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Some studies on Rainfall of Rajasthan with particular reference to Trends

K. N. RAO

Meteorological Office, Poona

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1. Introduction

In the Symposium on 'The Rajputana Desert' held in 1952 under the auspices of the National Institute of Sciences of India, considerable attention was devoted to a discussion of the rainfall of Rajputana. Several references were made to trends in rainfall and comparison of normals of different periods. In view of the different views expressed, it was considered desirable to make a more critical examination of the rainfall of the area from the point of view of trends etc. The data considered in the paper for individual stations are for the uniform period 1901 to 1950. This has been done specially to see, if the analysis of data of uniform periods brings out features of interest. The data of a few stations with long term records have also been examined. Besides the data of individual stations, a comparison of district averages and of the sub-divisions, east and west Rajasthan for different periods has also been made.

2. Rainfall of Rajasthan

Rajasthan has an area of 131,000 sq. miles. The average annual rainfall of Rajasthan based on all available data for the period up to 1940 is 21 inches. East Rajasthan has an average of 27 inches and west Rajasthan of 11 inches. 94 per cent of the annual rainfall of east Rajasthan and 90 per cent of west Rajasthan are received during the months June to September. July and August are the rainiest months and receive nearly the same amount of rainfall (about 35 per cent of the annual total). The winter rainfall is very small.

Table 1 gives the monsoon rainfall departures of east and west Rajasthan for the years 1875 to 1955. Table 2 gives the average annual rainfall of 198 raingauge stations of Rajasthan grouped under districts. The averages are based on available data for the period 1901 to 1950. This table includes standard deviation, coefficient of variability, extremes of rainfall, differences between 1920 and 1940 normals and differences between 1901 to 1950 averages and 1901 to 1930 and 1901 to 1940 averages wherever sufficient data are available. The last column of the table gives the difference between 1940 and 1920 normals based on all available data, *i.e.*, normals which have been computed using all the available length of data for each station.

Fig. 1 shows the annual rainfall distribution of Rajasthan and Fig. 2 the coefficient of variability. Rainfall varies from less than 5 inches in a small area to the west of Jaisalmer to more than 30 inches in the area to the east of a line joining Dungarpur and Sapotra. Only four stations have an average of over 40 inches. These are Manohar Thana (Jhalawar district) 44·4 inches, Kushalgarh

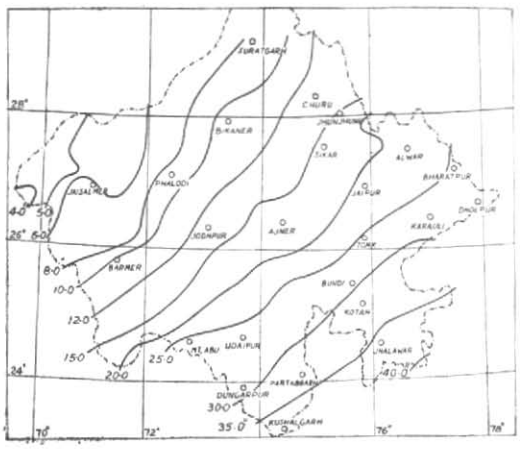

Fig. 1. Normal annual rainfall of Rajasthan

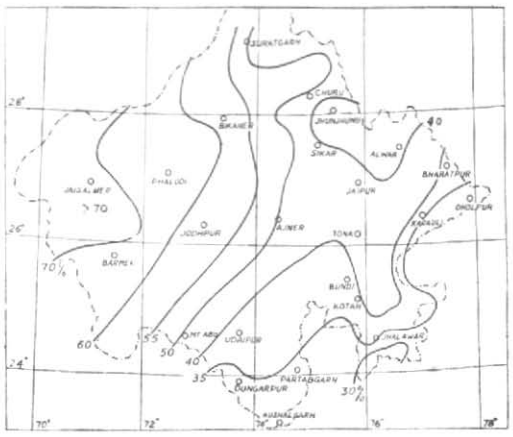

Fig. 2. Coefficient of variation (%)

(Banswara district) 42·4 inches, Chipabarad 41·11 inches and Chhabra 43·05 inches in Kotah district. The station Buili has the lowest annual rainfall (3·5 inches) in Rajasthan and also of the whole of the Indian Union. The average is based on records of 21 years. About half of Rajasthan has an annual rainfall of less than 15 inches. The isohyets of annual rainfall run practically parallel from northeast to southwest.

Variability—The coefficient of variability excepting for two stations in Jhalawar district (Pirawa and Iklera 27 per cent) is nowhere less than 30 per cent. It is more than 50 per cent over the western half of Rajasthan. The variability is a maximum in Jaisalmer district and adjoining areas where it is over 70 per cent. A few stations have as high standard deviation as the average rainfall itself. The coefficient of variability of monsoon rainfall of east Rajasthan is 28 per cent and of west Rajasthan 49 per cent. The coefficient of variability for all the months is given in Table 3 for these two sub-divisions.

3. Comparison of 1920 and 1940 district normals

The two principal sets of normals of rainfall published by the India Meteorological Department (*Mem. India met. Dep.*, Vol. 23, Part 7 and Vol. 27, Part 5) are those relating to periods ending 1920 and 1940. Along with the normals of individual stations, the normals of districts have also been given in each case. It must, however, be mentioned that the grouping of stations under districts followed the set up prevalent at the time of the respective publications. *This point is of great importance because normals of any district as published in 1920 and 1940 series are not comparable unless the same stations have been utilised in working out the district normals in both the cases.* It should also be remarked that the district normal as defined in these publications is simply the arithmetic mean of the normals of current stations in the district at the time of preparation. The 'district normal' has thus no additional significance. A few examples are given below to explain these points.

Examples

(*i*) *Jaisalmer District*

Normals	No. of stations	Annual normal (inches)
1920	3	6·94
1940	17	5·67
(1940)—(1920)		—1·27

TABLE 1

Rainfall of Rajasthan — Percentage departure from normal

Year	Rajasthan		Year	Rajasthan		Year	Rajasthan	
	East	West		East	West		East	West
1875	29	2	1902	— 7	— 26	1929	16	11
1876	18	93	1903	6	— 13	1930	— 7	—15
1877	—66	—75	1904	19	— 51	1931	13	32
1878	9	45	1905	—61	— 60	1932	—10	— 3
1879	16	17	1906	0	— 22	1933	48	32
1880	— 5	—16	1907	—26	9	1934	31	30
1881	11	47	1908	54	102	1935	11	— 8
1882	20	2	1909	10	35	1936	— 6	— 7
1883	—24	—36	1910	7	1	1937	1	5
1884	23	57	1911	—31	— 66	1938	—17	—27
1885	16	—33	1912	7	— 7	1939	—30	—56
1886	— 5	8	1913	—44	— 30	1940	— 9	1
1887	36	—38	1914	10	— 2	1941	—33	—17
1888	— 9	— 8	1915	—53	— 74	1942	63	22
1889	28	— 5	1916	39	34	1943	13	19
1890	— 3	—15	1917	98	119	1944	21	82
1891	—15	—36	1918	—56	— 78	1945	39	31
1892	48	63	1919	27	— 4	1946	34	—14
1893	17	77	1920	—18	— 33	1947	12	— 3
1894	26	18	1921	—12	— 24	1948	9	—21
1895	—18	—31	1922	8	— 17	1949	—15	—13
1896	—14	—12	1923	15	— 11	1950	16	13
1897	— 2	19	1924	49	— 6	1951	—44	—47
1898	—23	—36	1925	—24	— 32	1952	14	9
1899	—38	—83	1926	26	60	1953	—32	—14
1900	22	10	1927	1	22	1954	—12	— 9
1901	—34	—48	1928	—29	— 1	1955	23	

TABLE 2

Rainfall (inches) of Rajasthan

Station	No. of years	Mean	S.D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901–30) minus (1901–50)	τ_k	(1901–40) minus (1901–50)	τ_k	(1940) minus (1920)
JAIPUR District													
Jaipur	50	22·94	10·85	47	51·86	226	3·79	17	—0·47	—0·04	+0·12	+0·01	+0·07
Chatsu	49	21·00	8·22	39	42·38	202	5·55	26	+0·25	+0·03	—0·15	—0·02	—1·39
Amber	34	25·16	10·78	43	57·00	227	8·96	36			—0·12		
Jamwa Ramgarh	18	22·67	8·03	35	33·13	146	6·41	28					
Bairath	22	22·42	7·69	34	43·21	193	9·29	41					
Kotputli	50	20·31	7·70	38	40·68	200	4·14	20	+0·05	+0·006	—0·88	—0·11	—0·65
Dausa	50	21·83	8·81	40	51·36	235	5·31	24	+0·28	+0·03	—0·35	—0·04	+0·20
Lalsot	50	24·92	10·30	41	62·16	249	6·09	24	+0·06	+0·006	—0·09	—0·009	—0·65
Sambhar	49	19·64	7·08	36	39·82	203	5·37	27	—0·52	—0·07	—0·26	—0·04	—0·14
Mozamabad	14	17·65	7·47	42	29·40	167	6·99	40					
Pawata	14	20·12	7·99	40	39·60	197	8·47	42					
Sanganer	49	21·84	9·59	44	50·67	232	4·14	19	+0·18	+0·02	—0·32	—0·03	—0·18
Chomu	48	20·72	9·01	43	54·34	262	5·17	25					—0·17
Samodh	49	22·41	14·19	63	90·88	406	4·94	22					—0·63
Bandikui	49	24·23	10·23	42	59·52	246	6·41	26	+0·33	+0·03	—0·04	—0·004	+0·60
Baswa	19	22·78	7·94	35	37·94	167	10·04	44					
SAWAI MADHOPUR District													
Sawai Madhopur	50	34·95	17·39	50	94·89	271	7·87	23	—1·38	—0·12	—2·29	—0·19	+1·26
Khandar	21	28·27	9·06	32	45·36	160	7·84	28					
Malarna	18	27·80	10·79	39	46·14	166	6·73	24					
Gangapur	50	25·86	11·87	46	73·64	285	6·92	27	—1·38	—0·12	—2·29	—0·19	—1·54
Hinduan	50	26·01	9·06	35	53·78	207	9·34	36	+0·35	+0·04	—0·40	—0·04	+0·48
Joda Bhim	30	23·19	8·38	36	39·97	172	11·13	48					
Mahwa	50	22·67	10·58	47	60·96	269	6·84	30	+0·68	+0·06	+0·19	+0·01	+0·06
Karauli	50	27·91	9·83	35	51·87	186	7·15	26	—0·64	—0·06	—0·96	—0·10	—0·23
Machilpur	49	27·61	9·99	36	52·36	190	8·10	29	—0·29	—0·03	—0·58	—0·06	+0·28
Mandrael	50	26·66	9·80	37	47·90	180	7·63	29	+0·32	+0·03	—0·56	—0·06	—0·26
Sapotra	50	29·19	9·99	34	62·02	212	6·88	24	—1·14	—0·11	—0·44	—0·04	+1·49

TABLE 2 (*contd*)

Station	No. of years	Mean	S.D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901-30) minus (1901-50)	τ_k	(1901-40) minus (1901-50)	τ_k	(1940) minus (1920)
SIKAR District													
Sikar	50	17·36	6·51	38	31·89	184	7·06	41	—0·65	—0·10	—0·57	—0·09	+0·15
Toda Raisingh	21	24·12	6·35	26	34·16	142	8·27	34					
Nimkathana	50	19·75	7·47	38	48·79	247	3·32	17	—0·04	—0·005	+0·07	+0·01	+0·40
Sri Madhopur	50	18·79	8·18	43	44·19	235	5·15	27	—0·17		—0·38		—0·65
BHARATPUR District													
Bharatpur	50	26·53	10·21	39	54·45	205	8·34	31	+0·89	+0·09	+0·06	+0·006	—0·13
Kaman	49	25·50	10·75	42	61·81	242	8·68	34	+0·67	+0·06	—0·46	—0·04	—1·45
Nadhai	43	24·35	8·91	37	45·00	185	9·16	38					—0·20
Biana	50	25·34	9·97	39	53·65	212	7·57	30	+1·10	+0·11	+0·39	+0·04	—0·56
Dholpur	50	28·45	9·76	34	51·38	181	11·52	40	—0·04	—0·004	—0·57	—0·06	—0·95
Bari	46	28·70	10·54	37	59·45	207	8·72	30					
Rajakhera	49	27·39	8·74	32	54·04	197	11·70	43	—0·86	—0·10	—0·42	—0·05	—0·03
Gauli Sandro	41	24·16	8·46	35	43·37	180	7·56	31					—0·38
Angai	46	25·46	9·58	38	51·28	201	8·18	32					+0·03
Baseri	43	25·14	12·08	48	75·81	302	5·67	23					+0·24
Sepao	44	27·95	8·89	32	47·48	170	10·50	38					+1·13
Sirmuthra	43	26·34	9·19	35	46·25	176	6·18	23					+1·36
Kesarbagh	42	27·48	9·66	35	45·28	165	6·37	23					+0·25
Mania	42	26·27	9·25	35	49·61	189	5·39	21					+0·78
TONK District													
Tonk	50	26·27	11·83	45	59·35	226	6·64	25	—1·37	—0·11	—1·76	—0·14*	+0·10
Nizamat (Aligarh)	20	25·65	10·72	42	46·90	183	11·74	46					
Malpura	50	20·22	7·49	37	42·56	210	6·74	33	—0·36	—0·05	—0·24	—0·03	+0·09
Niwai	23	22·70	9·71	43	42·56	187	1·87	8					
Uniara	49	25·12	10·01	40	56·79	226	7·84	31	—0·34	—0·03	—0·56	—0·06	+0·08
ALWAR District													
Alwar	50	25·17	9·71	39	49·62	197	7·82	31	+0·34	+0·04	+0·10	+0·01	—1·20
Kishangarh	49	23·92	8·96	37	49·95	209	7·34	31	—0·62	—0·07	—0·65	—0·07	+0·68
Mandawar	49	22·53	9·02	40	50·15	223	4·11	18	—0·99	—0·11	—0·62	—0·07	+0·97
Lachmangarh	49	22·44	9·18	41	46·94	209	7·14	32	—1·23	—0·13	—0·64	—0·07	+1·19
Tijara	50	23·25	9·05	40	56·54	243	8·70	37	—0·86	—0·10	—0·26	—0·03	—0·08
Ramgarh	35	24·50	9·83	40	48·37	197	7·72	31					—0·07

*Significant at 5 per cent level

TABLE 2 (*contd*)

Station	No. of years	Mean	S.D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901-30) minus (1901-50)	τ_k	(1901-40) minus (1901-50)	τ_k	(1940) minus (1920)
						ALWAR District (*contd*)							
Nimrana	46	22·25	8·74	39	53·50	240	9·65	43					
Govindgarh	38	23·25	9·51	41	50·29	216	7·37	32					+0·31
Kotkasim	21	29·52	10·86	37	62·43	211	8·82	30					
						JHUNJHUNU District							
Jhunjhunu	50	15·26	5·46	36	29·84	196	3·65	24	—0·33	—0·06	—0·45	—0·08	+0·36
Chirana	49	16·07	6·49	40	34·68	216	3·75	23	—0·17	—0·03	—0·35	—0·05	
Khetri	50	22·06	7·99	36	44·90	204	3·49	16	—0·85	—0·11	—0·82	—0·10	—0·23
Nawalgarh	35	16·61	6·26	38	34·75	209	5·22	31					—0·87
						UDAIPUR District							
Udaipur	48	25·09	8·12	32	48·14	192	11·83	47					
Kherwara	50	26·67	8·64	32	44·43	167	10·40	39					
Bhim	46	23·29	12·39	53	42·09	182	5·60	24					
Kotra Cantt	39	30·73	12·24	40	62·05	205	10·29	35					
						BANSWARA District							
Banswara	46	35·53	11·93	34	62·52	176	8·40	24	—1·29	—0·11	—1·09	—0·09	—1·04
Garhi	32	33·62	11·21	33	61·71	184	16·51	49					—3·20
Kushalgarh	32	42·37	15·93	38	80·51	190	11·71	28					+1·99
Bhungra	21	37·85	14·09	37	63·46	168	2·28	6					
Khamera	22	38·27	12·23	32	68·29	178	16·28	43					
Danpura	22	39·61	13·61	34	71·11	180	22·55	57					
Shergarh	22	33·81	11·74	35	54·48	161	12·75	38					
Khandu	21	33·47	10·46	31	56·47	169	17·77	53					
Arthuna	21	36·20	12·75	35	57·18	158	15·99	44					
Loharia	11	34·15	14·35	42	65·76	193	17·27	51					
Sajjangarh	19	36·19	12·18	34	54·90	152	14·74	41					
Jagpura	21	34·79	11·82	34	65·32	188	18·05	52					
Sallopat	22	37·30	10·75	29	58·80	158	18·60	50					
						DUNGARPUR District							
Dungarpur	50	28·84	11·53	40	75·89	246	10·61	37	—1·50	—0·13	—0·92	—0·08	+2·05
Sagwara	41	26·57	8·68	33	50·31	189	10·80	41					—3·58
Dhombole	20	32·49	12·38	38	56·51	174	14·84	46					
Nithawa	20	31·55	13·87	44	65·87	209	14·09	45					

TABLE 2 (*contd*)

Station	No. of years	Mean	S.D.	C.V. %	Highest	% of mean	Lowest	% of mean	(1901–30) minus (1901–50)	τ_k	(1901–40) minus (1901–50)	τ_k	(1940) minus (1920)
CHITTOR District													
Chittor	9	39·70	12·07	30	60·38	152	21·70	55					
Partabgarh	50	32·64	11·51	35	70·58	216	14·89	46	—3·07	—0·27*	—2·20	— 0·19*	
Kapasin	9	30·77	12·17	40	60·22	196	17·12	56					
Nimbahara	20	26·60	8·25	31	38·37	144	11·23	42					
BHILWARA District													
Shahpura	50	25·83	9·69	37	59·30	230	7·57	29	—0·26	—0·02	—0·39	— 0·04	+0·62
Gangapur	43	21·72	9·36	43	58·55	270	5·17	24					—1·54
KOTAH District													
Kotah	49	31·11	12·06	39	69·96	202	6·74	22	—3·33	— 0·28*	—1·54	— 0·13	+0·35
Mangrol	46	31·83	14·26	45	67·93	213	5·96	19					+0·87
Sangod	45	34·92	13·36	38	65·90	189	13·66	39					+0·73
Sultanpur	43	31·00	14·39	46	69·36	224	8·46	27					+0·45
Indargarh	48	32·61	14·25	44	67·59	207	9·08	28					+2·27
Mandana	48	33·37	13·61	41	62·84	188	13·31	40					+2·06
Chechat	50	30·74	10·75	35	56·50	184	12·43	40	—2·16	— 0·20	—1·70	— 0·16*	+0·14
Antah	46	31·67	13·77	43	62·82	198	3·68	12					—1·40
Atru	50	38·95	13·77	35	65·24	167	8·05	21	+0·11	+ 0·008	+0·09	+ 0·007	+1·18
Baran	50	34·79	11·60	33	59·28	170	9·89	28	—1·18	— 0·10	—1·10	— 0·09	—0·91
Itawah	50	29·11	10·68	37	58·53	201	12·12	42	—2·29	— 0·21	—0·88	— 0·08	+1·15
Shahabad	49	34·54	11·19	32	59·95	174	13·02	38	—1·81	— 0·16	—1·06	— 0·09	+0·62
Kishenganj	40	37·50	15·43	41	81·83	218	15·69	42					+0·03
Chipabarad	50	41·11	13·22	32	72·15	175	13·01	32	—2·73	— 0·21	—1·71	— 0·13	+0·46
Chhabra	19	43·05	12·77	30	68·62	159	19·62	46					
Sironj	15	39·33	9·02	23	57·43	146	22·05	56					
BUNDI District													
Bundi	50	29·86	11·39	38	60·36	202	12·47	42	—1·60	—0·14	—1·65	—0·14	—0·10
Hindoli	20	29·70	11·40	38	54·29	183	11·33	38					
Patan	20	30·69	12·90	42	49·94	163	21·00	68					

*Significant at 5 per cent level

TABLE 2 (*contd*)

Station	No. of years	Mean	S.D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901–30) minus (1901–50)	τ_k	(1901–40) minus (1901–50)	τ_k	(1940) minus (1920)
JHALAWAR District													
Jhalawar	50	37·02	12·73	34	66·86	181	16·35	44			—3·02	—0·24	+0·50
Dug	50	37·07	11·16	30	63·14	170	21·17	57	—3·67	—0·33*	—2·08	—0·19*	+1·17
Pirawa	15	36·92	9·78	27	54·20	147	18·52	50					
Bakani	50	38·95	12·04	31	69·09	177	16·41	42	—2·50	—0·21*	—1·44	—0·12	+0·57
Iklera	50	37·58	10·12	27	57·61	153	18·28	49	—2·07	—0·20	—0·81	—0·08	+1·10
Manohar Thana	50	44·43	14·87	33	80·22	181	16·95	38	—3·94	—0·26*	—1·60	—0·11	+2·39
Khanpur	50	38·62	13·10	34	70·26	182	7·29	19					
Bhavaniganj	49	33·52	14·47	43	69·90	209	14·01	42	—3·60	—0·25*	—2·67	—0·12	+3·21
BIKANER District													
Bikaner	50	11·96	6·11	51	29·46	246	1·06	9	—0·21	—0·03	—0·24	—0·04	—0·24
Lunkanasar	45	9·19	5·16	56	23·25	362	1·61	18					—1·34
Gajner	43	9·42	5·17	55	23·26	247	0·01	0					
Palana	45	11·22	6·84	61	38·83	346	2·37	21					+0·45
Sirpura	38	10·75	6·35	59	32·39	301	1·20	11					+0·09
CHURU District													
Churu	45	14·48	5·70	39	30·56	213	3·04	21					—0·43
Ratangarh	45	13·92	5·66	41	30·31	218	1·40	10					+1·17
Sajangarh	45	14·65	7·72	53	51·62	352	2·77	19					—0·98
Sardarshahr	45	11·06	6·18	56	42·75	387	2·83	26					—1·63
Rajgarh	45	13·62	6·16	45	34·67	255	2·99	22					—2·10
Taranagar	45	11·87	6·89	58	35·44	299	0·80	7					—2·46
Dungargarh	45	10·24	4·99	49	29·88	292	3·00	29					—0·61
GANGANAGAR District													
Sriganganagar	45	9·10	5·24	58	27·84	306	1·57	17					
Karanpur	22	7·42	3·19	43	12·89	174	2·02	27					
Padampur	22	7·77	3·90	50	17·28	222	2·89	37					
Raisinghnagar	22	8·01	4·41	55	18·44	230	3·30	41					
Anupgarh	45	7·54	4·36	58	19·58	260	0·61	8					+0·03
Suratgarh	45	8·93	4·03	45	20·92	234	2·51	28					—1·37
Hanumangarh	45	11·36	5·53	49	23·56	207	2·34	21					—0·94
Nohar	45	12·33	5·54	45	30·71	249	3·86	31					—2·22
Bhadra	45	16·34	7·92	49	46·65	285	5·50	34					+0·33

* Significant at 5 per cent level

TABLE 2 (*contd*)

Station	No. of years	Mean	S. D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901–30) minus (1901–50)	τ_k	(1901–40) minus (1901–50)	τ_k	(1940) minus (1920)
						JODHPUR District							
Jodhpur	21	11·50	7·46	65	28·83	251	2·74	24					
Jodhpur Obsy.	50	14·34	8·20	58	42·35	302	1·16	8	—0·81	—0·10	—0·87	—0·11	+0·65
Bilara	49	17·32	9·67	56	47·83	276	1·25	7	+0·71	+0·07	—0·06	—0·006	—0·97
Phalodi	50	9·28	5·25	57	25·68	276	1·23	13	—0·34	—0·06	—0·11	—0·02	—0·22
Shergarh	50	10·42	5·26	51	32·50	312	1·24	12	+0·34	+0·06	+0·11	+0·02	+0·07
						PALI District							
Pali	50	16·19	7·67	47	37·19	230	3·10	19	—0·12	—0·01	—0·32	—0·04	—0·17
Jaitarana	49	15·10	7·50	50	44·96	298	2·05	14	—0·87	—0·11	—0·14	—0·02	+0·18
Desuri	50	24·63	10·98	45	60·68	246	7·28	30	—0·12	—0.01	—0·52	—0·05	—0·38
Bali	50	22·22	10·42	47	57·10	257	8·30	37	—1·25	—0·12	—0·67	—0·06	+1·89
Sojat	49	18·98	10·49	55	51·30	270	0	0	—0·26	—0·02	—0·15	—0·01	+0·95
Marwar (Jn.)	39	15·40	11·27	73	49·47	321	0	0					—0·85
						JALOR District							
Jalor	50	14·29	7·25	51	33·73	236	1·07	7	—0·59	—0·08	—0·85	—0·12	—0·13
Sachor	50	15·00	8·60	57	39·18	261	1·93	13	—0·01	—0·001	—0·32	—0·04	—0·46
Jaswantpura	49	18·77	9·58	57	49·17	262	6·47	34	—0·13	—0·01	—0·67	—0·07	—0·91
Bhinmal	22	18·49	8·07	44	33·06	179	6·84	37					
						BARMER District							
Barmer	50	10·90	6·78	62	37·01	340	1·13	10	—0·58	—0·09	—0·09	—0·01	+0·04
Sheo	50	8·17	5·91	72	27·99	343	0·41	5	+0·45	+0·08	+0·27	+0·05	—0·09
Siwana	49	13·62	7·62	56	40·11	294	2·84	21	+0·49	+0·06	—2·20	—0·30*	+1·46
Gudha	48	10·55	6·07	57	29·26	277	1·83	17					—1·40
Pachpadra	49	10·71	6·21	58	31·82	297	2·25	21	+0·22	+0·04	—0·25	—0·04	—0·59
Jasol	49	11·19	7·67	69	36·74	328	0	0	+0·10	+0·01	—0·03	—0·004	—0·60
Balotra	21	11·15	7·18	64	30·71	275	1·87	17					
						NAGORE District							
Nagore	50	12·20	5·77	47	31·75	260	2·48	20	+0·41	+0·07	+0·10	+0·02	—0·39
Didwana	50	14·05	7·57	54	49·27	351	1·88	13	+0·80	+0·11	+0·21	+0·03	—0·62
Merta Road	40	15·27	6·25	44	39·12	256	2·54	17					+1·84
Merta City	50	16·49	8·53	52	50·66	307	3·00	18	+0·51	+0·06	+0·28	+0·03	+0·24
Parabatsar	49	15·18	6·77	45	33·63	222	2·72	18	—0·21	—0·03	—0·09	—0·01	+1·04
Nawa	50	18·46	7·71	42	46·23	250	2·88	16	—0·66	—0·09	—0·79	—0·10	+1·17

* Significant at 5 per cent level

TABLE 2 (*contd*)

Station	No. of years	Mean	S.D.	C.V. (%)	Highest	% of mean	Lowest	% of mean	(1901-30) minus (1901-50)	τ_k	(1901-40) minus (1901-50)	τ_k	(1940) minus (1920)
						SIROHI District							
Sirohi	49	22·49	11·31	50	54·85	244	5·51	25	—1·05	—0·09	—1·41	—0·13	—0·01
Sheoganj	39	19·58	8·25	42	45·21	231	6·19	32					—0·13
						JAISALMER District							
Jaisalmer	50	7·03	4·81	68	22·77	324	0	0	+0·21	+0·04	+0·21	+0·04	—0·22
Devikot	48	6·06	4·46	74	21·00	347	0	0	—0·45	—0·10	—0·45	—0·10	—0·17
Bap	49	7·20	4·96	69	21·33	296	0·50	7	—0·67	—0·13	+0·25	+0·06	+0·34
Fategarh	21	7·27	3·95	54	17·63	243	1·97	27					
Lakhan	21	7·75	8·56	111	30·31	391	0	0					
Mayajalar	21	6·55	6·13	94	27·57	421	0	0					
Shahgarh	21	4·58	3·71	81	14·82	324	0	0					
Khuiala	21	4·54	2·87	63	10·77	237	0·60	17					
Tanot	21	4·14	4·17	101	20·00	483	0	0					
Kishengarh	22	4·87	3·76	77	14·70	302	0	0					
Builí	21	3·49	1·90	54	7·10	203	0·64	18					
Mohangarh	21	5·33	3·61	68	12·73	239	0	0					
Nokh	22	6·97	4·64	67	18·27	262	2·10	30					
Dawa	49	4·72	3·60	76	17·84	378	0	0	+0·39	+0·11	—0·03	—0·01	—0·72
Ramgarh	49	5·40	4·14	77	22·90	424	0·21	4	+0·10	+0·02	—0·01	—0·002	—0·23
Khaba	49	6·07	4·21	69	21·81	359	0	0	+0·40	+0·09	—0·13	—0·03	—0·39
Lathi	20	5·75	2·79	49	11·69	203	0·82	14					
						AJMER-MERWARA District							
Ajmer	50	20·05	8·47	42	44·58	422	5·86	29	—0·86	—0·10	—0·18	—0·02	—0·10
Sawar	49	20·57	8·47	41	40·05	412	6·94	34	+1·47	+0·17	+0·57	+0·07	+0·21
Kekri	48	23·74	8·86	37	50·67	373	7·42	31					+0·62
Pisangan	49	16·00	8·66	54	48·93	541	3·26	20	+0·91	+0·11	+0·45	+0·05	—0·36
Goela	49	17·59	8·32	47	49·81	473	5·70	32	+1·23	+0·15	+0·78	+0·09	—1·16
Beawar	49	18·26	7·89	43	45·62	432	1·17	6	—0·30	—0·04	+0·06	+0·008	—0·12
Jawaja	47	18·15	9·02	50	45·69	497	2·25	12	—1·09	—0·12	—0·79	—0·09	+0·86
Todgarh	48	23·09	11·05	48	62·34	479	5·84	25					+0·15

TABLE 3

Month	Mean rainfall (inches)	σ (inches)	*D* (inches)	Coefficient of variability (%)
		Rajasthan (West)		
Jan	0·13	0·29	0·19	223
Feb	0·21	0·32	0·25	152
Mar	0·14	0·22	0·14	157
Apr	0·10	0·17	0·13	170
May	0·28	0·51	0·35	182
Jun	1·13	1·08	0·87	96
Jul	3·43	2·03	1·64	59
Aug	3·93	3·00	2·49	76
Sep	1·44	2·11	1·62	147
Oct	0·17	0·43	0·19	253
Nov	0·06	0·20	0·11	333
Dec	0·10	0·18	0·14	180
Jun—Sep	9·93	4·85	3·63	49
		Rajasthan (East)		
Jan	0·29	0·31	0·27	107
Feb	0·25	0·38	0·29	152
Mar	0·21	0·34	0·27	162
Apr	0·13	0·30	0·18	231
May	0·39	0·54	0·37	139
Jun	3·07	1·92	1·57	63
Jul	8·94	3·37	2·61	38
Aug	8·45	4·24	3·56	50
Sep	4·13	3·21	2·57	78
Oct	0·56	0·84	0·53	150
Nov	0·20	0·29	0·19	145
Dec	0·21	0·36	0·27	171
Jun—Sep	24·59	6·84	5·40	28

Note (*i*) Mean rainfall — Based on available data up to 1940

(*ii*) σ (Standard deviation) } Based on data up to 1944
(*iii*) *D* (Mean deviation) }

(*iv*) Coefficient of variability $= \frac{\text{S.D.}}{\text{Mean}} \times 100$

Taking the same 3 stations as in 1920, but using 1940 normals, the 1940 district normal is 6·92 inches.

$$(1940)_3 - (1920)_3 = -0{\cdot}02 \text{ inch}$$

The number of stations in 1940 is 14 more than in 1920.

(*ii*) Due to the regrouping of stations, a number of new districts which were not in the 1920 publication appear in the 1940 publication, *e.g.*, Pali and Pachpadra are new districts appearing in the 1940 normals.

(*iii*) *Sirohi District*

Normals	No. of stations	Annual normal (inches)
1920	1	21·36
1940	4	30·12
(1940)—(1920)		8·76

If, however, we took only the station on which the 1920 district normal is based, the corresponding 1940 normal is 21·35 inches. The difference $(1940)_1 - (1920)_1 = -0{\cdot}01$ inch. Besides the number of stations being 4 in 1940 tables, due to a mistake the 1940 normal has been worked out taking the hill station Mount Abu which is against the standing practice of excluding all stations above 3500 ft a.s.l. except in the case of Kashmir stations.

It is clear from the above examples that great caution has to be exercised in comparing district normals as they appear in the publications from time to time. Any conclusions regarding the variation of rainfall in time based on such figures is likely to be misleading.

In Table 4, the 1920 and 1940 district normals have been compared using the same district groupings as prevailed in the 1920 series.

TABLE 4

S. No.	District	No. of stations in 1920	1940 district normal calculated using same stations as in 1920	(1940)—(1920) normals using same stations as in 1920	(1940)—(1920) normals according to the published district normals	Col. (5) / Col. (4) × 100
			(inch)	(inch)	(inch)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Jaisalmer	3	6·92	— 0·02	— 1·27	0·3
2	Bikaner	16	11·37	— 0·64	— 2·11	5
3	Alwar	7	22·71	0·22	— 5·56	1
4	Bharatpur	4	25·61	— 0·53	— 0·54	2
5	Karauli	4	27·36	0·32	— 0·85	1
6	Bundi	1	27·92	0·10	— 0·31	4
7	Deoli	1	29·59	— 0·12	— 0·12	4
8	Kotan	18	35·91	— 0·70	— 3·12	2
9	Ajmer-Merwara	9	20·31	0·08	— 0·14	0·4
10	Udaipur	2	25·25	— 0·21	— 3·41	0·8
11	Dungarpur	2	27·40	— 0·27	— 0·32	1
12	Banswara	2	34·50	— 2·12	— 2·45	6
13	Jodhpur	30	13·53	— 0·07	1·04	0·5
14	Jaipur	23	21·38	— 0·19	0·21	0·1
15	Sirohi	2	41·45	— 0·13	8·76	0·3
16	Tonk	1	25·11	0·10	0·10	0·4
17	Shapur	1	25·19	0·62	0·62	2
18	Jhalawar	1	35·64	1·17	0·97	3
19	Pratabgarh	1	32·11	0·67	0·60	2
20	Kushalgarh	1	36·89	1·99	1·99	5
21	Dholpur	10	26·05	0·19	0·23	0·7

As may be seen from column 5 of Table 4, the differences except in a very few cases are less than 1 inch. In the case of 11 out of 21 districts the differences are less than 0·25 inch numerically. It is interesting to remark that 18 of the differences are less than 0·75 inch. As both positive and negative values occur in west Rajasthan, the sign alone would not support any decrease or increase of rainfall even in small amounts. This result is in such striking contrast to what one may conclude from the values in column 6 of the table.

In Table 5 are given the differences between 1940 and 1920 annual normals corresponding to the districts as used in the present rainfall tables (see also Fig. 3). The present grouping differs considerably from the 1920 and even 1940 districts.

This table also shows that the difference in rainfall between 1940 and 1920 normals of districts using the same stations in both cases is *small* and negligible. In the case of each district the average has also been added to give an idea of the order of difference. The percentage difference is given in the last column.

The above analysis shows clearly that the apparent substantial differences between the 1920 and 1940 published normals for some districts in Rajasthan are ascribable to differences in the number of stations that enter the normals and not due to differences in rainfall incidence in the areas between the periods.

4. Comparison of 1901 to 1930 and 1901 to 1940 averages with 1901 to 1950 averages of individual stations

The differences between 30 and 40-year averages and 50-year average are given in Table 2 for a number of stations. In some cases the periods may not be exactly 30/40 years but a few years less.

The following test is employed to find out if the differences are statistically significant. If $x_1, x_2 \ldots\ldots\ldots x_n$ are n observations, we wish to compare the mean of the first k observations with the mean of the entire series.

$$Let,\ \bar{x}_k = \frac{1}{k} \sum_{1}^{k} x_r \qquad (1 \leqslant k < n)$$

$$\bar{x} = \frac{1}{n} \sum_{1}^{n} x_r \text{ (mean of the entire series)}$$

$$ns^2 = \sum_{1}^{n} (x_r - \bar{x})^2 = \sum_{1}^{n} x_r^2 - n\ (\bar{x})^2$$

$$\tau_k = \frac{\bar{x}_k - \bar{x}}{s}$$

It can be shown (Cramer 1946) that

$$t = \tau_k \left\{ \frac{k\,(n-2)}{n-k-k\tau_k^2} \right\}^{\frac{1}{2}}$$

has Student's distribution with $n-2$ degrees of freedom. The test is based on the assumption that the series is normally distributed.

TABLE 5

District as in the present rainfall tables (1)	No. of stations (2)	1940 minus 1920 normals (3)	1940 normal (4)	(3) / (4) × 100 (5)
1. Jaipur	10	—0·29	21·77	—1
2. Swai Madhopur	8	0·19	26·59	0·7
3. Sikar	3	—0·03	19·07	—0·2
4. Bharatpur	14	—0·03	29·56	—0·1
5. Tonk	3	0·09	23·12	0·4
6. Alwar	8	0·23	22·62	1
7. Jhunjhunu	4	—0·19	17·55	—1
8. Udaipur	3	0·06	24·51	0·2
9. Banswara	3	—0·75	35·35	—2
10. Dungarpur	2	—0·77	27·40	—3
11. Chittor	No station with 1920 normal			
12. Bhilwara	2	—0·46	24·63	—2
13. Kotah	14	0·57	32·50	2
14. Bundi	1	—0·10	27·92	—0.4
15. Jhalawar	7	1·36	36·97	4
16. Bikaner	4	—0·26	10·49	—3
17. Churu	7	—1·01	12·30	—8
18. Ganganagar	5	—0·83	10·91	—8
19. Jodhpur	4	—0·12	12·65	—1
20. Pali	6	0·27	18·19	1
21. Jalor	3	—0·50	15·92	—3
22. Barmer	6	—0·20	10·75	—2
23. Nagore	7	0·45	15·80	3
24. Sirohi	2	—0·07	19·83	—0·4
25. Jaisalmer	6	—0·23	6·04	—4
26. Ajmer-Merwar	8	0·01	20·07	0·05
	140			

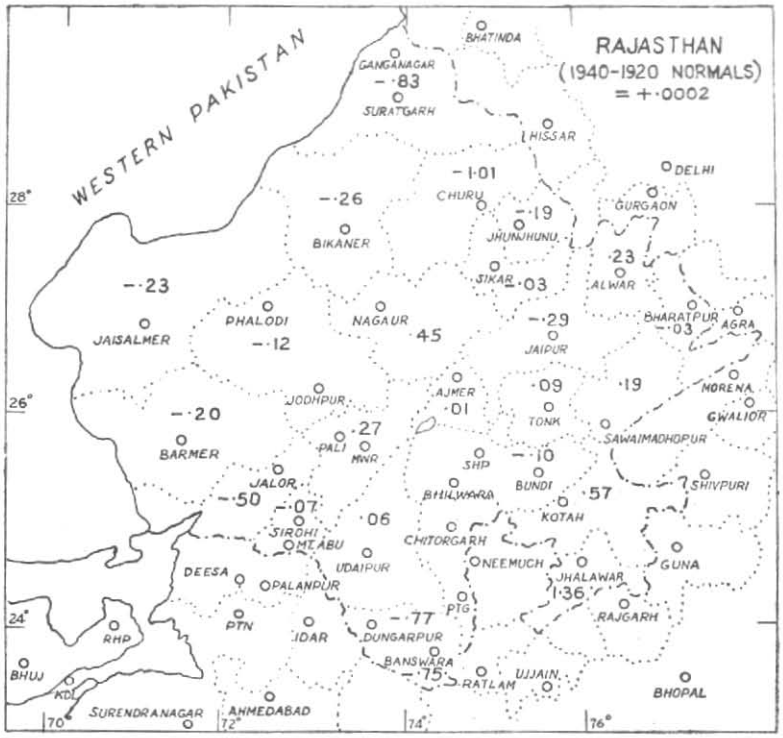

Fig. 3. Differences between 1940 and 1920 normals of Districts

Writing τ_k in terms of t,

$$\tau_k = t\ [(n-k)/k\ (n-2+t^2)]^{\frac{1}{2}}$$

Values of τ_k corresponding to 5 per cent and 1 per cent values of t are as follows: $n = 50$; number of degrees of freedom: $n-2=48$.

		k	k	k
		10	30	40
τ_k	5%	·59	·23	·14
	1%	·74	·29	·18

Calculated values of τ_k should exceed these for significance. τ_k calculated in this manner is entered in Table 2 for a large number of stations. Those which are significant at 5 per cent are indicated by an asterisk. It will be seen that in the large number of cases considered, only a very few differences are found to be significant.

This analysis indicates that considering Rajasthan as a whole, there has been no significant change in the normals during the fifty-year period, 1901 to 1950.

5. Trend

Linear regression equations have been fitted to the data of one or two stations in each district. Only those stations which have records extending to over 45 years have been considered. The linear equation fitted is

$$R = by + \text{constant},$$

where R = rainfall, y = year and b = regression coefficient. The regression coefficients b have been tested by F-test for significance. Values of b and F for about 50 stations are given in Table 6. Those which are significant at 5 per cent level are indicated by an asterisk. Linear regression equations have also been fitted to the data of seven stations which have records for long periods.

TABLE 6

Rajasthan—Rainfall

Coefficient of Linear Trend and *F*

Station	No. of years	Regression coefficient	*F*	Station	No. of years	Regression coefficient	*F*
Sawai Madhopur	50	+·39324	2·0598	Churu	45	+·03622	·3009
Gangapur	50	+·15018	1·6876	Ratangarh	45	+·12262	3·7835
Jaipur (Obsy.)	50	+·04628	·2256	Sriganganagar	45	—·00046	·0001
Kotputti	50	—·02134	·0787	Anupgarh	45	—·01926	·1463
Chechat	50	+·20790	4·1531*	Jodhpur	50	+·04876	·3611
Atroo	50	—·00672	·0024	Phalodi	50	+·00524	·0102
Shahapura	50	+·09704	1·0446	Pali	50	+·02962	·1531
Gungapur	43	+·05329	·2101	Desuri	50	+·06072	·3137
Jhunjhunu	50	+·05208	·9465	Jalor	50	+·06788	·9111
Khetria	50	+·06976	·7874	Sachor	50	+·01124	·0174
Alwar	50	—·06450	·4554	Ajmer	50	+·09172	1·2449
Tijara	50	+·02092	·0546	Sawai	36	—·15626	1·3380
Tonk	50	+·20894	3·4105	Barmer	50	+·05444	·6284
Malpura	50	+·05444	·5454	Sheo	50	—·01736	·0980
Bharatpur	50	—·04414	·1964	Sirohi	48	+·15890	1·9795
Biana	50	—·06398	·4246	Shaoganj	39	+·10316	·9318
Sikar	50	+·08418	1·7719	Bap	49	+·00804	·0252
Nimkathana	50	+·02058	·0776	Ramgarh	49	—·01298	·0947
Bundi	50	+·15558	1·9990	Dungarpur	50	+·18098	2·6536
Jhalawar	50	+·35264	1·8509	Nagam	50	—·02558	·2011
Dug	50	+·34860	2·1839	Didwana	50	—·03872	·2679
Bikaner	50	+·01946	·1036	Partabgarh	50	+·38108	14·5846*

Station	No. of years	Mean	S.D.	Coefficient of variability (%)	Regression Coefficient	*F*
Phalodi	66	14·34	7·18	52	—·0215	·856
Nagaur	66	8·90	4·8	55	—·0087	·078
Madawa	53	20·65	8·8	43	—·0055	·0048
Nawa	60	8·21	5·5	67	—·0487	1·4502
Sikar	64	17·53	6·7	38	+·0223	·2374
Jhunjhunu	74	19·86	7·3	37	+·0020	·0026
Partabsar	60	17·60	7·9	46	+·1447	6·561*

* Significant at 5 per cent level

Excepting for a very small number of stations, the regression coefficients are not statistically significant.

This analysis also supports the results of Section 4.

6. Rainfall of east and west Rajasthan subdivisions

We have considered in the earlier Sections comparison of normals of districts and of individual stations and also examined for trend data of a number of stations. We will now examine for trend and also test if the differences in the means of decades and other periods of east and west Rajasthan divisions are statistically significant. The series considered for this analysis are the actual values of rainfall expressed as percentage of the normal, from 1875 to 1955. Percentage departures from normal are given in Table 1.

(*i*) *Normality of Rainfall*

The normality of the distribution of percentage departures of rainfall given in this table for the east and west Rajasthan subdivisions separately have been tested by calculating Fisher's g_1 and g_2 together with their standard errors. The results are shown below—

	East Rajasthan	West Rajasthan
g_1	$\cdot 02 \pm \cdot 27$	$\cdot 16 \pm \cdot 27$
g_2	$\cdot 64 \pm \cdot 53$	$\cdot 90 \pm \cdot 53$

It is seen from the above that all the values of g_1 and g_2 being less than twice their standard errors, there is no significant departure from normality in the distribution of departures of rainfall in Rajasthan.

(*ii*) *Testing for the homogeneity of variances*

Decade-wise frequency distributions of the rainfall are shown in Tables 7 and 8.

We will now test for the homogeneity of the decade variances. If $s_1^2, s_2^2 \ldots s_k^2$ are the estimated variances each with n degrees of freedom, then the statistics required to be calculated is —

$$M = n\, k \log_e \sum_1^k \frac{s_t^2}{n} - n \sum_1^k \log_e s_t^2$$

M is distributed as χ^2 with $(k-1)$ degrees of freedom. The values of M for east and west Rajasthan were found to be 9·7 and 11·7 respectively which are evidently not significant at 5 per cent when compared with the values given in Table 32 (*Biometrika Tables*).

(*iii*) *Comparison of means and variances of different periods*

East Rajasthan

The decade with the highest mean 115·9 is 1941 to 1950. Comparing it with the mean for 1901 to 1950 and applying the test indicated in Section 4,

$t = 1 \cdot 53$ with 78 degrees of freedom.

This is not significant at even 5 per cent level. Having selected the highest difference for testing significance the appropriate test to be applied is the one corresponding to the distribution of the maximum. But t is not significant even with the ordinary test. None of the decade means differs significantly from the mean for the entire period.

West Rajasthan

(*a*) The decade with the highest mean 116 is 1926 to 1935. The decade 1896 to 1905 has the lowest mean 83. Comparing these decade means with the mean for the period 1875 to 1955 and applying the test of Section 4 we find,

(*i*) 1926—1935 $\quad t = 1 \cdot 656$

(*ii*) 1896—1905 $\quad t = 1 \cdot 5$

Neither of these is significant even at 5 per cent level of significance.

(*b*) The difference between the means of rainfall of west Rajasthan for the two periods, 1875 to 1924 ($\bar{x}_1$) and 1925 to 1946 ($\bar{x}_2$), is $\bar{x}_2 - \bar{x}_1 = 1 \cdot 27$ inches. Applying the usual t-test for comparison of the two means we have the following—

$$(n_1 - 1)\, s_1^2 = \sum_{n=1875}^{1924} (x_n - \bar{x}_1)^2$$

$$= 1392 \cdot 9 \qquad (n_1 = 50)$$

$$(n_2 - 1)\, s_2^2 = \sum_{n=1925}^{1946} (x_n - \bar{x}_2)^2$$

$$= 240 \cdot 3 \qquad (n_2 = 22)$$

x_n = Rainfall in year n

$s_1^2 = 28 \cdot 43$; $\quad s_1^2/n_1 = 0 \cdot 5686$

$s_2^2 = 11 \cdot 44$; $\quad s_2^2/n_2 = 0 \cdot 52$

$$t = \frac{\bar{x}_2 - \bar{x}_1}{\left[\sum_1^{n_1} (x_n - \bar{x}_1)^2 + \sum_1^{n_2} (x_n - \bar{x}_2)^2\right]^{\frac{1}{2}}} \times \left[\frac{n_1 n_2 (n_1 + n_2 - 2)}{n_1 + n_2}\right]^{\frac{1}{2}} = 1 \cdot 002$$

This is not significant at 5 per cent level of significance. The difference in means is not significant.

TABLE 7

Frequency distributions of actual monsoon rainfall expressed as percentage of normal according to decades from 1881

East Rajasthan

Actual rainfall expressed as % of normal	1875–1880	1881–1890	1891–1900	1901–1910	1911–1920	1921–1930	1931–1940	1941–1950	1951–1955	Total 1875-1955
31–40	1			1						2
41–50					2					2
51–60					1				1	2
61–70			1	1	1		1	1	1	6
71–80		1	1	1		2				5
81–90			3		1	1	2	1		8
91–100	1	2	1	1		1	2			8
101–110	1	1		4	2	2	1	1		12
111–120	2	3	1	1		2	2	3	2	16
121–130	1	2	2		1	1		1	1	9
131–140		1			1		1	2		5
141–150			1			1	1			3
151–160				1						1
161–170								1		1
171–180										
181–190										
191–200					1					1
Mean	100·2	109·3	100·3	96·8	96·9	104·3	103·2	115·9		102·8
Highest		134	148	154	198	149	148	139		198
Lowest		41	62	39	44	71	70	67		34
Range		93	86	115	154	78	78	96		164
Variance										863·84
S.D.										29·6
Range/S.D.										5·54

TABLE 8

Frequency distributions of actual monsoon rainfall expressed as percentage of normal according to decades from 1881

West Rajasthan

Actual rainfall expressed as % of normal	1875–1880	1881–1890	1891–1900	1901–1910	1911–1920	1921–1930	1931–1940	1941–1950	1951–1955	Total 1878–1955
1– 20			1							1
21– 40	1			1	3					5
41– 60				2			1		1	4
61– 80		3	3	2	2	2	1	1		14
81–100	1	3	1	1	3	5	3	4	2	23
101–120	2	2	3	2		1	2	2	1	15
121–140				1	1	1	3	2	1	9
141–160	1	2				1				4
161–180			2							2
181–200	1							1		2
201–220				1	1					2
Mean (100+)	11·0	—2·1	—1·1	—7·3	—12·8	—1·3	—0·1	9·9	—15·3	—1·25
Highest	193	157	177	202	219	160	132	182	109	219
Lowest	25	62	17	40	22	68	44	79	53	17
Range	168	95	160	162	197	92	88	103	56	202

As the ratio of the variances appeared large, this was tested to see whether s_1^2 exceeds significantly s_2^2. The F-test applied for this purpose gives $F = s_1^2/s_2^2 = 2{\cdot}4$ with $n_1 - 1 = 49$ and $n_2 - 1 = 21$ degrees of freedom for s_1^2 and s_2^2. F is significant at 5 per cent but not at 1 per cent. Although significance is not definitely established, it was considered better to examine the difference $\bar{x}_2 - \bar{x}_1$ for significance by applying Fisher-Behren's test and also Welch's test.

(*a*) *Fisher-Behren's test* — The difference $\bar{x}_2 - \bar{x}_1$ is significant if it exceeds $d\,(s_1^2/n_1 + s_2^2/n_2)^{\frac{1}{2}}$ where d is 5 per cent or 1 per cent values in Table 6 of Fisher-Yates Tables. Now $d\,(s_1^2/n_1 + s_2^2/n_2)^{\frac{1}{2}} = 2{\cdot}088$ for 5 % level. $\bar{x}_2 - \bar{x}_1 = 1{\cdot}27$ inches is less than $d\,(s_1^2/n_1 + s_2^2/n_2)^{\frac{1}{2}}$ for 5 per cent level of significance. Hence the means are not significantly different.

(*b*) *Welch's test* —

$$v = \frac{\bar{x}_2 - \bar{x}_1}{(s_1^2/n_1 + s_2^2/n_2)^{\frac{1}{2}}} = 1{\cdot}221$$

$$C = \frac{s_2^2}{n_2} \Big/ \left\{ \frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} \right\} = 0{\cdot}48$$

$\bar{x}_2 - \bar{x}_1$ is significant if v exceeds the value corresponding to C and for $\nu_2 = n_2 - 1$ (21) and $\nu_1 = n_1 - 1$ (49). As seen from Table 11 of

Biometrika Tables (page 136), v is not significant even at the 5 per cent level of significance. The above supports the conclusion that the means are not significantly different.

(*iv*) *Trend*

Linear regression equations have been fitted to the data of rainfall (June—September) of east and west Rajasthan, for the period of 81 years from 1875 to 1955 ($R=by+$ constant).

(*a*) East Rajasthan :

$b = 0{\cdot}029$, $F = 0{\cdot}046$ (not significant)

There is no significant trend in east Rajasthan.

(*b*) West Rajasthan : $b = {\cdot}0007$

The regression coefficient is negligibly small. There is thus no trend in west Rajasthan also.

(*v*) Before concluding this Section a brief discussion will be given of time intervals between years when the monsoon rainfall was less than 80 per cent of the normal. All such years during the period 1875 to 1955 are listed (Table 9) for east Rajasthan for ready reference.

There were 17 occasions during 80 years when rainfall was less than 80 per cent of the normal. On an average one in five years is a year when rainfall is less than 80 per cent of normal. About 50 per cent of such occasions occurred at successive intervals of 3 years or less. During this period (1875—1955) there were a number of instances of the intervals being more than 5 years. Three of them were greater than 9 years, the highest being 15 years. It would be of interest to examine the random nature of the intervals and the homogeneity of this series. The tests to be applied are based on the assumption that the intervals follow the exponential law. Such tests have been indicated in a paper by Maguire and others (1951). If t_n is the largest of n independent time intervals and

TABLE 9

Year	Departure from normal —ve	Interval in years (t_i)
1877	66	
1883	24	6
1898	23	15
1899	38	1
1901	34	2
1905	61	4
1907	26	2
1911	31	4
1913	44	2
1915	53	2
1918	56	3
1925	24	7
1928	29	3
1939	30	11
1949	33	2
1951	44	10
1953	32	2

No. of occasions = 17
Total = 648
Average departure = 38·1 per cent
$\Sigma t_i = 76$, Mean $t_i = \bar{t}$
$= 4{\cdot}5$ years

The frequency distribution of t_i is given below—

t_i	Frequency	t_i	Frequency
1	1	7	1
2	6	8	1
3	2	10	1
4	2	11	1
6	1	15	1

$\bar{t}$ is the mean of n intervals, then

$$g = t_n / n\bar{t} = 0{\cdot}197.$$

This is less than the significant value of g at 5 per cent significance level which is ·31922 for n=16. The longest interval of 15 years is thus not significant.

In order to find out if there is any significant tendency for intervals to succeed one another in groups, sometimes longer and sometimes shorter, the test criterion used is

$$M = 2nk \left\{ \log_e \left(\frac{1}{k} \sum_i T_i \right) - \frac{1}{k} \sum_i \log_e T_i \right\}$$

where T_i is the sum of the inervals in the i^{th} group. Bartlett has shown that M/C is distributed as χ^2 with k—1 degrees of freedom, where, $C = 1 + \left(\frac{k+1}{6nk} \right)$

Dividing the intervals into four groups, M/C=1·44 with 3 degrees of freedom. This is not significant at 5 per cent level. Actually P=70 per cent in this case.

7. Conclusion

A critical examination of the rainfall series of east Rajasthan and west Rajasthan over a long period up to 1954 does not show any significant changes in the history of rainfall in the area.

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