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HYDROLOGICAL ASPECTS OF DROUGHT UPTO 1987-88 - A CASE STUDY IN RAJASTHAN

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PREFACE

A most important factor in understanding droughts, often not included in definition, is that it is a supply and demand phenomenon. Though a number of definitions of drought pertaining to various uses have been developed, however, a definition which does not include reference to water requirement or demand can be regarded as inadequate. To a hydrologist drought means below average availability of flow in streams and below average storages in reservoirs, lakes, tanks, ground water aquifers and soil moisture in soil column. The various hydrological variables which can be used to study hydrological aspects of drought include rainfall, groundwater levels, surface water storages and soil moisture.

The problem of drought in the country has been recurrent in nature. In late 80's the country has faced drought for three years in succession. Reliable estimates indicate that the drought of year 1987 is ranked second in the century, the first one being in year 1918. It has been estimated that about 1/3rd of the geographical area of the country (107 Mha) spread over 99 districts, are drought prone. The Central Water Commission (CWC) has carried out studies in these 99 districts for identifying drought proneness.

The National Institute of Hydrology initiated drought studies in the year 1986 with the major objectives to lay emphasis on hydrological aspects of drought and to develop suitable drought indices alongwith evolving short and long term drought management strategies. In this venture the institute has already carried out studies on various aspects of drought. In order to study the

gravity of problem, studies have been taken up using the field data to evaluate impacts of drought. In this pursuit the Institute has chosen six states namely, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan. The present report covers the study of six districts of Rajasthan state. These districts are Barmer, Banswara, Ajmer, Udaipur, Dungarpur, and Jodhpur.

The scientific teams of the Institute undertook visits to the state of Madhya Pradesh and contacted the relevant state/central Govt. agencies for collecting the required data. The study includes various kinds of analysis of rainfall and groundwater level data for assessing drought impacts. Based on the analysis, inferences highlighting the hydrological aspects of the recent droughts have been drawn up.

The study has been carried out by Shri V K Lohani, Scientist C, Shri Sudhir Kumar Goyal, Scientist B, Shri Yatveer Singh, R.A., Shri Mukesh Kumar Sharma, S.R.A., Shri Tanveer Ahmed, R.A. under the guidance of Dr G C Mishra, Scientist F. The manuscript has been typed by Shri Rajneesh Kumar Goel, L.D.C.

(SATISH CHANDRA)

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ABSTRACT

The occurrence of drought in India is not a recent phenomenon. In recent years the country faced three drought years in succession namely 1985, 1986, 1987. It has been reported intensity wise the drought of year 1987 ranks second in the 20th century, the first one being in the year 1918. Statistics on areal coverage indicate that out of the country'stotal geographical area of 328 m.ha., 107 m.ha., or about one third of the area and 29 percent of the population are affected by drought.

In view of severity of drought problem and less understanding the hydrological aspects associated with the droughts, the National Institute of Hydrology started studies in the year 1986 to better understand the drought impacts from hydrology point of view. In this venture the institute started collection, from field organisations, of the data concerning rainfall, streamflow and groundwater in selected areas, covering the period 1951 to 1988. Six states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh & Rajasthan were selected for the study. This report covers the analysis of rainfall, groundwater, & reservoir level data in respect of six selected districts Barmer, Banswara, Ajmer, Udaipur, Dungarpur & Jodhpur of State Rajasthan for the assessment of drought impacts.

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1.0 INTRODUCTION

1.1 General

In spite of all the inconveniences that drought causes all around the world, many drought phenomena are still insufficiently understood in terms of the characterization and impact assessment. There have been difficulties encountered in finding a generally accepted drought definition. The definitions currently in use are derived either on professional standpoints (meteorology, hydrology, geography etc.), or on the economic activity affected (agriculture, power, production, water supply etc.). A most important factor in understanding drought, often not included in definitions, that it is a "supply and demand" phenomena. A definition of drought which does not include reference to water requirement or demand can be regarded as inadequate. In general terms, the chief characteristics of drought is associated with a decrease of water availability in a particular period and over a particular area for specified use(s).

In India, the problem of droughts is recurrent. Estimates indicate that about one-third of the geographical area of the country (107 m.ha.) spread over 99 districts are affected by drought. In recent times, the country faced three drought years in succession namely, 1985, 1986 and 1987. It has been reported that intensity wise the drought of 1987 ranks second in the century, the first one being in year 1918. During the drought of 1987 about 50% of country's area was affected by drought with about 18% negative departure in monsoon rainfall all over India and about 45% negative departure in monsoon rainfall over the drought affected region (Upadhyay & Gupta, 1989). Sampath (1989) has reported that during 1987, 21 metecrological sub-divisions out

of 35 recorded deficient/scanty rains leading to drought conditions. A quick glance of foodgrains production figures indicates that during year 1987-88 the production was 138.41 million tonnes while in 1988-89 it was estimated to be about 172.0 million tonnes. The years 1985-86 through 1987-88 saw declining trend of food grains production which fell from 150.4 million tonnes in 1985-86 to 138.41 million tonnes in 1987-88. The fluctuation of foodgrain production clearly show dependability of agricultural activities on the rainfall.

The incidents of drought lead to reduction in stream flows, depletion of soil moisture storages, decline of reservoir and tank levels and fall in groundwater table. This in turn lead to reduced agriculture and fodder production. The drought characteristics and the associated problems vary from area to area depending upon the amount of variability of available water supplies and the demand of water for specified users.

1.2 Objectives of the Study

Inspite of repeated occurrence of droughts in the country, the hydrological aspects of droughts have not been studied to the desired extent. Such studies have a direct bearing on evolving strategies for planning judicious use of water resources.

The Institute, therefore, initiated studies to lay emphasis on Hydrological Aspects of Droughts in year 1985. Keeping in view the successive three drought years of 1985,1986 and 1987, in major parts of the drought prone areas of the country, study areas were chosen in six states namely: Andhra Pradesh, Maharashtra, Karnataka, Rajasthan, Gujarat and Madhya Pradesh.

Studies laying focus on hydrological aspects of drought

for 1985-86 with two districts in each of chosen states and for 1986-87 with four districts in each of the states have been completed. The studies for year 1987-88 were carried out in six districts each in six states and in view of wider aerial coverage in each state it was decided to prepare separate study reports, contrary to the earlier study reports which presented results of studies in all states in one volume.

The present report therefore presents the results of studies carried out in six selected districts of State Rajasthan. The districts included for studies are Barmer, Banswara, Ajmer, Udaipur, Jodhpur & Dungarpur. The report includes analysis of rainfall and groundwater level data for finding deficits in rainfall and its consequent effects on groundwater tables. The report is an attempt towards developing comprehensive hydrological drought indices for characterising drought situations. List of offices and places from where data & other relevant informations were collected in the state of Rajasthan are given in Appendix-II.

2.0 DESCRIPTION OF STUDY AREA

2.1 General

There are 99 districts spread over 13 states which have been identified as drought prone districts in the country and are shown in fig. 2.1. This report covers the study of six drought prone districts of state Rajasthan namely; Barmar, Banswara, Ajmer, Udaipur, Jodhpur and Dungarpur. The locations of the districts are shown in the state map shown in fig. 2.2. Rajasthan state is situated in North-western part of India and lies between $23^{\circ}3'$N and $30^{\circ}12'$N latitudes and $69^{\circ}30'$E and $78^{\circ}17'$E longitudes. The area of the state is about 3,42,239 sq.km. The average rainfall of the state varies from 5 cm to 12.5 cm.

2.2 Population-Man & Cattle

The state of Rajasthan has the population 3,42,61 thousand as per census 1981 comprising 27051 thousand rural and 7210 thousand urban. The density of population per sq.km. as per census of 1981 is 100 for the state Rajasthan. The details of the population for cattle are given in table. 2.1.

Table 2.1: Live Stock Census 1983 (Provisional)

Sl.No.	Animal	Nos.
1.	Sheep	1,33,86,115
2.	Goats	1,54,09,451
3.	Camels	7,52,887
4.	Cattle & Buffaloes	1,95,00,876
5.	Others	4,36,641
	Total	4,94,85,970

Source: Desert Development Programme, Annual Plan 1987-88
Govt of Rajasthan, Jaipur

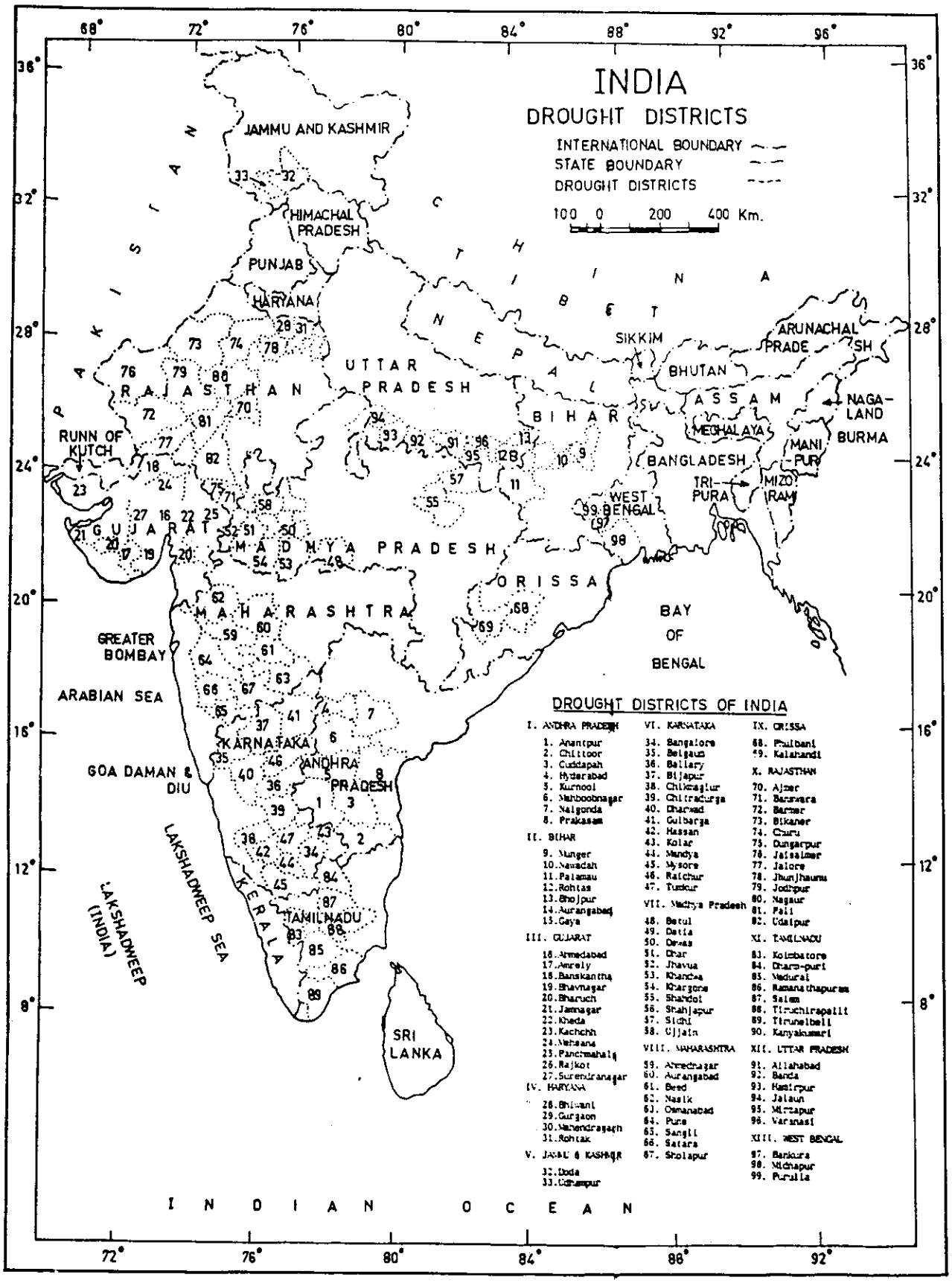


FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

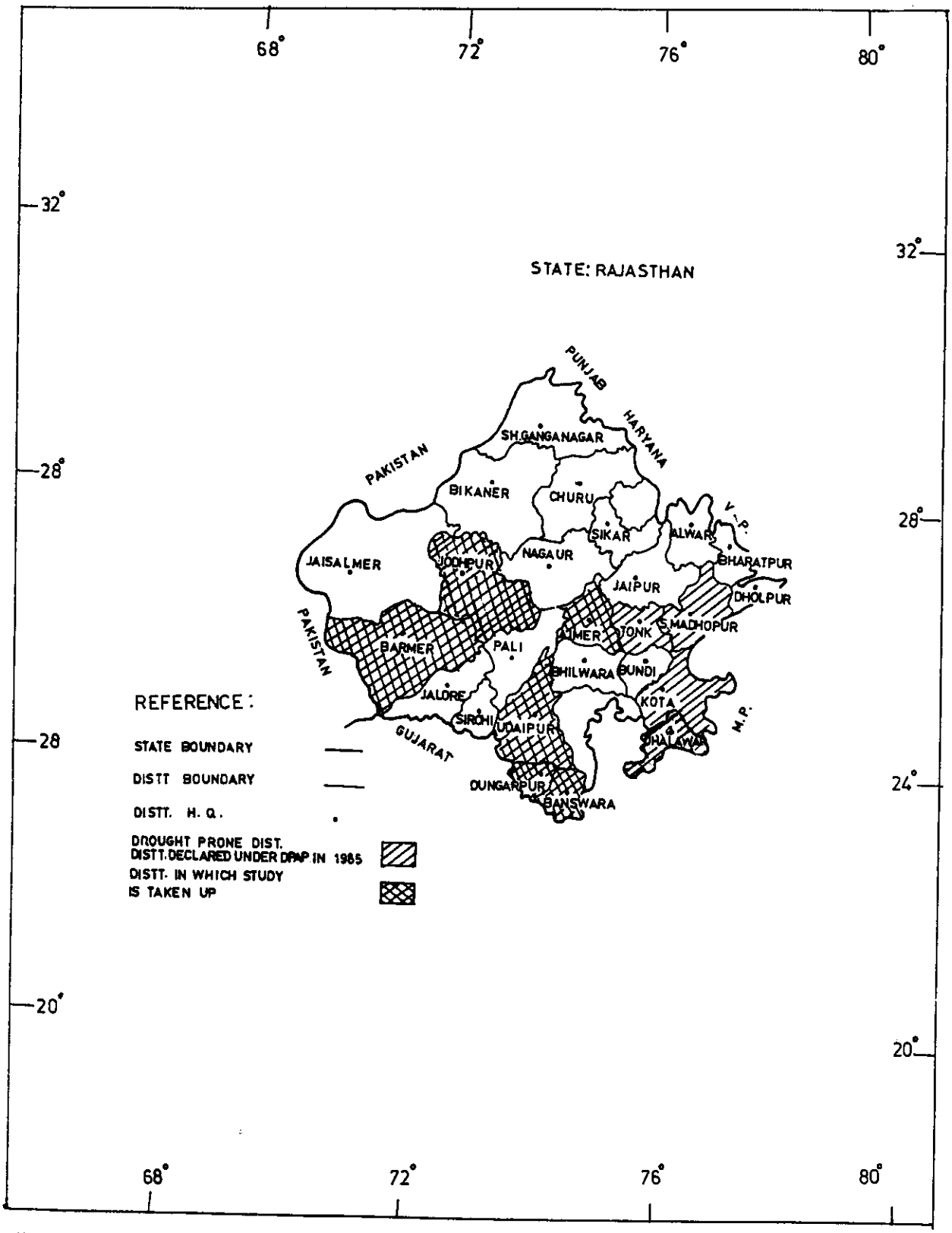


FIG. 2.2 : DROUGHT PRONE DISTTS. IN RAJASTHAN

2.3 Land Use and Vegetal Cover

The details of divisionwise land use classification with the base year 1985-86 are shown in table 2.2 for the state Rajasthan.

2.4 Soils

The soils of state Rajasthan can be divided into eight broad groups. With more information available on the morphological characteristics of soils in different climatological and physiographical characteristics of soils in different climatological and physiographic units of the state, 12 basic soil associations have been established. Fig. 2.3 shows the details of soils in the state Rajasthan (Deptt. of Agriculture, 1970).

2.5 Surface Water Availability

The details of storage built up, under construction and those under proposal in the state Rajasthan are given in Table 2.3.

Table 2.3: Storages in the Projects of State Rajasthan

Sl.No.	Type of Projects	Gross storage in m.ha.m.	Live Storage in m.ha.m.
1.	Projects completed	0.5523	0.3589
2.	Projects under construction	0.2714	0.2313
3.	Total	0.8237	0.5902
4.	Proposed Projects	0.0546	0.0488

Source: CWC Report on Water Resources of India, 1988

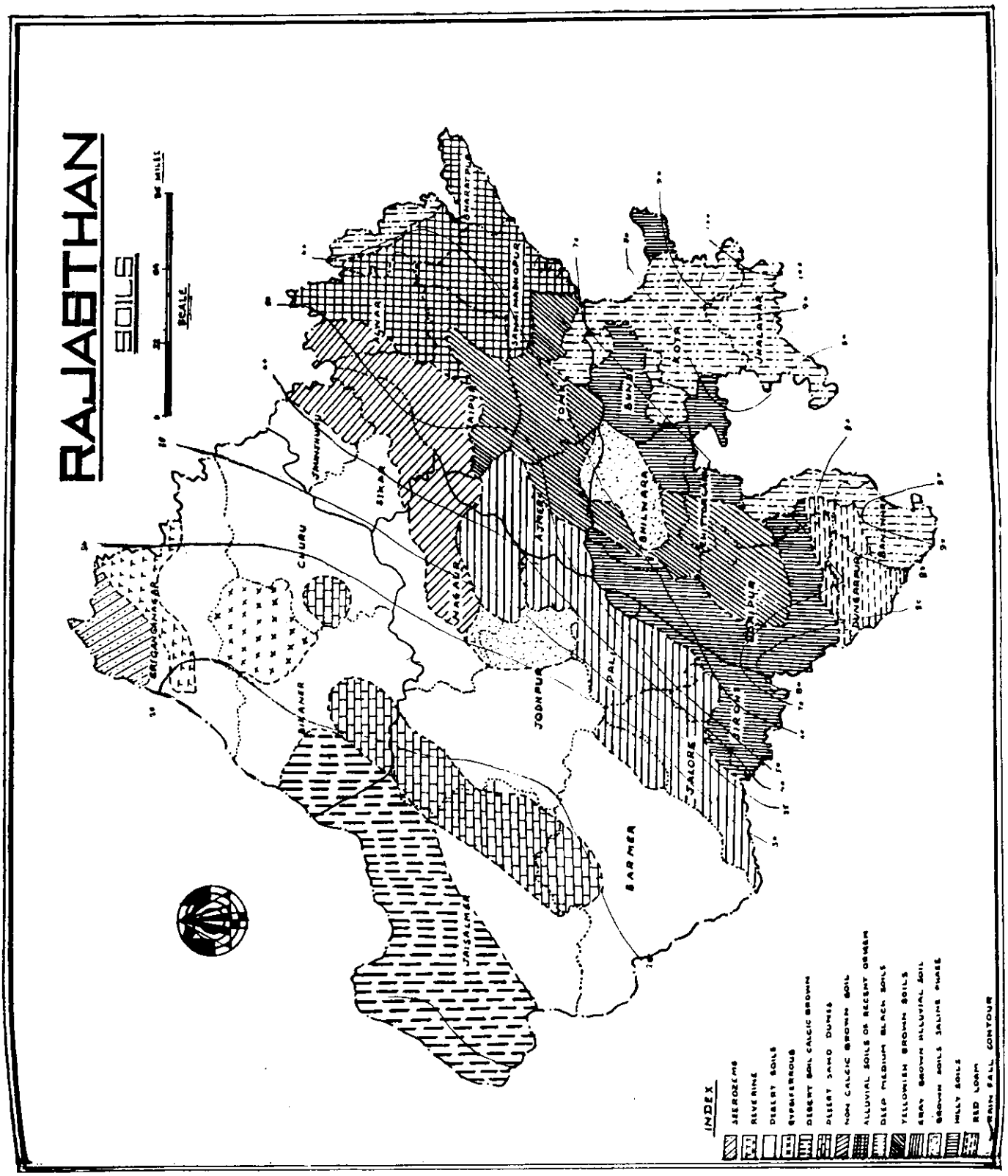


Fig.2.3 Soil Map of State Rajasthan

Table 2.2 : Land Utilization 1985-86

(Area in hect.)

Districts	Culturable waste	Total	Fallow land			Net area sown	Gross area sown	Double cropped area
			old fallow	Current fallow	Total			
AJMER DIVISION								
Ajmer	86115	166572	40587	80683	121270	363609	421374	57765
Jaipur	76070	187727	81384	83850	165234	792818	1027248	234430
Sikar	14888	61645	47849	50486	98335	512409	622525	110116
Jhunjhunu	6972	51363	15937	20359	36296	435867	564035	128168
Total-	184045	467307	185757	235378	421135	2104703	2635182	530479
BHARATPUR DIVISION								
Alwar	14715	40885	17656	19466	37122	502834	745326	242492
Bharatpur	6000	16479	9984	12947	22931	383636	510796	127160
Dholpur	14765	35916	10563	10883	21446	142118	178230	36112
S.Madhopur	29852	98546	20798	21642	42440	510003	654980	144977
Total-	65332	191826	59001	64938	123939	1538591	2089332	550741
BIKANER DIVISION								
Bikaner	1274103	1331774	251544	179170	430714	775121	796919	21798
Churu	28933	76700	142164	114113	256277	1275372	1312359	36987
Ganganagar	115871	140167	56984	110813	167797	1570098	1860891	290793
Total-	1418907	1548641	450692	404096	854788	3620591	3970169	349578
JODHPUR DIVISION								
Jodhpur	80511	202127	472735	275975	748710	1077560	1098990	21430
Jaisalmer	2909003	3023921	136233	52255	188488	187254	187264	10
Jalore	27537	79293	87409	113398	200806	638715	717339	79624
Barmer	227217	500511	323448	244202	567650	1532510	1549424	16914
Nagaur	26266	101437	101015	236716	337731	1169089	1209289	40200
Pali	44506	139477	120254	127176	247430	568614	603483	28869
Sirohi	12829	46358	25430	31150	56580	159312	188181	28869
Total-	3387669	4093124	1266523	1080872	2347395	5333114	5553970	220956
KOTA DIVISION								
Kota	57612	112709	28880	23905	52785	582864	708482	125618
Bundi	35022	59135	22797	19489	42286	245971	323136	77165
Jhalawar	67192	119673	13932	9910	23842	310125	412679	102554
Tonk	53617	116710	18039	34393	52432	455931	510644	54713
Total-	213443	408227	83648	87697	171345	1594891	1954941	360050
UDAIPUR DIVISION								
Banswara	18516	49327	25455	18366	43821	219527	307812	38285
Dungarpur	25991	68668	20964	20251	41215	118272	161533	43261
Udaipur	245405	407043	65150	40861	106011	346462	493180	146718
Total-	289912	525038	109569	79478	189047	684261	962525	278264
BHILWARA DIVISION								
Bhilwara	211285	331093	54515	42642	97157	325828	435593	109765
Chittore	217240	297260	18725	21821	40546	361641	535692	174051
Total-	428525	628353	73240	64463	137703	687469	971285	283816
STATE-	5988033	7862516	2228430	2016922	4245352	15563620	18137404	2573784

2.6 Ground Water Availability

In the state of Rajasthan depth to water table ranges from 1.99 m (Ballop, District Bundi) to 122.2 m (Rama, District Jaisalmer). In general in the Eastern side of the Aravallis the depth to water is comparatively shallower than that in Western side. The altitude of the water table in the state varies between 721.15 m.above mean sea level(amsl) (Dewair, District Udaipur) and 36.53 m. amsl (Dewa, District Jalore). In the eastern side slope of water table ranges from 0.25 m/km to 3.3 m/km and in the Western side it ranges from 0.4 m/km to 10 m/km. (Source: Report of CGWB, Jaipur, 1985). The statement given in table 2.4 shows the number of wells, Tube-wells, electrified wells, and diesel pump-sets in Rajasthan. The ground water resource potential in the state as in 1983-84 is given in table 2.5

Table 2.5: Groundwater Resource Potential of Rajasthan

Sl.No.	Groundwater	Quantity
1.	Utilizable resource	1.457 Mham
2.	Net Draft	0.447 Mham
3.	Potential available for future development	1.010 Mham
4.	Stage of groundwater development	31 percent

2.7 Water Use

The annual requirement of water in the state of Rajasthan for domestic purposes during 1981 was of the order of 0.072 m.ha.m. which has been estimated to increase to a level of 0.1332 m.ha.m. by 1991 (CWC, 1988). The water availability and water requirement figures for drought prone districts of the state Rajasthan are given in table 2.6. The sourcewise gross and net

Table 2.4: Statement Showing the No. of Wells, Tube-wells, Electrified Wells & Diesel Pump Sets in Rajasthan

Districts	Wells (1984-85) In use	Out of use	Tube-wells	1983 Diesel pump sets	Upto Jan.86 Electrified Wells
AJMER DIVISION					
Ajmer	50875	18648	46	3935	10989
Jaipur	106793	30673	152	28682	53398
Sikar	27938	8081	59	2640	22657
Jhunjhunu	9979	3058	103	2205	15495
Total-	205585	60460	360	37462	102539
BHARATPUR DIVISION					
Alwar	47096	12900	15990	53982	18756
Bharatpur	9472	12005	20763	22922	7905
Dholpur	13411	2494	4762	8434	1273
S.Madhopur	43611	8452	2451	21571	11964
Total-	113590	35851	43966	106909	39898
BIKANER DIVISION					
Bikaner	81	-	54	1	26
Churu	376	66	385	1	498
Ganganagar	-	-	4536	1754	4765
Total-	457	66	4975	1756	5289
JODHPUR DIVISION					
Jodhpur	13243	2179	583	4524	6601
Jaisalmer	73	-	100	3	23
Jalore	27801	6637	181	18213	10591
Barmer	4945	861	98	3256	2568
Nagaur	19282	9232	447	3009	11808
Pali	33728	9869	200	10032	13865
Sirohi	11458	1771	-	4765	6156
Total-	110530	30549	1609	43802	51612
KOTA DIVISION					
Kota	30979	6333	57	6024	6669
Bundi	16743	6245	21	3144	4103
Jhalawar	43924	6691	1	5321	7445
Tonk	35601	8253	-	5956	4605
Total-	127247	27522	79	20445	22822
UDAIPUR DIVISION					
Banswara	7042	11432	75	5842	3204
Dungarpur	10177	8567	76	3601	1985
Udaipur	91252	29563	25	7837	15542
Total-	108471	49562	176	17280	20831
BHILWARA DIVISION					
Bhilwara	84476	25438	6	3284	13207
Chittore	74223	4651	46	11123	23662
Total-	158699	30089	52	14407	36869
STATE-	824579	234099	51219	252061	279860

irrigated area in various divisions of the state Rajasthan is given in Table 2.7 and table 2.8 respectively.

Table 2.6: Water Availability and Water Requirement for Drought Prone Districts

Unit : cubic km

Sl.No.	District	Water Availability		Total Requirement
		50% Dependability	75% Dependability	
1.	Amjer	2.37	1.88	0.65
2.	Banswara	2.15	1.60	0.15
3.	Barmer	0.39	0.39	0.33
4.	Bikaner	2.83	2.83	2.54
5.	Churu	0.20	0.20	0.15
6.	Dungarpur	1.05	0.69	0.19
7.	Jaisalmer	3.78	3.78	3.79
8.	Jalore	0.63	0.63	0.73
9.	Jhunjunun	0.22	0.22	0.21
10.	Jodhpur	0.73	0.47	0.49
11.	Nagour	0.39	0.39	0.43
12.	Pali	0.82	0.79	1.10
13.	Udaipur	2.74	2.18	1.18

Source : CWC 1988

2.8 Crops & Fodder

The agricultural production of the state is dependent on rainfall. The principal crops of the state are Jowar, Bajra, Maize, Gram, wheat, oilseeds, cotton, sugarcane and tobacco etc. The total production of foodgrain in the state in the years 1986-87 was 67,230 tonnes. The statement showing cropwise area under different crops during the years 1976-77 to 1985-86 is given in table 2.9. The statement showing the cropwise irrigated area under different crops during the years 1976-77 to 1985-86 is given in table 2.10. The statement showing the cropwise productivity under different crops during the year 1976-77 to 1985-86 is given

Table 2.7 : Gross Irrigated Area (Sourcewise) 1985-86

Districts	Canal	Tanks	Tube-wells	Wells	Others	Total
AJMER DIVISION						
Ajmer	2219	6159	56	90446	423	99303
Jaipur	8303	1272	221	418977	141	428914
Sikar	266	-	156	129494	-	129916
Jhunjhunu	287	-	-	70185	564	728605
Total-	11075	7431	433	709102	564	728605
BHARATPUR DIVISION						
Alwar	7081	-	55708	110101	927	173817
Bharatpur	4835	104	81974	15802	1259	103974
Dholpur	17312	372	15769	26459	2634	62526
S.Madhopur	39232	4195	10794	110867	1138	166226
Total-	68460	4671	164245	263209	5958	506543
BIKANER DIVISION						
Bikaner	64162	-	9	-	284	64455
Churu	-	-	-	1956	-	1956
Ganganagar	1002243	-	1201	2	-	1003446
Total-	1066405	-	1210	1958	284	1069857
JODHPUR DIVISION						
Jodhpur	-	-	2786	64707	225	67718
Jaisalmer	2	-	99	4	6	111
Jalore	275	-	149	145048	-	145472
Barmer	-	-	434	32751	-	33185
Nagaur	75	84	4865	88517	126	93667
Pali	-	4020	-	53846	30	57896
Sirohi	-	4020	-	53846	30	57896
Total-	352	4971	9325	490670	387	505705
KOTA DIVISION						
Kota	181599	4734	824	52490	3697	243344
Bundi	115842	572	2678	30561	757	150410
Jhalawar	4948	642	-	63841	698	70129
Tonk	13155	2082	-	66115	169	81521
Total-	315544	8030	3502	213007	5321	545404
UDAIPUR DIVISION						
Banswara	45947	3559	154	7998	4361	62019
Dungarpur	177	1165	266	11446	844	12898
Udaipur	-	25838	77	102738	3660	132313
Total-	46124	30562	497	122182	8865	208230
BHILWARA DIVISION						
Bhilwara	-	24480	-	114023	29	138532

Chittore	3101	18259	256	138229	467	160312
Total-	3101	42739	256	252252	496	298844
STATE-	1510974	98491	179468	2052380	21875	3863188

Table 2.8 : Net Irrigated Area (Source-wise) 1985-86)

(Area in hect.)

Districts	Canal	Tanks	Tube-wells	Wells	Others	Total
AJMER DIVISION						
Ajmer	1472	5660	40	69353	361	76886
Jaipur	8154	1069	174	344510	123	354030
Sikar	266	-	103	98825	-	99194
Jhunjhunu	287	-	-	57776	-	58063
Total-	10179	6729	317	570464	484	588173
BHARATPUR DIVISION						
Alwar	6661	-	52916	97522	811	157910
Bharatpur	4453	103	79499	14777	1073	99905
Dholpur	16780	372	15528	25836	2592	61108
S.Madhopur	38622	4078	10306	104815	1075	158896
Total-	66516	4553	158249	242950	551	477819
BIKANER DIVISION						
Bikaner	43007	-	1	-	170	43178
Churu	-	-		1278	-	1278
Ganganagar	735121	-	915	2	-	736038
Total-	778128	-	916	1280	170	780494
JODHPUR DIVISION						
Jodhpur	-	-	2123	48573	50	50746
Jaisalmer	2	-	97	3	6	108
Jalore	219	-	147	130236	-	130602
Barmer	-	-	319	16783	-	17102
Nagaur	35	52	3142	69248	101	72578
Pali	-	813	896	86571	-	88280
Sirohi	-	3486	-	42205	12	45703
Total-	256	4351	6724	393619	169	405119
KOTA DIVISION						
Kota	153709	3525	636	47802	3337	209009
Bundi	91713	416	2678	23994	654	119506
Jhalawar	4718	453	-	59176	657	65004
Tonk	12390	1818	-	57586	141	71935
Total-	262530	6263	3314	188558	4789	465454
UDAIPUR DIVISION						
Banswara	33250	3463	132	7180	4146	48171
Dungarpur	86	1041	211	8383	765	10486
Udaipur	-	21554	77	79592	3640	104863
Total-	33336	26058	420	95155	8551	163520
BHILWARA DIVISION						
Bhilwara	-	20785	-	81412	29	102226
Chittore	3101	15508	201	107611	432	126853
Total-	3101	36293	201	189023	461	229079
STATE-	1154046	84247	170141	1681049	20175	3109658

Table 2.9 : Statement Showing the Crop-wise Area under Different Crops During the Year 1976-77 to 1985-86

(Area in '000 ha.)

Crops	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
CEREALS:										
Kharif										
Rice	159	184	211	186	170	140	118	160	170	131
Jowar	840	724	826	848	1002	962	951	985	938	984
Bajra	3614	4066	4535	4266	5032	4945	4808	4996	4367	4764
Maize	763	749	808	880	900	918	885	894	912	973
S.Millets	69	58	57	47	47	49	43	45	37	34
Total	5445	5781	6437	6227	7151	7014	6809	7080	6324	6886
Rabi										
Wheat	1799	1833	1991	2072	1635	1768	2070	2159	1718	1773
Barley	590	468	406	423	410	450	339	299	258	326
Total	2389	2301	2397	2495	2045	2218	2409	2458	1976	2099
Total cereal	7834	8082	8834	8722	9196	9232	9218	9538	8300	8985
PULSES										
Kharif-										
Kharif Pulses	2394	2105	1772	1594	1858	1787	1721	1832	1764	1881
Arhar	41	33	45	27	35	32	22	28	41	23
Total	2435	2138	1807	1621	1893	1819	1743	1860	1805	1904
Rabi -										
Gram	1776	1862	1748	1377	1225	1935	1756	1796	1533	1941
Rabi Pulses	31	37	47	32	29	32	34	45	39	35
Total	1807	1899	1795	1409	1254	1967	1790	1841	1572	1976
Total Pulses	4242	4037	3602	3030	3147	3786	3533	3701	3377	3880
Total Kha.	7880	7919	8244	7848	9044	8833	8552	8940	8129	8790
FOOD-RABI	4196	4200	4192	3904	3299	4185	4199	4299	3548	4075
GRAINS-Total	12076	12119	12436	11752	12343	13018	12751	13239	11677	12865
OILSEEDS										
Kharif-										
Sesamum	377	363	423	318	428	429	449	377	418	520
Groundnut	235	244	384	292	212	161	186	183	252	245
Soyabean	-	-	-	-	7	10	14	23	31	43
Casterseed	3	3	3	6	4	6	5	9	19	10
Total	615	610	810	616	651	606	654	592	720	818
Rabi -Rape										
& Mustard	230	353	315	349	363	651	607	820	1081	808
Taramira	-	-	-	-	-	-	-	157	131	203
Linseed	78	87	101	80	39	85	74	89	106	98
Total	308	440	416	429	402	736	681	1066	1318	1109
" Oilseeds	923	1050	1226	1045	1053	1342	1335	1658	2038	1927
OTHERS										
Kharif										
Sugarcane	44	61	60	34	29	39	38	34	31	26
Cotton	289	370	403	392	357	380	397	416	335	333
Guar	2405	1957	2121	1435	1965	1669	1996	2208	2038	1806
Others	342	473	454	1100	879	1127	1063	940	797	209
Rabi										
Others	820	894	796	613	724	1020	815	383	370	244
Total kha.	11575	11390	12092	11425	12925	12654	12700	13130	12050	11982
Cropped Area Rabi	5324	5534	5404	4946	4425	5943	5695	5748	5236	5428
Total	16899	16924	17496	16371	17350	18597	18395	18878	17286	17410

Table 2.10 : Statement Showing the Crop-wise Irrigated Area under Different Crops during the Year 1976-77 to 1985-86

(Area in '000 ha.)

Crops	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
CEREALS:										
Kharif										
Rice	57	56	80	77	72	44	34	55	54	51
Jowar	1	1	3	14	10	16	18	5	6	10
Bajra	23	18	29	149	150	194	193	85	102	137
Maize	39	46	71	296	210	155	211	45	61	146
S.Millets	4	3	3	2	2	1	1	1	Neg	Neg
Total	124	124	186	538	444	410	457	191	223	344
Rabi										
Wheat	1274	1219	1544	1634	1391	1398	1716	1780	1475	1486
Barley	430	352	313	323	302	288	238	223	211	243
Total	1704	1671	1857	1957	1693	1686	1954	2003	1686	1729
Total cereal	1828	1795	2043	2495	2137	2096	2411	2194	1909	2073
PULSES										
Kharif										
Kharif Pulses	3	2	2	7	6	6	7	5	5	9
Arhar	Neg	Neg	1	2	2	1	Neg	1	2	1
Total	3	2	3	9	8	7	7	6	7	10
Rabi -										
Gram	287	271	306	400	392	396	329	285	231	306
Rabi Pulses	10	12	16	19	14	13	15	20	19	13
Total	297	283	322	419	406	409	344	305	250	319
Total Pulses	300	285	325	428	414	416	351	311	257	329
Total Kha.	127	126	189	547	452	417	464	197	230	354
FOOD-RABI	2001	1954	2179	2376	2099	2095	2298	2308	1936	2048
GRAINS-Tota	2128	2080	2368	2923	2551	2512	2762	2505	2166	2402
OILSEEDS										
Kharif-										
Sesamum	Neg	Neg	Neg	3	2	3	3	1	1	1
Groundnut	3	3	9	25	16	15	28	12	32	60
Soyabean	-	-	-	-	7	10	10	08	14	19
Castorseed	Neg	Neg	1	1	2	1	2	2	7	5
Total	3	3	10	29	27	29	43	23	54	87
Rabi -Rape										
& Mustard	92	186	181	229	249	318	348	501	710	480
Taramira	-	-	-	-	-	-	-	8	10	11
Linseed	2	4	5	3	3	7	2	4	6	2
Total	94	190	186	232	252	325	350	513	726	493
" Oilseeds	97	193	196	261	279	354	393	536	780	580
OTHERS										
Kharif										
Sugarcane	43	57	54	31	29	36	36	32	29	25
Cotton	236	313	346	348	317	327	360	381	305	300
Guar	72	54	59	69	124	112	88	90	98	69
Others	88	83	81	74	154	156	185	196	184	30
Rabi										
Others	312	387	347	378	295	225	264	274	268	183
Total Kharif Cropped	569	636	739	1096	1101	1076	1176	919	900	907
Area Rabi	2407	2531	2712	2988	2648	2646	2912	3095	2930	2724
Total	2976	3167	3451	4084	3749	3722	4088	4014	3830	3631

in table 2.11. The statement showing the cropwise production under different crops during the years 1976-77 to 1985-86 is given in table 2.12. By the table it can be seen that the production of different crops get reduced due to prevailing drought conditions in the year 1985-86.

2.9 Description of Districts

The details about the state in respect of physiography, climate, soils, land use,crops and water resources availability have been presented in the above sections. This section gives brief summary of various such details in respect of the districts chosen for study & the location of raingauges and groundwater observation wells selected in the districts of Barmer, Banswara, Ajmer, Udaipur, Jodhpur and Dungarpur are given in Figures 2.4 to 2.6 respectively.

2.9.1 Barmer

The Barmer district forms part of Rajasthan west region and this district is a drought affected one. The geographical location of the district is between $24^{o}39'$ to $26^{o}-32'$ north latitude and $70^{o}5'$ to $72^{o}52'$ east longitude. The district has an area of 28387 sq.km. The district consists of five tehsils, namely Barmer, Sheo, Chohtan, Siwana and Pachpadra and has 837 inhabited, 20 uninhabited villages and two towns as per 1971 census. The population of Barmer district is 1113823 and density of population 39 person per sq.km. as per 1981 census.

The soils in the district are generally of five types viz. desert soils, red desertic soils, sand dunes, saline soils of depressions and lithosols and regosols of hills. The land use in the district as per data from 1970-71 to 1979-80 forests is 13526.4 ha., land put to non agricultural uses 55030 ha., barren and uncultivable land 145999.4 ha. and with the 2391144.9 ha. culturable area. The total irrigated area in the district is 18087.3 ha. and the sourcewise distribution of 17934.5 ha. by

Table 2.11 : Statement Showing the Crop-wise Productivity Under Different Crops During the Year 1976-77 to 1985-86

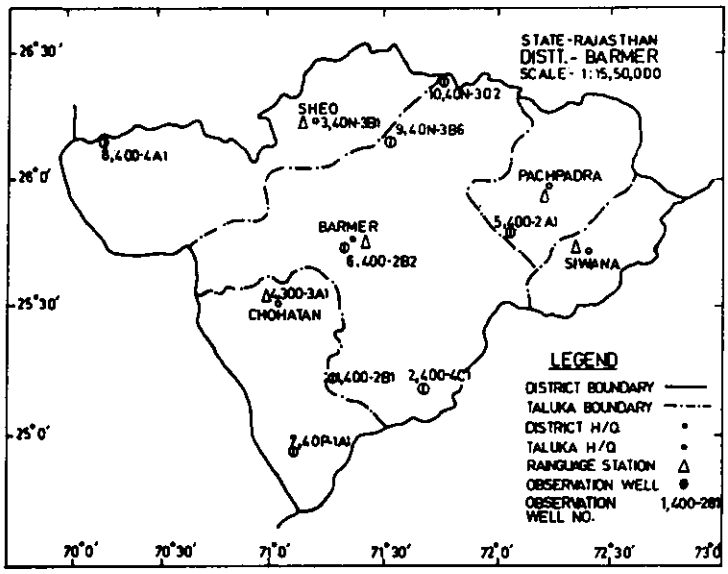
(Productivity in kg/ha.)

Crops	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
CEREALS:										
Kharif										
Rice	1340	1286	1109	540	884	992	746	1358	1252	902
Jowar	428	387	401	181	337	421	374	600	494	381
Bajra	366	198	253	89	225	163	289	491	366	153
Maize	760	688	970	652	873	822	741	1376	1230	661
S.Millets	362	362	263	85	64	143	98	476	394	18
Total	460	322	390	195	338	301	367	637	532	272
Rabi										
Wheat	1279	1424	1444	1303	1464	1659	1830	1594	1625	2209
Barley	1161	1402	1345	1154	1270	1296	1384	1482	1457	1759
Total	1250	1419	1427	1279	1425	1585	1767	1580	1603	2140
Total cereal	700	634	671	505	578	609	733	880	787	708
PULSES										
Kharif-										
Kha.Pulses	252	244	145	40	151	133	126	296	200	49
Arhar	417	303	311	180	349	375	338	503	541	253
Total	255	245	150	43	155	137	130	299	208	52
Rabi -										
Gram	766	799	909	454	697	650	751	606	632	836
Rab Pulses	645	630	617	750	755	788	810	749	966	982
Total	764	795	901	549	698	651	751	610	641	839
Total Pulses	472	503	524	279	371	404	444	454	409	453
Total Kha.	396	300	337	163	299	267	318	567	460	224
FOOD-RABI	1040	1137	1202	1015	1148	1146	1334	1165	1177	1509
GRAINS-Total	620	591	630	446	526	550	653	761	678	631
OILSEEDS										
Kharif-										
Sesamum	157	138	177	38	79	117	91	173	175	52
Groundnut	667	715	617	243	406	670	572	949	683	610
Soyabean	-	-	-	-	1000	1000	1000	688	855	745
Castorseed	317	219	320	206	270	156	206	201	243	203
Total	353	370	386	138	197	279	247	434	385	258
Rabi -Rape										
& Mustard	437	462	648	427	685	704	730	791	808	735
Taramira	-	-	-	-	-	-	-	794	355	347
Linseed	313	359	376	210	332	335	366	504	351	361
Total	409	440	581	387	649	661	690	768	726	631
" Oilseeds	372	400	453	240	369	488	473	648	605	472
OTHERS										
Kharif										
Sugarcane	45086	46377	56600	34290	39493	36848	37579	44179	44434	38142
Cotton	217	208	240	210	185	190	237	231	224	242
Guar	355	351	356	100	160	187	141	300	177	79
Others										

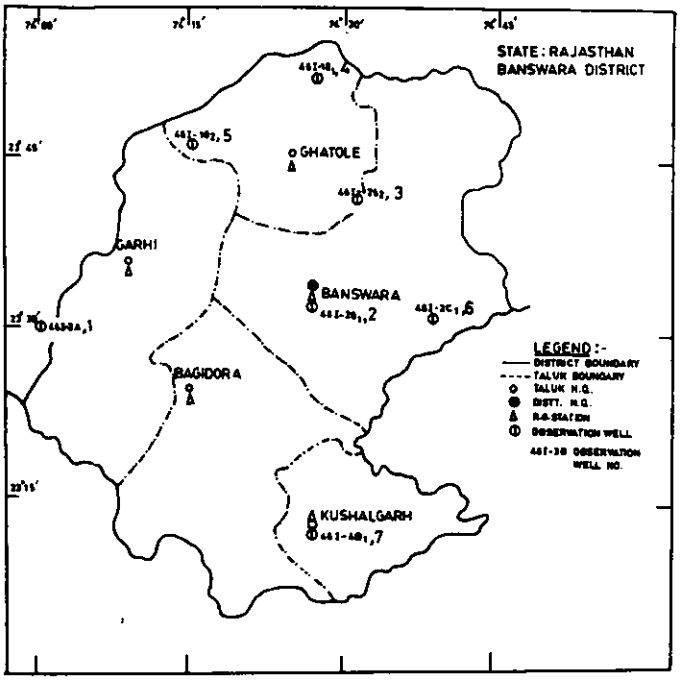
Table 2.12 : Statement Showing the Crop-wise Production Under Different Crops During the Year 1976-77 to 1985-86

(Prod. in '000 tonnes/bales)

Crops	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
CEREALS:										
Kharif										
Rice	213	237	234	100	150	139	88	218	213	119
Jowar	360	280	331	153	338	408	356	591	414	375
Bajra	1324	804	1147	381	1135	804	1390	2451	1599	731
Maize	580	516	784	574	786	755	659	1230	1127	644
S.Millets	25	21	15	4	3	7	5	22	14	1
Total	2502	1858	2511	1212	2412	2113	2498	4512	3362	1870
Rabi										
Wheat	2301	2610	2874	2701	2394	2933	3787	3442	2792	3918
Barley	685	656	546	489	521	583	469	443	376	574
Total	2986	3266	3420	3190	2915	3516	4256	3885	3168	4492
Total Cereal	5488	5124	5931	4402	5327	5629	6754	8397	6530	6362
PULSES										
Kharif-										
Kha.Pulses	604	513	257	65	281	238	217	542	353	93
Arhar	17	10	14	5	12	12	8	14	22	6
Total	621	523	271	70	293	250	225	556	375	99
Rabi -										
Gram	1361	1488	1589	750	854	1257	1318	1089	969	1623
Rab Pulses	20	23	29	24	22	25	27	34	38	34
Total	1381	1511	1618	774	876	1282	1345	1123	1007	1657
Total Pulses	2002	2034	1889	844	1169	1532	1570	1679	1382	1756
Total Kha.	3123	2381	2782	1282	2705	2363	2723	5068	3737	1969
FOOD-RABI	4367	4777	5038	3964	3791	4798	5601	5008	4175	6149
GRAINS-Total	7490	7158	7820	5246	6496	7161	8324	10076	7912	8118
OILSEEDS										
Kharif-										
Sesamum	59	50	75	12	34	50	41	65	73	27
Groundnut	157	175	237	71	86	108	106	174	173	150
Soya bean	-	-	-	-	7	10	14	16	26	32
Castorseed	1	1	1	3	1	1	1	2	3	4
Total	217	226	313	85	128	169	162	257	277	211
Rabi -Rape										
& Mustard	101	163	204	149	248	458	443	648	874	595
Taramira	-	-	-	-	-	-	-	125	46	70
Linseed	25	31	38	17	13	28	27	45	37	35
Total	126	194	242	166	261	486	470	818	957	700
" Oilseeds	343	420	555	251	389	655	632	1075	1234	911
OTHERS										
Sugarcane	1991	2829	2196	1160	1161	1437	1430	1485	1369	1010
Cotton	348	452	570	484	388	425	554	579	441	474
Guar	855	687	755	144	315	313	282	663	360	142



(a) DISTT. BARMER



(b) DISTT. BANSWARA

FIG. 2.4 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

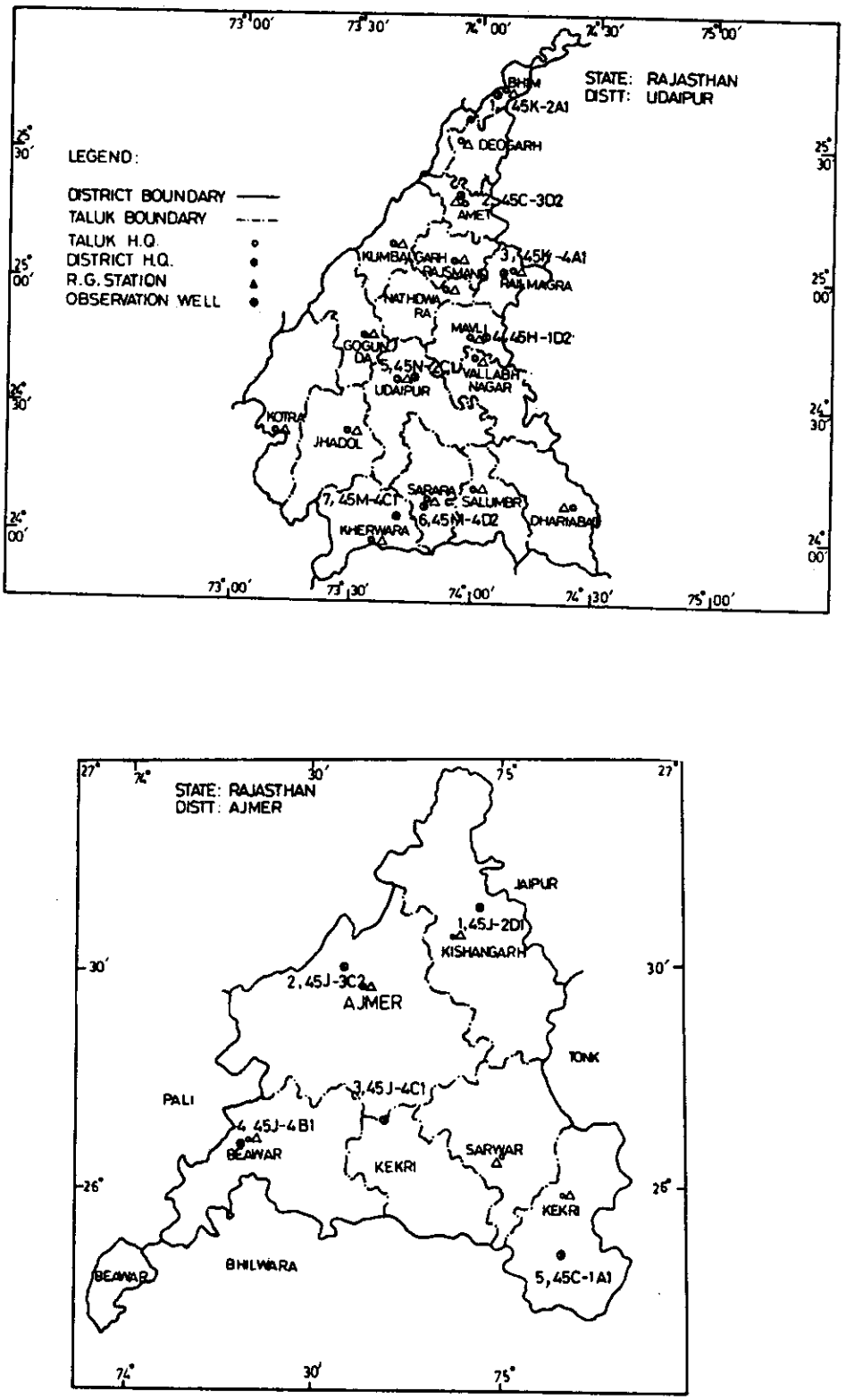


Fig. 2.5 : LOCATION OF RAINGAUGE STATION AND GROUNDWATER WELL

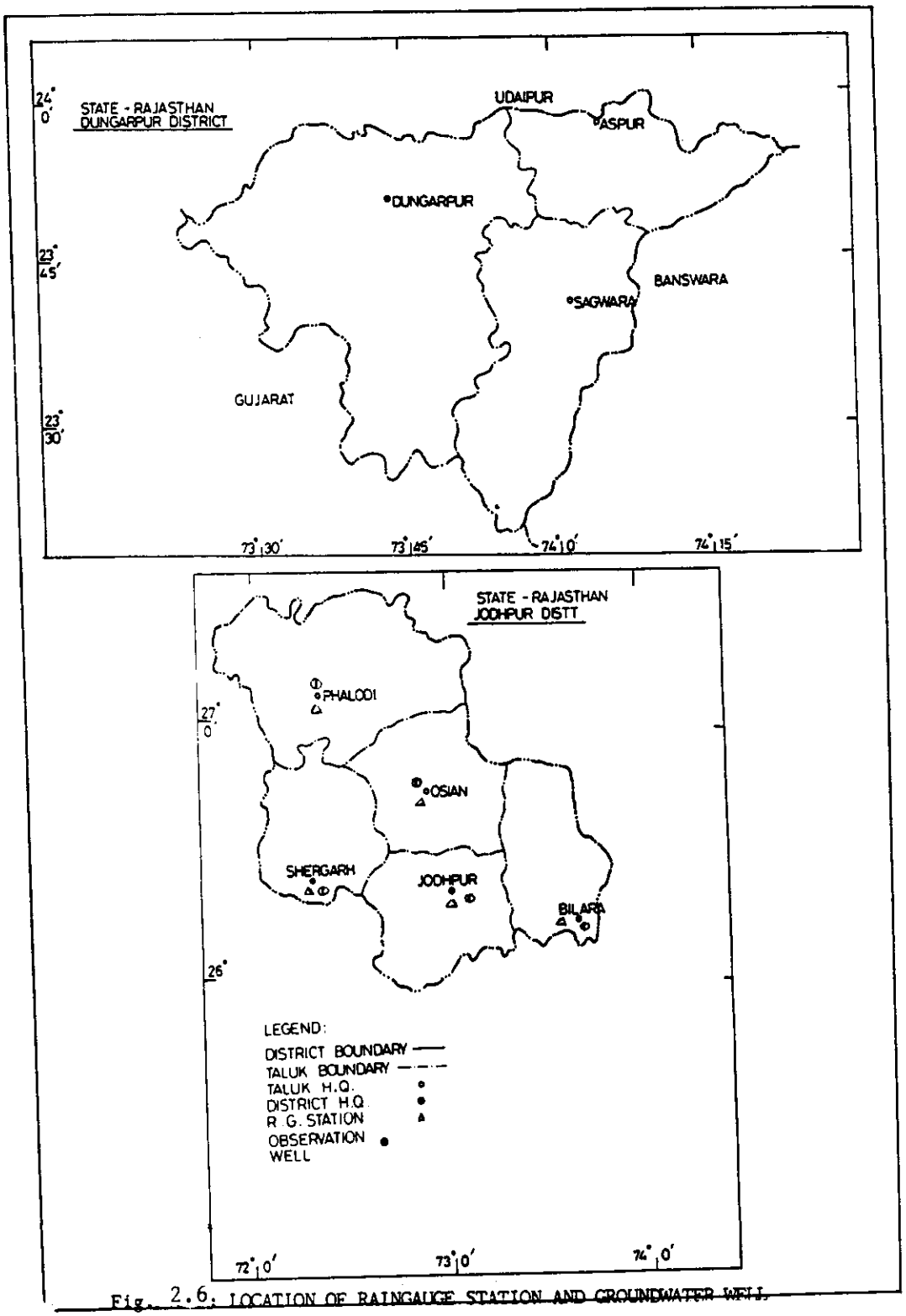


Fig. 2.6: LOCATION OF RAINGAUGE STATION AND GROUNDWATER WELL

ground water and 128.10 ha. by surface water and 4.7 ha. by other sources.

Luni is one main river flowing through the Barmer district. The catchment area of river basin in the district is 4328.0 sq.km.

As per CWC studies of 1982 the normal rainfall of the district is 266.7 mm. Normally there are 13.17 days in a year according to analysis of data from 1901 to 1980. There are 10 raingauge stations located in the district and the density of raingauge station is 2952.1 sq.km. per raingauge station as per study of year 1982. The maximum annual rainfall in the district was experienced as 795.5 mm in year 1944. The south west monsoon gives about 91.7% of annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as 55.14% for the district.

The ground water potential of the district as per SGWB data of one year is that the annual recharge of ground water is 385.037 M.CM., while the draft is 67.995 M.CM. and the surplus is 317.075 M.CM. in one year.

As per CWC (1982) observation the district faced 67 years hydrological drought during the period 1901-1980.

2.9.2 Banswara

Banswara district is the second smallest district of Rajasthan state. The district has been identified as drought prone district. Banswara district, having an area of 5037 sq.km. is located between 23^{o}-11/ to 23^{o}-56/ latitudes and 74^{o}-00/ to 74^{o}-47/ longitudes. The district consists of five tehsils namely, Banswara, Ghatole, Garhi, Bagidora and Kushalgarh. The district has 1439 inhabited and 23 uninhabited villages. The population of the district as per 1981 census is 885701 of which the rural

population constituted 93.7%. The density of population is 176 persons per sq.km. in the district.

The district has got four different varities of soils namely; Bhuri, Kali or black cotton soils, Lal soil & barangi soils. As per data from 1972-73 to 1976-77 the land use in the district include forests 92321 ha., barren and uncultivable land 94144 ha., land put to non agriculturable uses 7511 ha.

It has been reported that the total irrigated area of the district is 15506 ha. as per 1969-77. The sourcewise distribution of irrigated area is 4522 ha. by surface water and 5003 ha. by ground water.

Through Banswara district the main river which flows is Mahi. The catchment area of Mahi river is 1632.5 sq.km. in the district.

According to CWC study of 1982 the normal annual rainfall of the district is 906 mm. The district gets 95.2% of the annual rainfall from the south-west monsoon as per analysis of data from 1901 to 1981.

As per CGWB data for the ground water potential is that annual recharge to ground water is 258.28 M.C.M., draft 36.56 M.C.M and surplus 221.72 M.C.M in one year.

2.9.3 Ajmer

The Ajmer district is located on the Eastern region of Rajasthan state. This is one of the drought affected districts of the state. The district is situated between 25°-$30'$ to 26°-$58'$ North latitude and 73°-$54'$ to 75°-$22'$ East longitude. The geographical area of the district is 8479 sq.km. as per 1981 census. The district is divided in five talukas namely, Ajmer, Kishangarh, Beawar, Sarwar and Kekri.

According to 1971 census there are 954 inhabited and 19 uninhabited villages and eight towns in Ajmer district. The total population of the district is 1431609 as per 1981 observation and average density of population per sq.km. in 1981 was 169 persons.

As per information available, the soils in the district may be classified as sandy loam, loam, black cotton soil and rich alluvial soils. The land use details of the district as per data available from 1970-71 to 1979-80 include the forests 34601 ha., land put to non-agricultural uses 38243 ha., barren and uncultivable land 107696 ha. and cultivable area is 375134 ha. As per data from 1960-61 to 1979-80 the total irrigated area was 105547 ha. in the district. The sourcewise distribution includes 80287 ha. by groundwater and 25115 ha. by surface water and 145 ha. by other sources.

The Luni, Banas and Menda are the main rivers that flow through the district. The catchment area of the rivers in the district of the order of, Luni 1796 sq.km., Banas 5534 sq.km., and Menda 1149 sq.km.

As per CWC study of 1982 the district receives rainfall mainly from south west monsoon. The normal annual rainfall in the district is 469.3 mm. There are normally 24.6 rainy days in one year according to analysis from 1901 to 1980. About 91.7% of normal rainfall is received during the south west monsoon. The Twenty no. of raingauge stations are located in the district and the density of raingauge stations is one station per 422.5 sq. km. A maximum rainfall of 1209.5 mm was received in 1917 in the district and the coefficient of annual rainfall is 37.4% during the period 1901 to 1980.

As per Central Ground Water Board organization data the ground water potential in one year is that recharge to ground water is of the order of 1734.35 mcm. while the draft is 256.21

MCM and surplus is 1478.14 MCM. The Ajmer district faced 14 years of hydrological drought during the period 1957-1980.

2.9.4 Udaipur

The district Udaipur is one of the drought prone district of Rajastnan state. The district having an area of 17279 sq.km., is located between 23^{o}-46/ to 26^{o}-02/ North latitudes and 73^{o}-0/ to 74^{o}-35/ East longitudes. It has got 17 tehsils namely, Bhim, Geogarh, Amet, Kumbhalgarh, Rajsamand, Railmagra, Nathdwara, Mavli, Gogunda, Vallabhnagar, Girwa, Kotra, Jodal, Sarada, Dhariyawas, Salumbar and Kherwara. The district has 3116 inhabited villages, 39 uninhabited villages and eight towns as per 1981 census.

The population of the district according to the 1981 census is 2351639 and density of population of the district is 136 persons per sq.km. as per 1981 analysis.

It has been reported that generally four types soils are found in the district namely, Sandy loam, clay loam, red clay, heavy clay. As per data from 1971-72 to 1980-81 the land use in district include forests 340358 ha., barren and uncultivable land 492397 ha. and land put to non-agricultural uses 234561 ha. and 674769 ha. with culturable area.

The total irrigated area of the district is 132149 ha. and the sourcewise distribution of irrigated area are 23928 ha. by surface water, 106516 ha. by ground water and 1705 ha. by othersources. The three main rivers Banas, Mahi and Luni flow through the district.

As per CWC analysis of 1982, the normal annual rainfall of the district is 620.24 mm./& there are normally 30.39 rainy days in a year. Forty one number of raingauge stations are located in the district and the density of raingauge stations are 421.14

sq.km. per raingauge station as per data from 1901 to 1980. The south west monsoon gives about 92.5% of the annual rainfall and the coefficient of variation for annual rainfall is 39.53%.

As per CGWB, the ground water potential data estimate, recharge to ground water/is 385.83 MCM and the draft 403.40 MCM and the surplus/is 982.43 MCM. As per CWC (1982) study the district faced 11 years of hydrological drought during the period 1957-80 except 3 years.

2.9.5 Jodhpur

The district Jodhpur is one of the drought prone district of Rajasthan state. The district having an area of 22,850 sq.km. is located between $26^{\circ}0'$ to $27^{\circ}37'$ north latitudes and $71^{\circ}55'$ to $73^{\circ}52'$ east longitude. It consists of five tehsils namely Jodhpur, Bilara, Shergarh, Phalodi and Osian. The district has 702 inhabited villages, 5 uninhabited villages and four towns as per 1971 census.

The population of the district according to the 1981 census is 16,50,933 and density of the population of the district is 73 persons per sq.km. as per 1981 census.

It has been reported that generally two types of soils are found in the district namely Desertic soils and Red desertic soils. As per data from 1970-71 to 1979-80, the land use in district include forests 1581 ha, barren and uncultivable land 106086 ha. and land put to non-agricultural uses 93767 ha and 19.08,098 ha with culturable area.

The total irrigated area of the district is 35,296 ha and the sourcewise distribution of irrigation are 1705 ha by surface water, 32713 ha by ground water and 878 ha by other sources. Luni is the main river flowing through the district as per CWC analysis of 1982, the normal annual rainfall of the

ha. by ground water and 495 by others sources. The Som and Mahi are the main rivers that flow through the district. The catchment area of the rivers in the district is of the order of Som 1076 sq.km. and Mahi 2199 sq.km.

As per CWC study of 1982 the district receives rainfall mainly from south west monsoon. The normal rainfall of the district is 713.7 m.m. there are normally 33.8 rainy days in one year according to analysis from 1901-80. The district gets 94.3% of normal rainfall from south-west monsoon. There are 13 raingauges stations located in the district with the density of one raingauge station per 314.2 sq.km. A maximum annual rainfall of 1226.2 mm was received in 1944 in the district and the coefficient of variation of annual rainfall is 33% for the period 1901 to 1980.

As per Central Ground Water Board Organisation data the ground water potential in one year is that recharge to ground water is of the order of 297.37 MCM. while the draft is 30.43 MCM and the surplus is 266.94 MCM The Dungarpur district faced 28 years of hydrological drought during the period 1901 to 1980.

3.0 RAINFALL ANALYSIS

3.1 General

As has already been described in chapter 2.0 six districts, namely Barmer, Banswara, Ajmer, Udaipur, Jodhpur and Dungapur from state of Rajasthan have been taken up for rainfall analysis in the present report. One representative raingauge station from each taluk in each of the six districts has been selected for the study. The locations of raingauges on the district maps have been shown in figures presented in chapter 2.0. The raingauge stations selected for the study are the ones which were selected by central water commission for carrying out studies for identification of drought prone areas in 1982. The analysis of rainfall data has been carried out with the data from year 1901-1988. The data from 1901 to 1980 have been extracted from CWC reports (CWC, 1982). The remaining data from 1981 to 1988 have been collected during visits of scientific teams to various central/state Govt. offices in the state Rajasthan.

3.2 Rainfall Departure Analysis

3.2.1 Seasonal Rainfall Departure

In order to compute the deficiency of rainfall on seasonal basis, seasonal rainfall departure analysis has been carried out. The data from period 1970-87 have been used for this analysis. Seasonal normals for the chosen six districts of Rajasthan have been calculated as the summation of normals for the months (June to September) as provided in CWC reports. Only four months i.e. June , July, August and September are taken into account while estimating seasonal normals as the South-West monsoon is active for these four months in the state. The results

of analysis are given in table 3.1. The graphical representation of seasonal deficiencies are shown in figures 3.1. The major inference that are drawn from the seasonal analysis are :

All the six selected districts of Rajasthan experienced continuous deficiency in seasonal rainfall with the extremes lying between 20% to 65% except in case of Banswara & Dungarpur which recorded slight positive departure in seasonal rainfall. The deficiency pattern has been more or less same in the district of Ajmer, Jodhpur, Udaipur and Barmer.

3.2.2 Monthly Rainfall Departure for the year 1987-88

In order to observe deficiency in monthly rainfall during the year 1987-88, monthly departures have been worked out for the six districts. This analysis has been done for all the taluks and districts as a whole. Monthly rainfall values from June 87 to May 1988 alongwith monthly normals of representative raingauges of various taluks have been considered for the purpose. Monthly rainfall values for a district from June 1987 to May 1988 have been computed as weighted average rainfall of all the taluks considered for analysis in the district. Monthly normals of districts have been directly taken from reports of CWC (CWC, 1982). It may be mentioned tnat in case of some districts/taluks monthly departure analysis has been limited to some months only due to data availability constraints.

The variations in rainfall month-wise (monthly rainfall and corresponding normals) have been plotted for all the six districts for water year June 1987 to May 1988 and are shown in fig.3.2. The departure figures for one representative taluk of each of the six districts have shown in appendix III-I . The results of monthly departure analysis for the districts as a whole

Table 3.1 : Districtwise Seasonal Rainfall Departures

Distt. Banswara (Rajasthan)

Year	Seasonal Rainfall	Seasonal Normal Rainfall	Percent Departure
1	2	3	4
1970	960.4	872.11	+10.12
1971	922.6		+ 5.78
1972	591.6		-32.16
1973	1681.1		+92.76
1974	716.6		+17.83
1975	1028.9		+17.92
1976	1241.6		+42.71
1977	N.A.		-
1978	N.A.		-
1979	1101.9		26.3
1980	797.0		- 8.6
1981	1043.54		+19.60
1982	725.46		-16.81
1983	648.84		-25.6
1984	1031.2		+16.17
1985	550.5		-36.87
1986	925.35		+ 6.10
1987	901.77		+ 3.40

Distt. Barmer (Rajasthan)

Year	Seasonal Rainfall	Seasonal Normal Rainfall	Percent Departure
1	2	3	4
1970	246.32	230.3	+ 6.95
1971	195.03		-15.32
1972	167.8		-27.14
1973	487.28		+111.58
1974	83.3		-63.82
1975	540.02		+134.5
1976	444.8		+93.14
1977	240.08		+ 4.2
1978	264.52		+14.85
1979	287.2		+24.7
1980	162.4		-29.5
1981	187.4		-18.62
1982	174.88		-24.06
1983	352.14		+52.9
1984	184.2		-20.01
1985	165.0		-28.35
1986	75.24		-67.33
1987	77.74		-66.24

Distt. Ajmer (Rajasthan)

Year	Seasonal Rainfall	Seasonal Normal Rainfall	Percent Departure
1	2	3	4
1970	574.96	455.10	26.34
1971	441.87		- 2.51
1972	206.27		-54.68
1973	708.99		55.79
1974	358.25		-21.28
1975	872.65		91.75
1976	701.63		54.17
1977	536.35		17.85
1978	462.19		1.56
1979	475.28		4.43
1980	322.62		-29.11
1981	381.23		-16.23
1982	442.92		- 2.68
1983	700.22		53.86
1984	393.91		-13.45
1985	274.57		-39.67
1986	317.68		-30.20
1987	237.19		-47.88

Distt. DUNGARPUR (Rajasthan)

Year	Seasonal Rainfall	Seasonal Normal Rainfall	Percent Departure
1	2	3	4
1970	724.97	673.10	7.71
1971	683.67		1.71
1972	582.72		-13.43
1973	996.17		48.00
1974	376.42		-44.08
1975	813.82		20.91
1976	840.60		24.88
1977	1164.16		72.96
1978	651.08		-3.27
1979	524.06		-22.14
1980	632.72		- 6.00
1981	652.41		- 3.07
1982	478.35		-28.93
1983	675.39		0.34
1984	924.91		37.41
1985	254.77		-62.15
1986	518.77		-22.93
1987	717.97		6.67

Distt. Jodhpur (Rajasthan)

Year	Seasonal Rainfall	Seasonal Normal Rainfall	Precent Departure
1	2	3	4
1970	401.97	288.80	39.19
1971	205.92		-28.70
1972	171.83		-40.50
1973	424.77		47.08
1974	173.14		-40.25
1975	575.19		99.17
1976	440.79		52.63
1977	332.46		15.12
1978	313.14		8.43
1979	246.10		-14.78
1980	219.26		-24.08
1981	154.96		-46.34
1982	188.61		-34.69
1983	415.25		43.78
1984	102.42		-64.54
1985	157.95		-45.31
1986	123.76		-57.15
1987	108.69		-62.37

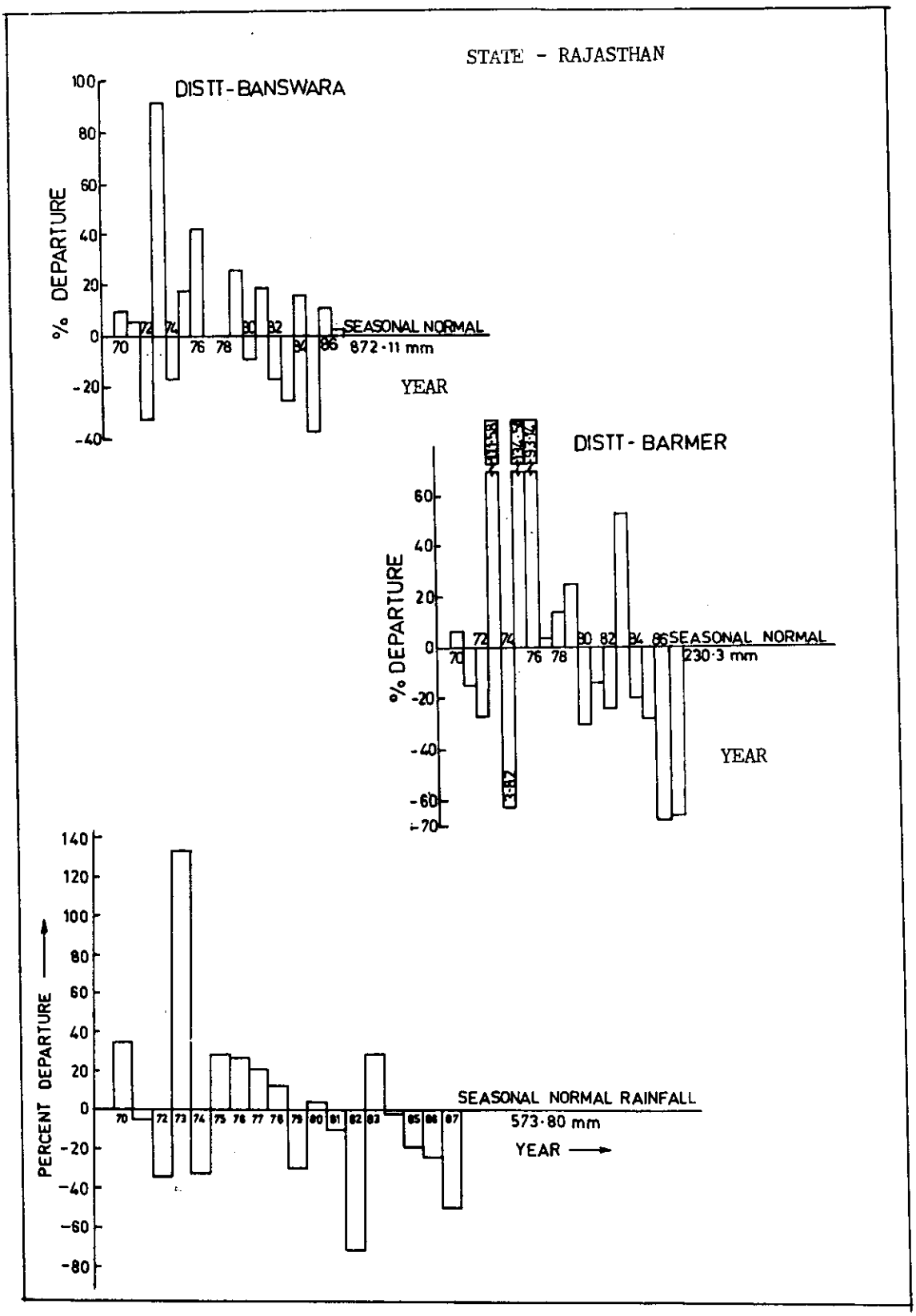


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

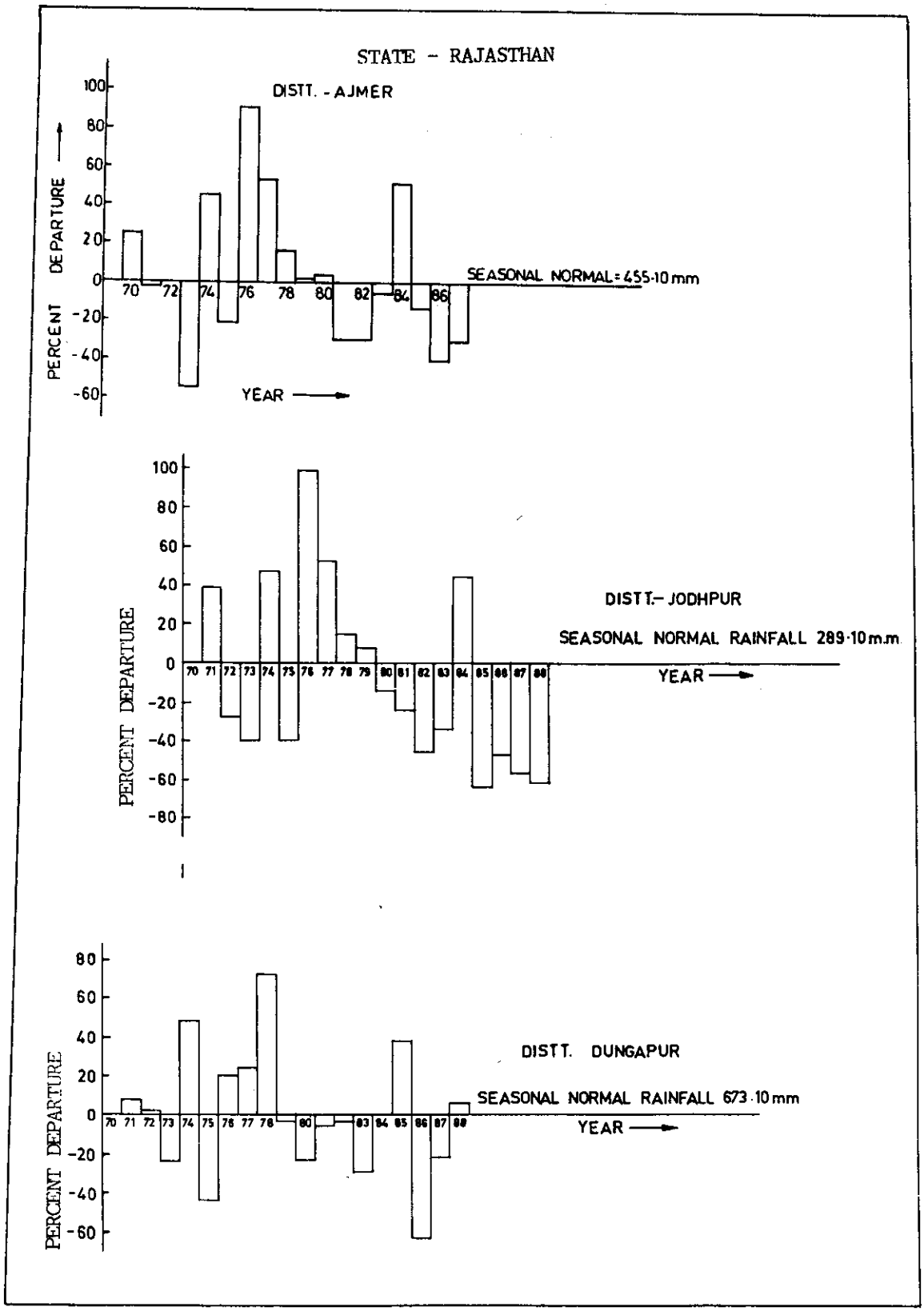


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

are presented in table 3.2.

Based on the Monthly departure values, two categories of monthly departures i.e. 20-50% & more than 50% have been made for deriving monthly deficiency inferences. Table 3.2 gives description of districts in the state which experienced rainfall deficit during months of June 1987 to May 1988 in these two ranges viz 20 to 50% and more than 50%. The following inferences can be drawn from the results shown/presented in fig.3.2, Appendix III-1 and table 3.2.

In the state of Rajasthan, almost all districts experienced severe monthly deficits during monsoon season of 1987 with the extremes lying between 20-100%. In case of Banswara, however, positive departure was recorded in the month of August.

3.3 Frequency of Rainfall

3.3.1 Probability Analysis of Annual Rainfall

Probability is a constant characterizing given set of objects or incidents in a particular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy the relative frequency of occurrence in different group intervals of annual rainfall. It is also possible to work out the percentage probability of occurrence of 75% of annual rainfall or more for identification of drought proneness of district /taluks/tehsil.

Two taluks from each district and district as a whole have been selected for probability analysis of annual rainfall. The analysis has been carried out based on the data available from 1901 to 1987 and probability expressed both in number of years of occurrence and the percentage of years for each group interval.

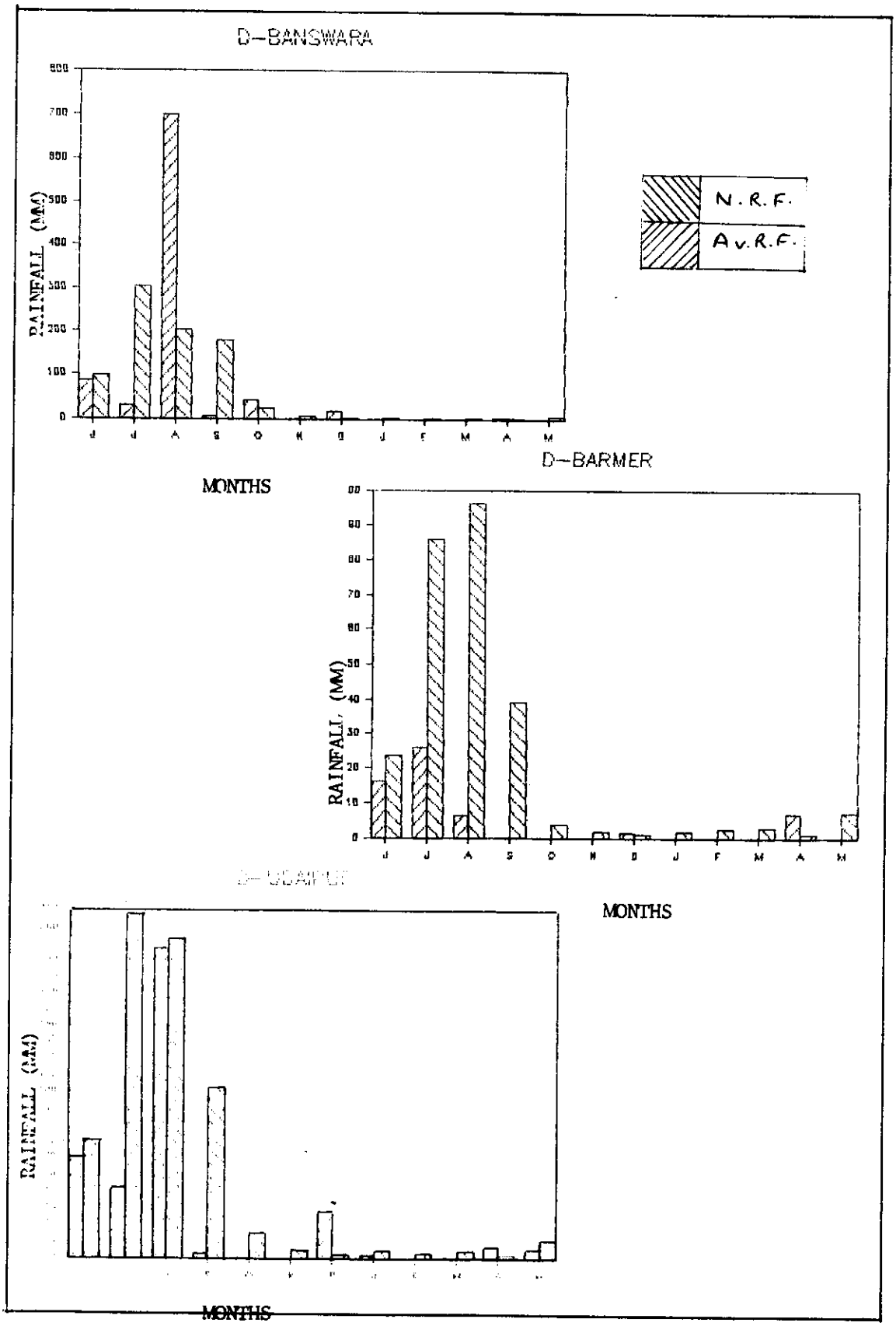


Fig.3.2 : Districtwise Monthly Rainfall Departure for y . 1987-88

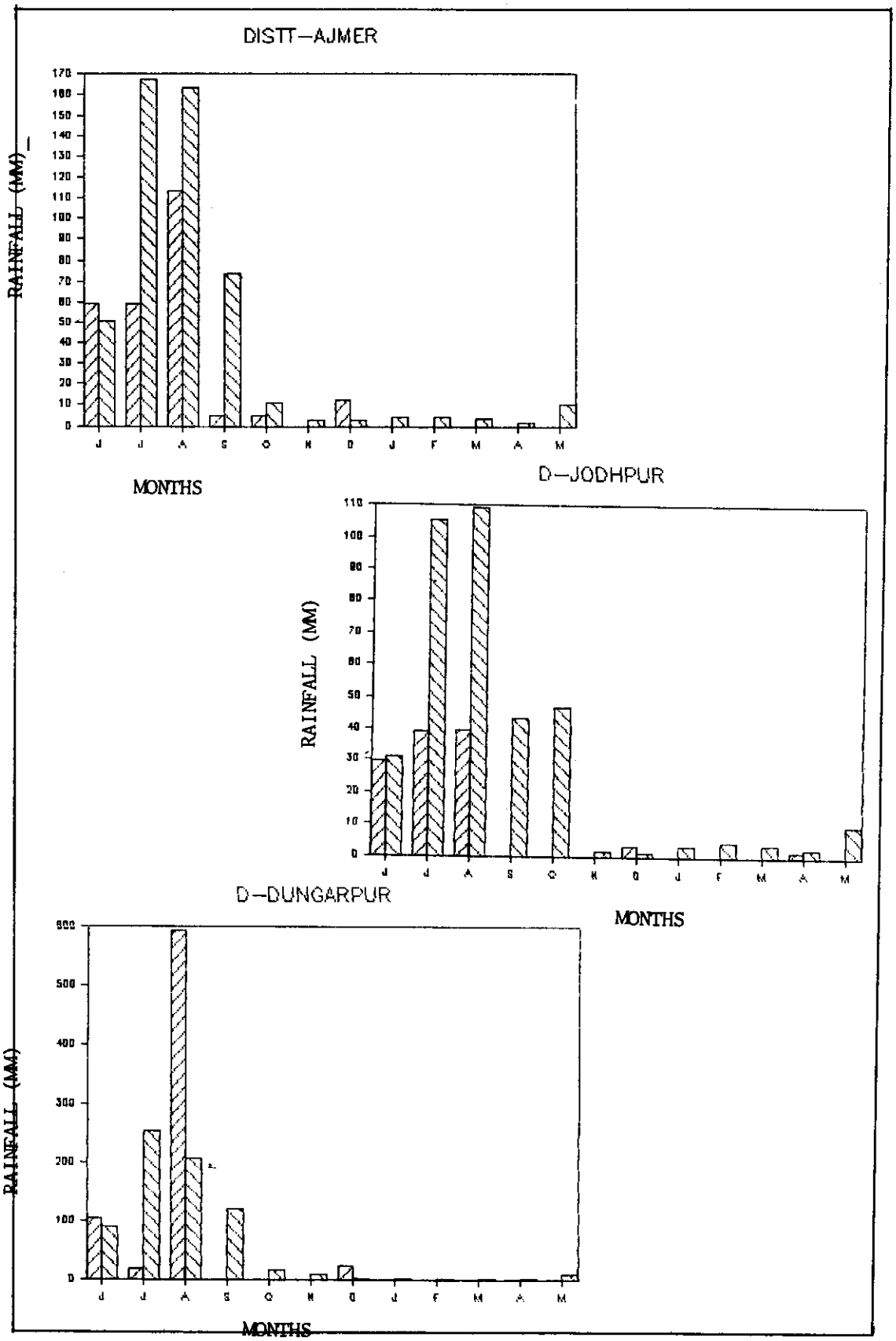


Fig.3.2 : Districtwise Monthly Rainfall Departure for year 1987 -88

Table 3.2 : Monthly Rainfall Deficits in District as a Whole During 1987-88

State	Months	Group of range of deficiency in rainfall (expressed in percentage of normals)	
		20 to 50%	50% and above
Rajasthan (No. of districts taken 6)	June'87	Barmer	
	July		Barmer, Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	August	Ajmer	Barmer, Jodhpur
	September		Barmer, Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	October		Barmer, Jodhpur,Dungarpur, Ajmer, Udaipur
	November		Barmer, Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	December		
	January'88		Barmer, Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	February		Banswara,Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	March		Barmer, Jodhpur,Dungarpur, Banswara, Ajmer, Udaipur
	April	Jodhpur	Dungarpur, Ajmer
	May	Udaipur	Barmer, Jodhpur,Dungarpur, Banswara, Ajmer

Group interval of 100 mm has been considered for the analysis.

The probability distribution curves has been drawn by plotting the values of percentage of cumulative probability in respect of various groups at their corresponding midpoint. The cumulative percentage have been worked out starting from the maximum rainfall group downwards adding the successive percentage.

Probability graphs for all the six districts and also for two selected taluks in each districts of the state have been shown in figures 3.3 and Appendix III-2 respectively. The range of annual rainfall at 75% probability level can be established using these graphs. and such values for all the six selected districts and two taluks in each district are given in table 3.3. In order to find drought proneness of the districts, the percentage probability of occurrence of 75% of normal rainfall of the district has been worked out and the results are given in table 3.3. It can be seen from the table that all the districts have less than 80 percent of probability except in case of Ajmer and Udaipur which has 84 and 81 respectively of getting 75% of normal rainfall indicating proneness of districts for drought conditions. This indicates that the districts Ajmer and Udaipur, are not drought prone as per IMD criteria.

3.3.2 Probability of Occurrence of Rainfall Equivalent to 75% of Normal Rainfall

For identification of drought proneness of the district/taluk the percentage probability of occurrence of rainfall equivalent to the 75% of normal rainfall or more has also been worked out for the figures 3.3 and Appendix III-2. As per IMD criteria, an area would be classified as drought prone if

Table 3.3 : Probability Distribution of Annual Rainfall of State Rajasthan

Sl. No.	District	Name of Taluk	At 75% probability and above (Range in mm)	Probability of occurrence of rainfall equivalent to 75% normal (in %age)
1.	Barmer	1. Barmer	100-200	74
		2. Siwana	200-300	78
		3. District as a whole	200-300	79
2.	Banswara	1. Banswara	800-900	72
		2. Khushalgarh	700-800	77
		3. District as a whole	700-800	79
3.	Ajmer	1. Ajmer	300-400	85
		2. Kekri	400-500	79
		3. District as a whole	400-500	84
4.	Udaipur	1. Udaipur	500-600	82
		2. Kherwara	500-600	79
		3. District as a whole	500-600	81
5.	Dungarpur	1. Dungarpur	500-600	77
		2. Sagwara	500-600	73
		3. District as a whole	500-600	78
6.	Jodhpur	1. Jodhpur	200-300	74
		2. Bilara	300-400	73
		3. District as a whole	200-300	79

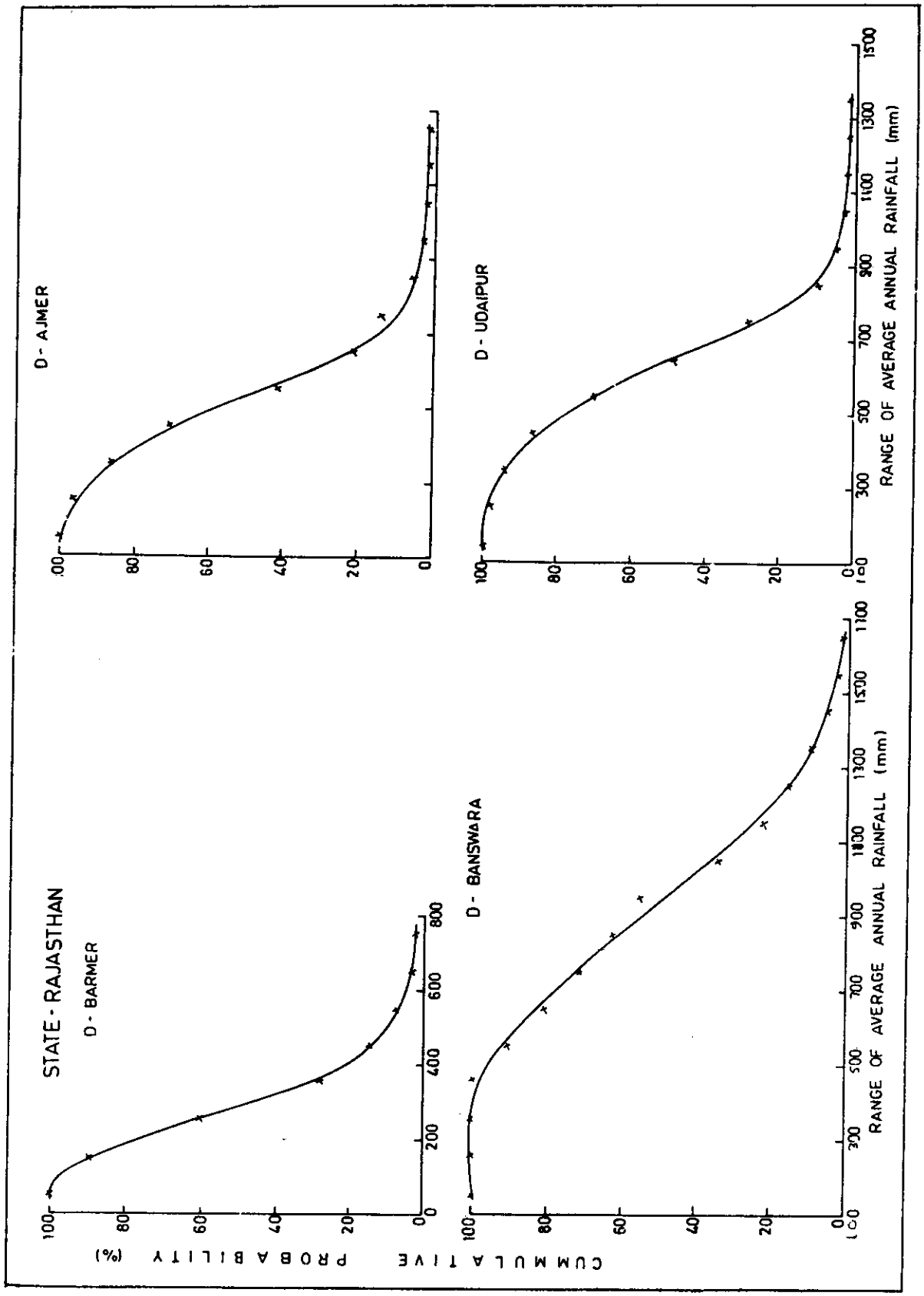


Fig. 3.3 : Districtwise Probability of Annual Rainfall

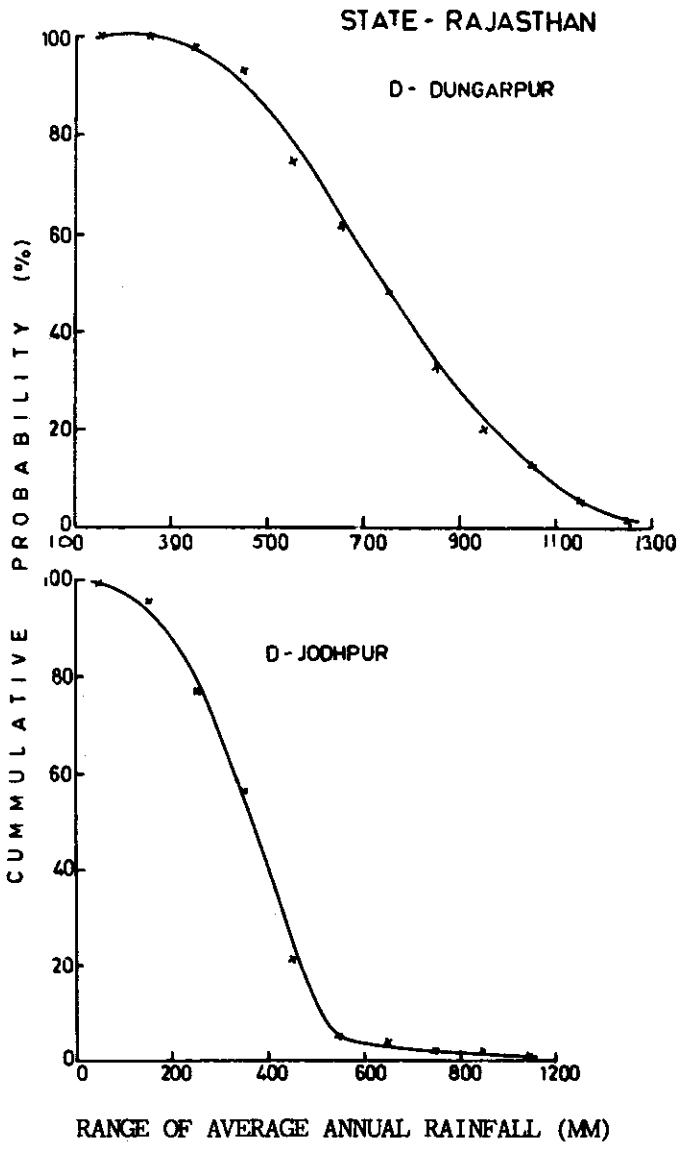


Fig. 3.3. : Districtwise Probability of Annual Rainfall

probability of getting rainfall, equivalent to 75% of normal, is below 80% indicating that more than 20% of years, the area experienced scarcity of rain. Central Water Commission has carried out analysis and identified drought prone areas on this ground (CWC,1982). Using this criteria, inferences drawn from values in table 3.3 are as below:

The probability values of occurrence of 75% normal rainfall in the districts namely Barmer, Banswara,Dungarpur and Jodhpur are 79, 79,78,and 79 respectively which are all below 80% indicating that the districts are drought prone based on this analysis as per IMD criteria.This infers that the districts of Barmer, Banswara, Dungarpur and Jodhpur experienced rainfall less than 75% of normal in 21, 21, 22,and 21 percent of years, respectively. The taluks of all the six districts showed similar results

3.4 Excess/Deficit Rainfall Using Herbst Approach

3.4.1 Model Description

Herbst et al (1966) evolved a new method of drought analysis using monthly rainfall data, whereby it was possible to determine the duration and intensity of droughts and their months of onset and termination.

The model uses the following steps to calculate indices to evaluate onset and termination of droughts.

A. Calculation of mean monthly rainfall, MMR

From the long record of monthly rainfall, the mean rainfall for all the months (i.e. mean monthly rainfall, MMR) is

calculated:

$$MMR(J) = \frac{\sum_{J=1}^{NYR} RF(J,J)}{NYR} \qquad \text{--- (1)}$$

Here MMR = Mean monthly rainfall

RF = Rainfall

NYR = Number of years of record

Suffix I and J denote years and months respectively.

B. Calculation of mean annual precipitation (MAP)

Mean annual precipitation (MAP) is calculated for entire period of record

$$MAP = \sum_{J=1}^{NMN} MMR(J) \qquad \text{--- (2)}$$

where NMN = Number of months in a year

C. Calculation of Effective Rainfall

For calculation of drought criteria, the carry over effects from month to month is considered. For this purpose, the mean monthly rainfall for a month, say (J) is subtracted from the actual rainfall for that month (J) so that deficit or excess for that month is obtained. This deficit or excess is multiplied by a 'weighting factor' for the next month (J+1) and the product whether negative or positive, is added algebraically to the rainfall figure of that month (J+1). This sum becomes the 'Effective rainfall' (ER) for that month (J+1).

The 'weighting factor' for a month used to calculate carryover effects is derived from an empirical formula as suggested by Herbst et al (1966).

$$W(J) = 0.1 * \left[1 + \frac{MMR(J)}{1/12 * MAP}\right] \quad ...(3)$$

W(J) = weighting factor for j^{th} month

The carry over for j^{th} month and corresponding effective rainfall is calculated as under:

$$CO(I,J) = ER(I,J-1) - MMR(J-1) \quad ...(4)$$

$$ER(I,J) = RF(I,J) + CO(I,J) * W(J) \quad ...(5)$$

Here CO = Carry over factor

For the first month of first year of record, the effective rainfall has been assumed as equal to monthly rainfall. Thus for I = 1 and J = 1,

$$ER(1,1) = RF(1,1) \quad ...(6)$$

There upon the effective rainfall for each month of every year was calculated by allowing for the carry over effect of a surplus or deficit of rainfall in the preceding month. The process is continued to obtain the effective monthly rainfall for the full period of record.

D. Calculation of mean annual deficit

The difference of effective rainfall for a month and 'Mean Monthly Rainfall' for that month is obtained for full period of record and termed as 'Difference'.

$$DIFF(I,J) = ER(J,J) - MMR(J) \quad ...(7)$$

These 'differences' for various months of the record, if greater than or equal to zero, were reported as zero. Thus the

'Mean Monthly Deficits (MMD)' were based not only on those months in which a negative difference occurred, for positive differences (i.e., negative deficits) were taken as zero and thus also included in the computation.

$$MD(I,J) = 0.0 \text{ : for } DIFF(I,J) > 0.0 \qquad ...(8)$$

$$MD(I,J) = DIFF(I,J) \text{ ; for } DIFF(I,J) < 0.0 \qquad ...(9)$$

In this way 'Mean Monthly Deficit' for each month of every year was calculated:

$$MMD(J) = \left[\sum_{I=1}^{NYR} MD(I,J)\right] * \frac{1}{NYR} \qquad ...(10)$$

The summation of Mean Monthly Deficits yields Mean annual deficit (MAD) or,

$$MAD = \sum_{J}^{NMN} MMD(J) \qquad ...(11)$$

Here MD = Monthly deficits or monthly differences

MMD = Mean monthly deficit

MAD = Mean annual deficit

Mean annual deficit is used in testing for onset and termination of drought.

The analysis includes establishment of another set of termination drought. This includes maximum parameters used for test of start and termination drought. This includes maximum of Mean Monthly Rainfall (MMR), the sum of two highest values of mean monthly rainfall, the sum of three highest values of mean monthly rainfall and so on up to the sum of mean monthly rainfall of all the months yielding a value equal to mean annual rainfall.

E Test to Determine onset of drought

From the given record, a month with a negative difference is found, while inspecting delete negative difference, the following two cases may arise.

Case (A) Delete negative difference < MMMR

Case (B) Delete negative difference > MMMR

Case (A) Delete negative difference < MMMR

If delete negative difference is less than MMMR, the difference of the next month is inspected and if negative is added to the negative difference of the previous month and compared with the second values on the sliding scale, (MMMR + x). If sum of these two delete negative difference exceeds (MMMR + x), the drought is deemed to have started from the previous month. In this manner the absolute value of sum of all negative differences occurring from the first month over a period of a year is tested sequentially against the twelve values of the sliding scale. If at any time the summed value of delete negative difference from the first to the J^{th} month exceeds the value MMMR+(J-1)x, drought is deemed to have started from the first month.

Case (B) Delete negative difference ≥ MMR

In this case when the delete negative difference is greater than or equal to MMMR, the drought is deemed to have stated from this month.

F Tests to determine the termination of drought

Once the start of the drought is found, the program begins to search for a month with a positive difference.

A precondition to be satisfied is that at least one of the two months following the initial month with a positive difference should also have a positive difference. Once this condition is met. then only the initial month is qualified for further testing for termination of drought. Thus for further testing for termination of drought a precondition to be satisfied is that two consecutive months should have positive difference.

Once this condition is met, the following two tests are carried out for testing for termination of drought:

i) In this test the differences are algebrically summed up from the month, the drought started to the month of the termination test. If the sum became positive, the drought is deemed to have terminated otherwise second test is carried out for testing of termination.

ii) The second tests comprises of ten sequential tests. Firstly the actual rainfall values from the first to the third month of testing are summed up and compared with the sum of three highest values of mean monthly rainfall. If the sum of actual rainfall is higher the drought is considered to have been terminated. If the sum of actual rainfall is not exceeded, then the sum of actual rainfall of first four month is compared with the sum of the four highest values of mean monthly rainfall, and so on should the drought not yet have been terminated, upto a comparison of the sum of the rainfall of the rainfall of the twelve months following and including the month from which the test commenced, with the mean annual rainfall. By this stage either the drought had been terminated, in which case it was deemed to have ended in the month from which the multiple test had been initiated or the drought

conditions prevailed over this period and test for the termination recommenced at the first month with a positive difference following that from which the previous unsuccessful test had proceeded.

Once a termination had occurred testing for the start of the next drought began at the first month with a negative difference following the month in which the drought ended.

(G) **Evaluation of drought index**

Drought intensity is evaluated by dividing the total deficits beyond the monthly mean deficit for the period of drought (D) by the sum of the mean monthly deficits for the same period.

$$\text{Drought Intensity (I)} = \frac{\sum_{J=IDST}^{IDEND} [MMR(J)-ER(J)]-MMD(J)}{\sum_{J=IDST}^{IDEND} [MMD(J)]} \quad \ldots(12)$$

WHERE IDST = Month of start of drought

IDEND = Month of termination of drought

In above equation if nominator is less than 0.0 (i.e., negative), then nominator is equalled to zero for calculation of drought intensity.

Severity Index : Severity Index is defined as product of drought intensity and drought duration

$$SI = I \times D \quad \ldots(13)$$

This analysis has been performed for all the six selected districts. Monthly rainfall data for the period 1951 to

1987 of selected raingauge stations located at taluk headquarters of each district have been used for analysis. A computer programme using the above approach has been developed for the analysis. The analysis has yielded the distinc spells of drought alongwith monthly and overall intensity of drought for all the spells. The results of analysis in tabular form for all the six selected districts are given in Appendix III-3. The graphical representations of the drought spells with intensity for all districts are shown in figures 3.4.

The following inferences can be drawn from the analysis (Reference fig. 3.4 and Appendix III-3):

In the state Rajasthan, the rainfall data analysis using Harbst approach yielded that all the six districts experienced continuous or intermittent drought spells during the period 1984-87. The intensity of drought was found higher in case of Banswara during the year 1985, but in the subsequent years the spell did not continue in this district. Rest of the five districts experienced continuous drought spells during 1985-87. The no. of drought spells varied from 7 to 13 during the period 1951-87. The maximum no. of drought spells were experienced in the district of Dungarpur while Ajmer had minimum no. of drought spells. The pattern of drought intensity and duration was found similar in districts of Udaipur and Durgapur. The approach has yielded comparable results of drought analysis and has further scope for improvement taking into account the version of monthly weightage factors keeping in view the agriculturally more important months in the state.

3.5 Dry Spell Analysis

Agriculture is the worst sufferer of droughts as the ultimate effects of drought results in partial or total crop

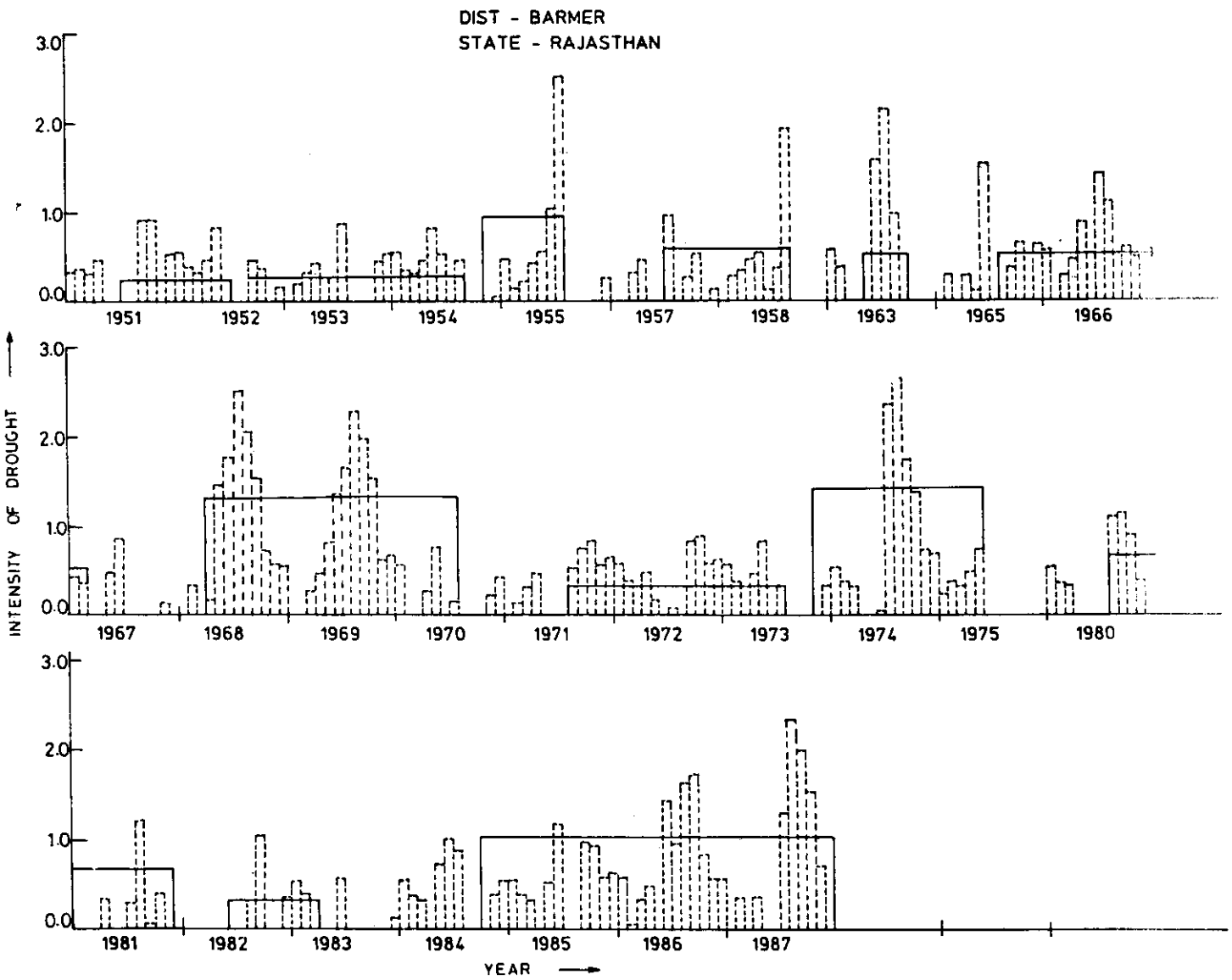


FIG. 3·4. OVERALL AVERAGE & MONTHLY INTENSITY OF DROUGHT

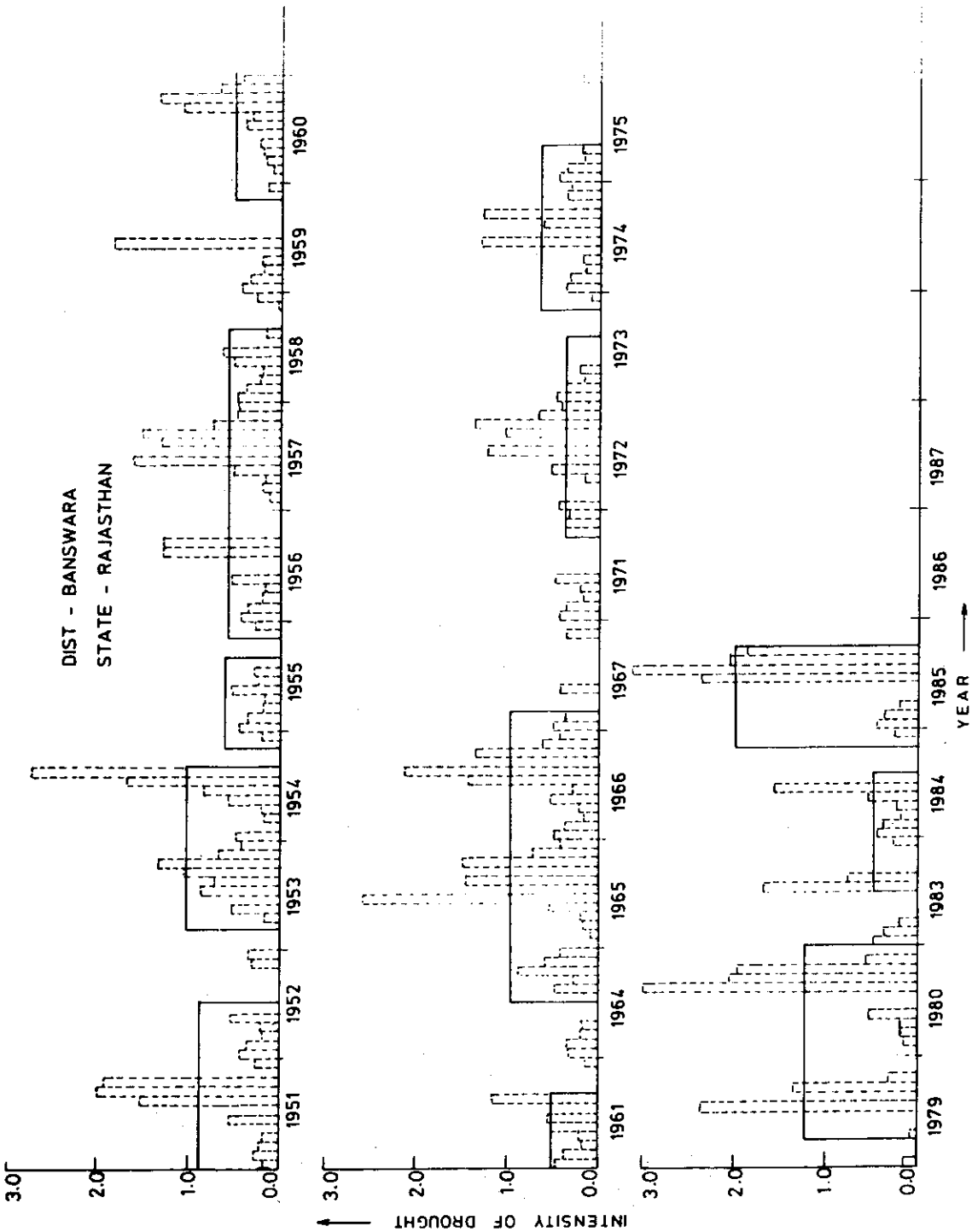


FIG. 3·4. OVERALL AVERAGE & MONTHLY INTENSITY OF DROUGHT

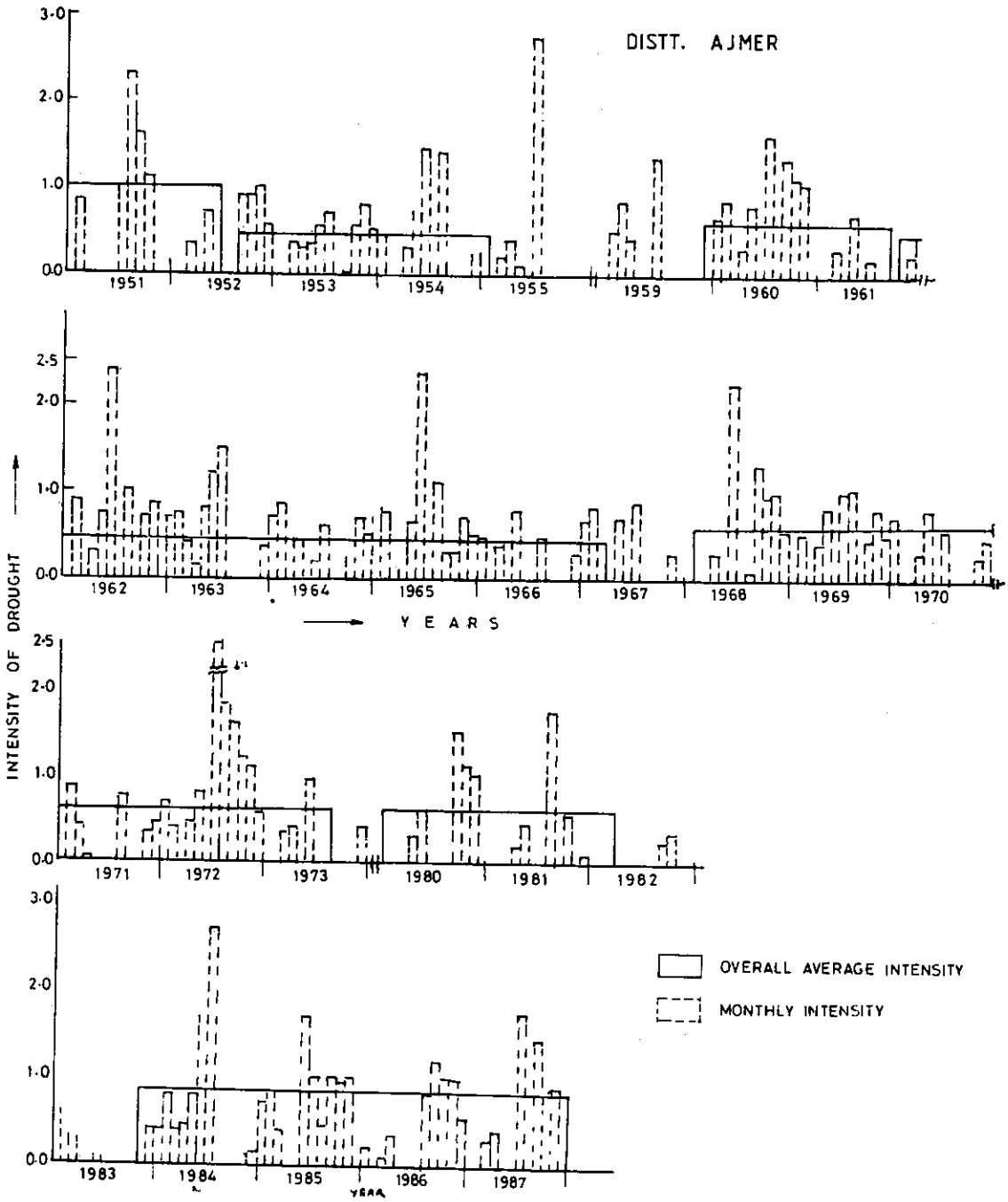


FIG.3.4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT.

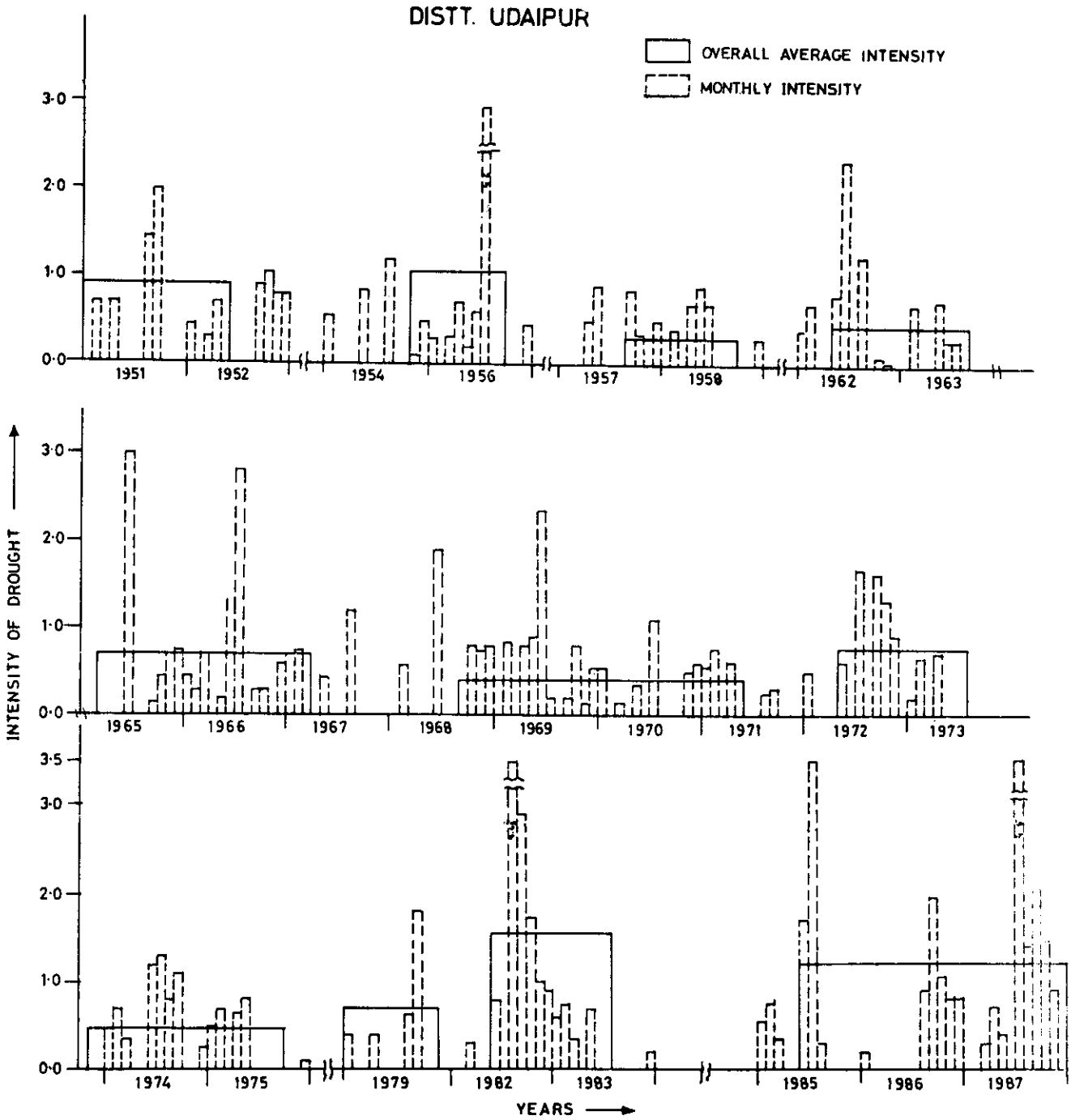
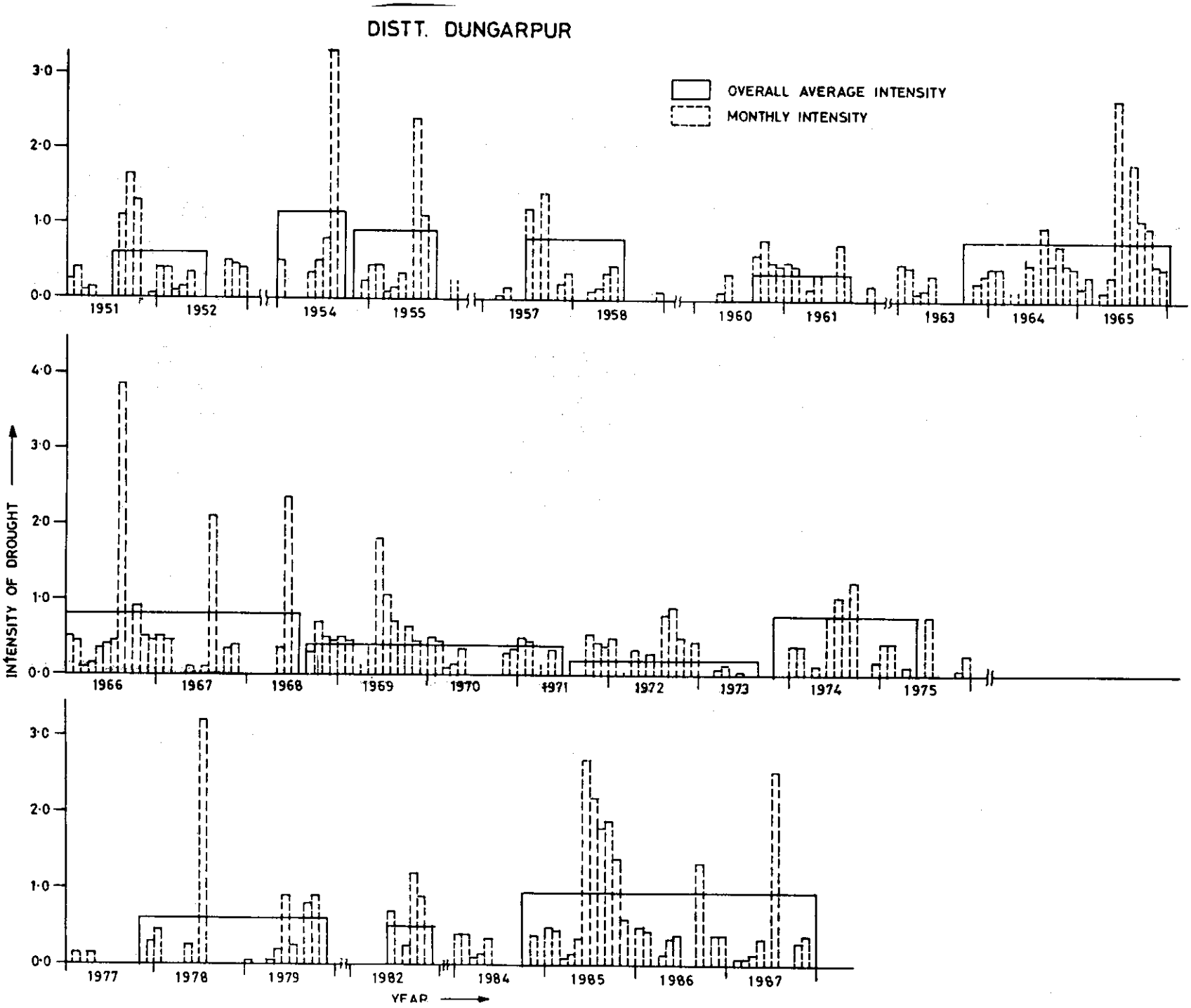


FIG. 3·4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT


DISTT. DUNGARPUR
OVERALL AVERAGE INTENSITY
MONTHLY INTENSITY
INTENSITY OF DROUGHT
YEAR
3·0
2·0
1·0
0·0
4·0
1951
1952
1954
1955
1957
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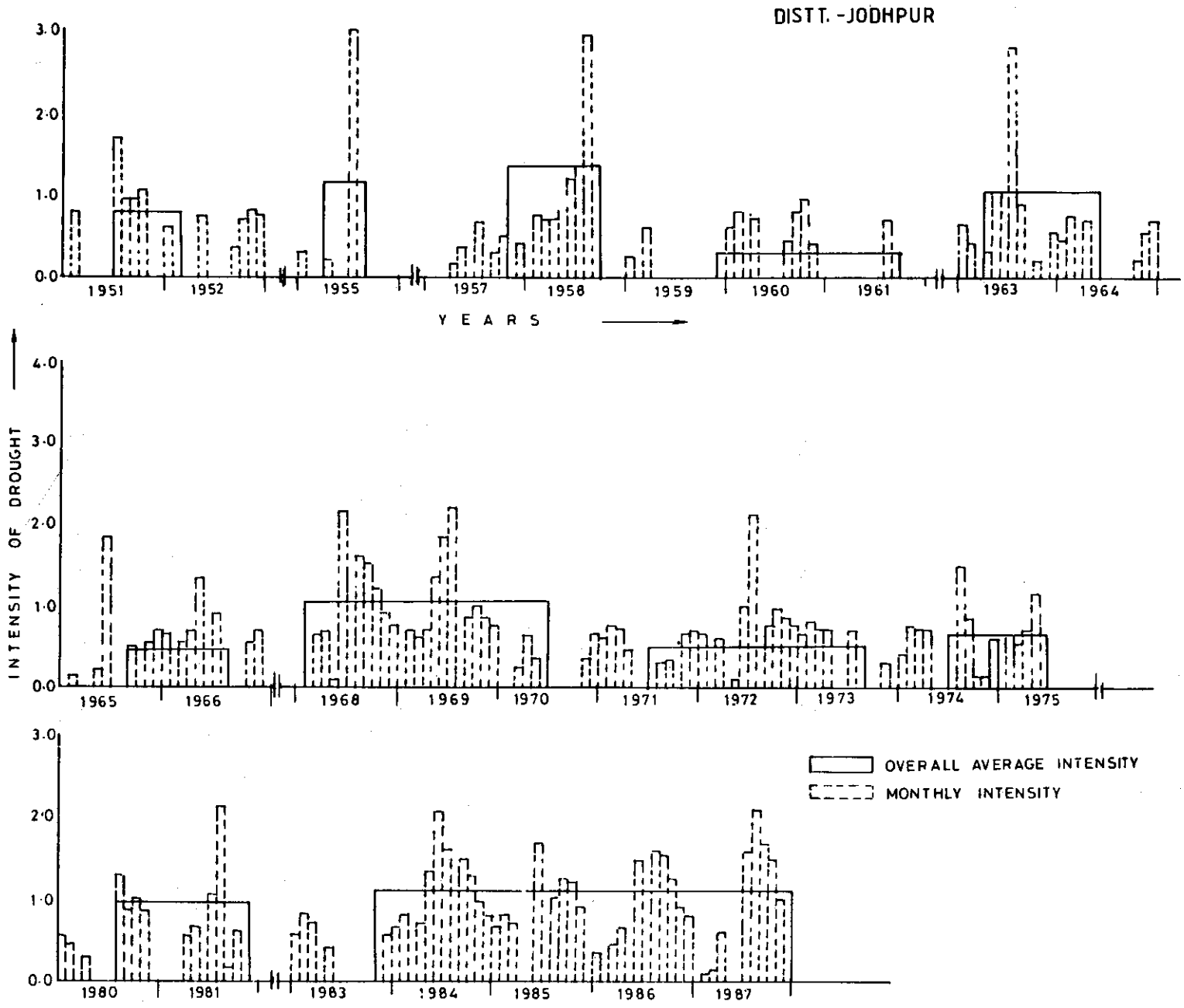

FIG. 3·4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

failure. Out of the various growing stages of crops, some are sensitive to moisture stress known as critical growing stages. Agricultural droughts are the result of occurrence of dry spells specially during critical growth stages of crops. Therefore the analysis of dry spells (≥ 2 weeks) within monsoon season has significance specially for rainfed agriculture in the country. Therefore, an attempt has been made to identify the dry spells of two or more than two weeks duration during monsoon period (4th June to 15th September) by selecting one taluk from each of the 6 selected districts of state Rajasthan.

The criteria for selection of dry spells is that the daily rainfall should be less than or equal to 5 mm (as a day is assumed as rainy day if daily rainfall exceeds 5 mm) occurring continuously for at least two weeks (i.e. 14 days) or more. For counting number of spells the start of monsoon season has been assumed from fourth June of (beginning of 23rd standard week) every year. The duration and time of occurrence and number of such dry spells for all the 6 six districts of state Rajasthan have been presented in Appendix-III-4(A). The number of dry spells have been counted starting from the monsoon season of 1981 to 1987. The study has been carried out for one taluk in each district.

For statistical analysis, the duration of dry spells were represented as range (in days) and number of spells falling in that range were counted. The number of spells falling in various ranges of duration of spells were represented as percentage of total number of spells occuring from 1981-87 and cumulative percentage was obtained starting from the maximum duration of dry spell group downwards adding successive percentages (Appendix-III-4(B)). The probability curves have been showing range of duration of dry spells on the abscissa and

cumulative percentage of number of spells as ordinates. The plots are shown in figure 3.5. Probability distribution graphs as shown in figure have been used to read the values of duration of dry spells (in days) at 75% probability level and have been given in table 3.4. If can be observed from the table that at 75% probability, the duration of dry spell ranges from 21-28 days for all the six representative taluks selected for all the six districts respectively.

The analysis is specially important from the view point of agriculture as it can give some idea about likelihood of dry spells during monsoon period based on which alternate arrangements can be made for providing water during critical growth stages to avoid hazardous effects on crop yields, especially in rainfed agriculture.

Table 3.4 : Range of Duration of Dry Spells for 75% Probability of State Rajasthan

S.No.	Taluk	Distt.	At 75% probability, duration of dry spells (in days)
1.	Barmer	Barmer	21-28
2.	Banswara	Banswara	21-28
3.	Ajmer	Ajmer	21-28
4.	Girwa	Udaipur	21-28
5.	Jodhpur	Jodhpur	21-28
6.	Durgapur	Durgapur	21-28

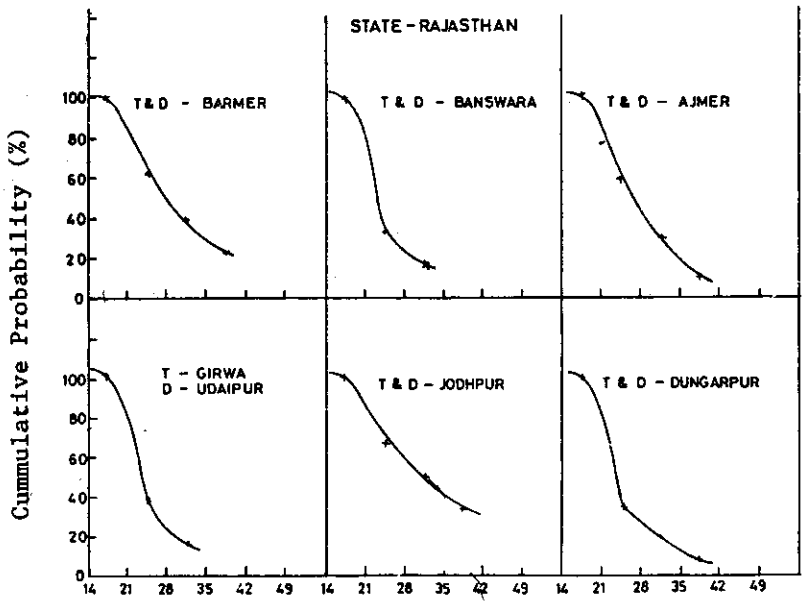

Fig.3.5 : Probability distribution of dry spells

4.0 GROUND WATER DEFICIT

4.1 General

The main objective of ground water management is to ensure that ground water will be available at an appropriate time and in an appropriate quantity and quality to meet the most important demand of the society. The measurement of ground water levels and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table reflect the effect of infiltration, of precipitation and of discharge of ground water to streams and lakes or withdrawal of water from wells. Usually the change in ground water storage is a seasonal phenomenon. However, during the period of scarcity and droughts, more dependence comes on ground water storages and steep decline in ground water levels are experienced. Because of improper management of ground water aquifers after development, numerous undesirable consequences such as the depletion of aquifers and ground water mining emerge, especially during drought years. Statistics recently compiled on the use of ground water and surface water show that in a number of states ground water is being over exploited in certain pockets resulting in a fall in the water table. During droughts, due to deficiency of rainfall and higher rate of evapotranspiration, the demand for irrigation gets enhanced, thereby the water level goes down. This results in increased use of energy for pumping water from greater depths involving higher expenditure. As a policy, the withdrawal of ground water should be restricted to average annual recharge. This will conserve water over exploitation during drought periods.

Therefore, there is a long standing need to better understand the relationship between precipitation and ground water levels. The relationship can be developed by carrying out statistical analysis of precipitation data & well level measurements. Beside, information regarding well,abstractions should be available for evaluating effects on water table on, only due to reduced precipitation.

In order to see the effects of scarce rainfall as experienced during three successive drought years (1985-1987) on ground water regime, statistical analysis of ground water level data vis a vis precipitation has been carried out.

In the present analysis of state Rajasthan, five districts namely Ajmer, Udaipur, Jodhpur, Barmer, and Banswara were chosen for the study of pre-monsoon and post-monsoon ground water levels and seasonal rainfall fluctuations. Due to non-availability of groundwater level data of district Dungarpur the study is restricted to five districts only. Due to non-availability of abstraction data, the effects of withdrawal could not be introduced in the analysis.

4.2 Ground Water Level Analysis

The data concerning ground water level fluctuations were collected in respect of observation wells in all the five districts namely Udaipur, Ajmer, Jodhpur, Barmer and Banswara of state Rajasthan. The informations regarding period of data used, no. of observation wells and the source of data is given in table 4.1.

Table 4.1: Status of Ground Water Data of State Rajasthan

S. No.	Name of District	Data available (four time in a year)	No. of Wells taken	Source of data availability
1.	Ajmer	1976-88	5	C.G.W.B.
2.	Banswara	1979-88	7	-do-
3.	Barmer	1979-88	10	-do-
4.	Jodhpur	1981-88	7	-do-
5.	Udaipur	1978-88	5	-do-

It is evident from table 4.1 about 5-10 wells were chosen in each district for evaluating impacts on ground water regime. It was assumed that these wells are evenly distributed with in the district. The locations of the wells on the district map have already been shown in the figures presented in chapter 2.

The ground water level analysis was attempted with the help of quarterly/seasonal data depending upon the frequency of the data collected from central and state Govt. agencies of the state. Appendix IV-1 gives the details of various observation wells spread over 5 selected drought prone district of Rajasthan state with their latitude and longitude. The analysis has been carried out for ground water level data from 1976-88.

The water level in the wells have been calculated with respect to mean sea level and for each district average ground water level has been calculated using Thiessen method. The Thiessen weight of all wells considered in each district was established and ground water level calculated with respect to mean sea level multiplied by Thiessen weight gave average ground water level for the district.

4.3 Inference

The ground water level analysis was restricted to districts (Banswara, Barmer, Ajmer, Udaipur and Jodhpur) in the state of Rajasthan. The district of Dungarpur was not included in the study due to non-availability of data. The seasonal rainfall values for all districts except Banswara showed deficient rainfall with the extreme lying between 47-66%. Due to severe deficient rainfall in the monsoon season of '87 the rainfall trends have also shown steeper decline as compared to previous year. The analysis of post monsoon levels have indicated that in case of Ajmer, Udaipur and Jodhpur districts higher rate of decline in post monsoon levels were obtained. However, the districts of Banswara, and Barmer showed slightly positive trend in post monsoon ground water table levels, though the rate of rise was less as compared to previous year for Barmer district. In case of Banswara district slightly higher rate of rise in post monsoon levels have been observed during 1987-88 as compared to previous year, which can be attributed to slight positive departure in the seasonal rainfall. The analysis of pre-monsoon water table levels have shown declining trend in all districts except Barmer. The rate of decline has been observed higher in all cases except Banswara as compared with the previous year. In case of Barmer district, however, the trend of pre-monsoon levels shows positive slopes, however, the rate of rise has reduced as compared to previous year 1986-87. The trends in water table levels and seasonal rainfall for all the chosen five districts are shown in fig. 4.1 to 4.5.

The analysis of ground water levels based on the water table fluctuation data of past 10-12 years has yielded in knowing the ground water level trends (pre and post) as a result of

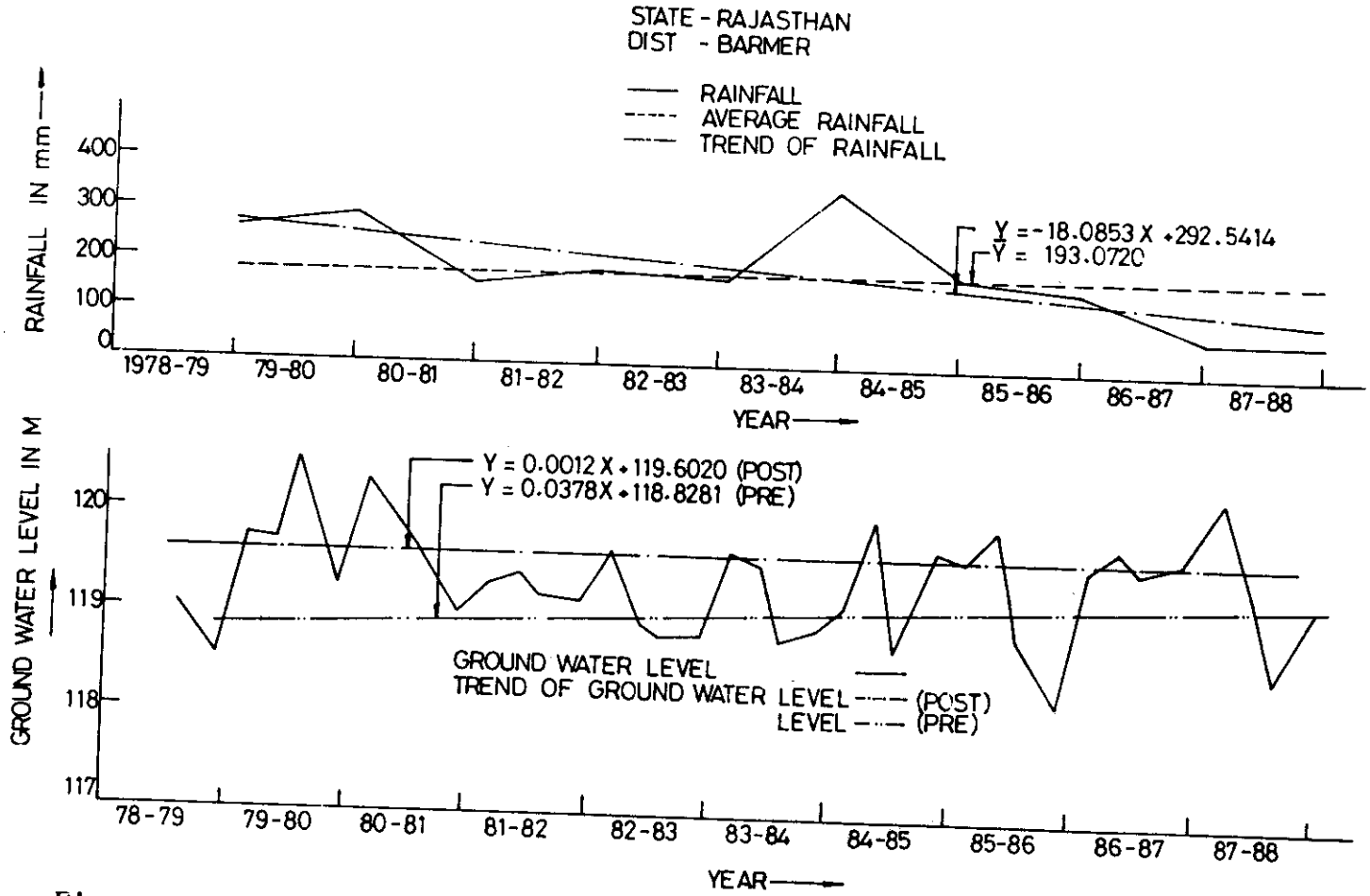

Fig. 4.1 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

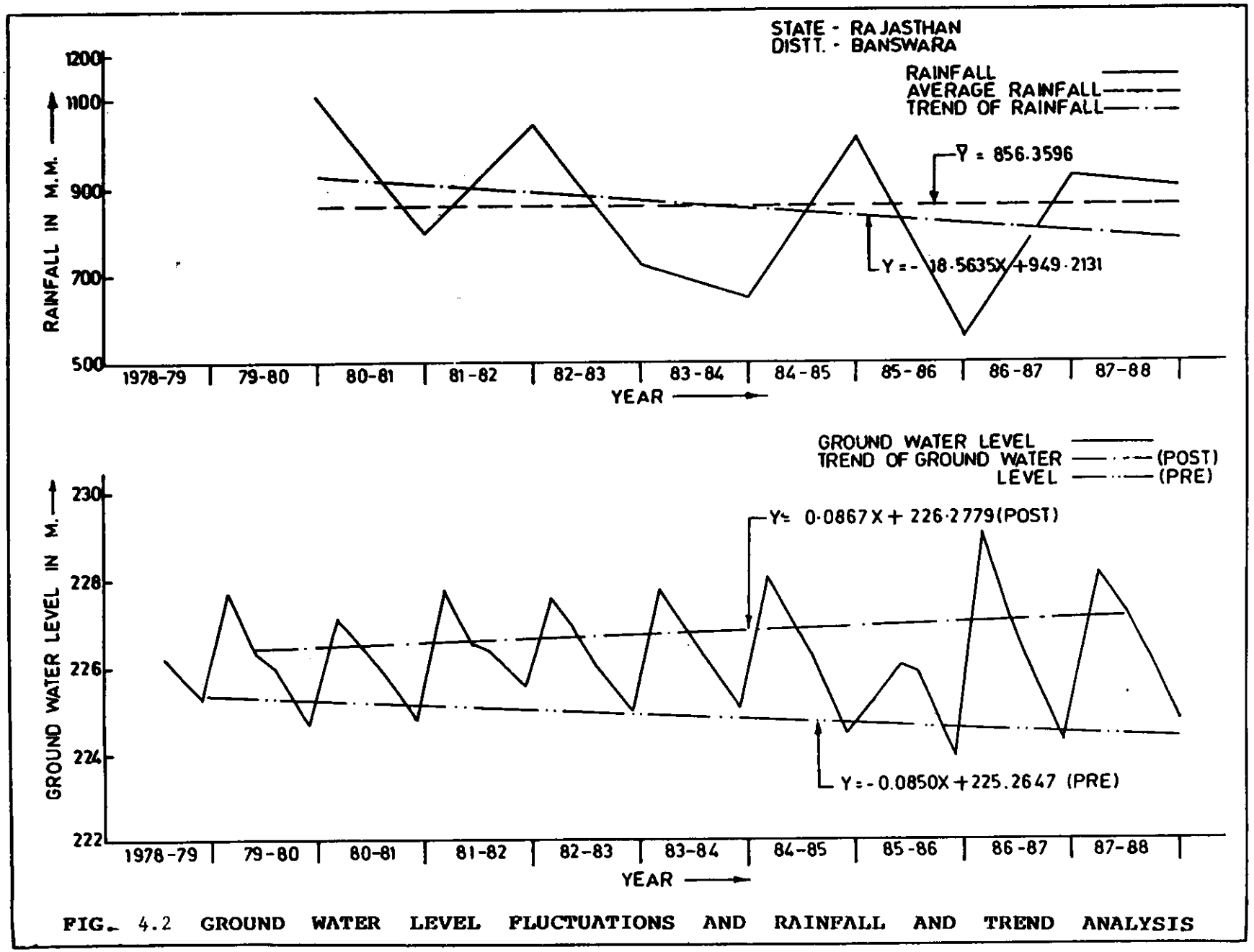

FIG. 4.2 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

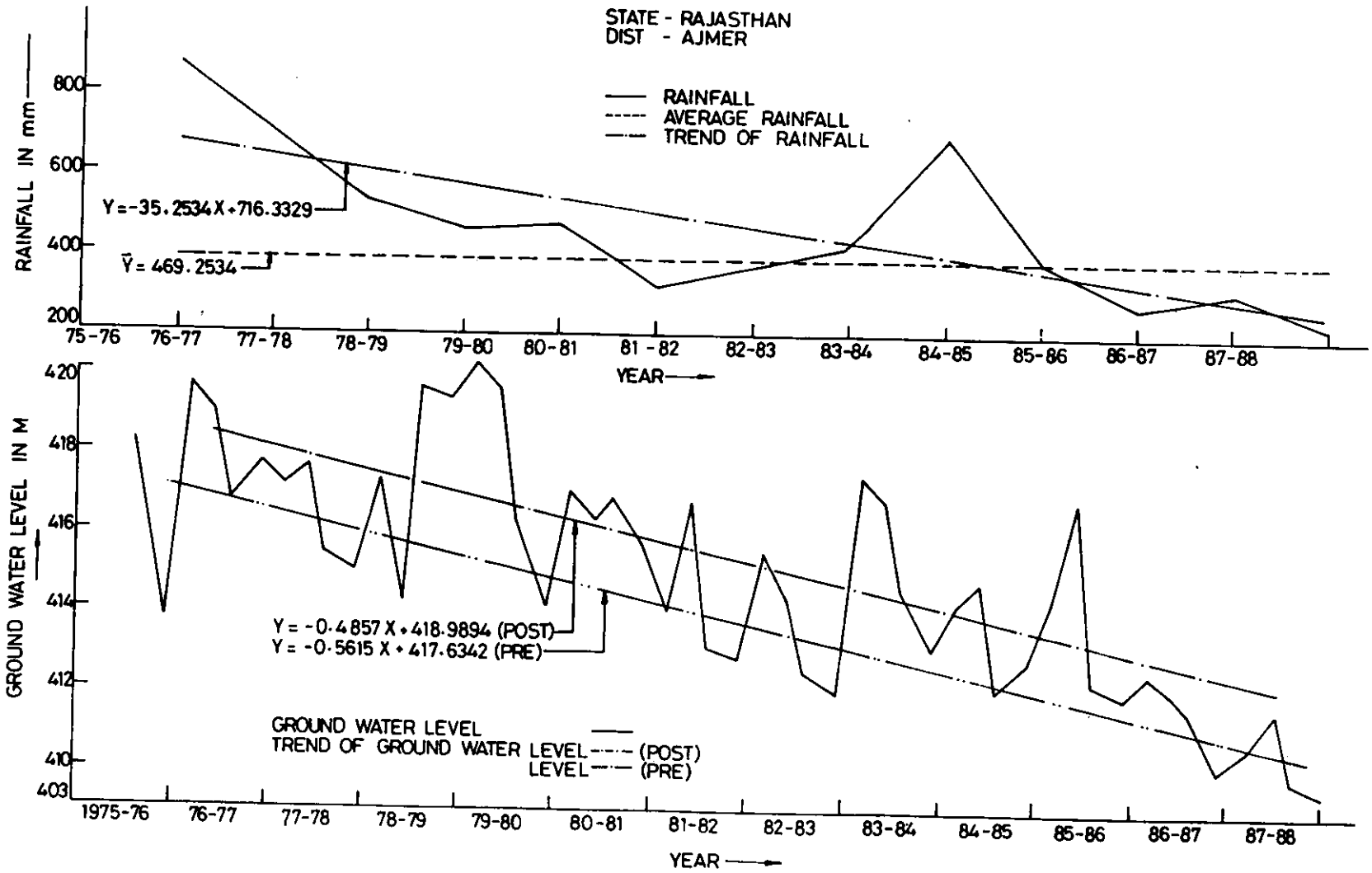

FIG: 4.3 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

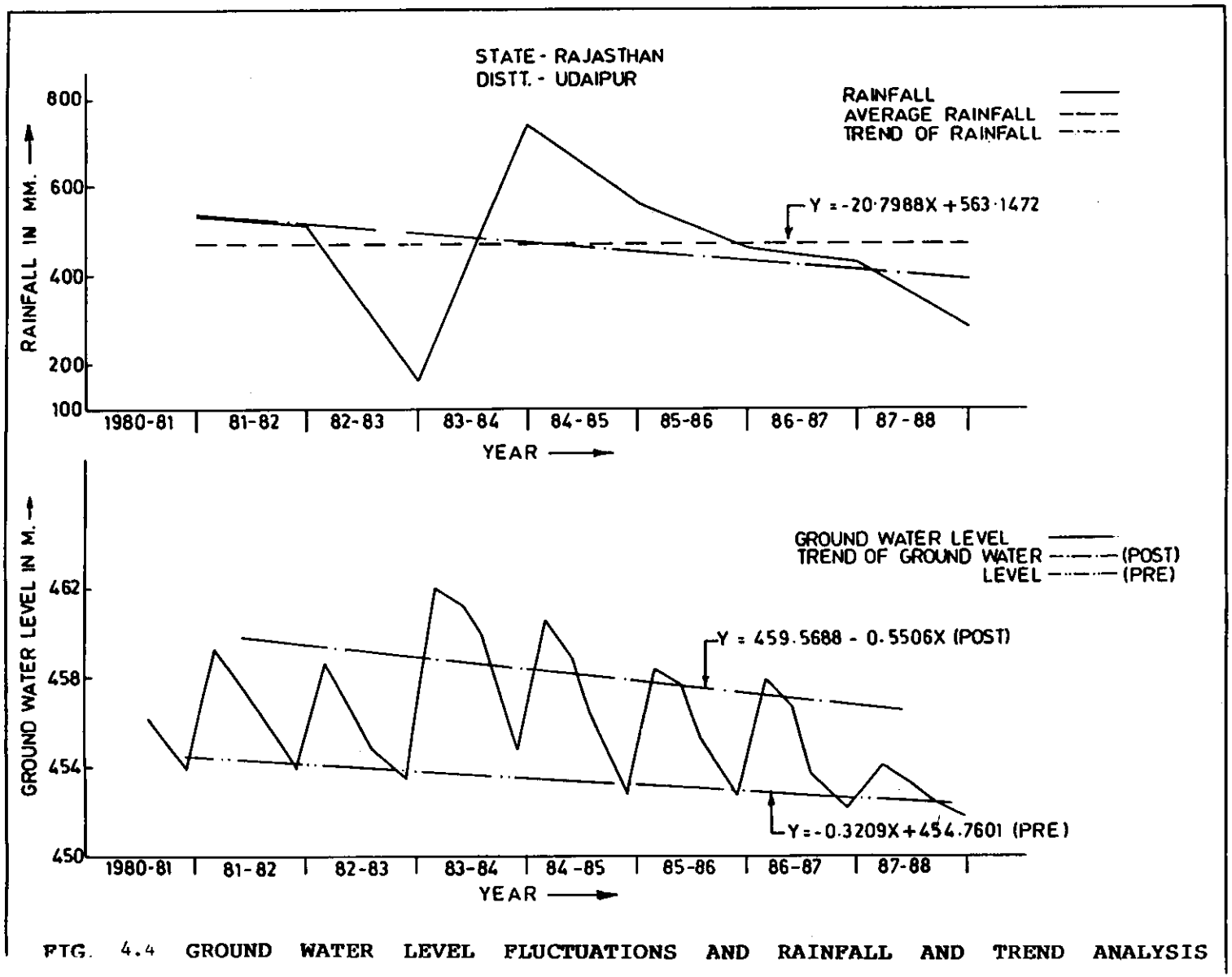

FIG. 4.4 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

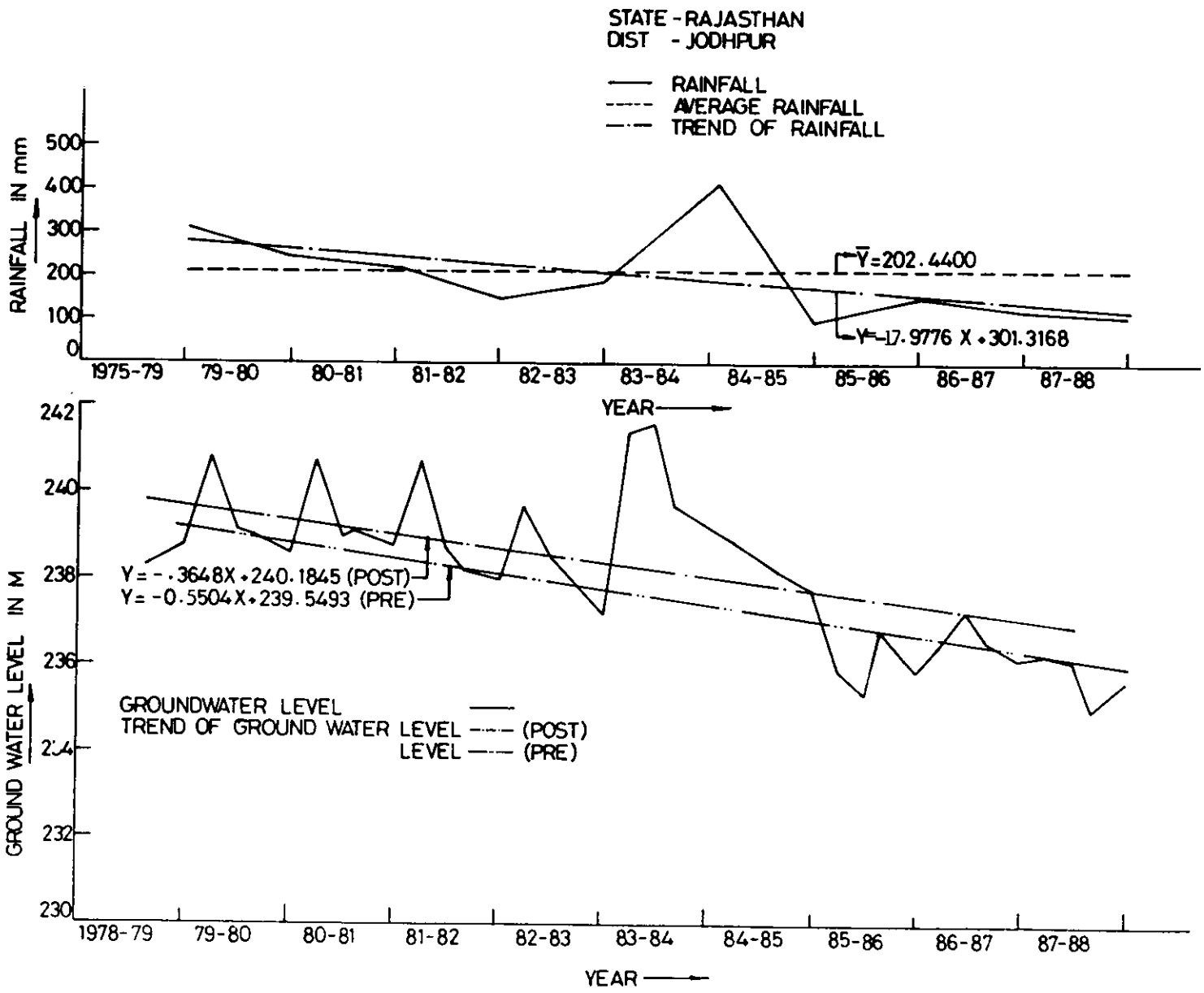

FIG 4.5 GROUND WATER FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

seasonal rainfall departure. In most cases the water table has been recorded falling or the rate of recharge was found lesser in 1987-88 as compared to previous year. The continuous decline in water table is certainly attributed to failure of monsoon due to which the draft of ground water also gets increased because of increase in demand. The rise in water table as found in some cases can be attributed to the positive ground water imbalances created by surface water irrigation projects as has been observed in case of Barmer district. Better analysis to correlate rainfall failure and ground water regime can be done by taking into account the well abstraction data, which has not been done in the present case due to its non-availability.

5.0 ANALYSIS OF RESERVOIR STORAGES

In order to see, the impacts of failure of monsoon on storages of the reservoirs, an attempt has been made to compare the storages in one selected reservoir of the state Rajasthan. For this purpose, live storage and corresponding reservoir levels in some selected months have been plotted against time. The weekly reservoir levels data as supplied by Central Water Commission from 1984 till 1987 have been used for this analysis. Fig. 5.1 shows the position of storages during 1984 to 1987 in the Rana Pratap Sagar reservoir of Chambal basin. It can be seen from the figure that live storage during May'86 was lower than the other years. However, during May and October'87 the live storages were recorded lower than the previous years. The Oct'87 live storage was 31% to the previous year Oct's live storage which indicates reservoir storage was severely affected by the drought conditions during 1987.

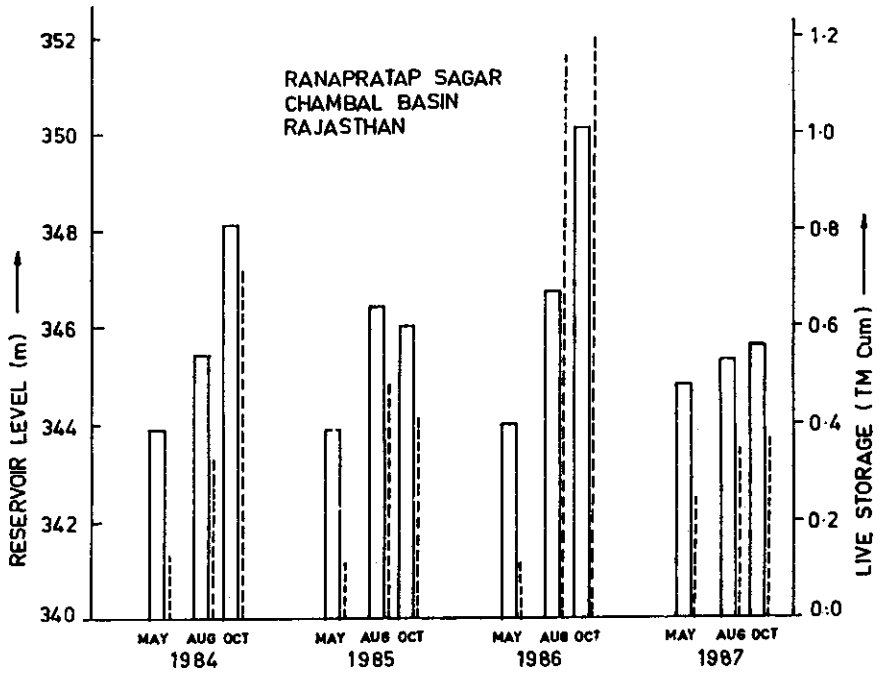

Fig.5.1 : Reservoir levels and storages in Rana Pratap Sagar

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. Studies were carried out in six districts of Rajasthan state to evaluate impacts of drought on hydrologic regime. For this purpose, analysis of rainfall data and ground water level data was carried out on water year basis.

2. The present report describes analysis of water year 1987-88 which is based on the data collected from the published reports.

3. The rainfall analysis done on seasonal basis to evaluate the status of deficiency during the year in six districts indicated that there has been continuous seasonal deficiency of the order of 20-65% in all the districts. Except in Banswara, the pattern of deficiency has been similar in Jodhpur, Udaipur, Ajmer and Barmer.

4. The deficiency in rainfall on monthly basis indicated that departure from normal rainfall in various months of the year have been in the range of 20-100%. In case of Banswara some positive departure were noticed.

5. The probability analysis of rainfall for working out the range of rainfall at 75% probability level using annual rainfall data indicated that for most of the districts, the rainfall works out to be 500-600 mm with the extreme of 200-300 mm and 700-800 mm. Using this analysis, the probability of occurrence of 75% of the normal rainfall was evaluated which was found as 79, 79, 84, 81, 78 and 79% for the districts of Barmer, Banswara, Ajmer, Udaipur, Dungarpur and Jodhpur, respectively. This means all districts except Ajmer & Udaipur have chances of having less than 75% of normal

rainfall in more than 20 years per 100 years which further confirms drought proneness of these districts.

6. Analysis of monthly data using Herbst Approach indicate that all districts experienced drought during year 1984-87. In fact most districts experienced continuous drought spells during 1985-87 except Banswara. Using this approach the no. of drought spells as experienced in these districts ranged from 7-13 during the period 1951-87. While Dungapur experienced thirteen nos of drought spells, Ajmer recorded twelve nos. drought spells as per analysis. The dry spell analysis was performed for working out duration of dry spells at each level of probability. It was observed that for all the districts, the dry spell duration worked out in the range of 21-28 days.

7. Ground water analysis was attempted for five districts for working out effects of drought on ground water levels. For this purpose, data as recorded in the observation wells in these districts were analyzed. The length of data used varied from district to district and about 10 years of data was used for the analysis. The analysis indicated that in case of Ajmer, Udaipur and Jodhpur, a high rate of decline while the district of Banswara and Barmer showed slightly positive trend. In most of the districts the levels were observed as falling except Banswara. The continuous fall in ground water levels is certainly attributed to less recharge and increasing demand during water scarce periods.

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APPENDIX - II

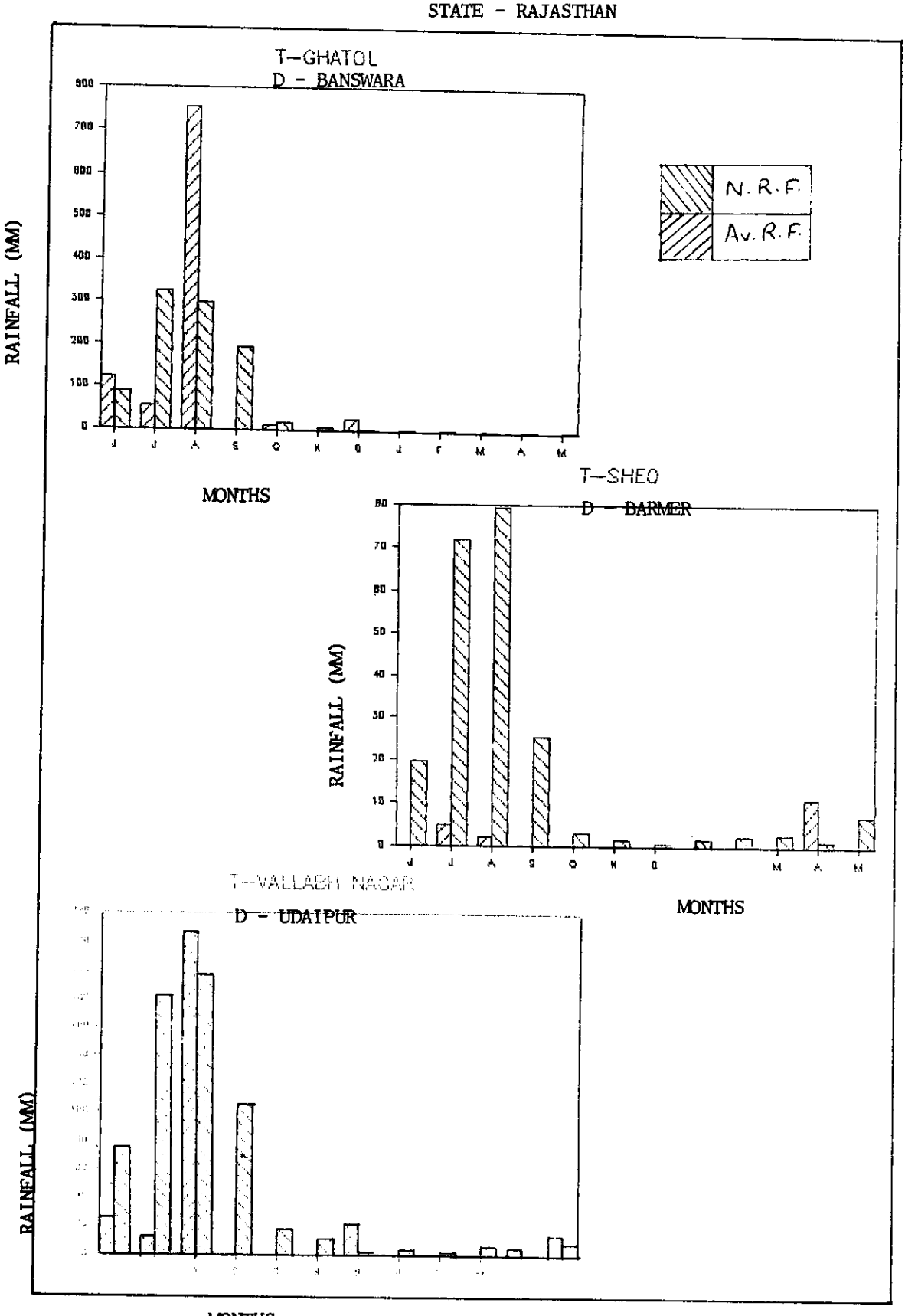
LIST OF OFFICES AND PLACES FROM WHICH DATA AND INFORMATION WERE COLLECTED

RAJASTHAN

PLACE	
Jaipur	Chief Engineer, Irrigation Department
	Dy. Director (Hydrology), Rajasthan Irrigation Deptt.
	Supdt. Engineer (Special Schemes), Rajasthan Irrigation Deptt.
	Director, Irrigation Research, Rajasthan Irrigation Deptt.
	Agronomist (Irrigation) Rajasthan Irrigation Deptt.
	Directorate of Agriculture, Rajasthan
	S.E. (Soil Conservation) Deptt. of Agriculture, Rajasthan
	Secretary, Special Schemes Organisation Rajasthan
	Secretary, Relief Rajasthan
	Deptt. of Economics and Statistics, Rajasthan
	Directorate of Evaluation, Rajasthan
	Public Health Engg. Deptt., Rajasthan
	Soil Survey Officer, Rajasthan
	Central Water Commission Field Office
	Central Ground Water Board, Regional Office

Ajmer	Irrigation Department
Udaipur	Agriculture Department
Banswara	Soil Conservation
Dungarpur	District Rural Development Authority (DRDA)
Barmer	Land Record Office
Jodhpur	Ground Water Deptt.
	Central Arid Zone Research Institute
	Chief Engineer, Rajasthan State Ground Water Department.

STATE - RAJASTHAN



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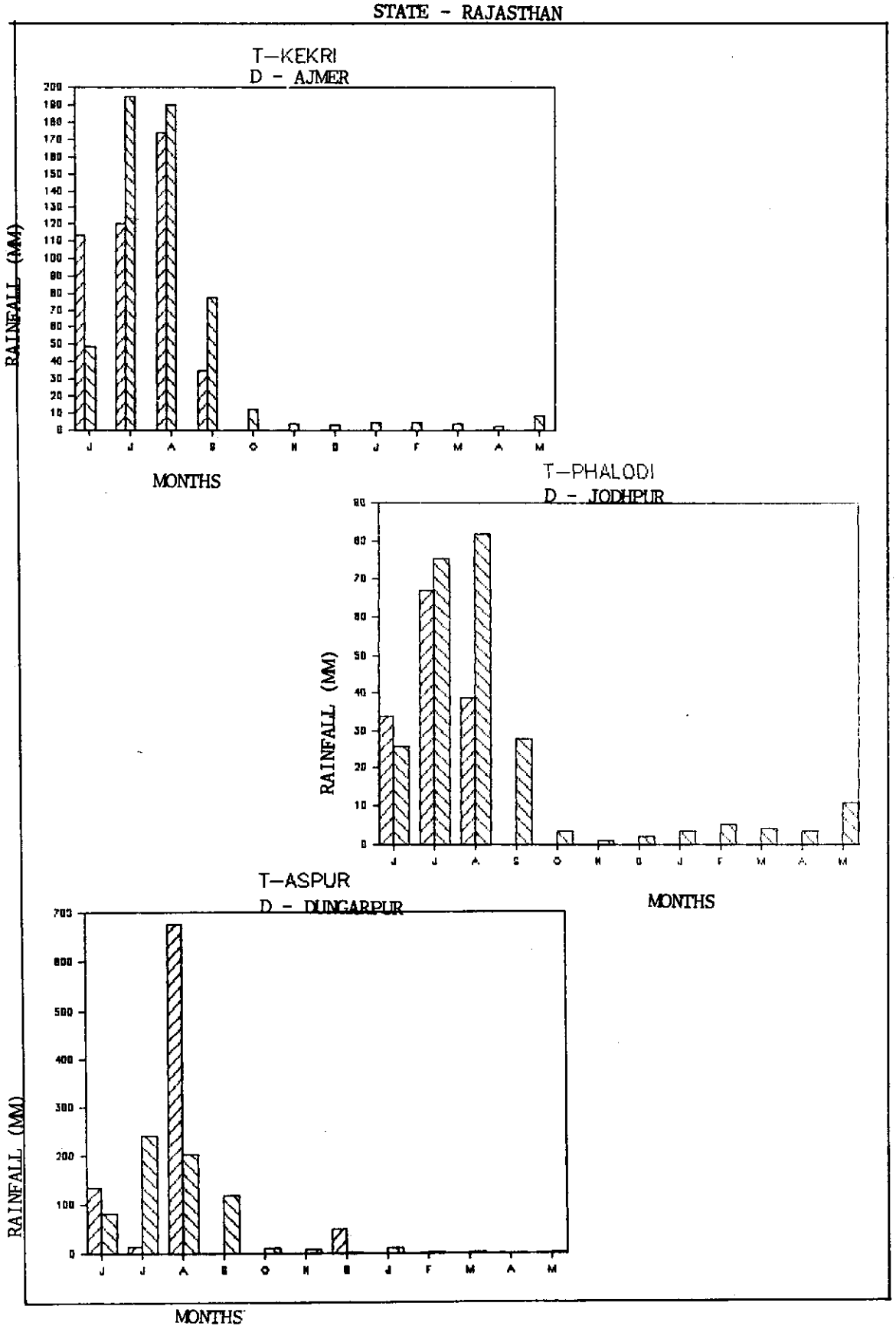
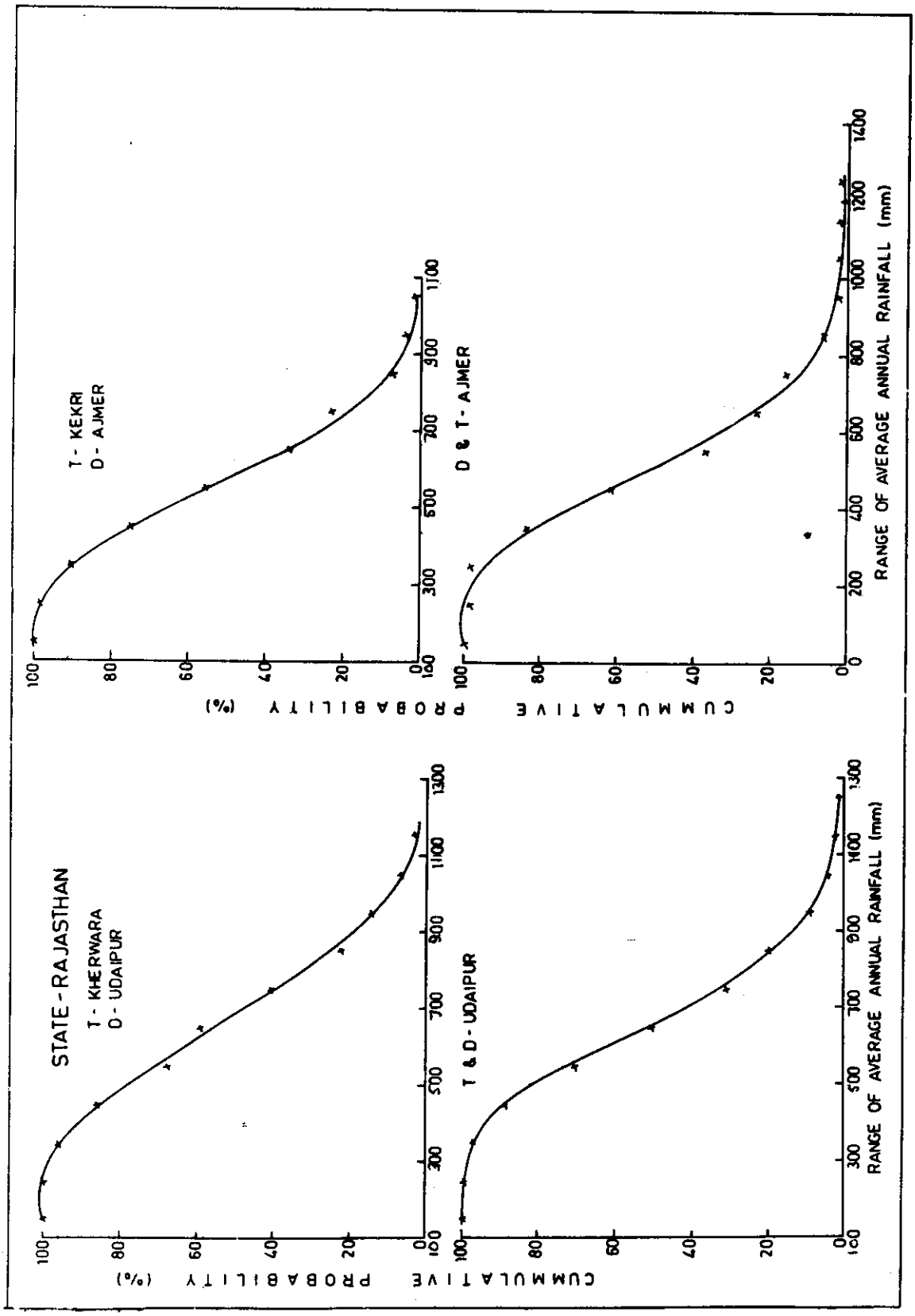
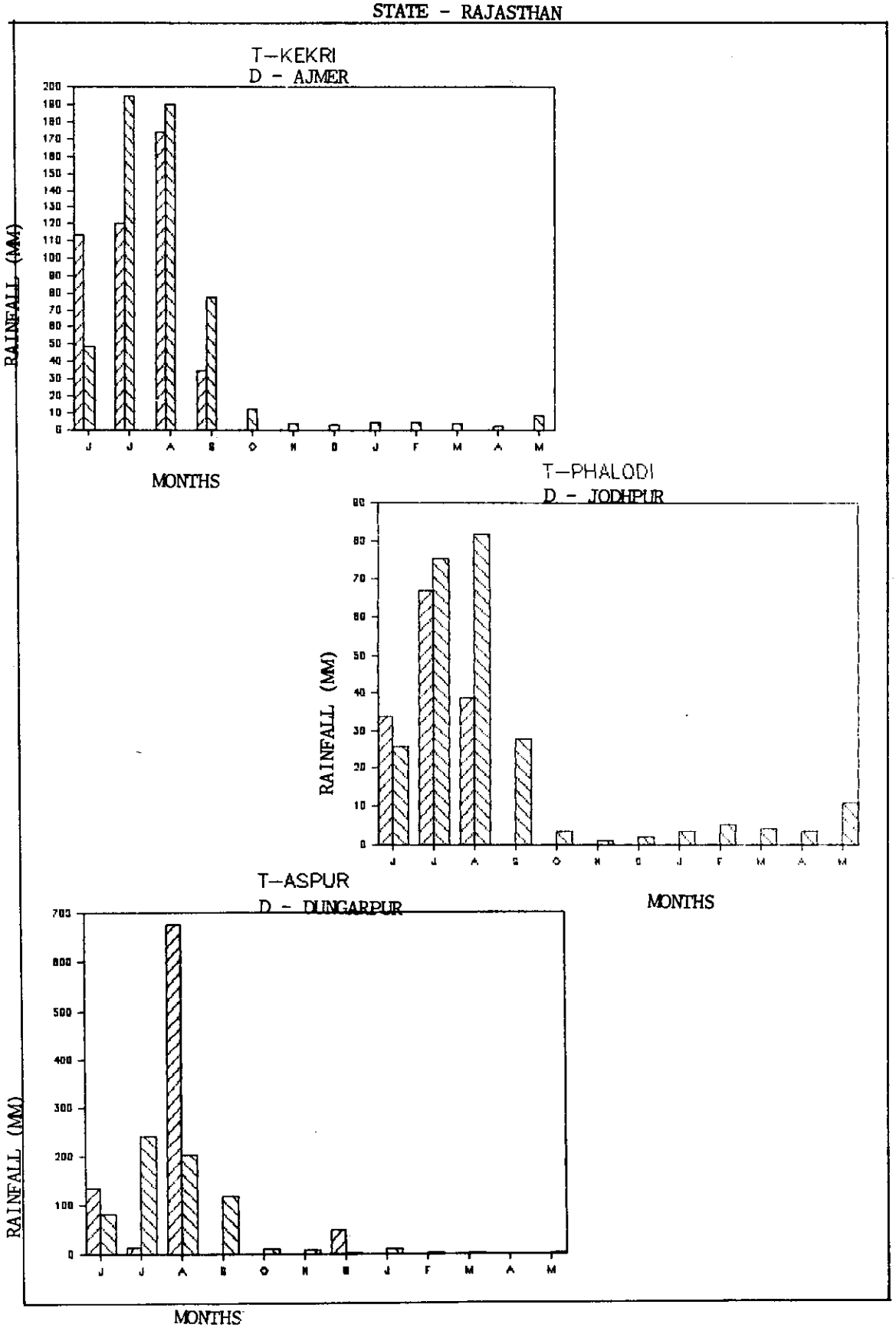
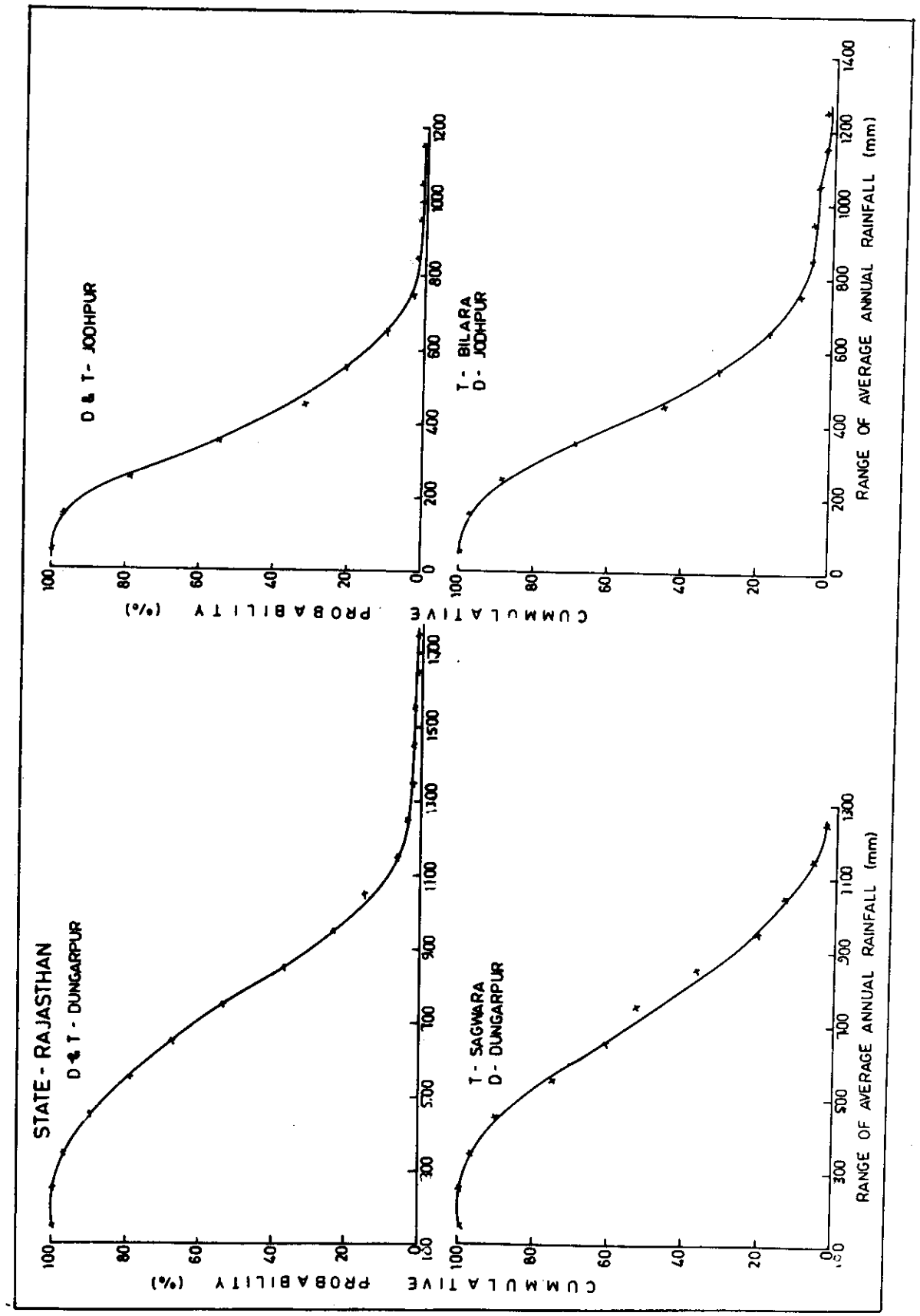
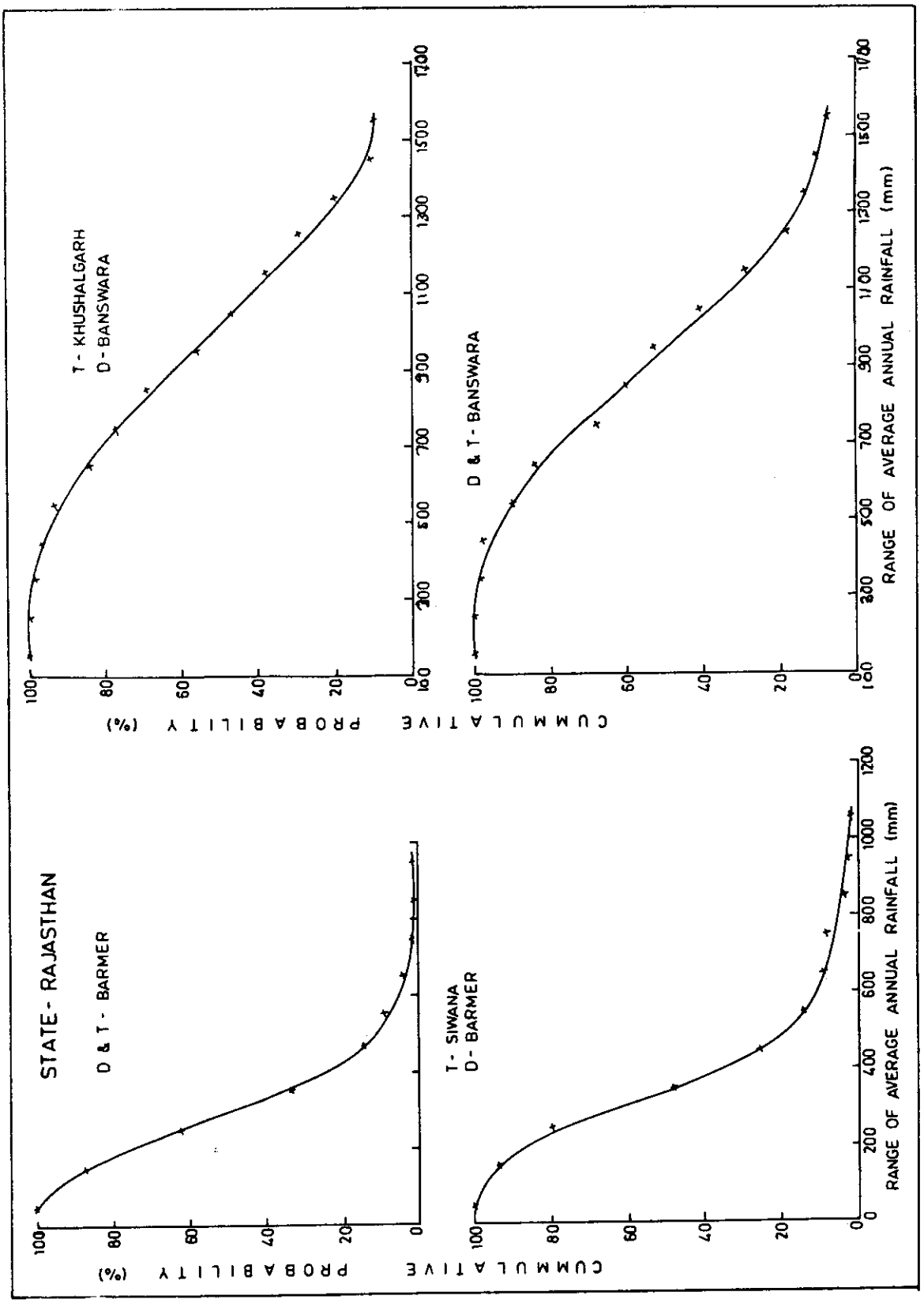



STATE-RAJASTHAN
T - KHERWARA
D - UDAIPUR
T & D - UDAIPUR
T - KEKRI
D - AJMER
D & T - AJMER
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)

STATE - RAJASTHAN




STATE - RAJASTHAN
D & T - DUNGARPUR
T - SAGWARA
D - DUNGARPUR
D & T - JODHPUR
T - BILARA
D - JODHPUR
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)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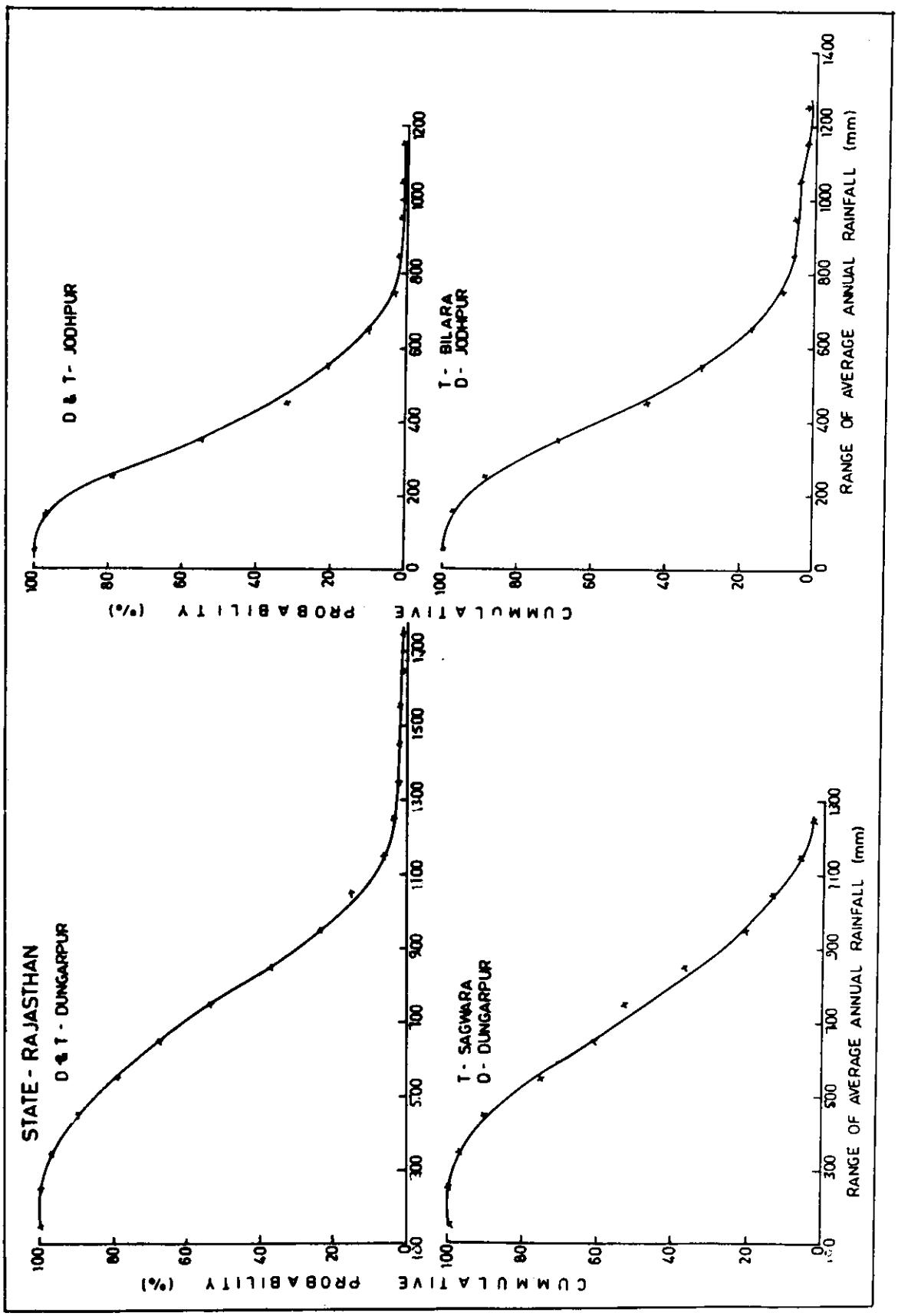
D & T - BARMER
T - SIWANA
D - BARMER
T - KHUSHALGARH
D - BANSWARA
D & T - BANSWARA
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)


STATE - RAJASTHAN
D & T - DUNGARPUR
T - SAGWARA
D - DUNGARPUR
T - BILARA
D - JODHPUR
D & T - JODHPUR
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT BANSWARA

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.159	0.293	0.139	0.199	0.000	0.551	0.000	1.513	1.488	1.956	0.000	0.25
1952	0.410	0.367	0.196	0.199	0.505	0.000	0.000	0.000	0.000	0.000	0.334	0.341
1953	0.000	0.000	0.000	0.187	0.504	0.000	0.863	0.737	1.008	1.749	0.584	0.447
1954	0.451	0.000	0.151	0.197	0.505	0.829	1.697	2.718	0.000	0.000	0.000	0.197
1955	0.401	0.364	0.196	0.199	0.505	0.000	2.788	0.000	0.000	0.000	0.000	0.22
1956	0.406	0.356	0.196	0.199	0.505	0.037	0.000	1.276	1.293	0.000	0.000	0.00
1957	0.000	0.105	0.167	0.198	0.505	0.000	1.556	0.054	1.294	1.502	0.717	0.44
1958	0.455	0.367	0.197	0.199	0.505	0.606	0.000	0.155	0.000	0.000	0.337	0.271
1959	0.417	0.358	0.196	0.199	0.000	1.854	0.000	0.000	0.000	0.000	0.000	0.15
1960	0.000	0.000	0.156	0.198	0.225	0.000	0.545	0.304	1.095	1.364	0.188	0.441
1961	0.451	0.367	0.197	0.199	0.505	0.510	0.000	1.178	0.000	0.000	0.000	0.135
1962	0.389	0.351	0.195	0.199	0.505	0.000	0.000	0.000	0.000	0.000	0.307	0.12
1963	0.000	0.000	0.097	0.194	0.505	1.227	0.000	0.000	0.000	0.000	0.000	0.07
1964	0.377	0.348	0.195	0.199	0.000	0.000	0.000	0.471	0.272	0.938	0.586	0.411
1965	0.000	0.075	0.169	0.198	0.505	2.570	0.155	1.413	1.234	1.484	0.714	0.447
1966	0.455	0.367	0.197	0.199	0.505	0.298	1.423	2.109	0.986	1.336	0.681	0.44
1967	0.451	0.367	0.000	0.000	0.439	0.000	0.000	0.000	0.000	0.000	0.382	0.000
1968	0.000	0.135	0.000	0.054	0.498	2.451	0.000	0.000	0.000	0.615	0.524	0.39
1969	0.443	0.365	0.197	0.199	0.505	0.000	0.000	0.000	0.000	0.720	0.151	0.297
1970	0.422	0.360	0.196	0.199	0.505	0.000	0.000	0.000	0.000	0.000	0.361	0.35
1971	0.454	0.363	0.197	0.199	0.470	0.000	0.000	0.000	0.000	0.000	0.555	0.35
1972	0.454	0.000	0.000	0.153	0.504	0.000	1.220	0.000	1.044	1.571	0.689	0.44
1973	0.451	0.367	0.197	0.199	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.09
1974	0.380	0.349	0.195	0.199	0.000	1.272	0.000	0.653	1.253	0.000	0.345	0.35
1975	0.433	0.362	0.197	0.199	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.190
1976	0.000	0.045	0.163	0.197	0.505	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1978	0.233	0.000	0.118	0.000	0.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.121	0.000	0.000	0.049	0.000	0.000	2.359	0.000	1.303	0.277	0.000	0.00
1980	0.000	0.115	0.170	0.198	0.505	0.000	0.000	2.961	2.044	1.969	0.246	0.00
1981	0.000	0.000	0.000	0.000	0.000	2.351	0.000	0.000	0.000	0.000	0.000	0.00
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.897	1.007	0.607	0.421
1983	0.447	0.365	0.197	0.000	0.000	0.000	1.669	0.745	0.000	0.000	0.000	0.247
1984	0.411	0.357	0.196	0.199	0.505	1.569	0.000	0.000	0.000	0.000	0.000	0.247
1985	0.411	0.357	0.196	0.000	0.000	2.366	5.110	2.040	1.561	0.000	0.000	0.00
1986	0.260	0.518	0.000	0.184	0.505	0.000	0.000	0.000	0.745	1.191	0.650	0.451
1987	0.000	0.000	0.000	0.187	0.000	0.000	3.914	0.000	0.000	0.000	0.000	0.00

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	7	1952	19	[illegible]	[illegible]
5	1953	4	1954	19	1.[illegible]	[illegible]
11	1954	9	1955	11	[illegible]	[illegible]
11	1955	4	1956	25	[illegible]	12.[illegible]
11	1956	9	1961	25	0.[illegible]	11.72
7	1964	5	1967	35	0.[illegible]	21.[illegible]
10	1971	8	1973	23	0.[illegible]	[illegible]
11	1973	5	1975	19	0.[illegible]	12.[illegible]
4	1977	12	1980	21	1.[illegible]	[illegible]
7	1983	8	1984	14	0.[illegible]	[illegible]
11	1984	10	1985	12	1.99	[illegible]

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT BARMER

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.333	0.376	0.335	0.451	0.000	0.000	0.000	0.000	0.919	0.914	0.420	0.54
1952	0.547	0.335	0.335	0.462	0.823	0.000	0.000	0.000	0.458	0.369	0.000	0.190
1953	0.000	0.200	0.326	0.460	0.255	0.000	0.667	0.000	0.000	0.000	0.399	0.53
1954	0.546	0.585	0.336	0.462	0.623	0.527	0.000	0.435	0.000	0.000	0.000	0.05
1955	0.495	0.153	0.218	0.442	0.594	1.034	2.500	0.000	0.000	0.000	0.000	0.26
1956	0.000	1.291	0.331	0.451	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.314	0.458	0.000	0.000	0.975	0.000	0.278	0.745	0.000	0.10
1958	0.000	0.287	0.330	0.461	0.537	0.109	0.391	1.931	0.000	0.000	0.000	0.000
1959	0.211	0.000	0.301	0.000	0.617	1.244	0.000	0.000	0.000	0.000	0.000	0.17
1960	0.506	0.363	0.000	0.157	0.509	0.009	0.000	0.000	0.000	0.052	0.441	0.00
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1962	0.475	0.381	0.336	0.461	0.625	1.522	0.000	0.000	0.074	1.429	0.506	0.569
1963	0.552	0.355	0.000	0.000	0.504	1.587	2.156	0.965	0.000	0.000	0.000	0.00
1964	0.170	0.365	0.335	0.461	0.000	0.000	0.000	0.000	0.000	0.000	0.451	0.551
1965	0.000	0.275	0.000	0.226	0.151	1.545	0.000	0.000	0.384	0.605	0.537	0.60
1966	0.553	0.000	0.277	0.452	0.622	0.000	1.477	1.004	0.000	0.302	0.464	0.000
1967	0.402	0.377	0.000	0.000	0.493	0.876	0.000	0.000	0.000	0.000	0.140	0.000
1968	0.000	0.325	0.000	0.161	0.000	1.455	1.755	2.524	2.019	1.545	1.701	0.96
1969	0.000	0.000	0.276	0.432	0.522	1.373	1.667	2.264	1.965	1.514	0.695	1.60
1970	0.562	0.000	0.001	0.298	0.776	0.000	0.160	0.000	0.000	0.000	0.297	0.43
1971	0.000	0.127	0.322	0.459	0.000	0.000	0.000	0.549	0.757	0.921	0.574	0.62
1972	0.555	0.385	0.336	0.402	0.155	0.003	0.073	0.000	0.331	0.853	0.502	0.427
1973	0.556	0.565	0.335	0.452	0.625	0.000	0.311	0.000	0.000	0.000	0.000	0.32
1974	0.524	0.564	0.335	0.000	0.000	0.019	2.301	2.619	1.705	1.364	0.669	0.67
1975	0.221	0.558	0.335	0.451	0.726	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1976	0.000	0.000	0.000	0.364	0.702	0.675	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.000	0.270	0.000	0.000	0.000	0.000	0.000	0.000	0.235	0.431	0.57
1978	0.550	0.000	0.173	0.000	0.799	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1979	0.128	0.000	0.000	0.331	0.000	0.000	0.000	0.000	0.041	0.000	0.000	0.25
1980	0.518	0.353	0.335	0.000	0.000	0.000	0.000	1.111	1.117	0.890	0.342	0.00
1981	0.000	0.000	0.000	0.315	0.000	0.000	0.275	1.293	0.615	1.395	0.000	0.00
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.321	1.013	0.000	0.000	0.30
1983	0.522	0.364	0.336	0.000	0.000	0.557	0.000	0.000	0.000	0.000	0.000	0.131
1984	0.504	0.335	0.336	0.000	0.711	0.969	0.375	0.000	0.000	0.000	0.388	0.52
1985	0.545	0.365	0.336	0.000	0.517	1.195	0.000	0.000	0.993	0.955	0.378	0.63
1986	0.556	0.049	0.317	0.45	0.000	1.319	0.947	1.603	1.709	[illegible]	0.574	0.5
1987	0.000	0.327	0.000	0.395	0.000	0.000	1.277	2.338	1.993	1.531	0.597	0.00

DROUGHT BEGAN MONTH	DROUGHT BEGAN YEAR	DROUGHT TERMINATED MONTH	DROUGHT TERMINATED YEAR	DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
7	1951	7	1952	13	0.25	3.2[illegible]
[illegible]	1952	9	1954	25	0.27	[illegible]
11	1954	8	1955	10	0.9[illegible]	9.[illegible]
7	1957	9	1958	15	0.5[illegible]	8.72
5	1959	10	1963	6	1.04	6.24
8	1965	5	1967	20	[illegible]	10.[illegible]7
4	1969	8	1970	29	1.33	3[illegible]
8	1971	8	1973	25	0.34	8.51
11	1973	5	1975	20	1.43	28.60
8	1980	11	1981	15	0.57	19.7[illegible]
6	1982	4	1985	11	0.33	3.67

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT NAME

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.325	0.847	0.023	0.000	0.000	0.000	0.975	2.315	1.594	1.093	0.000	0.00
1952	0.000	0.000	0.365	0.000	0.728	0.000	0.000	0.000	0.887	0.909	0.990	0.55
1953	0.000	0.000	0.356	0.328	0.345	0.550	0.707	0.000	0.037	0.567	0.833	0.52
1954	0.446	0.000	0.000	0.275	0.699	1.445	0.000	1.401	0.000	0.000	0.000	0.25
1955	0.000	0.000	0.218	0.397	0.075	0.000	2.759	0.000	0.000	0.000	0.000	0.00
1956	0.000	0.685	0.000	0.000	0.776	0.418	0.000	0.000	0.000	0.000	0.000	0.00
1957	0.000	0.000	0.000	0.167	0.584	0.019	0.052	0.000	0.521	1.423	0.766	0.00
1958	0.000	0.553	0.411	0.387	0.247	0.000	0.000	1.642	0.000	0.000	0.000	0.00
1959	0.478	0.840	0.424	0.000	0.000	1.356	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.652	0.863	0.000	0.291	0.795	0.000	1.606	0.913	1.345	1.092	1.061	0.00
1961	0.000	0.000	0.299	0.001	0.696	0.000	0.177	0.000	0.000	0.000	0.000	0.26
1962	0.689	0.868	0.000	0.287	0.762	2.399	0.000	0.992	0.405	0.715	0.647	0.39
1963	0.700	0.730	0.385	0.154	0.782	1.215	1.519	0.000	0.000	0.000	0.000	0.35
1964	0.695	0.869	0.425	0.445	0.000	0.222	0.624	0.000	0.000	0.266	0.697	0.50
1965	0.035	0.764	0.000	0.102	0.645	2.374	0.458	1.126	0.264	0.261	0.704	0.50
1966	0.477	0.024	0.387	0.436	0.783	0.000	0.000	0.518	0.000	0.000	0.000	0.29
1967	0.691	0.868	0.000	0.000	0.684	0.000	0.874	0.000	0.000	0.000	0.271	0.00
1968	0.000	0.000	0.000	0.324	0.000	2.261	0.000	0.074	1.505	0.962	1.004	0.55
1969	0.000	0.500	0.355	0.429	0.805	0.309	1.000	1.054	0.000	0.457	0.781	0.52
1970	0.711	0.000	0.000	0.310	0.797	0.000	0.563	0.000	0.000	0.000	0.265	0.44
1971	0.704	0.870	0.425	0.054	0.000	0.000	0.000	0.766	0.000	0.000	0.372	0.49
1972	0.705	0.405	0.404	0.440	0.804	0.000	3.100	1.784	1.555	1.209	1.112	0.57
1973	0.000	0.000	0.343	0.427	0.000	0.952	0.000	0.000	0.000	0.000	0.000	0.33
1974	0.700	0.869	0.000	0.000	0.000	0.000	0.000	0.735	1.332	0.000	0.000	0.00
1975	0.505	0.844	0.120	0.374	0.527	0.000	0.000	0.000	0.000	0.000	0.000	0.16
1976	0.000	0.000	0.215	0.000	0.000	1.209	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.000	0.330	0.000	0.000	0.000	0.000	0.000	0.000	0.561	0.734	0.51
1978	0.710	0.000	0.000	0.002	0.780	0.000	0.000	0.000	0.000	0.000	0.000	0.34
1979	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.786	0.799	0.000	0.00
1980	0.000	0.000	0.000	0.261	0.573	0.000	0.000	1.452	1.490	1.126	1.039	0.00
1981	0.000	0.004	0.000	0.210	0.443	0.000	0.000	1.745	0.511	0.957	0.000	0.1
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.247	0.363	0.000	0.00
1983	0.529	0.000	0.330	0.000	0.000	0.098	0.000	0.000	0.000	0.000	0.056	0.41
1984	0.591	0.829	0.423	0.445	0.804	1.690	2.709	0.000	0.000	0.000	0.000	0.14
1985	0.679	0.866	0.425	0.059	0.000	1.759	1.024	0.468	0.993	0.951	0.994	0.00
1986	0.216	0.000	0.099	0.369	0.000	0.000	0.000	0.809	1.201	1.034	1.035	0.50
1987	0.000	0.000	0.329	0.425	0.000	0.000	1.742	1.578	1.440	0.695	0.886	0.00

DROUGHT BEGAN MONTH	DROUGHT BEGAN YEAR	DROUGHT TERMINATED MONTH	DROUGHT TERMINATED YEAR	DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
1	1951	6	1952	18	1.02	18.36
9	1952	1	1955	29	0.47	13.64
12	1959	9	1961	22	0.55	12.31
11	1961	3	1967	65	0.47	30.29
2	1968	8	1973	67	0.60	40.52
1	1980	3	1982	27	0.61	16.54
11	1985	12	1987	50	0.84	42.17

TEMS - 2/2

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT UDAIPUR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.405	0.709	0.304	0.714	0.000	0.000	0.000	1.457	2.002	1.345	0.000	0.00
1952	0.441	0.000	0.291	0.711	0.000	0.000	0.000	0.000	0.913	1.040	0.830	0.81
1953	0.000	0.000	0.275	0.000	0.775	0.000	0.010	0.000	0.000	0.200	0.611	0.71
1954	0.364	0.000	0.000	0.000	0.245	0.000	0.000	1.210	0.000	0.000	0.101	0.46
1955	0.000	0.000	0.286	0.710	0.211	0.503	4.579	0.000	0.000	0.000	0.023	0.44
1956	0.539	0.000	0.000	0.495	0.724	0.000	0.000	0.265	0.000	0.000	0.000	0.00
1957	0.000	0.000	0.000	0.501	0.591	0.000	0.000	0.000	0.570	0.356	0.254	0.51
1958	0.000	0.378	0.350	0.721	0.883	0.722	0.000	0.000	0.000	0.000	0.000	0.25
1959	0.000	0.604	0.336	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.022	0.625	0.000	0.253	0.435	0.000	0.000	0.000	0.051	0.446	0.606	0.55
1961	0.000	0.000	0.302	0.714	0.000	1.001	0.000	0.950	0.000	0.000	0.000	0.00
1962	0.457	0.716	0.000	0.000	0.781	2.546	0.000	1.251	0.000	0.104	0.040	0.00
1963	0.480	0.725	0.000	0.000	0.770	0.355	0.339	0.000	0.000	0.000	0.000	0.00
1964	0.380	0.703	0.339	0.000	0.000	0.000	0.000	0.000	0.348	0.746	0.753	0.77
1965	0.000	0.000	0.000	0.000	0.000	2.995	0.000	0.000	0.101	0.456	0.676	0.74
1966	0.000	0.470	0.352	0.721	0.000	0.235	1.375	2.784	0.000	0.511	0.525	0.57
1967	0.552	0.740	0.000	0.000	0.477	0.000	0.000	1.193	0.000	0.000	0.037	0.00
1968	0.074	0.638	0.000	0.000	0.000	1.935	0.000	0.000	0.242	0.787	0.764	0.78
1969	0.595	0.869	0.369	0.782	0.922	2.575	0.191	0.000	0.000	0.789	0.175	0.55
1970	0.549	0.000	0.144	0.000	0.364	0.000	1.115	0.000	0.000	0.000	0.527	0.67
1971	0.560	0.742	0.340	0.595	0.000	0.000	0.000	0.272	0.282	0.000	0.000	0.07
1972	0.504	0.000	0.066	0.000	0.622	0.000	1.676	0.503	1.524	1.295	0.697	0.64
1973	0.611	0.667	0.338	0.722	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1974	0.443	0.717	0.339	0.000	0.000	1.19	1.317	0.858	1.397	0.000	0.000	0.23
1975	0.523	0.734	0.004	0.642	0.797	0.000	0.000	0.000	0.000	0.000	0.000	0.11
1976	0.000	0.000	0.286	0.710	0.569	1.445	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.000	0.184	0.430	0.000	0.000	0.000	0.000	0.000	0.511	0.640	0.71
1978	0.565	0.000	0.201	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1979	0.384	0.000	0.000	0.579	0.000	0.000	0.068	0.642	1.831	0.765	0.000	0.00
1980	0.000	0.571	0.335	0.722	0.693	0.000	0.000	0.000	0.404	0.505	0.749	0.00
1981	0.000	0.254	0.000	0.640	0.796	0.031	1.053	0.000	0.000	0.253	0.000	0.00
1982	0.000	0.051	0.321	0.000	0.000	0.622	0.000	4.441	2.591	1.750	1.016	0.27
1983	0.581	0.747	0.340	0.000	0.731	0.000	0.000	0.000	0.000	0.000	0.000	0.21
1984	0.517	0.735	0.339	0.725	0.898	0.969	0.000	0.000	0.000	0.558	0.599	0.75
1985	0.567	0.744	0.340	0.000	0.000	1.692	3.491	0.521	0.000	0.000	0.000	0.00
1986	0.224	0.000	0.015	0.000	0.000	0.000	0.000	0.575	1.958	1.050	1.855	0.61
1987	0.000	0.000	0.311	0.716	0.404	0.000	4.500	1.417	2.050	1.442	0.937	0.00

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	5	1952	17	0.89	15.19
11	1954	9	1955	11	1.04	11.42
9	1957	9	1958	13	0.32	4.20
5	1962	8	1963	16	0.46	7.45
3	1965	3	1967	25	0.70	17.49
9	1968	5	1971	33	0.59	19.00
5	1972	7	1973	15	0.74	11.14
11	1973	9	1975	23	0.47	10.82
1	1979	11	1979	11	0.69	7.58
6	1982	7	1983	14	1.55	21.68
8	1985	12	1987	51	1.23	37.99

DROUGHT ANALYSIS FOR DISTRICT As A WHOLE FOR DISTRICT NUMBER

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.537	0.751	0.000	0.000	0.000	0.000	1.662	0.000	0.961	1.048	0.000	0.00
1952	0.397	0.000	0.000	0.000	0.756	0.000	0.000	0.000	0.346	0.726	0.795	0.75
1953	0.000	0.340	0.000	0.000	0.000	1.561	0.056	0.000	0.000	1.141	0.655	0.76
1954	0.000	0.000	0.000	0.000	0.556	0.305	0.961	0.000	0.215	0.000	0.000	0.47
1955	0.000	0.000	0.000	0.000	0.191	0.000	0.000	5.039	0.000	0.000	0.000	0.00
1956	0.000	0.000	0.000	0.000	1.176	0.026	0.000	0.000	0.000	0.000	0.000	0.25
1957	0.000	0.000	0.000	0.000	0.155	0.365	0.000	0.675	0.000	0.310	0.523	0.00
1958	0.197	0.741	0.734	0.694	0.626	1.255	1.341	2.964	0.000	0.000	0.000	0.00
1959	0.265	0.229	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.814	0.790	0.734	0.694	0.000	0.000	0.000	0.469	0.815	0.972	0.436	0.00
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.717	0.000	0.000	0.257	0.00
1962	0.416	0.767	0.000	0.000	0.729	1.819	0.000	0.551	0.000	0.000	0.026	0.58
1963	0.649	0.575	0.000	0.342	1.050	1.078	2.625	0.878	0.000	1.251	0.000	0.58
1964	0.473	0.774	0.719	0.692	0.000	0.000	0.000	0.000	0.000	0.179	0.561	0.70
1965	0.000	0.197	0.000	0.000	0.175	1.672	0.000	0.000	0.475	0.000	0.371	0.70
1966	0.655	0.000	0.554	0.674	1.378	0.000	0.000	0.000	0.000	0.000	0.542	0.69
1967	0.657	0.795	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1968	0.000	0.000	0.643	0.684	0.000	2.150	0.000	1.530	1.527	1.224	0.910	0.77
1969	0.000	0.565	0.543	0.677	1.378	1.654	2.224	0.788	0.741	0.975	0.860	0.76
1970	0.000	0.000	0.245	0.640	0.360	0.000	0.000	0.000	0.000	0.000	0.570	0.661
1971	0.217	0.744	0.734	0.477	0.000	0.000	0.000	0.509	0.556	0.214	0.672	0.72
1972	0.559	0.000	0.642	0.000	0.159	0.963	2.137	0.000	0.771	0.943	0.649	0.76
1973	0.662	0.796	0.739	0.694	0.000	0.000	0.726	0.000	0.000	0.000	0.293	0.00
1974	0.455	0.769	0.737	0.694	0.000	0.001	0.000	1.523	0.849	0.000	0.156	0.56
1975	0.561	0.543	0.545	0.675	1.161	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1976	0.000	0.000	0.303	0.041	0.617	0.751	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.000	0.658	0.000	0.000	0.000	0.000	0.000	0.000	1.259	0.000	1.51
1978	0.644	0.000	0.000	0.000	1.191	0.000	0.000	0.000	0.305	0.157	0.000	0.01
1979	0.640	0.000	0.000	0.541	0.000	0.000	0.000	0.000	0.143	0.234	0.000	0.00
1980	0.544	0.465	0.000	0.513	0.000	0.000	0.000	1.510	0.647	0.988	0.653	0.00
1981	0.000	0.000	0.000	0.551	0.679	0.000	1.066	2.114	0.152	0.664	0.000	0.00
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.740	0.000	0.000	0.00
1983	0.566	0.784	0.736	0.000	0.388	0.000	0.000	0.000	0.000	0.000	0.000	0.55
1984	0.647	0.794	0.739	0.694	1.379	2.042	1.605	1.402	1.510	1.335	0.942	0.76
1985	0.665	0.796	0.739	0.000	0.000	1.755	0.000	0.978	1.260	1.204	0.910	0.00
1986	0.565	0.000	0.449	0.652	0.000	1.556	0.059	1.603	1.572	1.247	0.921	0.77
1987	0.000	0.097	0.144	0.629	0.000	0.000	1.627	2.105	1.727	1.449	0.969	0.00

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
7	1951	2	1952		0.53	6.04
4	1953	8	1953	5	1.16	5.80
11	1957	9	1958	11	1.34	14.74
12	1959	9	1961	22	0.30	6.67
4	1963	5	1964	14	1.08	15.07
9	1965	8	1966	12	0.45	5.43
2	1968	6	1971	29	1.05	30.05
7	1971	8	1973	26	0.62	15.57
7	1974	5	1975	12	0.65	7.95
5	1980	11	1981	16	0.95	15.40
11	1985	12	1987	50	1.14	57.18

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT DUNGARPUR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.465	0.383	0.104	0.145	0.000	0.000	0.126	1.119	1.640	1.303	0.000	0.04
1952	0.423	0.437	0.106	0.146	0.347	0.000	0.000	0.000	0.000	0.553	0.460	0.45
1953	0.000	0.000	0.000	0.097	0.345	0.000	0.292	0.000	0.192	0.486	0.452	0.45
1954	0.461	0.000	0.000	0.025	0.345	0.535	0.838	3.275	0.000	0.000	0.020	0.27
1955	0.457	0.449	0.107	0.146	0.347	0.000	2.491	1.134	0.000	0.000	0.000	0.24
1956	0.453	0.447	0.107	0.145	0.347	0.000	0.000	0.000	0.831	0.000	0.000	0.00
1957	0.000	0.000	0.077	0.140	0.000	0.000	1.215	1.172	1.393	0.053	0.213	0.34
1958	0.000	0.001	0.091	0.143	0.346	0.464	0.000	0.000	0.000	0.000	0.000	0.13
1959	0.456	0.442	0.107	0.000	0.000	0.567	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.000	0.000	0.036	0.133	0.346	0.000	0.000	0.000	0.592	0.615	0.502	0.45
1961	0.464	0.458	0.107	0.146	0.347	0.000	0.000	0.777	0.000	0.000	0.000	0.25
1962	0.451	0.447	0.107	0.146	0.347	2.449	0.000	0.000	0.000	0.000	0.281	0.37
1963	0.472	0.454	0.107	0.146	0.347	0.000	0.000	0.000	0.000	0.000	0.271	0.36
1964	0.471	0.453	0.107	0.146	0.000	0.53	0.026	1.004	0.464	0.764	0.494	0.44
1965	0.405	0.362	0.104	0.145	0.347	2.731	0.000	1.651	1.120	1.018	0.533	0.46
1966	0.486	0.459	0.107	0.146	0.347	0.392	0.449	5.863	0.761	0.894	0.514	0.45
1967	0.465	0.458	0.000	0.000	0.126	0.000	0.096	2.134	0.000	0.360	0.452	0.00
1968	0.000	0.000	0.000	0.021	0.343	2.343	0.000	0.000	0.522	0.629	0.483	0.44
1969	0.465	0.458	0.107	0.146	0.347	1.797	1.160	0.689	0.290	0.674	0.452	0.45
1970	0.461	0.457	0.107	0.146	0.347	0.000	0.000	0.000	0.000	0.000	0.331	0.31
1971	0.474	0.455	0.107	0.146	0.347	0.000	0.000	0.000	0.262	1.553	0.464	0.45
1972	0.462	0.000	0.000	0.064	0.344	0.000	0.335	0.000	0.789	0.907	0.516	0.45
1973	0.000	0.000	0.086	0.142	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.00
1974	0.381	0.425	0.105	0.146	0.000	0.827	1.036	1.028	1.266	0.000	0.000	0.25
1975	0.452	0.447	0.107	0.146	0.000	0.000	0.520	0.000	0.000	0.000	0.125	0.31
1976	0.000	0.000	0.037	0.132	0.346	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1977	0.000	0.142	0.095	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.054	0.23
1978	0.458	0.000	0.000	0.000	0.253	0.000	3.189	0.000	0.000	0.000	0.000	0.00
1979	0.086	0.000	0.000	0.070	0.178	0.907	0.241	0.000	0.613	0.916	0.000	0.00
1980	0.000	0.240	0.099	0.144	0.347	0.000	0.000	0.570	0.875	0.947	0.525	0.00
1981	0.000	0.000	0.055	0.136	0.000	0.504	0.267	0.000	0.000	0.216	0.000	0.00
1982	0.000	0.000	0.045	0.000	0.000	0.654	0.000	0.249	1.219	0.299	0.000	0.00
1983	0.000	0.171	0.097	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1984	0.387	0.425	0.106	0.146	0.347	0.000	0.000	0.000	0.000	0.026	0.381	0.45
1985	0.477	0.456	0.107	0.146	0.347	2.731	2.214	1.797	1.890	1.415	0.595	0.4
1986	0.489	0.460	0.107	0.146	0.347	0.422	0.000	0.000	1.357	0.259	0.417	0.41
1987	0.000	0.072	0.094	0.145	0.346	0.000	2.367	0.000	0.000	0.292	0.423	0.00

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
7	1951	7	1952	13	0.83	5.24
1	1954	9	1954	9	1.14	10.24
11	1954	9	1955	11	0.90	9.95
7	1957	7	1958	13	0.78	10.19
9	1960	9	1961	13	0.34	4.39
10	1965	7	1966	58	0.81	47.14
9	1966	5	1971	34	0.39	13.29
3	1971	8	1973	25	0.22	5.45
11	1973	5	1975	19	0.10	1.91
11	1977	11	1979	25	0.59	14.67
5	1982	11	1982	6	0.53	3.15
10	1984	12	1987	39	0.95	36.98

Duration and Number of Dry Spells During Monsoon
(4th June to 15th September)

Banswara (Banswara)

First day of monsoon	Date of beginning of dry spell	Duration of dry spell (2 wseeks =n day)	Total no. of dry spell in a year
1	2	3	4
14.6.81	4.6.81 24.8.81	20	2
10.6.82	4.6.82 23.6.82 26.8.82	16 17 16	3
29.6.83	4.6.83	25	1
9.6.84	NIL	NIL	-
27.6.85	4.6.85 26.8.85	23 21	2
16.6.86	1.7.86 17.8.86	15 30	2
13.6.87	4.7.87 2.9.87	33 14*	2
			12

Barmer (Barmer)

1	2	3	4
26.6.81	4.6.81	22	3
	26.7.81	17	
	29.8.81	18	
20.6.82	4.6.82	16	4
	21.6.82	31	
	26.7.82	19	
	20.8.82	27*	
1.7.83	4.6.83	27	3
	2.7.83	20	
	19.8.83	14	
16.6.84	17.6.84	15	3
	9.7.84	27	
	6.8.84	41*	
16.7.85	4.6.85	42	3
	20.7.85	14	
	6.8.85	41*	
4.7.86	4.6.86	30	3
	5.7.86	24	
	10.8.86	37*	
15.7.87	4.6.87	41	2
	16.7.87	62*	
			21

Ajmer (Ajmer)

1	2	3	4
12.6.81	27.6.81 19.8.81	16 28	2
1982	Date not available		-
1983	Date not available		-
1.7.84	4.6.84	27	1
14.7.85	4.6.85 20.8.85	39 27*	2
21.6.86	4.6.86 17.8.86	17 30*	2
12.6.87	16.6.87 21.7.87 29.8.87	31 17 19*	3
			12

Girwa (Udaipur)

1	2	3	4
25.6.81	4.6.81	21	1
22.6.82	4.6.82	18	1
28.6.83	4.6.83 28.8.83	16 18	2
13.6.84	14.6.84 20.8.84	18 17	2
26.6.85	4.6.85 27.6.85 18.8.85	22 16 29*	3
17.6.86	24.6.86 17.8.86	23 30*	2
13.6.87	16.7.87 1.9.87	22 15*	2
			12

Jodhpur (Jodhpur)

1	2	3	4
10.7.81	4.6.81	36	2
	17.8.81	30	
14.7.82	4.6.82	40	3
	26.7.82	20	
	25.8.82	22*	
11.6.83	14.6.83	21	1
5.6.84	8.6.84	27	2
	21.7.84	57*	
14.7.85	4.6.85	40	3
	17.7.85	17	
	6.8.85	41	
15.7.86	4.6.86	41	3
	30.7.86	17	
	17.8.86	38*	
12.6.87	13.6.87	31	4
	17.7.87	22	
	9.8.87	17	
	28.8.87	19*	
			18

Dungarpur (Dungarpur)

1	2	3	4
25.6.81	4.6.81	21	2
	31.8.81	14	
22.6.82	4.6.82	19	2
	24.6.82	18	
22.6.83	4.6.83	23	2
	17.8.83	20	
8.6.84	15.6.84	17	3
	23.7.84	14	
	21.8.84	16	
16.6.85	4.6.85	42	2
	16.8.85	31*	
17.6.86	17.8.86	30	1
13.6.87	25.6.87	17	3
	14.7.87	23	
	31.8.87	16*	
			15

* - indicate the continuation of dry spell after 15th September

Appendix - III-4(b)

Probability Analysis of Dry Spells

Taluk/Station (Distt.)	Class Interval (in day)	No. of Spells	Percentage	Cummulative Probability
1	2	3	4	5
Barmer	14-21	8	38.1	100.0
(Barmer)	22-28	5	23.8	61.9
	29-35	3	14.3	38.1
	> 35	5	23.8	23.8
		21		
Banwara	14-21	8	66.6	100.0
(Banswara)	22-28	2	16.6	33.2
	29-35	2	16.6	16.6
	>35	-	-	-
		12		
Ajmer	14-21	4	40.0	100.0
(Ajmer)	22-28	3	30.0	60.0
	29-35	2	20.0	30.0
	>35	1	10.0	10.0
		10		
Girwa	14-21	8	61.5	100.0
(Udaipur)	22-28	3	23.1	38.5
	29-35	2	15.4	15.4
	>35	-	-	-
		13		

Contd...

Jodhpur (Jodhpur)	14-21	6	33.7	100.0
	22-28	3	16.6	66.6
	29-35	3	16.6	50.0
	>35	6	33.3	33.3
		18		
Dungarpur (Dungarpur)	14-21	10	66.6	100.0
	22-28	2	13.3	34.3
	29-35	2	13.3	21.0
	>35	1	7.7	7.7
		15		

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT-BARMER

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	40D-2B	BARMER	25 44 10	71 23 50	215.410	2027.04	0.0714
2.	40D-4D1	GUDA	25 11 45	71 43 15	47.765	2179.77	0.0768
3.	40N-3B1	BISUKALAN	26 10 30	71 18 20	243.390	2558.28	0.0901
4.	40D-3A1	CHOHTAN	25 25 30	71 04 00	108.350	3494.21	0.1231
5.	40D-2A1	KALURI	25 42 43	72 03 30	101.900	6395.72	0.2253
6.	40D-2B2	NIMRI	25 29 00	71 17 00	187.560	2950.19	0.1030
7.	40P-1A1	SIHANIYA	24 55 55	71 09 30	49.680	1562.72	0.0551
8.	40J-4A1	SUNDRA	26 05 45	70 13 10	115.540	3211.85	0.1131
9.	40N-3B5	SARAN KA TALA	26 18 30	71 30 45	231.740	2112.84	0.0744
10.	40N-3C2	UNDU	26 20 30	71 44 55	230.040	1393.76	0.0667

STATE-RAJASTHAN
DISTT-BANSWARA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	40I-3A1	ARTHUNA	23 29 45	74 06 00	153.730	736.05	0.1461
2	40I-2B1	BANSWARA	23 32 00	74 27 00	213.100	923.80	0.1834
3.	40I-2C2	BHUNGARA	23 41 00	74 31 00	240.625	747.59	0.1484
4.	40I-1B1	DUNGARIA	23 51 50	74 27 30	194.010	410.01	0.0814
5.	40I-1B2	GANORA	23 48 00	74 15 10	177.720	577.15	0.1146
6.	40I-2C1	HERIA BERI	23 31 00	74 39 00	357.275	363.03	0.0720
7.	40I-4B1	KUSHALGARH	23 12 00	74 27 00	292.725	1259.37	0.2500

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT-UDAIPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	45K-2A1	BHIM	25 44 00	74 00 00	524.42	669	0.0503
2.	45G-3D2	AMET	25 19 00	73 56 00		2220	0.1285
3.	45K-4A1	RAILMAGRA	25 02 00	74 07 00		966	0.0559
4.	45H-1D2	MAVLI	24 47 00	73 59 00	497.38	2124	0.1229
5.	45H-2C1	BHUWANA	24 37 00	73 43 00	482.68	5020	0.2905
6.	45H-4D2	SARADA	24 09 00	73 50 00		3572	0.2067
7.	45H-4C1	RIKHABDEV	24 05 00	73 41 00	356.85	2502	0.1452

STATE-RAJASTHAN
DISTT-AJMER

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	45J-2D1	KISHAN GARH	26 37 00	74 57 00	455.65	1837	0.2107
2.	45J-3D2	PUSHKAR	26 30 00	74 34 00	463.66	1307	0.1542
3.	45J-4C1	BANDANWARA	26 09 00	74 42 00	416.12	2261	0.2667
4.	45J-4B1	BEAWAR	26 06 00	74 20 00	447.93	1415	0.1666
5.	45C-4A1	KEKRI	25 50 00	75 10 00	356.00	1660	0.1958

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT- JODHPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	EL.OF W.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1	45B-3D6	NARWA	26 24 05	72 5o 45	25o.o05		0.2634
2	456-2D1	OSIAN	26 43 3O	72 55 00	32-.5O		0.2055
3	45A-451	PHALODI	27 07 4O	72 22 O7	23o.7O		0.2948
4	45F-3D2	RAMSIGAON	26 22 OO	73 45 1O	3oo.O3		0.1113
5	456-3B2	SHERGARH	2O 1> 45	72 16 OO	22o.29		0.1250