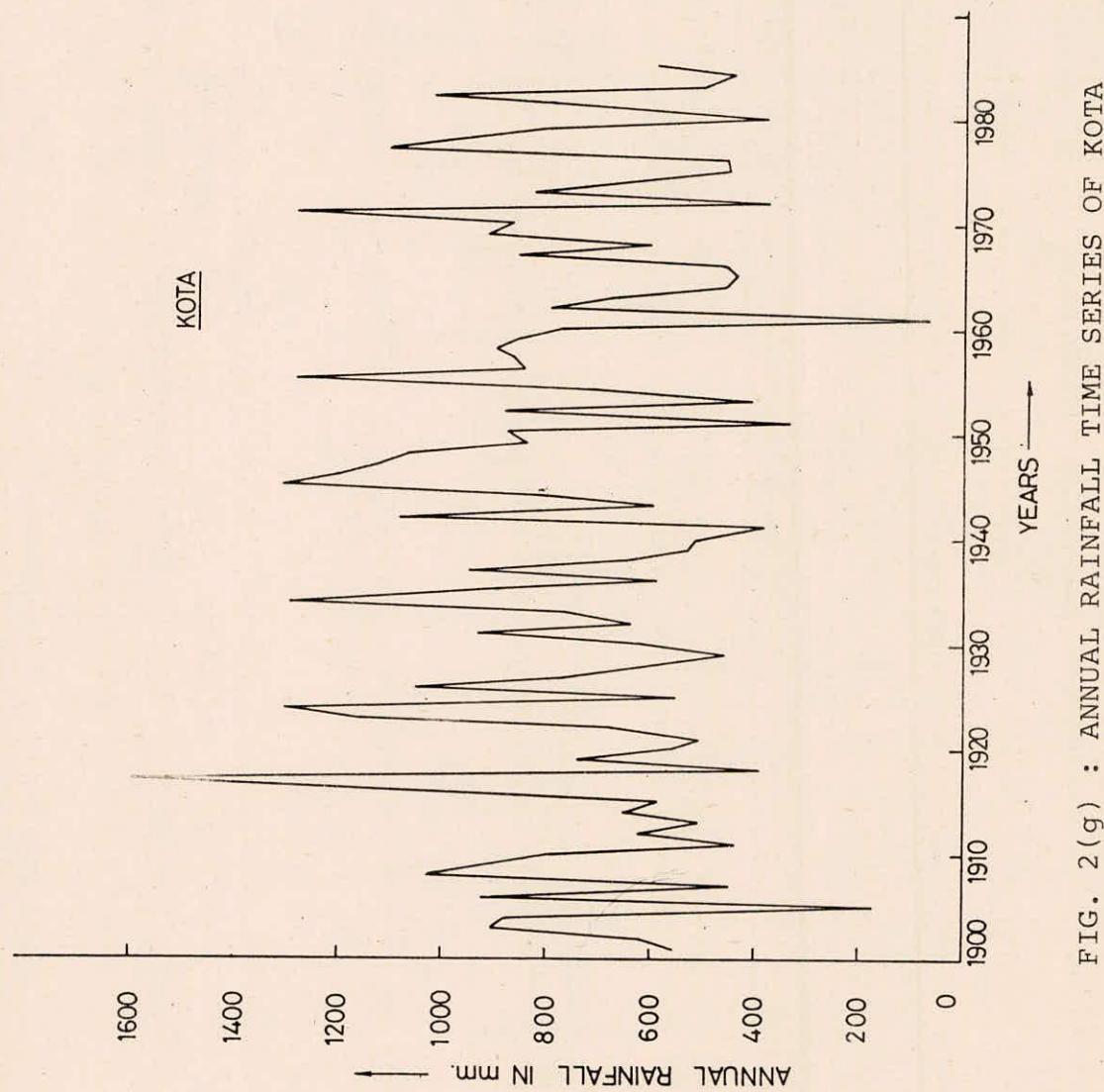
FIG. 2(g) : ANNUAL RAINFALL TIME SERIES OF KOTA
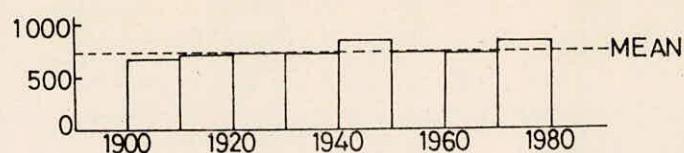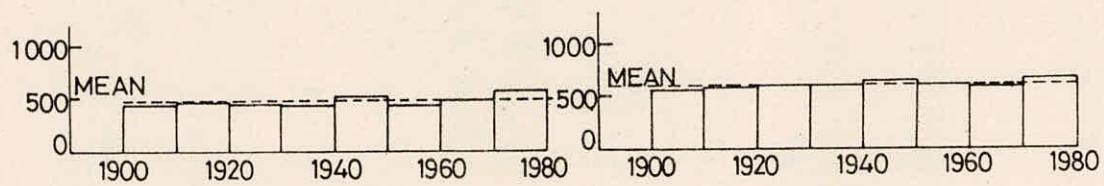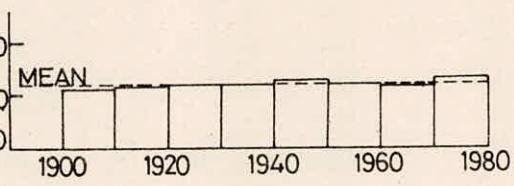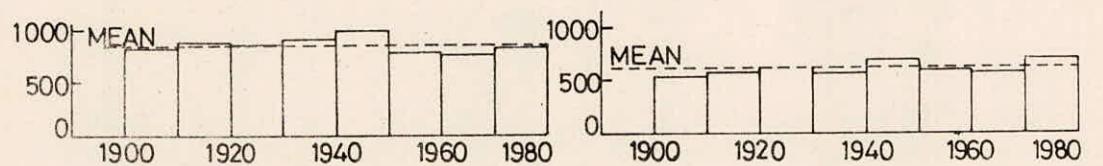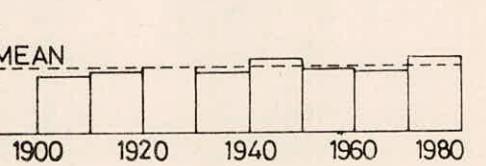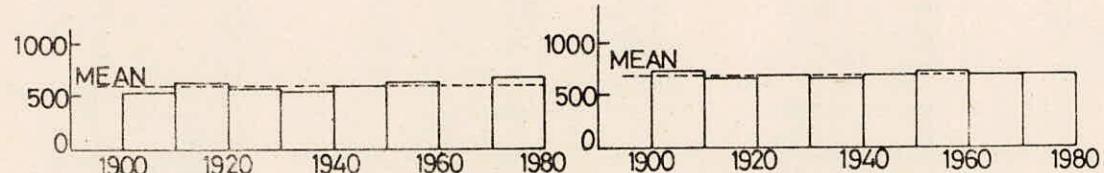
SAWAI MADHOPUR
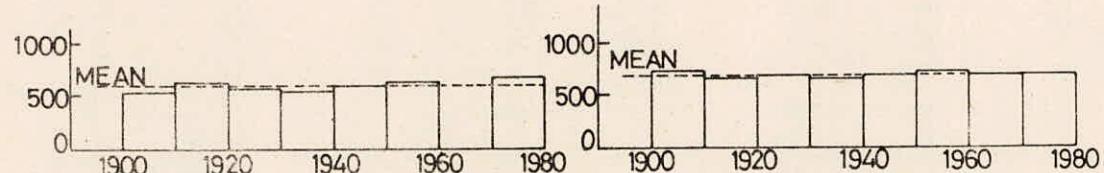
FIG. 3 : COMPARISON OF DECADE MEAN AND LONG PERIOD MEAN

23

Table 3 (a) : STATISTICAL PARAMETERS OF MONSOON
SEASON (JUN-OCT.) RAINFALL

District/ Station	Mean mm	Standard deviation mm	Coeff. of variation	Coeff. of skewness
Alwar District	537.10	198.58	37	0.30
Alwar	587.63	220.66	38	0.21
Govindgarh	550.55	205.03	37	0.24
Kotkasim	571.17	227.35	40	0.99
Tijara	549.18	216.73	41	0.49
Lachmangarh	508.00	216.73	43	0.61
Nimrana	501.07	239.37	48	0.83
Mandawar	531.72	217.68	41	0.15
Kishangarh	546.24	214.00	39	0.37
Ramgarh	569.99	193.23	34	0.08
Jhunjhunu District	400.18	159.27	40	0.41
Jhunjhunu	350.45	151.38	43	0.43
Chirawa	363.76	164.75	45	0.46
Khetri	483.79	205.93	43	0.75
Sawai Madhopur Distt.	684.88	248.69	36	0.09
Sawai Madhopur	810.24	387.11	48	1.05
Sapotra	715.38	264.66	37	-0.02
Karauli	668.98	249.99	37	0.00
Hindaun	607.51	243.02	40	0.47
Gangapur	644.71	281.92	44	0.84
Khandar	689.18	242.64	35	0.17
Bharatpur District	624.80	201.93	32	-0.06
Bharatpur	603.06	231.43	38	0.27
Sepao	667.09	231.92	35	0.39
Srimuthra	647.96	177.79	27	0.14
Kamen	586.39	239.46	41	0.69
Dholpur	664.32	247.27	37	0.32

Table 3 (a) (contd..)

Baseri	593.35	205.15	35	0.72
Rajakhera	635.51	228.40	36	0.19
Bari	696.37	223.09	32	0.59
Biana	614.62	238.98	39	0.41
Nadbai	620.11	245.86	40	0.43
Jaipur District	542.0	204.07	38	0.21
Jaipur	562.83	248.93	844	0.45
Sanganer	518.11	249.36	48	0.35
Lalsot	603.35	245.14	41	0.70
Dausa	548.13	236.07	43	0.80
Kotputli	474.70	203.45	43	0.54
Chatsu	530.52	242.79	46	0.37
Baswa	591.57	216.36	37	0.51
Tonk District	565.80	213.83	38	0.03
Tonk	622.62	266.38	43	0.50
Malpura	499.46	197.99	40	0.22
Niwai	611.18	225.76	37	0.38
Kota District	799.52	263.16	33	-0.04
Kota	705.26	294.44	42	0.20
Mangrol	770.78	283.22	37	0.97
Sangod	820.20	281.24	34	0.13
Shahbad.	801.44	294.81	37	0.41
Itawah	643.37	245.27	38	0.39
Baran	828.43	292.86	35	-0.09
Atru	894.19	325.67	36	-0.03
Chipabarod	914.79	317.54	35	0.05
Kisanganj	829.99	346.29	42	0.85

Table 3 (b) : STATISTICAL PARAMETERS OF NON-MONSOON (NOV. TO MAY)

District/ Station	Mean mm	Standard deviation mm	Coeff. of variation mm	Coeff. of skewness
Alwar District	56.43	37.46	66	0.90
Alwar	63.25	40.61	64	0.38
Govindgarh	46.13	37.31	81	1.05
Kotkasim	57.80	50.35	87	
Tijara	60.20	44.46	74	1.17
Lachmangarh	46.01	37.51	82	2.08
Nimrana	55.52	49.13	88	1.26
Mandawar	57.46	48.23	84	2.19
Kishangarh	58.49	43.88	75	0.77
Ramgarh	51.45	41.58	81	1.66
Jhunjhunu Distt.	54.84	34.22	62	0.85
Jhunjhunu	48.87	33.26	68	1.01
Chirawa	50.65	36.22	72	1.18
Khetri	64.70	44.26	68	0.94
Sawai Madhopur District	40.74	30.17	74	1.14
Sawai Madhopur	35.41	29.60	83	1.20
Sapotra	44.35	36.03	81	1.04
Karauli	45.16	40.63	90	1.09
Hindaun	38.94	32.66	84	1.07
Gangapur	40.59	34.73	85	1.14
Khandar	35.79	31.60	88	1.58
Bharatpur Distt.	47.42	32.27	68	0.87
Bharatpur	51.42	38.51	75	1.24
Sepao	27.01	29.11	108	1.44
Srimuthra	31.62	30.19	95	1.17
Kamen	62.15	43.72	70	0.93
Dholpur	47.82	37.37	78	1.01
Baseri	36.57	35.79	98	2.04

Contd....

26

Table 3 (b) contd.

Rajakhera	43.61	39.52	91	0.77
Bari	42.16	33.55	80	0.80
Biana	44.27	42.89	97	2.12
Nadbai	53.33	44.13	83	1.46
Jaipur District	45.24	37.88	71	1.34
Jaipur	52.46	34.30	72	1.00
Sanganer	40.92	33.62	84	1.08
Lalsot	38.56	43.03	87	1.32
Dausa	45.10	43.03	95	2.55
Kotputli	47.13	41.98	89	1.35
Chatsu	43.79	33.14	76	0.66
Baswa	48.51	39.97	82	1.54
Tonk District	34.98	28.37	81	1.34
Tonk	38.24	33.71	88	1.73
Malpura	31.53	28.54	90	1.07
Niwai	32.08	31.11	97	2.19
Kota District	39.70	30.79	77	1.55
Kota	39.57	33.04	83	1.29
Mangrol	36.73	31.37	85	1.18
Sangod	36.26	40.38	111	1.98
Shahbad	43.45	36.65	84	1.45
Itawah	33.31	27.46	82	1.27
Baran	39.40	33.69	85	1.47
Atru	43.50	43.69	100	1.58
Chipabarod	42.65	43.04	101	1.89
Kisanganj	35.56	35.47	100	1.62

Table 3 (c) : STATISTICAL PARAMETERS OF ANNUAL
JAN.-DEC. RAINFALL

District/ Station	Mean mm	Standard deviation mm	Coeff. of variation	Coeff. of skewness
Alwar District	598.01	192.22	32	0.45
Alwar	643.58	220.59	34	0.27
Govindgarh	594.34	211.64	36	0.21
Kotkasim	630.72	244.02	39	0.92
Tijara	611.51	228.84	37	0.77
Lachmangarh	557.19	217.81	39	0.79
Nimrana	566.60	245.65	43	0.95
Mandawar	598.12	223.36	37	0.52
Kishangarh	609.23	220.34	36	0.62
Ramgarh	620.17	200.69	32	0.06
Jhunjhunu Distt.	462.13	156.90	34	0.50
Jhunjhunu	406.32	148.02	36	0.38
Chirawa	419.13	170.04	41	0.60
Khetri	558.02	206.05	37	0.88
Sawai Madhopur Distt.	734.57	241.74	33	0.40
Sawai Madhopur	856.56	382.83	45	1.18
Sapotra	767.71	251.88	33	0.26
Karauli	725.71	245.88	34	0.30
Hindaun	654.91	241.37	37	0.76
Gangapur	692.72	277.87	40	1.05
Khandar	725.6	249.01	34	0.19
Bharatpur Distt.	681.24	190.19	28	0.37
Bharatpur	663.01	223.99	34	0.56
Sepao	694.39	236.19	34	0.41
Srimuthra	684.31	190.14	28	0.19
Kamen	653.88	243.24	37	0.82
Dholpur	723.39	235.21	33	0.63
Baseri	625.94	216.98	35	0.70

Contd....

Table 3 (c) contd.

Rajakhera	688.90	212.30	31	0.38
Bari	742.16	224.68	30	0.55
Biana	665.98	237.00	36	0.71
Nadbai	672.67	250.85	37	0.53
Jaipur District	597.00	204.12	34	0.45
Jaipur	622.72	250.01	40	0.49
Sanganer	568.25	248.39	44	0.33
Lalsot	648.55	239.34	37	0.95
Dausa	605.12	245.71	41	1.13
Kotputli	531.55	199.70	37	0.59
Chatsu	584.96	246.09	42	0.53
Baswa	644.15	229.98	36	0.48
Tonk District	603.10	208.42	35	0.31
Tonk	661.08	262.12	40	0.72
Malpura	538.02	199.06	37	0.39
Niwai	633.02	220.18	35	0.29
Kota District	847.14	254.13	30	0.39
Kota	750.17	288.02	38	0.37
Mangrol	807.25	294.05	36	1.17
Sangod	855.06	284.14	33	0.03
Shahabad	855.61	282.89	33	0.59
Itawah	683.81	241.84	35	0.74
Baran	874.71	284.05	32	0.18
Atru	947.96	313.10	33	0.24
Chipabarod	977.85	316.38	32	0.32
Kisanganj	856.91	363.88	42	0.74

Table 3 (d) : STATISTICAL PARAMETERS OF WATER
YEAR (JUNE TO MAY) RAINFALL

District/ Station	Mean mm	Standard deviation mm	Coeff. of variation mm	Coeff. of skewness
Alwar District	593.53	204.03	34	0.06
Alwar	650.88	228.00	35	0.09
Govindgarh	596.98	207.65	35	0.10
Kotkasim	628.97	235.35	37	0.83
Tijara	609.38	235.25	39	0.26
Lachmangarh	554.01	226.57	41	0.53
Nimrana	556.59	247.19	44	0.61
Mandawar	589.18	225.30	38	-0.10
Kishangarh	604.73	220.14	36	0.18
Ramgarh	621.44	193.45	31	-0.11
Jhunjhunu Distt.	455.02	163.55	36	0.25
jhunjhunu	399.32	155.40	39	0.33
Chirawā	414.41	173.10	42	0.40
Khetri	548.49	207.77	38	0.55
Sawai Madhopur Distt.	725.62	251.80	35	-0.01
Sawai Madhopur	845.65	387.19	46	0.97
Sapotra	759.73	267.29	35	-0.12
Karauli	714.15	255.07	36	-0.06
Hindaun	646.46	247.33	38	0.32
Gangapur	685.30	292.99	43	0.76
Khandar	724.97	243.35	34	0.2
Bharatpur Distt.	672.22	209.94	31	-0.09
Bharatpur	654.47	241.97	37	0.17
Sepao	694.10	228.83	33	0.36
Srimuthra	679.58	182.38	27	0.22
Kamen	648.54	248.04	38	0.51
Dholpur	712.14	253.73	36	0.32
Baseri	629.22	213.95	34	0.81

Table 3 (d)   contd..

Rajakhera	679.12	234.49	35	0.12
Bari	738.54	219.76	30	0.53
Biana	658.89	255.27	39	0.42
Nadbai	673.44	257.60	38	0.42
Jaipur District	587.23	208.19	35	0.09
Jaipur	615.29	251.23	41	0.41
Sanganer	559.03	250.50	45	0.29
Lalsot	641.91	250.22	39	0.58
Dausa	593.23	243.46	41	0.67
Kotputli	521.83	204.96	39	0.36
Chatsu	574.31	246.98	43	0.32
Baswa	640.08	226.82	35	0.48
Tonk District	600.78	215.17	36	-0.08
Tonk	560.86	266.73	40	0.34
Malpura	530.99	201.57	38	0.18
Niwai	643.27	222.84	35	0.33
Kota District	839.23	269.11	32	-0.05
Kota	744.83	297.86	40	0.09
Mangrol	807.51	283.71	35	1.04
Sangod	856.46	286.55	33	0.12
Shahbad	844.89	300.09	35	0.26
Itawah	676.68	247.66	36	0.33
Baran	867.83	295.30	34	-0.10
Atru	937.70	330.77	35	-0.02
Chipabarod	957.44	330.37	34	0.11
Kisanganj	865.55	350.76	40	0.90

Table 4 : SERIAL CORRELATION COEFFICIENT OF
RAINFALL SERIES

District/ Station	Lag in months			
	3	5	15	20
Alwar District	0.10	0.02	0.01	0.00
Alwar	0.10	0.02	0.05	0.02
Govindgarh	0.09	0.04	0.04	-
Kotkasim	0.05	0.01	0.03	-
Tijara	0.08	0.01	0.03	-0.02
Lachmangarh	0.04	0.01	-0.04	-0.04
Nimrana	0.09	0.04	0.03	0.00
Mandawar	0.08	0.00	0.02	0.02
Kishangarh	0.09	0.02	0.04	0.0
Ramgarh	0.08	0.09	-0.04	-
Jhunjhunu	0.01	-0.02	0.03	-0.01
Jhunjhunu	0.02	0.01	0.03	-0.01
Chirawa	0.01	0.0	0.03	0.04
Khetri	0.01	-0.03	0.04	-0.02
Bharatpur District				
Bharatpur	0.03	0.02	0.05	0.0
Sepao	0.05	-0.02	0.08	-
Srimuthra	-0.01	0.01	-0.05	-
Kamen	0.06	0.0	-0.01	-0.02
Dholpur	-0.05	-0.02	0.0	0.01
Baseri	0.02	0.07	-0.03	-
Rajakheru				
Bari	0.0	0.04	-0.06	-
Biana	0.03	0.03	-0.03	0.01
Nadbai				
Sawai Madhopur Distt.	0.02	0.0	0.02	0.0
Sawai Madhopur	-0.02	0.0	0.01	0.02
Sapotra	0.01	0.0	0.01	0.02
Karauli	0.01	0.01	0.04	-0.05
Hindaun	0.02	0.0	0.03	-0.02
Gangapur	0.02	0.02	0.01	0.02
Khandar	0.04	0.0	0.0	-

Table 4 (Contd.)

Jaipur District	0.04	-0.01	-0.01	-0.03
Jaipur	0.04	0.0	-0.04	-0.03
Sanganer	0.02	-0.02	0.0	-0.01
Lalsot	0.03	-0.01	-0.01	-0.0
Dausa	0.01	0.06	0.02	-0.02
Kotputli	0.06	-0.06	0.05	-0.02
Chatsu	0.0	0.0	-0.01	-0.04
Baswa	0.07	0.07	-0.01	-
Tonk District	-0.01	0.01	0.01	0.03
Tonk	-0.03	0.01	0.01	0.02
Malpura	0.0	0.03	0.01	0.06
Niwai	0.04	0.01	-0.02	-
Kota District	0.0	0.04	0.01	0.05
Kota	0.01	0.01	0.04	0.01
Mangrol	0.02	0.02	0.04	-
Sangod	-0.01	0.0	-0.02	-
Shahbad	0.01	0.03	0.01	0.02
Itawah	-0.01	0.02	0.04	0.07
Baran	-0.02	0.05	-0.03	0.02
Atru	0.01	0.02	0.02	0.02
Chipabarod	0.0	0.06	-0.01	0.03
Kishanganj	0.02	0.06	0.0	0.06

the rainfall series.

7.2   Trend Analysis

The decade means of rainfall at each raingauge station and also of the district averages have been worked out and compared with the long term (whole period) mean of the respective rainfall series. These are given in Table 5(a) to 5(g). A graph of the decadal means of the average rainfall of each of the seven districts is shown in Fig. 3. The progressive decadal means are given in tables 6(a) to 6(g). From the decadal means and progressive decadal means, it may be seen that rainfall during the period 1941-50 was above the whole period mean in Sawai Madhopur and Kota, whereas from 1971-80 it was more than the whole period mean in Sawai Madhopur, Alwar, Jhunjhunu, Tonk and Jaipur.

7.2.1   Linear regression

Linear regression analysis has been carried out on the monthly and annual rainfall series of the raingauge station in each district and the district average rainfall series. The linear correlation and regression coefficients alongwith their t values are given in tables 7(a) to 7(c) for the monsoon months July and August and annual rainfall respectively.

In general no trend, whatsoever, has been noticed in the rainfall series. Analysis of split sample series has, however, revealed a falling trend after 1945 at Sawai Madhopur.

7.2.2   Polynomial regression

Polynomial regression of 1st and 2nd order has been

34

fitted to the rainfall data series of monthly, monsoon season and water year total rainfall. The results are given in tables 8(a) to 8(b) respectively.

A few stations in each of the districts indicate a rising trend in rainfall. In case of Kota, however, while three stations indicate a rising trend, four station indicate a falling trend two of them significant. Two stations in Alwar district Govindgarh and Kotkasim also indicate a falling trend. None of the stations indicates a curvilinear trend.

Table 5 (a) : DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Alwar	652.68 (0.14)	564.27 (-1.21)	622.00 (-0.33)	624.18 (-0.29)	628.12 (-0.23)	651.00 (0.11)	714.89 (1.08)	698.74 (0.84)
Govindgarh	-	-	-	552.50 (-0.68)	580.97 (-0.22)	646.03 (0.35)	509.74 (-1.40)	607.82 (0.22)
Kotkasim	-	-	-	665.48 (0.49)	842.01 (3.24)	546.23 (-1.20)	524.75 (-1.52)	630.93 (0.00)
Tijara	590.25 (-0.31)	608.84 (-0.04)	532.31 (-1.16)	603.89 (-0.11)	573.74 (-0.55)	647.64 (0.53)	691.69 (1.18)	672.13 (0.89)
Lachmangarh	502.32 (-0.84)	499.17 (-0.89)	568.74 (0.18)	598.62 (0.63)	625.18 (1.05)	617.34 (0.93)	508.87 (-0.74)	506.33 (-0.78)
Nimrana	532.13 (-0.47)	586.66 (0.27)	533.56 (-0.45)	521.00 (-0.62)	604.02 (0.51)	461.34 (-1.44)	531.01 (-0.48)	769.39 (2.88)**
Mandawar	492.61 (-1.60)	570.50 (-0.41)	579.07 (-0.30)	585.19 (-0.19)	534.65 (0.55)	616.57 (0.28)	605.79 (0.11)	558.67 (0.91)
Kishangarh	514.53 (-0.98)	592.63 (-0.25)	518.07 (0.13)	588.73 (-0.31)	656.22 (0.86)	536.51 (-1.11)	590.23 (-0.29)	723.55 (1.75)
Ramgarh	-	-	-	657.05 (0.54)	604.14 (-0.28)	549.34 (0.51)	542.49 (1.35)	633.25 (0.22)
Distt..	551.49 (-0.81)	570.20 (-0.48)	578.86 (-0.33)	597.87 (0.00)	649.28 (0.89)	592.48 (-0.10)	574.50 (-0.41)	655.06 (0.99)

** Significant at 5% level of significance.

Table 5 (b) : DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Jhunjhunu	361.75 (-1.01)	403.33 (-0.07)	372.59 (-0.76)	366.77 (-0.89)	431.66 (0.57)	448.55 (0.95)	438.89 (0.73)	470.60 (1.46)
Chirawa	394.05 (-0.49)	410.21 (-0.17)	407.78 (-0.22)	384.74 (-0.67)	445.01 (0.51)	353.88 (-1.19)	448.70 (0.58)	542.44 (2.50)**
Khetri	535.94 (-0.36)	549.30 (-0.14)	530.80 (-0.44)	541.73 (-0.26)	644.45 (1.41)	476.74 (-1.33)	558.88 (0.01)	649.68 (1.50)
Distt	431.65 (-0.65)	455.22 (-0.15)	438.00 (-0.51)	432.19 (-0.64)	508.43 (0.99)	428.55 (-0.71)	482.93 (0.44)	555.19 (2.02)

** Significant at 5% level of significance

Table 5 (c) : DECADAL MEAN AND T'_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Sawai Madhopur	667.68 (-1.67)	822.30 (-0.30)	810.76 (-0.40)	986.01 (1.13)	1152.37 (2.68)**	935.20 (0.69)	750.26 (-0.93)	880.48 (0.21)
Sapotra	696.95 (-0.94)	682.30 (-1.14)	758.54 (-0.12)	783.41 (0.21)	785.31 (0.23)	756.62 (-0.15)	787.28 (0.26)	925.04 (2.13)*
Karauli	677.35 (-0.65)	677.09 (-0.66)	723.86 (-0.03)	659.73 (+0.90)	806.22 (1.10)	715.45 (-0.14)	667.37 (-0.79)	853.96 (1.77)
Hindaun	618.51 (-0.50)	680.86 (0.36)	709.61 (0.76)	593.32 (-0.85)	700.87 (0.53)	584.25 (-0.93)	665.68 (0.15)	725.46 (0.98)
Gangapur	646.34 (-0.56)	641.13 (-0.62)	578.30 (-1.39)	529.14 (-2.01)*	839.60 (2.14)**	757.33 (0.78)	658.08 (-0.42)	785.24 (1.12)
Khandhar	-	-	-	716.60 (-0.12)	743.91 (0.25)	700.49 (-0.35)	718.77 (0.09)	800.09 (1.04)
Distt	561.37 (-1.01)	700.71 (-0.47)	717.00 (-0.24)	704.62 (-0.41)	843.83 (1.52)	744.62 (0.14)	705.52 (-0.40)	827.94 (1.30)

** Significant at 5% level of significance
* Significant at 10% level of significance

Table 5 (d) : DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Bharatpur	725.38 (0.95)	651.03 (-0.18)	712.23 (0.73)	611.56 (-0.77)	667.94 (0.07)	603.13 (0.30)	628.06 (-0.52)	645.78 (-0.24)
Sepao	-	-	-	721.33 (0.39)	738.50 (0.64)	678.58 (-0.23)	540.03 (-0.79)	737.06 (0.62)
Srimuthra	-	-	-	593.43 (0.16)	700.05 (0.28)	714.09 (0.54)	674.61 (-0.17)	750.36 (1.20)
Kamen	713.90 (0.82)	541.56 (-0.17)	529.76 (-0.33)	554.70 (-1.37)	593.19 (0.54)	659.46 (0.08)	679.07 (0.35)	678.18 (0.33)
Dholpur	745.18 (0.32)	725.53 (0.03)	593.22 (-0.43)	667.86 (-0.79)	780.81 (0.82)	816.01 (1.32)	753.32 (0.64)	545.99 (-1.09)
Baseri	-	-	-	505.53 (-0.32)	510.13 (-0.12)	739.30 (1.84)	593.13 (1.07)	519.47 (-0.10)
Rajakhera	711.61 (0.36)	659.04 (-0.47)	635.87 (-0.03)	725.57 (0.58)	730.83 (0.56)	726.16 (0.59)	721.09 (0.52)	545.99 (-0.67)
Bari	-	-	-	659.50 (-1.28)	721.18 (-0.32)	753.74 (0.18)	701.75 (-0.62)	953.58 (3.57)***
Biana	676.07 (0.14)	658.70 (-0.10)	679.82 (0.19)	599.24 (-0.94)	504.07 (-0.87)	715.10 (0.59)	654.50 (-0.02)	700.59 (0.49)
Nadbai	-	562.53 (-0.14)	652.31 (-0.27)	601.49 (-0.95)	561.72 (-1.50)	652.00 (-0.28)	819.33 (2.01)*	678.14 (0.07)
Distt.	710.75 (0.52)	650.94 (-0.53)	571.14 (-0.18)	646.11 (-0.42)	588.09 (0.12)	724.29 (0.76).	695.53 (0.25)	681.87 (0.01)

***Significant at 1% level of significance
*Significant at 10% level of significance.

39

Table 5 (e) : DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Jaipur	504.14 (-1.60)	625.39 (0.04)	608.07 (-0.19)	605.79 (-0.23)	647.58 (0.33)	652.01 (0.39)	572.17 (-0.67)	733.34 (1.49)
Sanganer	515.25 (-0.71)	608.08 (0.53)	554.49 (-0.18)	508.21 (-0.81)	602.76 (0.46)	591.38 (0.31)	552.47 (-0.21)	606.68 (0.52)
Lalsot	589.79 (-0.82)	720.22 (1.00)	593.65 (-0.77)	619.55 (-0.40)	641.79 (-0.09)	644.68 (-0.05)	609.90 (-0.54)	761.97 (1.60)
Dausa	489.94 (-1.58)	589.05 (-0.22)	606.08 (0.01)	497.11 (-1.48)	590.83 (-0.19)	623.54 (0.25)	516.45 (-1.21)	756.82 (2.11)*
Kotputli	541.40 (0.16)	535.62 (0.07)	474.44 (-0.96)	473.44 (-0.97)	554.03 (0.37)	492.93 (-0.64)	571.26 (0.66)	608.79 (1.30)
Chatsu	531.37 (-0.73)	608.22 (0.31)	479.57 (-1.44)	499.14 (-1.17)	567.27 (-0.24)	705.24 (1.65)	644.93 (0.81)	521.21 (0.49)
Baswa	-	-	-	607.77 (-0.54)	545.58 (-1.50)	682.34 (0.57)	752.51 (1.65)	637.50 (-0.10,)
Distt	529.02 (-1.12)	614.38 (0.28)	552.14 (-0.73)	544.74 (-0.86)	593.08 (-0.06)	628.40 (3.51)	603.30 (0.10)	675.52 (1.29)

*Significant at 10% level of significance

40

Table 5 (f) : DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Tonk	563.33 (-1.25)	538.44 (-0.29)	695.36 (0.44)	593.36 (-0.86)	845.50 (2.42)**	678.22 (0.22)	508.10 (-0.67)	656.53 (0.07)
Malpura	505.39 (-0.55)	489.00 (-0.82)	519.21 (-0.31)	516.70 (-0.36)	537.44 (-0.01)	465.87 (-0.88)	515.82 (-0.37)	697.25 (2.78)**
Niwai	-	-	-	592.19 (-0.64)	572.17 (-0.95)	649.15 (0.25)	574.44 (-0.92)	772.00 (2.25)*
Distt.	534.39 (-1.10)	563.75 (-0.63)	601.97 (-0.02)	558.86 (-0.71)	577.33 (1.19)	597.74 (-0.09)	557.58 (-0.73)	705.65 (1.66)

** Significant at 5% level of significance

* Significant at 10% level of significance

Table 5 (g) DECADAL MEAN AND T_k VALUES OF ANNUAL RAINFALL SERIES

Station	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Kota	722.12 (-0.32)	720.16 (-0.35)	773.04 (0.26)	785.88 (0.41)	927.33 (2.10)*	784.91 (0.40)	614.81 (-1.59)	727.09 (-0.27)
Mangrol	-	-	-	927.22 (1.42)	906.15 (1.16)	716.35 (-1.07)	694.28 (-1.34)	897.52 (1.06)
Sangod	-	-	-	927.01 (0.87)	1022.87 (2.10)*	839.68 (-0.19)	800.52 (-0.55)	805.98 (-0.58)
Shahabad	790.31 (-0.77)	826.94 (-0.34)	825.88 (-0.35)	907.30 (0.61)	921.03 (0.77)	777.21 (-0.93)	884.33 (0.34)	936.59 (0.95)
Itawah	656.53 (-0.24)	690.44 (0.09)	686.93 (0.04)	824.84 (1.99)*	828.54 (2.04)*	638.70 (-0.62)	592.26 (-1.27)	621.46 (-0.86)
Baran	893.46 (0.22)	844.88 (-0.35)	822.55 (-0.61)	862.08 (-0.15)	1018.98 (1.72)	767.24 (-1.03)	870.83 (-0.05)	953.50 (0.93)
Atru	979.43 (0.33)	956.13 (0.09)	1040.91 (0.99)	990.21 (0.45)	1004.75 (0.63)	809.14 (-1.49)	904.50 (-0.46)	888.96 (-0.63)
Chipabarod	917.90 (-0.53)	1045.95 (0.73)	959.99 (-0.19)	1078.51 (1.07)	1217.29 (2.52)**	919.06 (-0.62)	822.74 (-1.55)	878.65 (-1.05)
Kishanganj	-	905.04 (0.44)	872.50 (0.14)	972.76 (1.08)	1059.52 (1.91)*	803.56 (-0.49)	590.47 (-1.55)	744.36 (-1.04)
Distt.	827.83 (-0.25)	858.20 (0.14)	854.57 (0.10)	915.41 (0.90)	991.10 (1.93)*	786.50 (-0.30)	758.43 (-1.17)	829.15 (-0.24)

*Significant at 10% level of significance
**Significant at 5% level of significance.

42

Table 6 (a)   PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-85
Alwar	652.68	608.47	512.93	515.78	618.25	623.71	636.73	644.48	593.01
Govindgarh	-	-	-	552.50	566.74	593.17	572.31	579.41	543.58
Kotkasim	-	-	-	665.48	753.75	584.57	644.52	541.88	594.34
Tijara	590.25	599.54	577.13	503.82	581.31	592.78	606.91	615.06	530.72
Lachmangarh	502.32	500.75	523.41	542.21	558.81	568.55	560.11	553.38	611.51
Nimrana	532.13	559.40	550.78	543.34	555.47	539.78	538.53	567.39	557.19
Mandawar	492.61	531.50	547.09	556.62	572.22	579.63	503.37	592.78	555.60
Kishangarh	544.53	558.58	535.03	585.99	602.04	591.11	590.99	607.56	598.12
Ramgarh	-	-	-	657.05	630.50	637.01	613.30	617.36	609.23
Distt.	551.49	560.85	563.85	574.61	589.54	590.03	587.81	596.22	520.17

Table 6(b) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-85
Jhunjhunu	361.75	382.54	379.22	376.11	387.22	397.44	403.36	411.77	452.13
Chirawa	394.05	402.13	404.01	399.20	408.35	400.11	407.05	423.93	406.32
Khetri	535.94	542.62	538.58	539.44	560.44	546.49	543.26	560.94	419.13
Distt.	431.55	443.44	441.62	439.27	453.10	449.01	453.05	456.52	558.02

Table 5 (c) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-85
Swai Madhopur	657.68	744.99	766.91	821.69	837.82	895.72	874.94	875.53	734.57
Sapotra	696.95	689.63	712.60	730.30	741.30	743.85	750.06	771.93	856.56
Karauli	677.35	577.22	692.77	584.51	703.85	709.95	703.87	722.63	757.71
Hindaun	618.51	549.69	659.65	550.58	550.63	547.90	650.44	559.82	725.71
Gangapur	545.34	643.73	621.92	598.73	656.92	673.55	571.43	505.65	654.91
Khandhar	-	-	-	716.50	730.25	720.33	719.94	735.97	592.72
Distt.	661.37	581.04	593.03	595.93	725.51	723.69	725.40	738.21	725.6

Table 6 (d) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-85
Bharatpur	726.38	686.71	696.55	575.30	573.83	576.33	568.62	555.82	581.24
Sepao	-	-	-	721.33	729.97	712.84	694.63	703.12	563.01
Srimuthra	-	-	-	593.43	695.74	702.52	695.55	706.51	594.39
Kamen	713.90	577.73	561.74	534.98	546.62	548.76	653.21	556.33	584.31
Dholpur	745.18	735.38	721.56	708.21	722.73	738.28	742.57	730.62	653.88
Baseri	-	-	-	505.63	611.88	554.35	554.05	655.13	723.39
Rajakhera	711.51	685.33	668.84	683.05	592.60	598.20	701.50	594.64	625.94
Bari	-	-	-	659.50	690.39	711.51	709.07	757.97	688.90
Biana	576.07	567.38	571.53	553.45	643.58	555.51	555.80	552.27	742.16
Nadbai	-	552.53	557.42	638.78	519.51	626.01	558.23	551.07	555.98
Distt.	710.75	580.84	577.51	569.73	673.41	581.89	583.85	683.50	572.67

Table 6 (e) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-85
Jaipur	504.14	554.77	579.20	585.85	598.19	607.16	602.16	618.55	597.00
Sanganer	515.25	561.65	559.27	545.51	557.75	563.35	561.81	557.41	622.72
Lalsot	589.79	655.01	634.55	630.80	633.00	634.95	631.37	647.69	568.25
Dausa	485.94	539.49	561.59	545.55	557.00	555.09	559.00	583.73	648.55
Kotputli	541.40	538.51	517.15	506.23	515.79	511.98	520.45	531.49	605.12
Chatsu	531.37	559.80	539.72	529.58	537.11	565.14	576.53	582.12	531.55
Baswa	-	-	-	607.77	576.57	511.90	647.05	545.14	584.96
Distt.	529.02	571.70	565.18	560.07	566.67	576.96	580.72	592.57	644.15

47

Table 6 (f) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-8
Tonk	563.33	500.89	532.38	522.62	567.20	559.03	550.33	561.10	563.10
Malpura	505.39	497.20	504.53	507.58	513.55	508.94	509.92	533.34	651.08
Niwai	-	-	-	592.19	502.18	604.50	596.99	631.99	536.02
Distt.	534.39	549.07	556.70	564.74	567.26	589.01	584.52	599.56	533.02

48

Table 6 (g) : PROGRESSIVE DECADE MEANS OF ANNUAL RAINFALL SERIES

Station	1901-10	1901-20	1901-30	1901-40	1901-50	1901-60	1901-70	1901-80	1901-9
Kota	722.12	721.14	738.44	750.30	705.71	785.57	761.18	756.92	847.14
Mangrol	-	-	-	927.22	916.63	849.91	811.00	828.32	750.17
Sangod	-	-	-	927.01	974.94	929.85	897.55	879.43	807.25
Shahabad	790.31	808.63	814.38	837.61	854.29	841.45	847.57	858.70	855.06
Itawah	566.53	678.49	681.30	717.19	739.45	722.56	704.03	693.71	855.61
Baran	893.46	869.17	853.63	855.74	888.39	871.53	871.43	881.59	683.81
Atru	979.43	957.81	992.17	991.68	994.30	953.44	955.02	946.76	874.71
Chipabarod	917.90	982.42	974.95	1000.06	1044.15	1023.30	994.55	980.01	947.56
Kishanganj	-	905.04	888.82	916.80	952.48	922.72	884.01	864.05	977.85
Distt.	827.83	843.02	846.90	864.03	889.44	872.30	856.03	852.57	856.91

49

Table 7 (a) : REGRESSION COEFFICIENTS OF
JULY RAINFALL

District/ Station	Correlation coefficient	Constant	Regression Coefficient	t-value
District Alwar	0.220	153.32	0.79	2.051*
Alwar	0.217	158.31	0.79	2.025*
Govindgarh	0.146	161.81	0.95	1.063
Kotkasim	0.151	249.22	-1.33	-1.125
Tijara	0.244	142.90	1.08	2.294**
Lachmangarh	0.138	161.85	0.53	1.265
Nimrana	0.238	124.22	0.20	2.235**
Mandawar	0.207	146.27	0.96	1.930
Kishangarh	0.215	150.95	0.87	2.003*
Ramgarh	0.172	169.05	1.15	1.238
District Jhunjhunu	0.073	133.89	0.29	0.662
Jhunjhunu	0.059	118.10	0.23	0.535
Chirawa	-	-	-	-
Khetri	0.121	151.05	0.62	1.110
District Sawai Madhopur	0.090	233.14	0.50	0.823
Sawai Madhopur	0.019	318.80	-0.17	-0.171
Sapotra	0.096	240.97	0.62	0.875
Karauli	0.112	218.62	0.64	1.030
Hindaun	0.038	206.44	0.20	0.346
Gangapur	0.167	197.74	1.01	1.545
Khandhar	0.210	198.19	1.83	1.582
District Bharatpur	0.065	201.36	0.27	0.595
Bharatpur	0.049	195.15	0.23	0.443
Sepao	0.061	245.28	-0.51	-0.455
Srimuthra	0.014	222.88	0.09	0.100
Kamen	0.050	178.75	0.21	0.458
Dholpur	0.019	227.13	-0.10	-0.174
Baseri	0.019	208.18	-0.14	-0.139
Rajakhera	0.092	194.22	0.39	0.839

Table 7 (a) contd.

Bari	0.159	201.74	1.30	1.197
Biawa	0.016	219.05	0.08	0.144
Nadabai	0.157	170.58	0.91	1.388
District Jaipur	0.215	161.47	0.95	2.003*
Jaipur	0.177	156.92	0.99	1.638
Sanganer	0.177	156.92	0.95	1.495
Lalsot	0.164	189.92	1.02	1.511
Dausa	0.291	144.53	1.60	2.770*
Kotputli	0.152	136.76	0.67	1.405
Chatsu	0.116	176.97	0.59	1.068
Baswa	0.313	146.89	2.04	2.402*
District Tonk	0.144	186.95	0.71	1.323
Tonk	0.044	229.05	0.27	0.401
Malpura	0.142	161.07	0.59	1.307
Niwai	0.253	168.05	2.33	1.941
District Kota	0.191	353.24	-1.19	-1.772
Kota	0.011	264.49	0.07	0.100
Mangrol	0.066	283.42	-0.56	-0.488
Sangod	0.291	359.84	-2.89	2.250
Shahabad	0.055	333.39	-0.44	-0.505
Itawah	0.160	294.16	-0.92	-1.476
Baran	0.202	869.99	-1.47	-1.883
Atru	0.162	389.51	-1.24	-1.496
Chipabarod	0.254	441.02	-2.20	-2.349*
Kishanganj	0.192	360.26	-1.50	-1.670

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

51

Table 7 (b) : LINEAR REGRESSION COEFFICIENTS OF AUGUST RAINFALL

District/ Station	Correlation coefficient	Constant	Regression coefficient	t-value
District Alwar	0.149	161.07	0.60	1.377
Alwar	0.084	184.09	0.40	0.769
Govindgarh	C.301	138.57	2.10	2.279**
Kotkasim	0.068	180.15	0.49	0.503
Tijara	0.179	160.19	0.85	1.659
Lachmangarh	0.036	167.47	0.17	0.324
Nimrana	0.080	157.46	0.39	0.732
Mandawar	0.203	143.71	0.94	1.892
Kishangarh	0.166	153.75	0.72	1.535
Ramgarh	0.009	189.57	-0.07	-0.066
District Jhunjhunu	0.168	111.83	0.51	1.552
Jhunjhunu	0.156	94.10	0.44	1.441
Chirawa	0.0	-	-	-
Khetri	0.092	147.04	0.36	0.838
District Sawai Madhopur	0.126	230.93	0.68	1.155
Sawai Madhopur	0.041	293.05	0.33	0.374
Sapotra	0.203	214.78	1.22	1.893
Karauli	0.118	232.17	0.69	1.082
Hindaun	0.057	222.14	0.35	0.524
Gangapur	0.198	192.36	1.15	1.776
Khandhar	0.033	245.27	0.26	0.246
District Bharatpur	0.153	205.63	0.70	1.412
Bharatpur	0.105	201.60	0.59	0.957
Sepao	0.148	222.62	1.24	1.109
Srimuthra	0.043	246.25	0.37	0.322
Kamen	0.173	182.38	0.93	1.599
Dholpur	0.054	239.59	0.30	0.497
Baseri	0.053	215.74	0.37	0.397
Rajakhera	0.017	237.44	-0.09	-0.158
Bari	0.221	209.37	2.07	1.681
Biana	0.160	187.17	0.88	1.479
Nadbai	0.219	167.84	1.50	1.953

Table 7 (b) contd.

District Jaipur	0.106	178.90	0.45	0.969
Jaipur	0.117	189.34	0.63	1.070
Sanganer	0.013	186.97	0.07	0.117
Lalset	0.045	216.76	0.24	0.408*
Dausa	0.196	149.98	0.95	1.816
Kotputli	0.100	155.66	0.45	0.913
Chatsu	0.093	173.44	0.46	0.852
Baswa	0.018	197.59	0.12	0.128
District Tonk	0.148	170.31	0.66	1.366
Tonk	0.059	202.27	0.33	0.539
Malpura	0.175	143.34	0.77	1.616
Niwai	0.096	196.88	0.70	0.714
District Kota	0.091	269.49	0.51	0.830
Kota	0.050	240.13	0.29	0.454
Mangrol	0.079	315.66	−0.78	−0.589
Sanged	0.030	318.78	−0.29	−0.225
Shahabad	0.079	254.02	0.46	0.726
Itawah	0.029	223.40	0.17	0.268
Baran	0.209	247.43	1.44	1.947
Atru	0.076	312.00	0.51	0.693
Chipabarod	0.158	281.90	1.14	1.458
Kisanganj	0.107	349.51	−0.95	−0.916

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

Table 7 (c) : LINEAR REGRESSION COEFFICIENTS
OF ANNUAL RAINFALL

District/ Station	Correlation coefficient	Constant	Regression coefficient	t-value
District Alwar	0.129	554.79	1.00	1.186
Alwar	0.123	596.51	1.09	1.124
Govindgarh	0.105	555.61	1.41	0.759
Kotkasim	0.264	743.49	-3.96	-2.015*'
Tijara	0.120	563.85	1.11	1.097
Lachmangarh	0.065	532.38	0.58	0.597
Nimrana	0.128	511.69	1.28	1.179
Mandawar	0.213	515.38	1.92	1.982*'
Kishangarh	0.140	555.43	1.25	1.290
Ramgarh	0.045	635.85	-0.59	-0.316
District Jhunjhunu	0.125	427.98	0.79	1.147
Jhunjhunu	0.156	366.01	0.94	1.442
Chirawa	-	-	-	-
Khetri	0.072	532.04	0.60	0.661
District Sawai Madhopur	0.108	688.92	1.06	0.993
Sawai Madhopur	0.013	847.98	0.20	0.117
Sapotra	0.167	694.25	1.71	1.547
Karauli	0.144	664.20	1.43	1.321
Hindaun	0.008	658.15	-0.08	-0.070
Gangapur	0.215	583.75	2.42	2.003
Khandar	0.006	722.92	0.09	0.045
District Bharatpur	0.011	677.49	0.09	0.103
Bharatpur	0.086	696.68	-0.78	--0.789
Sepao	0.037	709.69	-0.53	-0.275
Srimuthra	0.089	713.81	-1.02	-0.661
Kamen	0.004	652.49	0.03	0.030
Dholpur	0.050	744.01	-0.48	-0.768
Baseri ·	0.103	664.97	-1.35	-0.768

Table 7 (c) contd.

Rajakhera	0.034	701.53	-0.29	-0.311
Bari	0.200	663.46	2.71	1.518
Biana	0.064	539.64	0.61	0.582
Nadbai	0.185	591.78	2.05	1.641
District Jaipur	0.184	531.46	1.52	1.708
Jaipur	0.175	546.55	1.77	1.618
Sanganer	0.066	539.72	0.66	0.602
Lalsot	0.083	613.75	0.81	0.763
Dausa	0.309	473.04	3.07	2.955**
Kotputli	0.100	496.72	0.81	0.917
Chatsu	0.172	511.07	1.72	1.594
Baswa	0.112	599.23	1.60	0.819
District Tonk	0.178	538.38	1.50	1.650
Tonk	0.178	627.59	0.78	0.670
Malpura	0.219	462.19	1.76	2.042**
Niwai	0.188	560.68	2.49	1.420
District Kota	0.108	895.69	-1.10	-0.988
Kota	0.052	776.39	-0.61	-0.477
Mangrol	0.171	894.96	-3.02	-1.285
Sangod	0.296	1001.85	-5.06	-2.295**
Shahbad	0.066	822.93	0.76	0.606
Itawah	0.172	756.27	-1.69	-1.591
Baran	0.003	873.34	0.03	0.025
Atru	0.126	1016.69	-1.60	-1.157
Chipabarod	0.125	1046.58	-1.60	-1.145
Kishanganj	0.216	993.84	-3.60	-1.889

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

Table 8 (a) : POLYNOMIAL REGRESSION COEFFICIENTS
OF MONSOON RAINFALL SERIES

District/ Station	No. of obser- vation	Degrees of freedom	Intercept	1st reg. coeff.	2nd reg. coeff.	F Value
District Alwar	85	1	516.06	0.489	–	0.31
Alwar	85	1	576.21	0.265	–	0.07
Govindgarh	54	2	564.78	-4.969	0.122	0.94
Kotkasim	56	2	701.79	-7.183	0.069	1.67
Tijara	85	1	506.76	0.986	–	0.97
Lachmangarh	85	1	520.85	-0.299	–	0.10
Nimrana	85	2	469.21	0.196	0.010	0.48
Mandawar	85	1	477.84	1.253	–	1.71
Kishangarh	85	2	470.92	3.602	-0.032	0.64
Ramgarh	52	1	589.34	-0.730	–	0.16
Distt. Jhunjhunu	85	1	381.45	0.436	–	0.38
Jhunjhunu	85	1	321.80	0.666	–	0.99
Chirawa	85	1	342.93	0.484	–	0.44
Khetri	85	1	476.71	0.164	–	0.03
Distt. Sawai Madhopur	85	1	659.11	0.599	–	0.29
Sawai Madhopur	85	1	830.39	-0.468	–	0.07
Sapotra	85	2	582.85	6.462	-0.059	1.31
Karauli	85	1	638.94	0.698	–	0.40
Hindaun	85	1	617.33	-0.228	–	0.04
Gangapur	85	2	534.19	3.917	-0.023	1.24
Khandhar	56	1	690.09	-0.032	–	0.00
Distt. Bharatpur	85	1	631.34	-0.152	–	0.03
Bharatpur	85	2	596.26	2.119	-0.034	0.60
Sepao	57	1	669.94	-0.099	–	0.00
Srimuthra	57	1	670.55	-0.779	–	0.29
Kamen	85	1	584.79	0.037	–	0.00
Dholpur	85	1	705.93	0.968	–	0.78
Baseri	57	1	631.73	-1.324	–	0.64

Table 8 (a) contd...

Rajakhera	85	1	664.35	−0.671	−	0.44
Bari	57	2	538.80	10.628	−0.136	1.86
Biana	85	2	593.24	1.000	−0.009	0.04
Nadbai	78	2	586.21	−1.569	0.046	1.75
Distt. Jaipur	85	2	460.86	3.562	−0.029	0.91
Jaipur	85	2	432.98	6.253	−0.057	1.43
Sanganer	85	1	497.41	0.481	−	0.19
Lalsot	85	1	583.73	0.456	−	0.18
Dausa	85	2	486.95	−0.419	0.032	2.91
Kotputli	85	2	441.15	1.347	−0.010	0.18
Chatsu	85	1	487.68	0.996	−	0.86
Baswa	55	2	511.69	5.867	−0.081	0.44
Distt. Tonk	85	2	438.14	6.173	−0.056	1.89
Tonk	85	1	594.82	0.646	−	0.30
Malpura	85	2	428.56	1.958	0.005	1.48
Niwai	57	2	499.44	6.851	−0.078	1.01
Distt. Kota	85	1	866.72	−1.563	−	1.82
Kota	85	1	743.60	−0.892	−	0.47
Mangrol	57	2	859.37	−2.595	−0.012	1.04
Sangod	57	2	877.35	3.819	−0.151	3.07
Shahabad	85	1	821.35	−0.463	−	0.12
Itawah	85	1	721.28	−1.812	−	2.85
Baran	85	1	851.80	−0.543	−	0.17
Atru	85	2	912.37	2.923	−0.059	1.51
Chipabarod	85	1	1018.83	−2.420	−	3.04
Kishanganj	75	2	858.82	3.660	−0.088	1.79

Table 8 (b) : POLYNOMIAL REGRESSION COEFFICIENTS
OF WATER YEAR RAINFALL SERIES

District/ Station	No. of observation	Degree	Intercept	1st reg. coeff.	2nd reg. coeff.	F Value
Ditt. Alwar	85	1	582.82	0.249	–	0.03
Alwar	85	1	645.90	0.116	–	0.01
Govindgarh	54	1	554.01	1.552	–	0.73
Kotkasim	56	2	829.68	-12.653	0.149	3.12
Tijara	85	1	579.75	0.689	–	0.44
Lachmangarh	85	1	572.27	-0.425	–	0.18
Nimrana	85	2	556.66	-1.217	0.021	0.25
Mandawar	85	2	466.47	5.843	-0.052	1.58
Kishangarh	85	2	552.52	2.515	-0.023	0.29
Ramgarh	52	1	642.14	-0.781	–	0.19
Distt.Jhunjhunu	85	1	441.47	0.315	–	0.19
Jhunjhunu	85	1	378.13	0.493	–	0.51
Chirawa	85	1	395.06	0.450	–	0.34
Khetri	85	1	547.96	0.012	–	0.00
Distt. Sawai Madhopur	85	1	704.34	0.495	–	0.20
Sawai Madhopur	85	1	865.50	-0.461	–	0.07
Sapotra	85	2	642.43	5.766	-0.053	0.99
Karauli	85	1	687.77	0.613	–	0.29
Hindaun	85	1	667.15	-0.481	–	0.19
Gangapur	85	2	579.78	3.497	-0.018	1.16
Khandhar	56	1	723.20	0.062	–	0.00
Distt. Bharatpur	85	1	694.06	-0.508	–	0.30
Bharatpur	85	2	673.53	1.294	-0.031	0.96
Sepao	57	1	711.32	-0.594	–	0.10
Srimuthra	57	1	711.06	-1.086	–	0.54
Kamen	85	2	655.76	0.122	-0.005	0.05
Dholpur	85	1	765.48	-1.240	–	1.23
Baseri	57	1	673.94	-1.518	–	0.77

Table 8 (b) contd..

Rajakhera	85	1	719.85	-0.947	-	0.83
Bari	57	2	583.50	10.677	-0.139	1.81
Biana	85	1	654.91	0.092	-	0.01
Nadbai	78	2	660.55	-3.066	0.065	1.80
Distt. Jaipur	85	2	514.67	3.148	-0.026	0.71
Jaipur	85	1	561.81	1.244	-	1.26
Sanganer	85	1	549.53	0.221	-	0.04
Lalsot	85	1	626.35	0.362	-	0.11
Dausa	85	2	543.99	-1.258	0.042	2.92
Kotputli	85	2	509.71	0.359	-0.001	0.04
Chatsu	85	2	473.09	4.903	-0.045	0.87
Baswa	55	2	562.87	5.195	-0.066	0.41
Distt. Tonk	85	2	487.22	5.474	-0.050	1.47
Tonk	85	1	635.05	0.600	-	0.26
Malpura	85	2	478.66	1.081	0.002	1.04
Niwai	57	2	553.92	4.475	-0.036	0.91
Distt. Kota	85	1	913.61	-1.730	-	2.14
Kota	85	1	790.94	-1.072	-	0.66
Mangrol	85	2	915.03	-4.657	0.025	1.01
Sangod	57	2	923.21	3.048	-0.139	2.99
Shahabad	85	1	870.71	-0.600	-	0.20
Itawah	85	1	768.48	-2.135	-	3.94*
Baran	85	1	889.56	-0.505	-	0.15
Atru	85	2	958.15	2.939	-0.060	1.57
Chipabarod	85	1	1082.71	-2.913	-	4.13*
Kishanganj	75	2	903.88	3.037	-0.080	1.73

* Significant at 5% of level

59

8.0   CONCLUSIONS

From the analysis and results, it could be broadly concluded that except Sawai Madhopur, none of the rainfall series indicate the presence of any trend or persistence.

(i)   The coefficient of variation of monthly rainfall varies from 100% to 250% while that of the monsoon season and annual rainfall varies from 25% to 48%.

(ii)   The coefficient of skewness of monsoon season and annual rainfall is nearly zero indicating a near normal distribution of the rainfall. The C.S. of monthly rainfall is, however, positive and high indicating the presence of large number of low rainfall values.

(iii)   The non-monsoon season rainfall does not bear any relationship with the preceding monsoon season rainfall. Also the rainfall series of individual months in the monsoon season do not have any correlation among themselves nor do they bear any relationship with the total monsoon rainfall.

(iv)   Split sample analysis of Sawai Madhopur data had indicated a falling trend in the monthly rainfall series after 1945 which is significant, for the months April, August and September.

REFERENCES

1.   Bhargava, B.N. and R.K. Bansal, (1969),'A quasi-Biennial Oscillation in Precipitation at Some Indian Stations', Indian Jour. of Meteorology and Geophysics, Vol. 20, No. 2, pp. 127-128.

2.   Dhar, O.N., P.R. Rakhecha and A.K. Kulkarni, (1982), 'Trends and fluctuations of seasonal and annual rainfall of Tamil Nadu', Proc. of the Indian Academy of Sciences, Vol. 91, No. 2, pp. 97-104.

3.   Indian Institute of Tropical Meteorology, (1986-87) Annual Report.

4.   India Meteorological Department (1970),'Monthly and Annual Rainfall and Number of rainy days 1901-50' Part II.

5.   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.

6.   Mitchell, J.M. (1968),'Some remarks on the statistical predictability of drought and related climatic anomalies', Proc. of the Conference on the Drought in North-eastern United States (15-17 May 1967), pp. 129-159.

7.   Namias, J.(1968),'Further studies of drought over North-eastern United States',Proc. of Conference on the drought in the North-eastern United States (15-17 May 1967), pp. 57-94.

8.   National Institute of Hydrology (1986-87),'Statistical Analysis of Rainfall in Belgaum District, Karnataka Tech. Rept. TR-4.

9.   Ramanamurthy, K.v., M.K. Soman and S.S. Mulye, (1987), 'Long term variations in the rainfall over upper Narmada Catchment', Mausam, Vol. 38, No. 3, pp. 313-318.

10.   Ramasastri,K.S.,(1979),'On the desertification & trend of rainfall in the West Rajasthan',Proc. of the International Symp. on Hydrological aspects of droughts,pp.27-37.

11.   Sharma, S.N.(1986),'Twenty five monsoons in Rajasthan 1961-1985-A Schematic Study',Irrig. Deptt.,Govt. of Rajasthan.

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