CS-42

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

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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 no. of definitions of drought pertaining to various uses have beer. 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 M ha) 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 & Rajasthan. The present report covers the study of six districts of state Maharashtra. These districts are Ahmednagar, Sholapur, Pune, Satara, Sangli and Aurangabad. The scientific teams of the institute undertook visits to the state of Maharashtra and contacted the relevant state/central govt. agencies for collecting the required data. The study includes various kinds of analysis of rainfall, ground water level data for assessing drought impacts.

Based on the analysis, inferences, highlighting 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

Drought is a frequent hazard in India, striking in some part or the other. In recent years droughts were experienced in succession in years, 1985-86, 1986-87 and 1987-88 in different parts of the country causing local as well as regional imbalances. Drought occurrence results in reduced stream flows, reservoir levels, ground water levels and soil moisture levels. The problem posed by droughts vary from area to area depending upon the amount of precipitation and its variability and on the demand of water for the specified user.

The present report describes the results of studies carried out for the year 1987-88 in six selected districts of Maharashtra namely; Ahmednagar, Sholapur, Pune, Satara, Sangli, Aurangabad. The report includes analysis of rainfall, streamflow and groundwater data. The rainfall and groundwater data have been used for finding deficit of rainfall and trend of ground water table as a result of drought incidents. The Seasonal rainfall departure was observed of the order of 15-60 percent in the districts of Ahmednagar, Satara, Pune and Sangli in the year 1987-88. Some districts like Pune and Satara recorded continuous seasonal rainfall deficiency in last 15-16 years. In case of monthly rainfall analysis, deficiency figures indicate that in most of the months monthly rainfall deficiency ranges from 10% to 70%. The deficiency pattern was observed similar in the districts of Pune & Ahmednagar. However, in case of Sangli, Aurangabad and Sholapur districts excess monthly rainfall has also been recorded in few months of the year 1987-88. The frequency analysis shows that the probability of occurrence of 75% normal rainfall in all

the six districts are above 80 except Pune and Sholapur indicating that the districts selected for analysis are not drought prone based on this analysis as per IMD criteria. Herbst Analysis shows that Pune, Sholapur, Sangli & Aurangabad experienced drought during years 1984-87. The districts of Satara and Ahmednagar, however, did not record any drought spells during 1984-87 though drought spells were found in these districts from late 70's to early 80's. The maximum intensity of drought was recorded in the case of Satara district and the no. of drought spells varied from 4-11 in these districts during the period 1951-87. The district of Sangli experienced the largest spell of drought during 1983-84. The longest period of drought spell over the entire period was found in case of Ahmadnagar district during late 70's and early 80's. At 75% probability the duration of dry spell ranges from 21-28 days for all the six selected taluks situated in each of the six selected districts of the state.

An attempt has also been made to see the effects of scarce rainfall on groundwater regime by carrying out statistical analysis of groundwater level data. In all the six districts selected for the analysis, the seasonal rainfall picture for 1987-88 showed deficiency in the range of 9% to 60% except in case of Sholapur. The rate of decline in water table was found increasing in Pune & Sholapur. However, Ahmadnagar experienced relatively less declining rate as compared to previous years.

During 1987 the storages in the four selected reservoirs namely Jayakwadi, Khadakwasla, Koyana & Bhima were deficient as compared to previous 2-3 years with the exception of Jayakwadi.

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 characterisation 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 meteorological 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 hydrologic 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 has initiated studies to lay emphasis on Hydrological Aspects of Droughts starting year 1985 as these aspects were by and large neglected in past studies whatever carried out. Keeping in view the successive three drought years since 1985-86, in major parts of the drought prone area 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 chosen states have been completed and the study reports have been widely circulated.

Since the studies for the year 1987-88 covered six districts each in six states, it was decided to bring out separate reports for each of the six states. The present report, therefore, describes results of studies carried out for the year 1987-88 with six districts chosen in the state of Maharashtra. The report includes analysis of rainfall & groundwater level data for finding the impacts of deficit of rainfall and trend of groundwater tables. The status of storages in four selected reservoirs i.e. (i) Jayakwadi, (i) Khadakwasla, (iii) Koyana and (iv) Bhima in the state has been compared with previous years.The stream flow analysis for the sites of Krishna and Godavari basin, lying in the state of Maharashtra has been done basin-wise and has been presented in the report Hydrological Aspects of Drought 1987-88 - A case Study (CS-37).

The report is an attempt towards developing a comprehensive drought index for characterising hydrologic drought situations. List of offices and places from where data and information have been collected in the state of Maharashtra are shown 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 as shown in Fig. 2.1 (CWC, 1982). This report covers the study of six selected drought prone districts of state Maharashtra namely: Ahmadnagar, Sholapur, Pune, Satara, Aurangabad and Sangli. The locations of the districts are shown on the state map in Fig. 2.2.

Maharashtra is the third biggest state in the country both in respect of area and population. The state is situated entirely within the tropics, but because of the altitude the major portion of the state does not have a tropical climate associated with low annual variation in temperature and humidity. A large part of the state suffers, every now and then from crop failures, partial or even complete due to the vagaries of monsoon. The rainfall is the principal factor affecting yields of unirrigated crops and in this respect the major portion of Maharashtra is at a considerable disadvantage, since the irrigation facility in the state are very limited. Again unlike the deep alluvial soils of North India and parts of Gujarat, the soils in Maharashtra have a substratum of homogeneous rock of great depth. This makes the striking of dependable source of underground water very much matter of chance, apart from increased costs. Out of total cropped area of 200 lakh hectares the irrigated area which was 15.17 lack hectares (8.38%) in 1971-72 has increased to only 26 lakh hectares (13%) by 1983-84 of which 10.0 lakh hectares and 16.0 lakh hectares are under surface and groundwater irrigation respectively. The rest of the cropped area continues to be subject to the vagaries of nature.

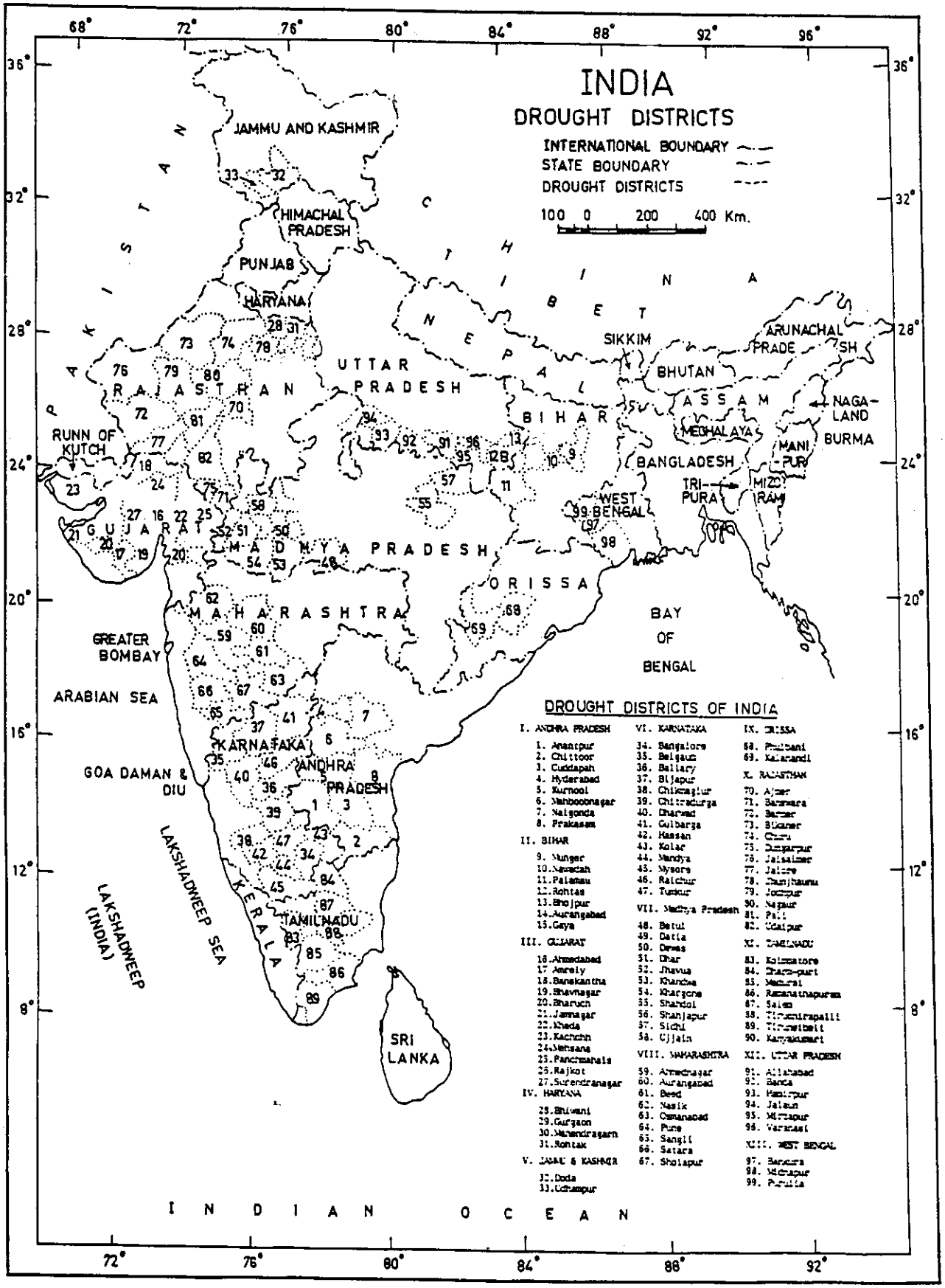


FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

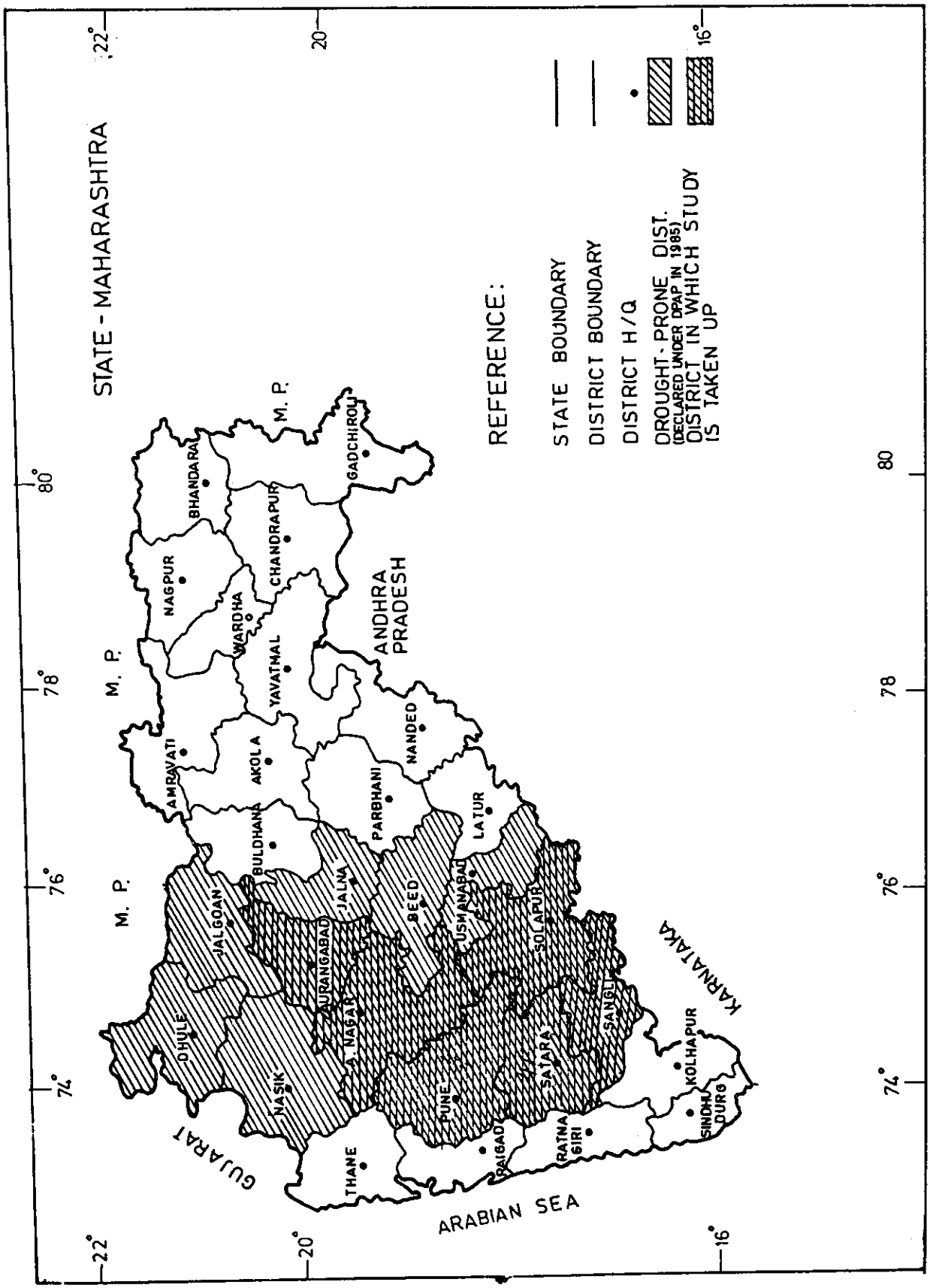


FIG. 2.2 : DROUGHT PRONE DISTTS. IN MAHARASHTRA

2.2 Area and Population

Maharashtra, the third largest State in India, with a total geographical area of 307.7 lakh hectares, covering 27 districts, forms about one tenth of the area of the country and occupies a major portion of the Peninsular India. It is located between 16°04/ to 22°01/N latitudes and 72°06/ to 80°10/E longitudes. The population of the State is over 5 crores and nearly 37% of the population is affected by droughts.

Administratively and meteorologically the state has been divided into four regions. The four regions and the districts they comprise are given below:

1. Konkan - Greater Bombay, Kolaba, Ratnagiri and Thane
2. Madhya Maharashtra - Dule, Jalgaon, Ahmednagar, Nasik, Pune, Kolhapur, Sangli, Satara, Sholapur
3. Marathwada - Aurangabad, Jalna, Bir, Nanded, Osmanabad and Pasbhani
4. Vidarbha - Akola, Amaravati, Bhandara, Buldana, Chandrapur, Nagpur, Wardha and Yevatmal.

2.3 Physiography

The Chief element in the lithological complex of the region of basaltic plateau which has been configurated by diastrophic movement that past and later on by sub-aerial processes resulting in several microforms in the present terrain.

Physiographically, the state could be divided as

i. The coastal belt of Konkan which is about 25 hectares above sea level.

ii. the undulating Deccan Plateau to the east of Satyadri range with altitude ranging from 150 to 600 meters and

iii. the Tapi trough running through the districts of Dhule, Jalgaon, Buldana and Akola flanked by Satpura and Satmala ranges on the north and south respectively.

2.4 landuse and Vegetal Cover

The land utilization pattern of state Maharashtra reveals about 60% under cultivation including about 8% under irrigation, 18% under forest and remaining 22% under miscellaneous land use. The land use pattern as per 1984 in the state is given in Table 2.1 and fig. 2.3.

Table 2.1 : Landuse Details of State Maharashtra

Present Land use	% coverage of the total area
Forest	17.4
Barren and uncultivated land	5.6
Land put to non-agricultural use	3.4
Cultivable waste	3.3
Permanent pasture and grazing land	5.1
Land under tree crops	0.61
Current fallows	2.8
Other fallows	2.7
Net sown area	59.1

Source : Epitome of Agriculture, Maharashtra 1987.

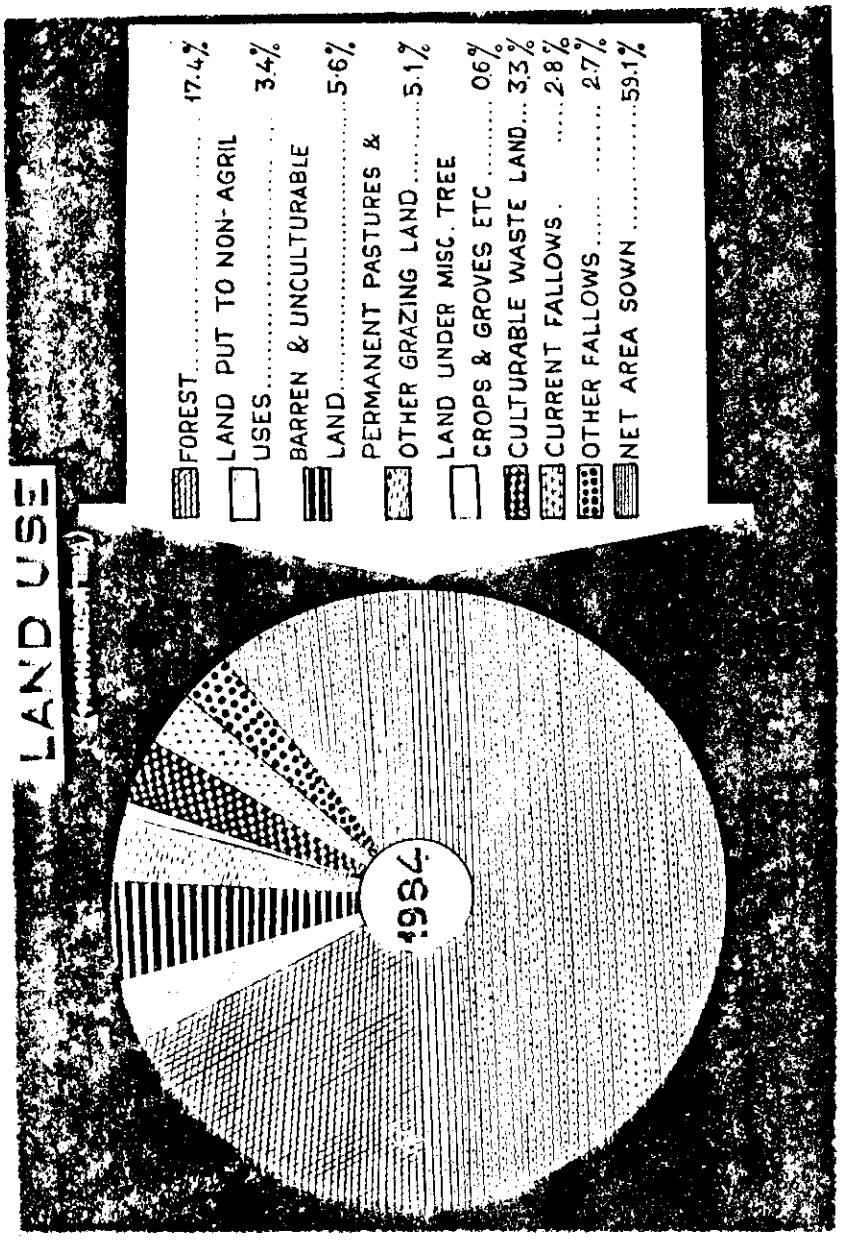
2.5 Soils

The soils of the state Maharashtra can be classified in 9 categories:

i. Coarse shallow soils (High level)

ii. Medium Black Soils (Plains)

iii. Deep Black Soils (Valleys)



Source : Epitome of Agriculture in Maharashtra, 1987-88

Fig. 2.3 : Landuse Details of State Maharashtra

iv. Redish Brown Soils of Hill Slopes (Trap)

v. Coastal Alluvium

vi Yellowish Brown Soils (High level)

vii. Yellowish Brown Soils of Plains

viii. Laterite and Lateritic Soils

ix. Coastal Saline

The soils over major part of the state to the East of the Western ghats and to the West of the Eastern Vidarbha is of the medium black variety interspersed by long patches of deep black soil. East of the coastal alluvium, the soil is laterite and redish brown laterite and brown. While Bhandara district in the state is having shallow black soils.

2.6 Surface Water Availability

The position of storages in the state of Maharashtra for already completed, under completion and proposed projects are given in Table 2.2 (CWC, 1988).

Table 2.2 : Storages in the Projects of the State Maharashtra

Sl. No.	Type of Projects	Gross Storage in M.ha.m.	Live Storage in M.ha.m.
1.	Project completed	2.2202	1.7343
2.	Projects under completion	1.6608	1.3805
3.	Total	3.881	3.1148
4.	Proposed Projects	1.671	1.511

Source : CWC report on Water Resources of India, 1988.

2.7 Groundwater Availability

The Groundwater Survey and Development Agency (GSDA) carried out assessment of groundwater potentiality on systematic basis in respect of small groups of elementary watershed, each watershed having an area of about 200 to 300 sq kms. As per the fourth assessment carried out in the year 1985, 31,03,874 hectare-metre of groundwater is annually replenishable against the total annual draft of 6,84,749 hectare-metre through the existing 10.57 lakh irrigation wells. The balance of 24,19,125 hectare-metre is left over for further development through additional 16.2 lakh new dug wells. The table 2.3 gives districtwise details of total groundwater recharge, withdrawal, balance and number of existing and additional feasible wells. Table 2.4 gives districtwise static water levels in observation wells in 1983, 1984, 1985 and 1986 (GSDA, Maharashtra).

2.8 Water Use

The annual requirement of water in the state for domestic & live stock purposes during 1981 was of the order of 0.1656 M.ha.m. which has been estimated to increase to a level of 0.2537 M.ha.m. by the year 1991 (CWC, 1988). Net area irrigated by different sources and gross area irrigated in Maharashtra state from 1978-79 to 1985-86 are shown in table 2.5. (Epitome of Agriculture, Maharashtra, 1987-88). Irrigated area under principal crops in Maharashtra State from 1979-80 to 1985-86 are given in table 2.6. The water availability and water requirement figures for drought prone districts of the state are given in table 2.7.

Table 2.3 : Districtwise Groundwater Assessment of state Maharashtra (1985)

Sl. No.	District	Annual Ground-water Net recharge Hect.M.	Net Ground-water with-drawal Hect.M.	Balance of Ground-water Hect.M.	Total No. of Exis-ting wells	Additional No. of feasible Wells
1	2	3	4	5	6	7
1.	Pune	135565.00	46507.00	89105.00	78781	60206
2.	Solapur	108659.04	48404.39	60477.11	82985	40883
3.	Satara	104267.96	32824.17	71443.79	53078	48273
4.	Sangli	80840.00	36484.00	44356.00	51494	29970
5.	Kolhapur	99957.00	27464.00	72691.00	31235	49055
6.	Thane	39066.00	3372.00	35694.00	7861	24118
7.	Raigad	52857.00	3578.00	50279.00	11568	33972
8.	Ratnagiri	42742.50	2345.00	40397.50	27725	13363
9.	Sindhudurg	27746.00	2686.00	25060.00	23048	16932
10.	Aurangabad	95646.00	33610.00	62035.00	46453	41916
11.	Jalna	126025.00	23636.00	102288.00	35007	69113
12.	Parbhani	146715.00	24162.00	122553.00	33105	82806
13.	Bhir	85131.00	17955.00	67176.00	31795	45389
14.	Nanded	117454.00	17030.00	100424.00	19686	67854
15.	Osmanabad	82715.00	23387.00	59328.00	33766	40086
16.	Latur	73880.00	15196.00	58684.00	19323	39651
17.	Nasik	128727.00	51633.00	77471.00	60321	52345
18.	Ahmednagar	213812.00	76093.00	138383.00	126599	93502
19.	Dhule	126761.00	37033.00	88928.00	47186	60086
20.	Jalgaon	111270.00	50033.00	58603.00	48552	39596
21.	Nagpur	135859.00	24158.00	112233.00	35129	75833
22.	Bhandara	123907.00	6888.00	117319.00	7631	79270
23.	Chandrapur	150312.00	3115.00	147198.00	5309	99458
24.	Gadchiroli	221272.00	1660.00	219612.00	3600	148386
25.	Wardha	60241.00	14959.00	45282.00	20461	30595
26.	Amravati	118493.00	25575.00	92139.00	30077	62256
27.	Akola	112041.00	12772.00	99269.00	23749	67074
28.	Buldhana	64908.00	13041.00	51867.00	47216	35045
29.	Yavatmal	117005.00	10149.00	106856.00	14842	72200
Total		3103874.50	684749.56	2417060.90	1057382	1619213

Table 2.4 : STATEMENT SHOWING DISTRICTWISE DETAILS OF STATIC WATER LEVELS OF OBSERVATION WELLS 1983-86 IN MAHARASHTRA

Sl. No.	District	No.of observations wells fixed	Details of Water Levels in Open Wells (in meters) 1983		1984		1985		1986	
			Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1	2	3	10	11	12	13	14	15	16	17
1.	Pune	69	7.57	4.12	6.84	4.80	7.00	5.17	7.50	5.31
2.	Solapur	67	8.26	5.73	7.84	5.29	8.01	6.04	9.05	6.33
3.	Satara	72	8.44	6.07	8.54	5.67	7.92	6.35	8.81	6.88
4.	Sangli	77	8.85	5.74	8.72	5.76	9.01	5.83	8.53	6.17
5.	Kolhapur	38	8.47	4.67	8.05	4.33	7.28	4.85	9.78	5.15
6.	Thane	36	5.27	3.30	4.47	3.17	4.09	3.51	-	3.70
7.	Raigad	37	4.86	2.31	5.04	2.99	4.62	2.88	4.73	2.95
8.	Ratnagiri	26	9.02	9.27	8.73	5.97	8.73	4.09	9.28	6.37
9.	Sindhudurg	37	6.85	4.14	6.20	4.33	6.14	4.37	5.77	6.15
10.	Aurangabad	52	10.16	5.18	8.97	8.97	10.96	7.22	9.58	7.83
11.	Jalna	42	9.31	3.59	8.62	6.33	9.47	7.19	10.73	8.20
12.	Parbhani	52	10.09	4.41	7.92	5.74	8.47	6.03	8.70	6.63
13.	Bhir	47	8.39	4.06	7.43	4.80	8.37	5.84	9.50	7.19
14.	Nanded	47	7.19	3.36	6.64	4.67	7.00	4.71	5.77	5.33
15.	Osmanabad	41	10.89	3.38	8.82	5.45	10.92	7.01	13.01	-
16.	Latur	43	12.79	4.10	10.27	6.10	11.17	6.65	12.09	10.24
17.	Nasik	138	7.67	4.65	7.16	4.61	6.71	4.94	6.26	5.70
18.	Ahmednagar	76	9.52	5.11	8.20	6.04	8.85	7.71	10.90	9.29
19.	Dhule	62	8.01	4.89	7.22	5.68	7.70	6.14	8.45	-
20.	Jalgaon	63	9.80	6.92	8.40	7.59	9.95	8.18	11.29	7.06
21.	Nagpur	59	9.02	4.05	7.84	4.80	7.74	4.83	7.65	6.67
22.	Bhamdara	64	9.37	3.46	8.33	5.13	9.61	4.40	9.67	4.45
23.	Chandrapur	61	8.17	3.60	8.05	5.00	9.03	3.84	8.47	4.57
24.	Gadchiroli	47	8.16	3.96	7.87	5.33	8.42	4.77	8.63	4.84
25.	Wardha	40	8.53	4.20	6.96	5.60	7.99	5.70	7.88	6.10
26.	Amravati	94	7.60	4.60	6.87	5.07	-	5.68	8.94	6.71
27.	Akola	96	9.16	5.43	8.01	6.74	9.29	5.73	8.39	3.93
28.	Buldhana	55	9.49	4.57	7.82	7.25	9.00	6.81	9.07	6.83
29.	Yavatmal	78	7.38	3.56	6.23	5.99	6.64	4.58	6.57	4.44

Note : The Pre Monsoon/Post Monsoon water levels shown are the averages of all the observation wells fixed in the District.

Table 2.6 : Irrigated Area under Principal Crops in Maharashtra State from 1979-80 to 1985-86

(Area in '00' hectares)

Irrigated Area							
	Years						
Crops	79-80	80-81	81-82	82-83	83-84	84-85	85-86
Rice	3,974	4,123	4,085	3,891	3,715	3,793	3,967
Wheat	5,710	5,788	6,122	5,384	6,502	5,485	4,842
Kharif Jowar	836	384	387	251	330	311	258
Rabi Jowar	4,120	3,366	3,498	3,424	3,531	3,750	3,593
Bajri	526	523	571	424	495	490	469
Maize ther Cereals	311	546	607	426	450	370	397
	21						
Total cereals	15,498	14,710	15,270	13,800	15,023	14,199	13,526
Tur	28	50	-	-	-	-	-
Gram	745	850	1,042	967	1,131	1,186	1,235
Other Pulses	89	-	-	-	50	-	38
Total Pulses	862	900	1,042	967	1,181	1,186	1,273
Total Foodgrains	16,360	15,610	16,312	14,767	16,204	15,385	14,799
Sugarcane	2,949	3,168	3,663	3,896	3,593	3,544	3,191
Cotton	1,040	1,523	1,411	1,187	1,038	1,003	1,094
Groundnut (kh.)	167	267	312	277	272	249	181
Turmeric	66						
Potato	112						
Chillies	629	4,592	5,162	5,183	6,226	4,999	5,354
Tobacco	17						
Other Crops	2,975						
Total Irrigated Area	24,315	25,160	26,810	25,310	27,333	25,180	24,619

Note : Figures for the years 1980-81 to 1985-86 are provisional.

Table 2.7 : Water Availability and Water Requirement for Drought Prone Districts of State Maharashtra

Sl. No.	District	Water Availability 50% Dependability	75% dependability	Total requirements
1.	Ahmednagar	3.47	3.03	3.81
2.	Aurangabad	3.99	3.39	1.75
3.	Bir	2.45	1.91	1.34
4.	Nasik	5.63	4.72	2.05
5.	Osmanabad	3.71	2.99	1.31
6.	Pune	4.97	4.33	2.95
7.	Sangli	1.86	1.66	2.49
8.	Satara	4.71	4.44	1.85
9.	Sholapur	3.05	2.59	3.66

Source : Central Water Commission, 1988

2.9 Crops and Fodder

Based on the rainfall, type of soil, topography and cropping pattern, the state of Maharashtra is divided into nine agro-climatic zones.

1. Very high rainfall zone with lateritic soils
2. Very high rainfall zone with non-lateritic soils
3. Ghat zone
4. Transition zone I with soils formed from basalt
5. Transition zone II with soils formed from basalt
6. Scarcity zone with soils formed from basalt
7. Assured rainfall zone with soils formed from basalt
8. Moderate rainfall zone with soils formed from basalt
9. High rainfall with soils formed from mixed parent materials.

Fig. 2.4 shows the agroclimatic zones of state Maharashtra. (Agriculture Bulletin No.574 Deptt. of Agriculture , Maharashtra), which are mostly drought prone, of the state where rainfall is small and its variability is high, agriculture is dependent to a large extent on the rainfall only and the yields are always uncertain. Dry farming is practiced in these areas by growing less water consuming crops like Jowar and Bajra. The dry farming area in the state accounts for nearly 70% of the geographical area of the state. Table 2.8 gives the details of cropwise area, production & yield of principal crops in Maharashtra state during the year 1985-96.

2.10 Districts Chosen for Study

The following section include description of individual districts taken up for study in the state.

2.10.1 Sholapur

Sholapur is one of the drought affected districts of Maharashtra state. The geographical location of the district is between 17^{o}-10/ to 18^{o}-32/ North latitude and 74^{o}-4 2/ to 76^{o}-15/ East longitude. The geographical area of the district is 15.021 sq.km. The district consists of eleven talukas all of which are generally vulnerable to drought. This district has 948 inhabited villages, 5 uninhabited villages and 10 towns. The population of the district is 2,607,172 & density of population is 174 person per sq.km. as per the census figure of 1981.

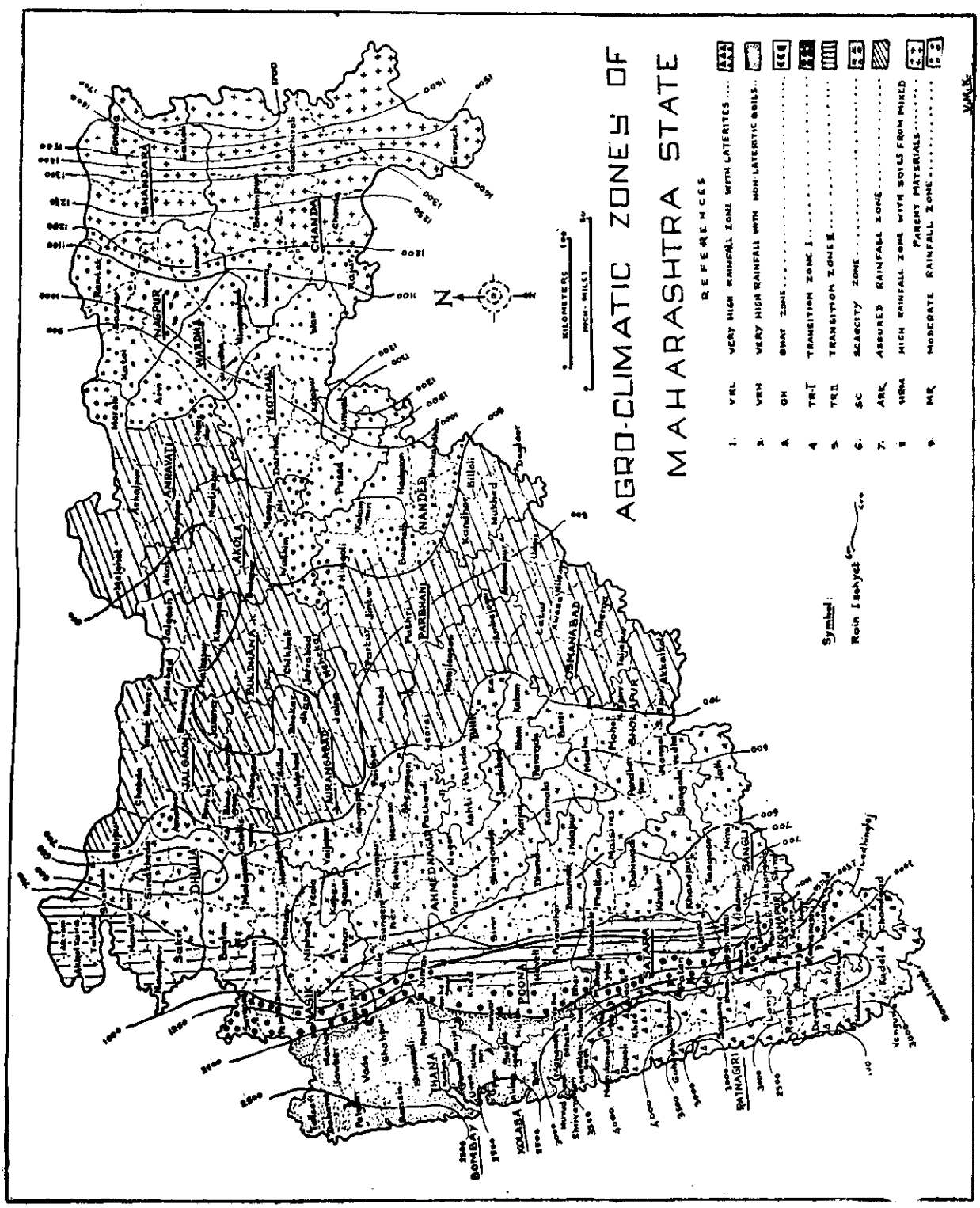
The soil in the district are generally classified into three groups viz. light soils, medium black soils and black cotton soils. The land use description in the district as per data from 1970-71 to 1977-78 is forests in 32,800 ha., land put to non-agricultural uses 3,300 ha., barren & unculturable land

Table 2.8 : Statement Showing State Level Estimates of Area, Production and Average Yield Principal Crops in Maharashtra State During the year 1985-86

Area in lakh ha.
Production in lakh tonnes.
Average yield in kg./ha.

Crop.	1985-86		
	Area	Production	Av.Yield
Rice	15.15	21.32	1407
Kharif Jowar	28.80	26.52	921
Bajri	17.03	4.20	246
Ragi	2.22	2.61	1178
Other Kharif cereals	2.21	1.48	670
Total kharif cereals	65.41	56.13	858
Tur	7.57	4.51	597
Other kharif pulses	13.83	4.86	351
Total kharif pulses	21.40	9.37	438
Total Kharif foodgrains	86.81	65.50	755
Rabi jowar	37.45	12.71	339
Wheat	8.82	6.44	731
Other rabi cereals	0.38	0.37	995
Summer rice	0.25	0.50	1988
Total rabi cereals	46.90	20.02	427
Gram	5.34	1.76	329
Other rabi pulses	1.86	0.51	277
Total rabi pulses	7.20	2.27	315
Total rabi foodgrains	54.10	22.29	412
TOTAL FOODGRAINS	140.91	87.79	623
Total cereals	112.31	76.15	678
Total pulses	28.60	11.64	407

Cotton	27.53	19.90(bales)	123(lint)
Sugarcane	2.65(H) 3.19(T)	237.06 (cane)	89.3 (tonnes/ha.)
Groundnut	6.26	4.22	673
Sesamum	1.30	0.31	239
Sunflower	2.00	0.78	392
Nigerseed	0.96	0.21	212
Soyabean	0.56	0.18	318
Castorseed	0.04	0.02	357
Total kharif oilseeds	11.12	5.72	514
Safflower	6.19	2.49	402
Linseed	2.47	0.54	218
Sunflower	1.25	0.57	458
Sesamum	0.97	0.19	193
Rape & mustard seed	0.05	0.02	292
Summer groundnut	0.37	0.47	1272
Total rabi oilseeds	11.30	4.28	379
TOTAL OILSEEDS	22.42	10.00	446



Source : Agriculture Bulletin No.574, Deptt. of Agriculture, Maharashtra State,

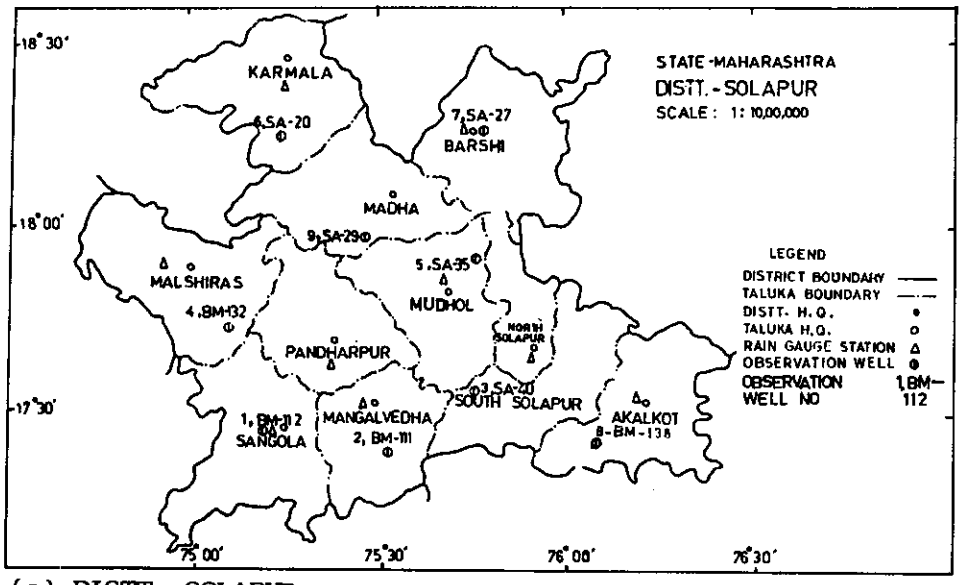
Fig. 2.4 : Agroclimatic Zones of State Maharashtra

68,900 ha., culturable area 1,334,100 ha. and culturable waste 43,100 ha. As per the data available from 1971-72 to 1977-78 the total irrigated area is 146,980 ha. in the district which has sourcewise distribution of 31,485 ha. by surface water and 115,495 ha. by ground water.

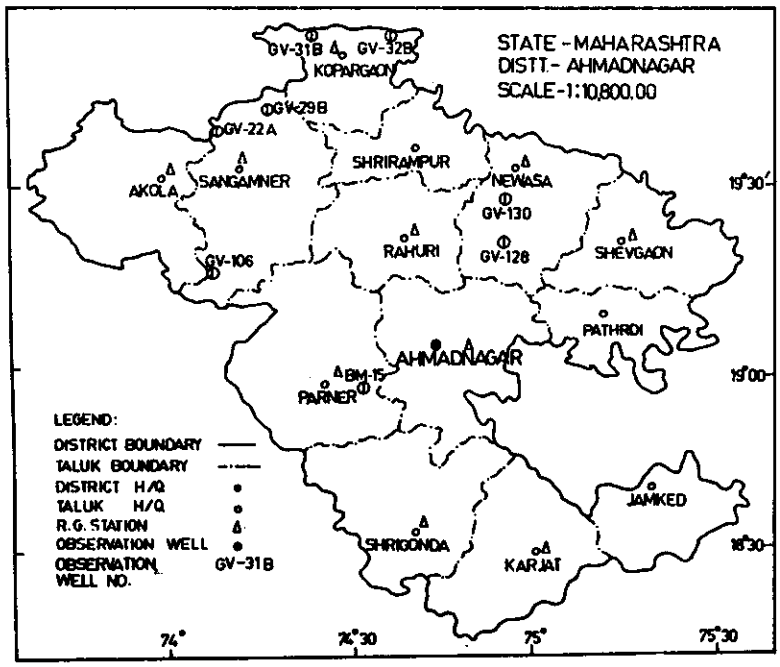
The Bhima is the main river flowing through the Solapur district. The catchment area of Bhima river within the district is 15,021,0 sq.km. As per CWC studies of 1982 the normal annual rainfall of the district is 616.70 mm. and normally there are 37.4 rainy days in a year according to analysis of data from 1901 to 1978. There are 54 raingauge stations located in the district and the density of raingauge station is 287.8 sq.km. per raingauge station.The maximum annual rainfall in the district was experienced as 1100.2 mm in year 1916. The south west monsoon gives about 74.0% of annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as 24.7% for the district. The Ground Water potential of the district as per CGWB data the annual recharge to groundwater is of the order of 561 m.cum., while the draft is 797 m.cum. resulting in over exploitation of the order of (-) 236 m.cum. in one year. As per CWC (1982) observations, the district faced 12 hydrological drought years during the period 1946 to 1978. The map of district showing location of raingauges and groundwater observation wells which have been chosen for analysis is shown in figure 2.5.

2.10.2 Ahmadnagar

Ahmadnagar is the second largest district of the Maharashtra State and is among the drought prone districts. The district is situated in the heart of Maharashtra state between $18^{o}-22'$ to $20^{o}-00'$ north latitudes and $72^{o}-32'$ to $75^{o}-30'$ east longitude. The geographical area of the district is 17,035 sq.km.



(a) DISTT. SOLAPUR



(b) DISTT. AHMADNAGAR

FIG. 2.5 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

as per the 1971 census. The district consists of 13 talukas and has 1,312 inhabited villages, 5 uninhabited villages and 6 towns. The population of Ahmadnagar district is 2,711,216 and the density of Population is 159 persons per sq.km. according to data available in 1981.

The soils in the district are mostly three types namely: black soils, red and laterite soils. The details of land use in the district as per data from 1970-71 to 1977-78 indicate the forests in 184,500 ha., land put to non agricultural uses 5,300 ha., barren and unculturable land 157,900 ha. and culturable area 1,312,200 ha. As per data available from 1971-72 to 1977-78 the total irrigated area in the district is 212,073 ha. with the source wise distribution as 140,023 ha. by ground water and 72,050 ha. by surface water.

Godavari & Bhima are the two main rivers flowing through the Ahmadnagar district. The catchment area of Godavari river within district is 10,979.5 sq.km. and Bhima river has 6,055.5 sq.km. as its catchment within the district.

As per CWC studies of 1982 the normal rainfall of the district (1901 to 1978) is 556.3 mm and there are normally 35.6 rainy days in a year in the district.There are 115 no. of raingauge stations located in the district and the density of raingauge stations is 145.80 sq.km. per rain-gauge station. The maximum annual rainfall of 921.7 mm was experienced in the district in year 1916 and rainfall generally depends on south west monsoon in the district. The south west monsoon gives about 77.0% of annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as 26.1% for the district. The ground water potential of the district as per CGWB data is that the annual recharge to ground water is 417 m.cum. while the draft is 1326 m. cum. resulting in over exploitation of the order

of 981 m.cum. in one year. As per CWC (1982) observations the district faced 13 hydrological drought years during the period 1946 to 1978. The location of raingauges and ground water observation wells is shown in the district map given as in Fig.2.5.

2.10.3 Pune

Pune is the largest district of Maharashtra state. The geographical location of the district is $17^{o}52'$ to $19^{o}23'$ north latitudes and $73^{o}20'$ to $78^{o}10'$ east longitudes with the area of 15,640 sq.km. The district consists of fourteen talukas and has 1481 inhabited villages, 17 uninhabited villages and 22 towns. The population of the district is reported as 4,162,284 as per 1981 census.

The soil of the district are of three types namely - light brown shallow soils, medium black soils and deep black cotton soils. The details of land use of the district as per 1970-71 to 1977-78 data include the forests is 189,000 ha; land put to non-agricultural uses 37,800 ha., barren and the unculturable land 159,800 ha., and the culturable area 1072,800 ha. The main rivers passing through the district are Bhima & Nira. The catchment area within district of Bhima is 11,404 sq.km. and Nira has 4,236 sq.km. catchment in the district.

As per the CWC studies of 1982 the normal rainfall of the district (1901 to 1978) is 1080.3 mm and normally there are 51.3 rainy days in a year in the district. There are 163 no. of raingauge stations located in the district and density of raingauge stations works out to be 96.2 sq.km. per raingauge station. The maximum annual rainfall of 1877.1 mm was experienced in the district in year 1956. This rainfall in the district generally depends on south-west monsoon which gives about 85.4

percent of the normal annual rainfall. The coefficient of variation for annual rainfall has been reported as 23.9% for the district. As per CGWB data the annual recharge to groundwater is of the order of 966 m.cum. while the draft is 836 m.cum. resulting in surplus of 130 m.cum.

The studies of CWC (1982) indicated that the district experienced 4 hydrologic drought years during the period (1940-78). The location of raingauges and groundwater observation wells is shown in the district map as given in figure 2.6.

2.10.4 Satara

Satara is one of the drought prone districts in Maharashtra with the geographical location of 17^{o}-05/ to 18^{o}-11/ north latitudes and 73^{o}-33/ to 74^{o}-54/ east longitudes. The geographical area of the district is 10,492 sq.km. The Satara district consists of 11 talukas. The district population is 2,041,409 and density of population is 195 persons per sq.km. as per the figure of 1981 census. The soils in the district are mostly three types namely; medium black or deep black soils, lighter soils of reddish brown colour and lateritic soils. The details of land use in the district as per data from 1970-71 to 1977-78 include forests are 148,600 ha., land put to non agriculture uses 25,500 ha., barren and unculturable land 115,300 ha., culturable area 676,300 ha., and the cultivable waste 52,400 ha.

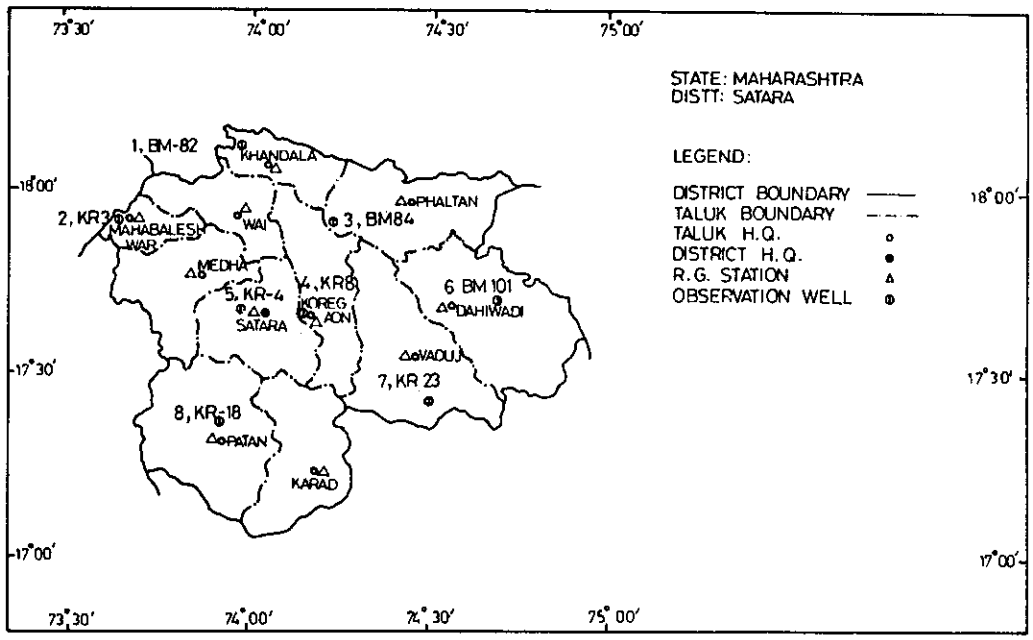
As per the data available from 1971-72 to 1977-78, the total area of irrigation in the district is 103,997 ha. and sourcewise distribution is by surface water as canals, tanks etc. is 47,992 ha., by ground water is 56,005 ha. In the Satara district mainly two rivers flow and one of them is Krishna. The catchment area of Krishna river within the district is 6917 sq.km.

The second main river is Bhima river which has catchment area of 3575 sq.km. within the district.

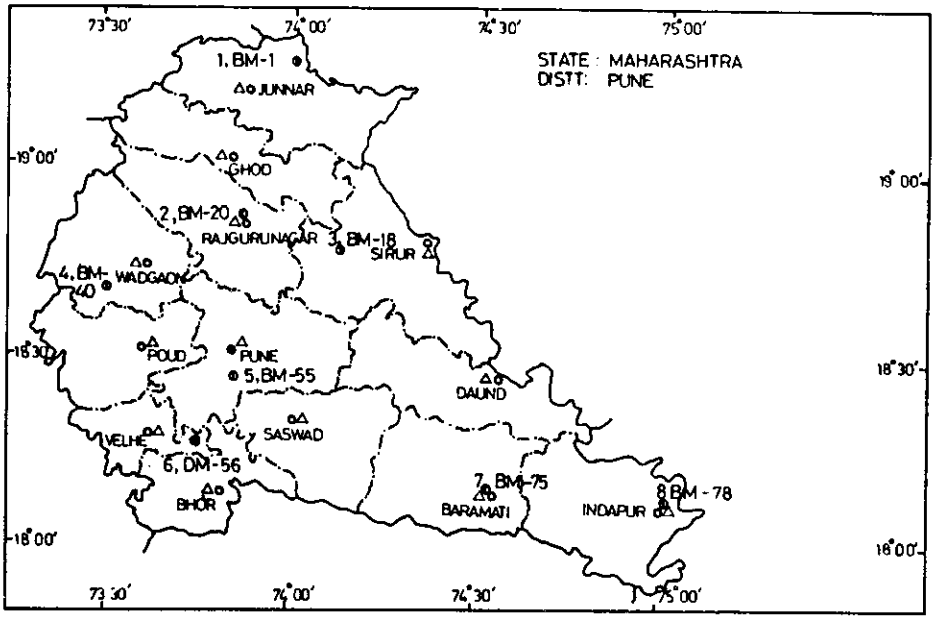
As per CWC studies of 1982, the normal rainfall of the district (1901 to 1978) is 1131.73 mm and normally there are 55.98 rainy days in the district. There are 84 no. of raingauge stations located in the district and density of raingauge stations works out to be 124.2 sq.km. per raingauge station. The maximum annual rainfall of 1673.36 mm was experienced in the district in the year 1978. This rainfall in the district generally depends on south-west monsoon which gives about 83.2 percent of the normal annual rainfall. The coefficient of variation for annual rainfall has been reported as 20.43% for the district. As per CGWB data the ground water potential of the district is annual recharge of 514 m.cum., draft of 416 m.cum. resulting in surplus 96 m.cum. As per CWC (1982) observations, the district faced 4 hydrological drought years during the period 1940-78. The figure 2.6 shows location of raingauges and ground water observation wells which have been chosen for analysis.

2.10.5 Aurangabad

Aurangabad is the third largest district of Maharashtra state and is among the drought prone districts. The geographical location of the district is between the parallels of $19^{\circ}17'30''$ to $20^{\circ}40'10''$ north latitudes and $74^{\circ}39'30''$ to $76^{\circ}40'$ east longitudes. The district has a geographical area of 16305 sq.km. and consists of 12 talukas. It has 1866 inhabited villages, 109 uninhabited villages and 10 towns. The population of the district is 2432010 and density of population is 149 persons per sq.km. as per the 1981 census.



(a) DISTT. SATARA



(b) : DISTT. PUNE

FIG. 2.6 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

The soils in the district are generally three types namely; coarse or shallow soil, medium deep soil and deep black soils. The land use in the district as per data 1967-68 to 1977-78 include forests is 83845 ha., barren and unculturable land 25555 ha., land put to non agricultural uses 52,754 ha. and culturable area 1,389,428 ha. As per data available from 1967-68 to 1976-77 the total irrigated area in the district is 111,266 ha. and source wise distribution is : by surface water 9,340 ha., by ground water 82,972 ha. and 423 ha. by other sources.

The main river passing through the district is Godavari. The catchment area of Godavari basin in the district is 15,337 sq.km.

As per CWC report 1982 the normal annual rainfall of the district is 724.16 mm and normally there are 44.0 rainy days in a year according to analysis of data from 1902 to 1980. There are 29 no. of raingauge stations located in the district, and the density of raingauge stations is 565 sq.km. per raingauge station. The maximum annual rainfall in the district of 1171.70 mm was experienced in year 1916. The rainfall of the district generally depends on south west monsoon, which accounts for 83 percent of the annual rainfall. The coefficient of variation of annual rainfall has been reported as 26.0% for the district. As per state GSDA data the annual recharge to ground water is 1505.16 m.cum. While the draft is 746.90 m.cum. resulting in surplus of 758.26 m.cum. in one year as per CGWB census. The district is reported to have faced 8 hydrological drought years during the period 1951 to 1979 as per CWC (1982) observations. The location of raingauges and groundwater observation wells in the district map are shown in fig.2.7.

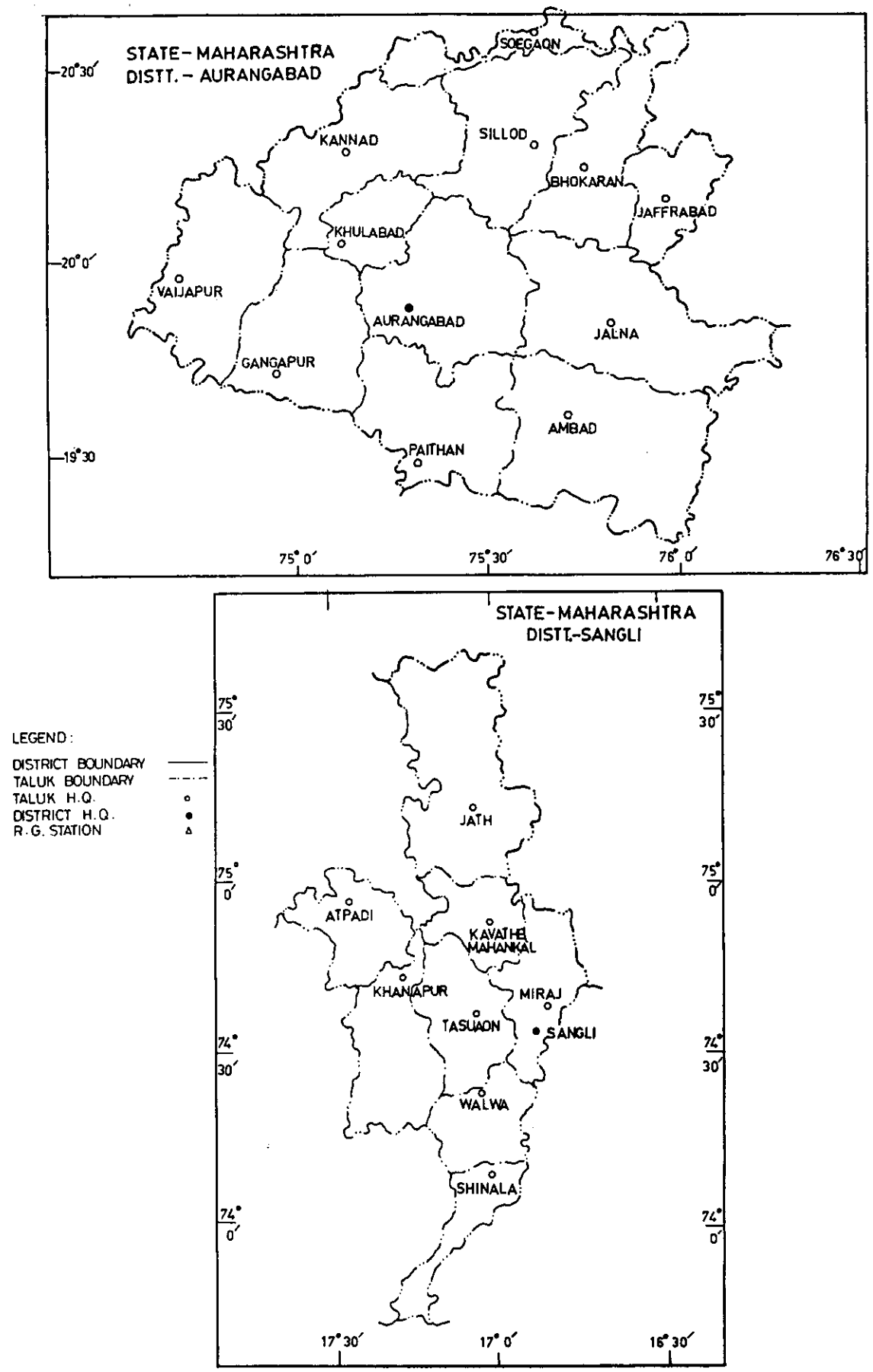


Fig. 2.7 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

2.10.6 Sangli

Sangli is one of drought prone districts in Maharashtra with the geographical location of $16^{o}43'$ to $17^{o}38'$ north latitudes and $73^{o}41'$ to $75^{o}41'$ east longitudes. The geographical area of the district is 5610.25 sq.km. The district consists of the eight talukas and has 539 inhabited villages, 4 uninhabited villages and 7 towns. The population of the district is 1826186 and density of population is 212 persons per sq.km. as per the 1981 census.

The soils in the district are mostly three types namely; black, red and laterite soils. The details of land use in the district as per data from 1970-71 to 1977-78 indicate the forests in 47100 ha., land put to non-agricultural uses 26200 ha., barren and unculturable lands 41900 ha., and culturable area 727500 ha. and the cultivable waste 18300 ha.

As per the data available from 1970-71 to 1977-78, the total irrigated area in the district is 74500 ha. with the source wise distribution of 27967 ha. by surface water and 46533 ha. by groundwater. The Krishna is the main river flowing through the Sangli district. The catchment area of Krishna river within the district is 1812 sq.km.

As per CWC studies of 1982 the normal rainfall of the district (1901 to 1980) is 635.1 mm. and normally there are 45.98 rainy days in a year in the district. There are 22 nos. of raingauge stations located in the district and the density of raingauge stations makes out to be 391.38 sq.km. per raingauge station. The maximum annual rainfall of 957.33 mm was experienced in the district in year 1932. The south west monsoon gives about 66.70 percent of normal annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as

31% for the district. The groundwater potential of the district as per CGWB data the annual recharge to groundwater is of the order of 350.00 m.cum., while the draft is 548.50 m.cum., resulting in over exploitation of the order of 198.50 m.cum. in one year. As per CWC (1982) observations the district faced 13 hydrological drought years during the period 1951 to 1980. Fig. 2.7 draws location of raingauges and groundwater wells in the district map.

Table 2.5 : Net Area Irrigated by Different Sources and Gross Area Irrigated in Maharashtra State from 1978-79 to 1985-86

(Figures in '00' ha.)

Particulars	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
Net area irrigated by Different sources-								
Surface irrigation	8299	8228	8410	8710	8268	9130	8190	8182
Well irrigation	10967	11408	11380	11540	10817	11620	10570	10627
Total net Area irrigated	19266	19636	19790	20250	19085	20750	18760	18809
Area irrigated more than once	4779	4679	5370	6610	6225	6580	6420	5810
Gross Irrigated Area	24045	24315	25160	26860	25310	27330	25180	24619

Note: Figures for the year 1980-81 to 1985-86 are provisional.

3.0 RAINFALL ANALYSIS

3.1 General

As has already been described in chapter 2.0, Six district, namely Ahmednagar, Sholapur, Pune, Satara, Aurangabad and Sangli from the state of Maharashtra have been taken up for rainfall analysis in the present report. One representative raingauge station from each taluk in each of the six district 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 Maharashtra.

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 six chosen districts of Maharashtra have been calculated as the summation of normals for the months (June to September) as provided in the CWC reports. Only four months i.e. June, July, August and September are taken in 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 Fig.3.1. The major inferences that could be drawn from the seasonal analysis are:

The seasonal rainfall departure pattern in the state Maharashtra has been deficient in all the six districts during 1987-88. All the districts except Sholapur have recorded continuous deficient seasonal rainfall since 1984 with the extremes lying in between 15 to 60 percent. Some districts like Pune and Satara recorded continuous seasonal rainfall deficiency in last 15-16 years.

Table 3.1 : Seasonal Rainfall Departure for Districts of Ahmednagar, Sholapur, Pune, Satara, Sangli and Aurangabad of Maharashtra State

District Ahmadnagar (Maharashtra)

Year	Seasonal rainfall	Seasonal normal rainfall	Percent departure
1970	464.66	501.46	- 7.35
1971	434.46		-13.35
1972	217.6		-56.6
1973	587.8		+17.2
1974	693.2		+38.2
1975	663.7		+32.3
1976	486.7		- 0.95
1977	367.4		-26.7
1978	-		-
1979	-		-
1980	-		-
1981	540.9		+ 7.8
1982	429.5		-14.9
1983	704.14		+40.4
1984	423.6		-15.5
1985	392.96		-21.6
1986	348.92		-30.42
1987	454.66		- 9.33

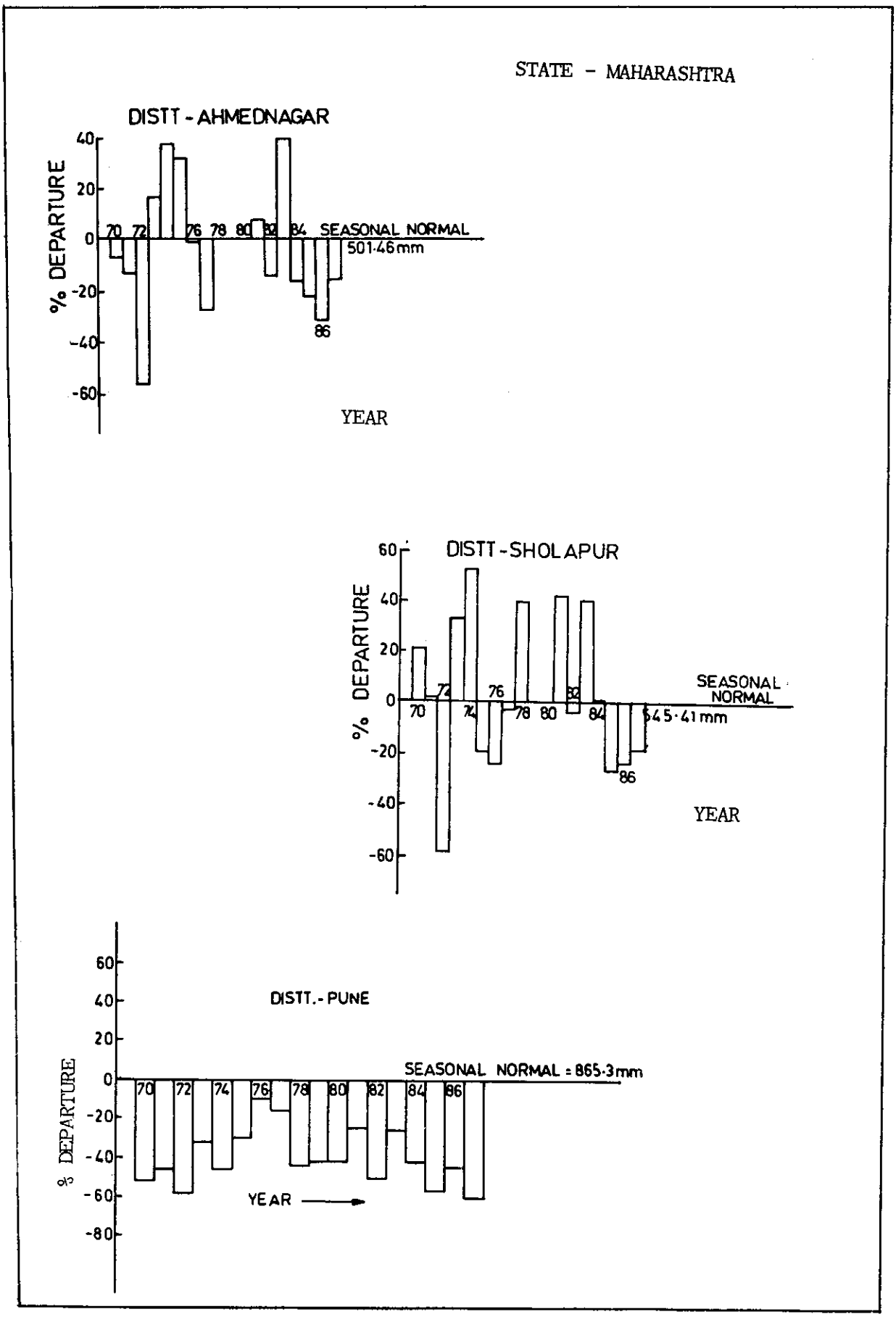


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

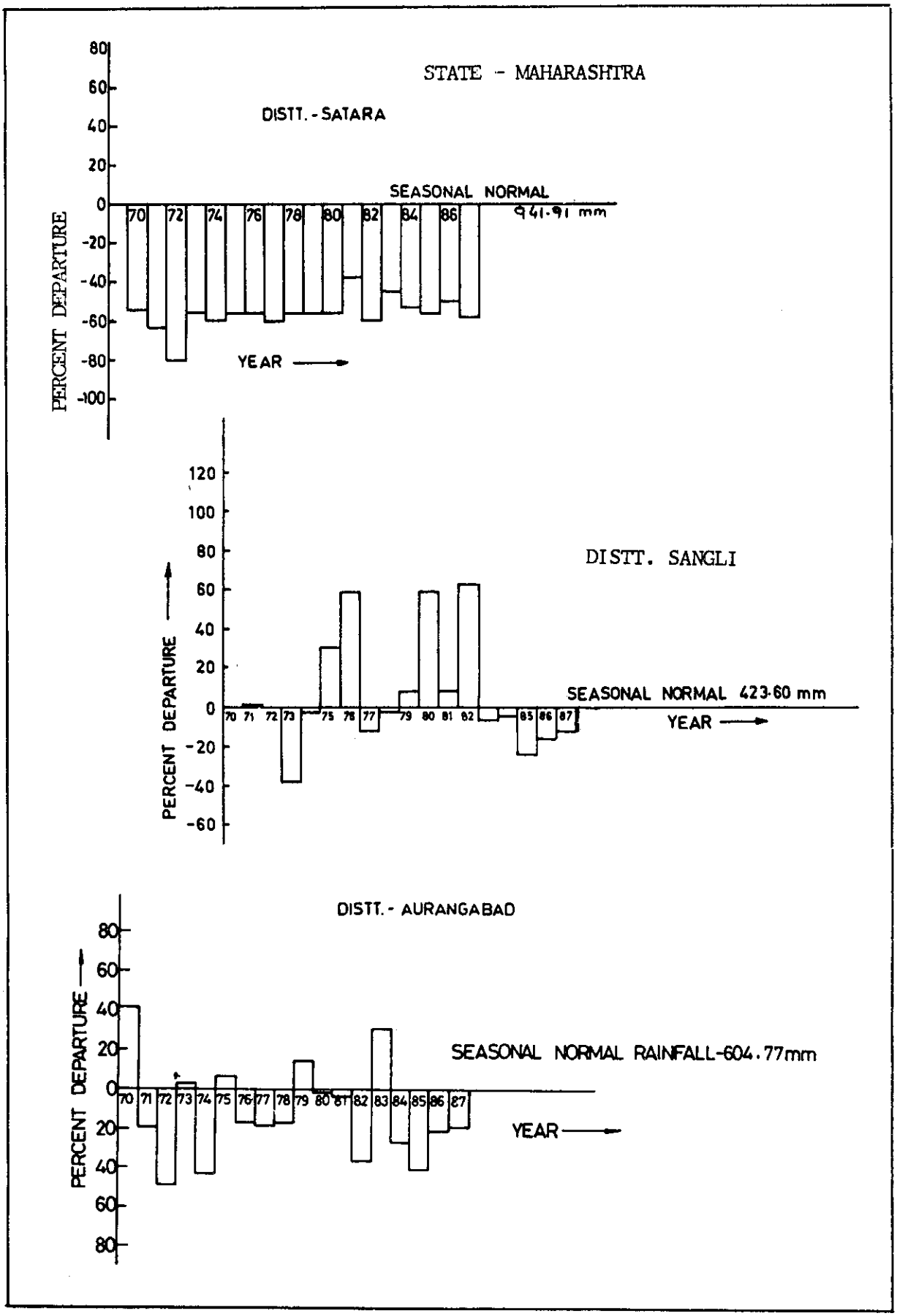


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

District Sholapur (Maharashtra)

1970	660.1	545.41	+21.0
1971	554.1		+ 1.6
1972	227.9		-58.2
1973	729.9		+33.8
1974	835.8		+53.2
1975	442.4		-18.9
1976	409.4		-24.9
1977	527.1		- 3.3
1978	760.6		+39.4
1979	-		-
1980	-		-
1981	782.6		+43.4
1982	525.2		- 3.7
1983	771.7		+41.5
1984	548.6		+ 0.58
1985	403.6		-26.0
1986	420.18		-22.96
1987	455.26		-16.52

District Pune (Maharashtra)

1970	419.24	865.30	-51.55
1971	467.79		-45.94
1972	355.41		-58.93
1973	586.11		-32.27
1974	473.02		-45.34
1975	605.02		-30.00
1976	773.63		-10.59
1977	726.32		-16.06
1978	486.17		-43.81
1979	507.65		-41.33
1980	507.65		-41.33
1981	657.31		-24.04
1982	431.78		-50.10
1983	648.50		-25.06
1984	510.14		-41.04
1985	377.04		-56.43
1986	478.70		-44.08
1987	342.22		-60.45

District Satara (Maharashtra)

1970	496.31	941.91	-47.31
1971	403.94		-57.11
1972	222.65		-76.36
1973	466.56		-50.47
1974	444.74		-52.78
1975	532.42		-43.47
1976	525.36		-44.22
1977	443.31		-52.94
1978	480.38		-49.00
1979	485.69		-48.44
1980	485.69		-48.44
1981	685.92		-27.18
1982	447.23		-52.52
1983	599.27		-36.38
1984	516.05		-45.21
1985	473.62		-49.72
1986	551.52		-41.45
1987	453.39		-51.86

District Sangli (Maharashtra)

1970	429.03	423.60	1.28
1971	423.61		0.00
1972	265.25		-37.38
1973	408.81		- 3.49
1974	557.16		31.53
1975	670.56		58.30
1976	370.20		-12.61
1977	411.86		- 2.77
1978	454.51		7.30
1979	673.61		59.02
1980	451.71		6.64
1981	685.42		61.81
1982	391.24		- 7.64
1983	402.02		- 5.09
1984	319.12		-24.67
1985	287.62		-32.10
1986	356.75		-15.78
1987	376.07		-11.22

1970	856.64	604.77	41.65
1971	488.90		-19.16
1972	307.67		-49.13
1973	621.39		2.75
1974	340.19		-43.75
1975	650.81		7.61
1976	510.01		-15.67
1977	490.38		-18.91
1978	501.88		-17.01
1979	688.17		13.79
1980	598.18		- 1.09
1981	592.44		- 2.04
1982	379.15		-37.31
1983	786.30		30.02
1984	442.78		-26.78
1985	361.72		-40.19
1986	479.66		-20.69
1987	485.09		-19.79

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 district as a whole. Monthly rainfall values from June'87 to May'88 alongwith monthly normals of representative raingauges of various taluks have been considered for the purpose. Monthly rainfall values for a district from June'87 to May'88 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 that 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 monthwise (monthly rainfall & corresponding normals) have been plotted for all the six districts for water year June'87 to May'88, and are shown in figures 3.2. The departure figures for one taluk of each of the six districts are shown in Appendix III-1. Based on monthly departure values, two categories of monthly departure i.e. 20-50% and 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'87 to May'88 in these two ranges viz. 20 to 50% and more than 50%. The following inferences can be drawn from the results shown/presented in figures 3.2, Appendix III-1 and Table 3.2.

In the state of Maharashtra, the monthly rainfall deficiency figures indicate that in case of most of the months monthly rainfall deficiency ranges from 10% to 70%. The deficiency pattern was experienced similar in the districts of Pune & Ahmednagar. In some cases excess monthly rainfall has also been recorded in few months. For example districts of Sangli, Aurangabad & Sholapur.

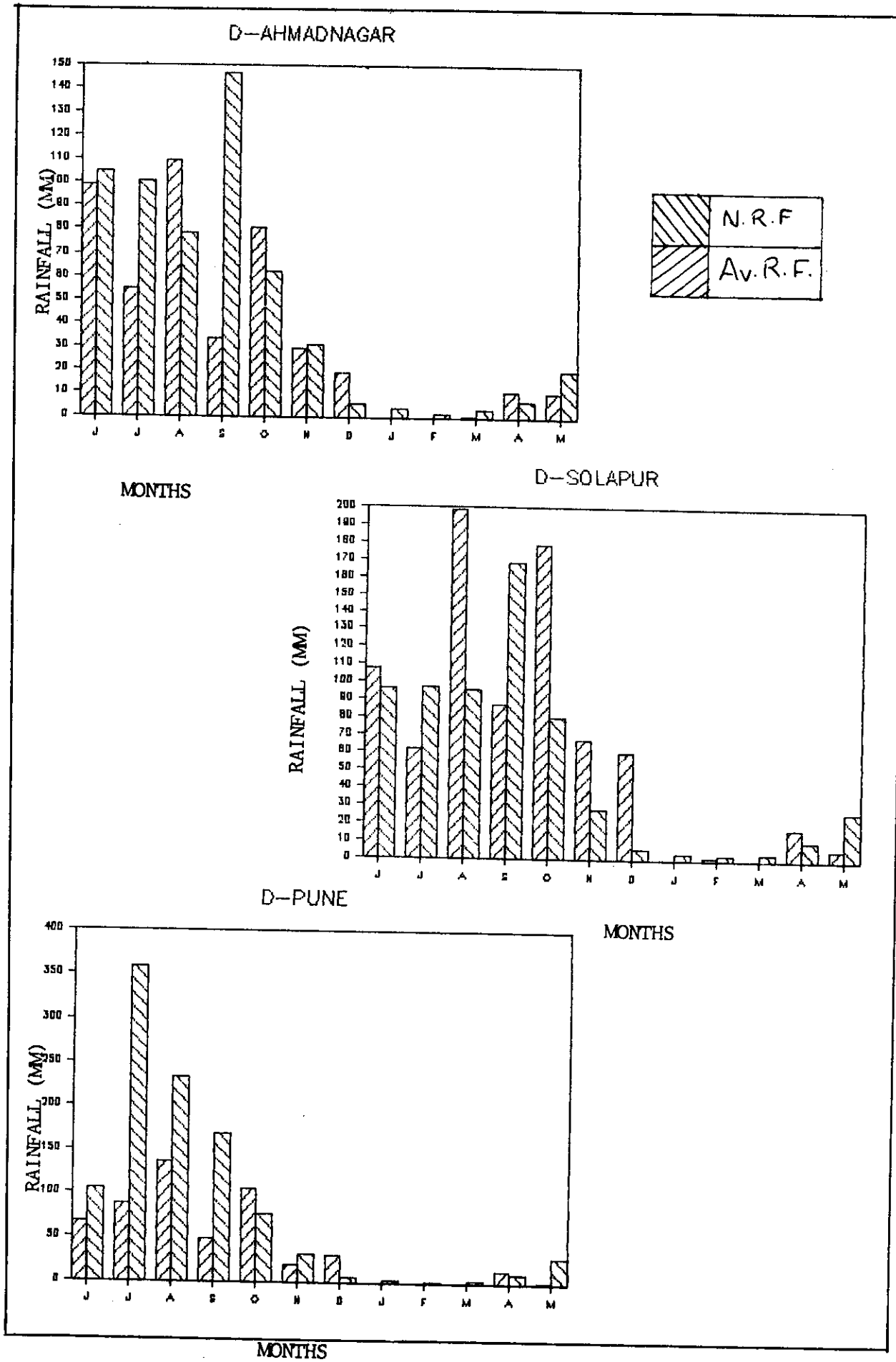


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

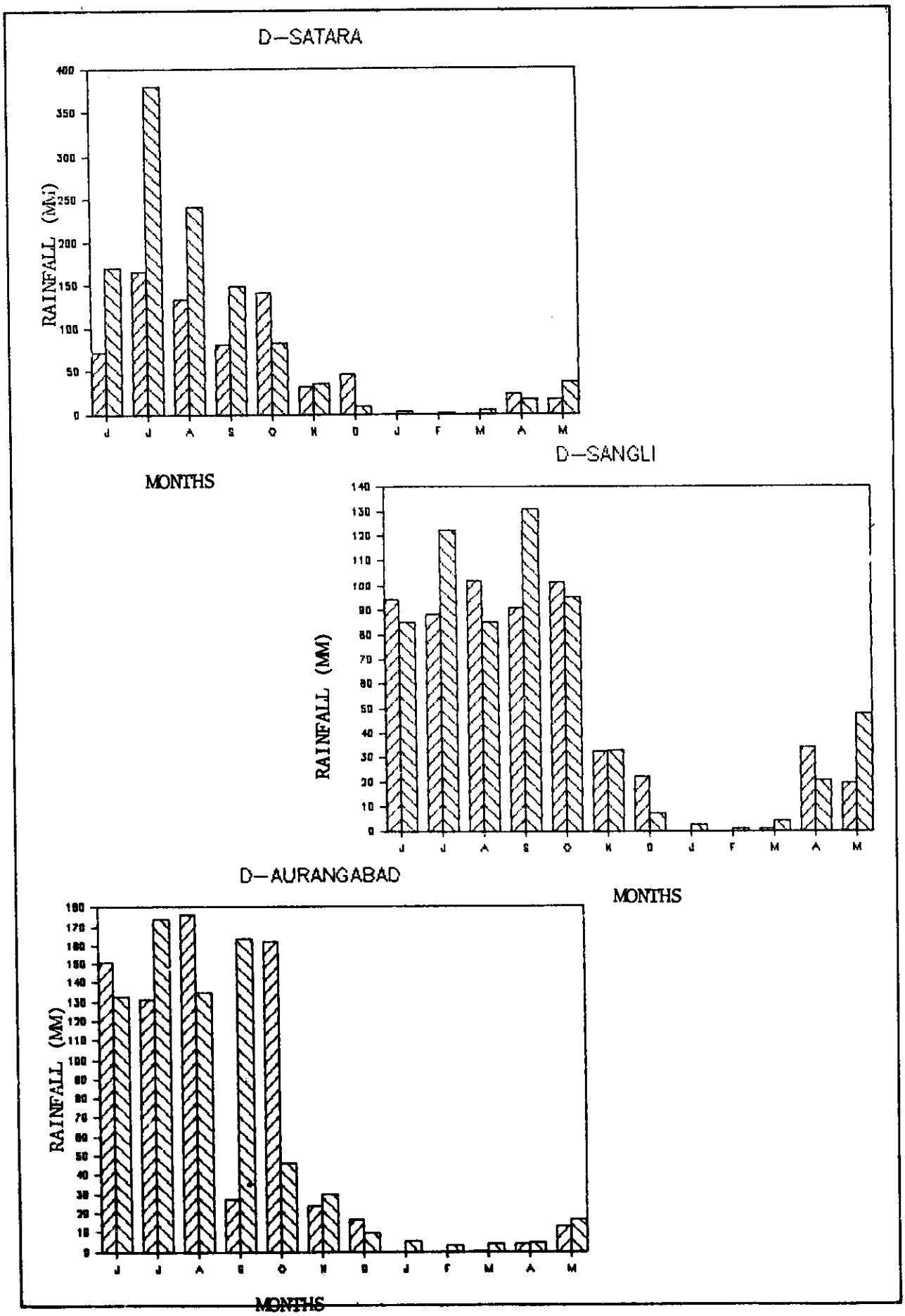


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

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

State	Months	Group Range of Deficiency in rainfall (expressed percentage of normals)	
		20 to 50%	50% and above
Maharashtra (No. of Distt.)	June'87	Pune	Satara
	July	Sangli, Sholapur, Ahmednagar Aurangabad	Satara, Pune
	August	Satara,Pune	
	September	Sangli Satara, Sholapur	Pune, Ahmednagar Aurangabad
	October		
	November	Pune	
	December		
	January'88		Sangli,Satara, Pune,Sholapur, Ahmadnagar
	February		Sangli,Satara, Pune, Sholapur, Ahmadnagar
	March		Sangli, Satara, Pune, Sholapur, Ahmadnagar
	April		
	May	Ahmadnagar	Sangli, Satara, Pune, Sholapur

3.3 Frequency of Rainfall

3.3.1 Probability analysis of annual rainfall

Probability is a constant characterising 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/taluk/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. Group interval of 100 mm has been considered for the analysis.

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

Probability groups for all the six districts and also for two selected taluks in each districts of the state have been shown in figure 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 districts and two taluks in district are given in Table 3.3. In order to find the drought proneness of the districts, the percentage probability of occurrence of 75% normal rainfall of the district has also been worked out and the results are given in table 3.3. It can also be

seen from the table that all the six districts except Pune and Sholapur have more than 80% of probability of getting 75% of normal rainfall indicating the districts are less prone to drought conditions.

Table 3.3 : Probability Distribution of Annual Rainfall of State Maharashtra

Sl.	District	Name of Taluks	75% probability & above (Range in mm)	Probability of occurrence of rainfall equivalent to 75 percent normal (in %age)
1.	Ahmednagar	Ahmednagar	500-600	81
		Akola	200-300	79
		District as a whole	500-600	83
2.	Sholapur	Sholapur	600-700	81
		Akalkot	300-400	67
		District as a whole	500-600	79
3.	Pune	Pune	600-700	83
		Khed	600-700	79
		District as a whole	900-1000	79
4.	Satara	Satara	900-1000	82
		Karad	600-700	84
		District as a whole	900-1000	84
5.	Sangli	Jath	400-500	82
		Tasgaon	500-600	82
		District as a whole	500-600	83
6.	Aurangabad	Karnad	400-500	73
		Aurangabad	600-700	84
		District as a whole	600-700	84

3.3.2 Probability of occurrence of rainfall equivalent to 75% of the 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 from the Figures 3.3 and Appendix III-2 and the values are presented in Table 3.3. As per IMD criteria, an area would be classified as drought prone if probability of 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 all the six districts namely Ahmednagar, Sholapur, Pune, Satara, Sangli and Aurangabad are 83, 79, 79, 84, 83 & 84 respectively. The values for Pune & Sholapur are below 80 indicating that these two districts can be classified as drought prone based on this analysis as per IMD criteria. This can also be infered that the districts of Pune & Sholapur both experienced rainfall less than 75% of normal in 21 percent of years. The taluks of all the six districts showed similar results.

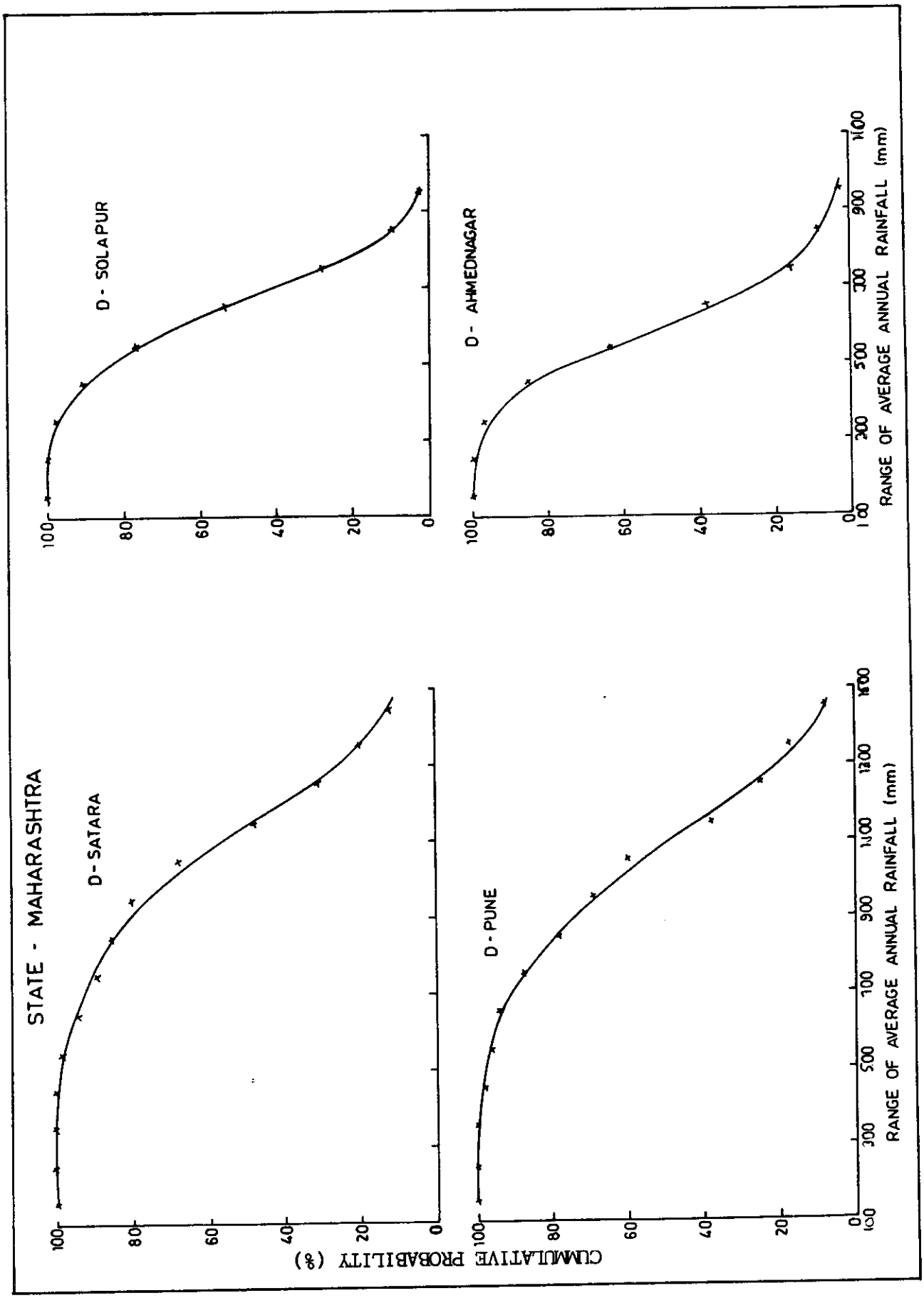


Fig. 3.3 : Districtwise Probability of Annual Rainfall

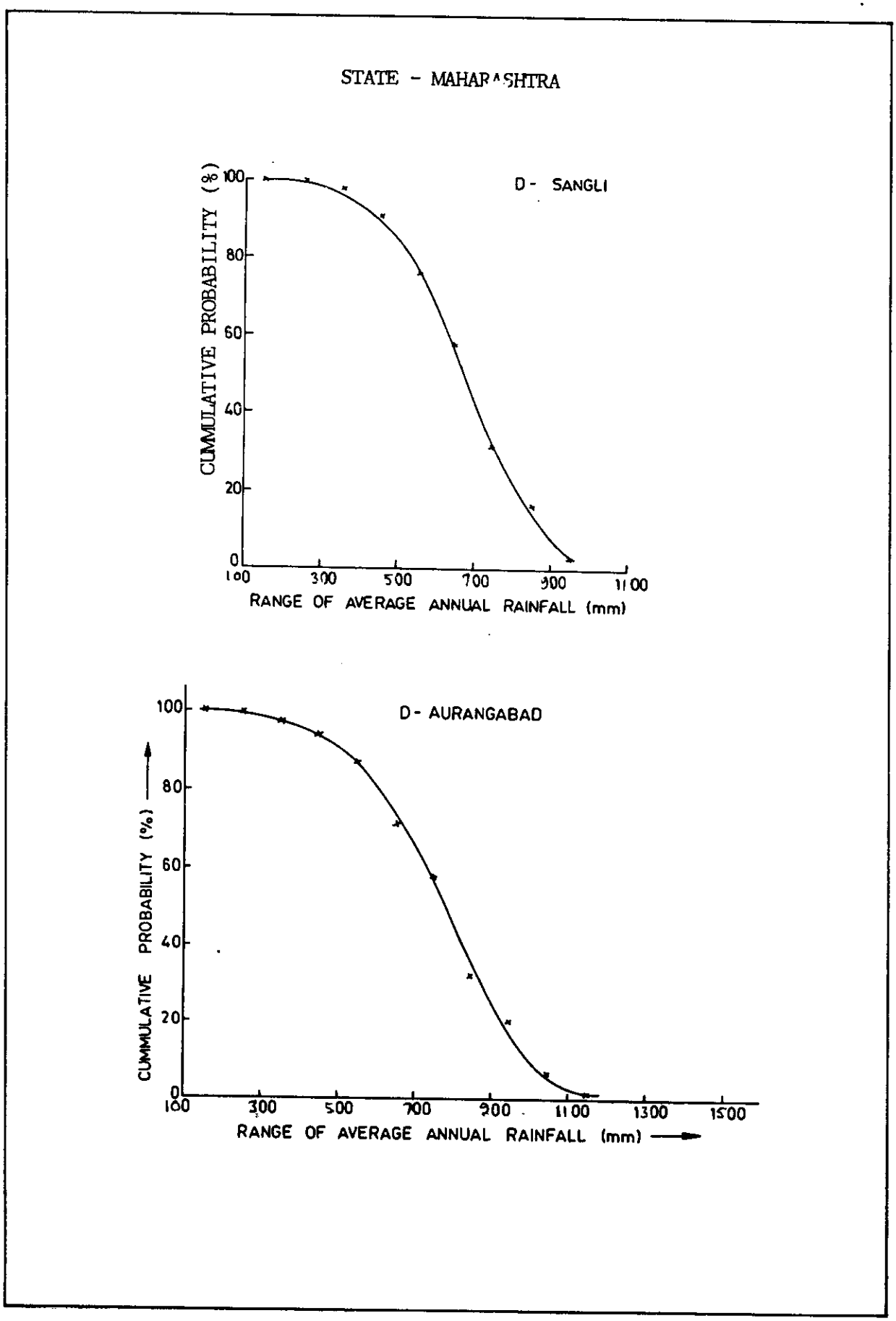


Fig. 3.3 : Districtwise Probability of Annual Rainfall

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:

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

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.

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

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 substracted 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).

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

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

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

$$CO(I,J) = ER(I,J-1) - MMR(J-1) \qquad \ldots(4)$$

$$ER(I,J) = RF(I,J) + CO(I,J)*W(J) \qquad \ldots(5)$$

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,

$$ER(1,1) = RF(1,1) \qquad \ldots(6)$$

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'.

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

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:

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

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 (MMMR), 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 ≥ MMMR

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 mmed 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 drcught

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

$$SI = I \times D \qquad ...(13)$$

This analysis has been performed for six selected districts of state Maharashtra. Monthly rainfall data for period 1951-1987 of selected raingauge station 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 in the distinct spells of drought alongwith monthly and the overall intensity of drought for all the spells. The results of analysis in tabular form for all 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 & Appendix III-3).

The Herbst's analysis has resulted in finding of drought spells during 1984-87 in all the six districts except Satara and Ahmednagar. However, drought spells were found in Satara & Ahmednagar districts from late 70's to early 80's. The maximum intensity of drought was recorded in the case of Satara district and the no. of spells varied from 4-11 in these districts during the period 1951-87. The district of Sangli experienced the longest spell of drought during 1983-84. The longest period of drought spell over the entire period was found in case of Ahmednagar district during late 70's and early 80's. The pattern

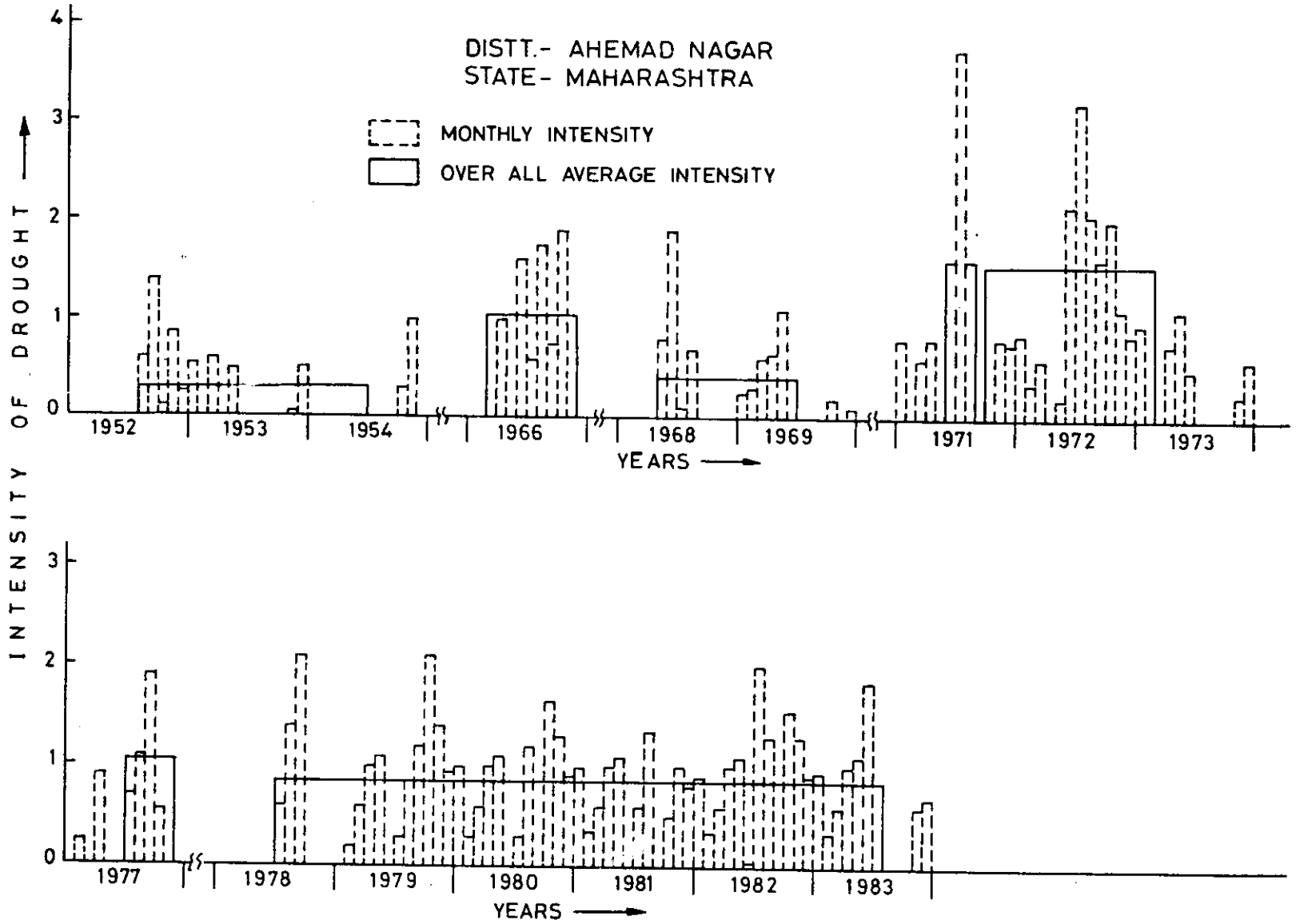


FIG. 3.4 OVER ALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

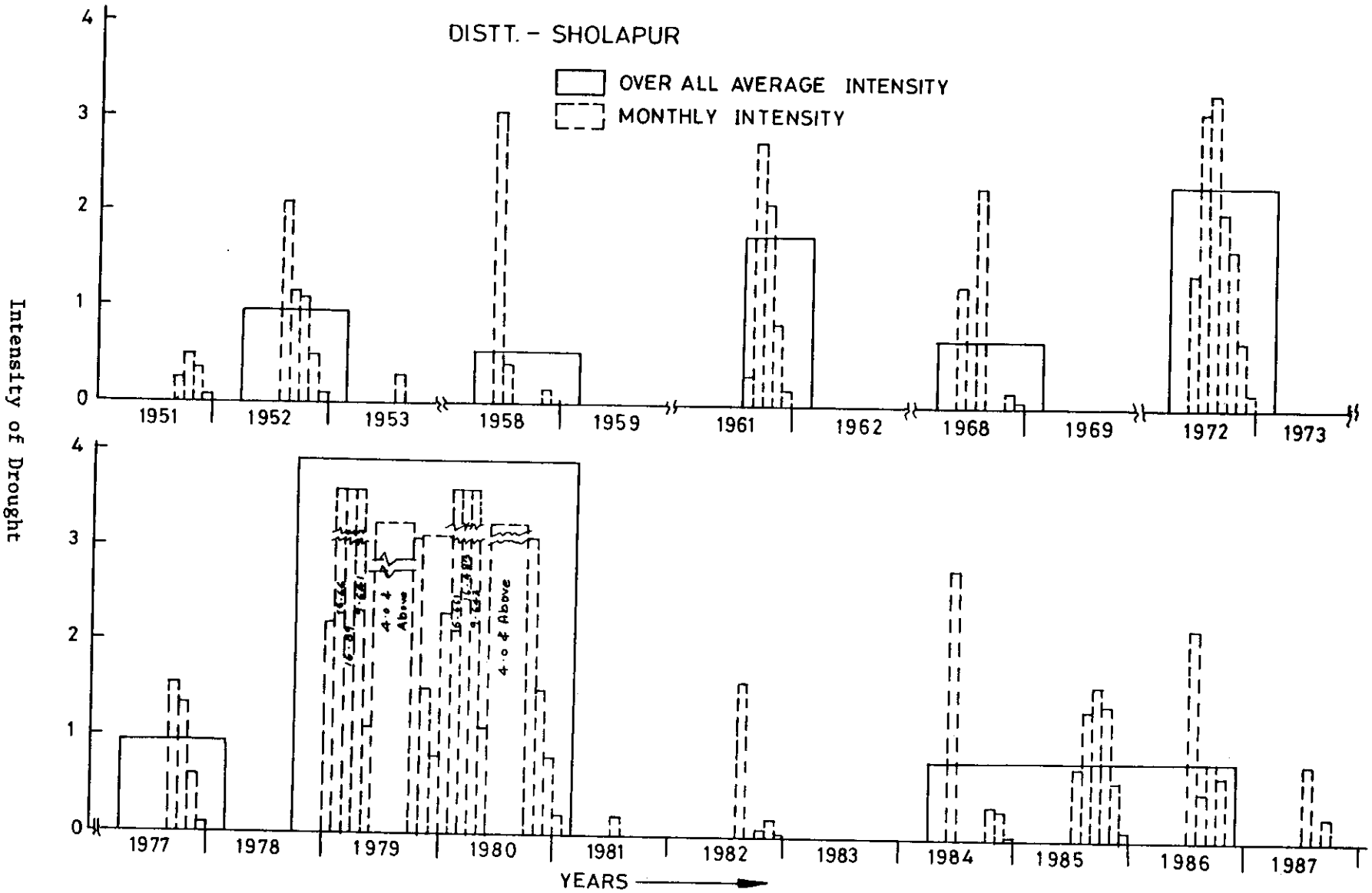


Fig. 3.4 : Overall Average and Monthly Intensity of Drought

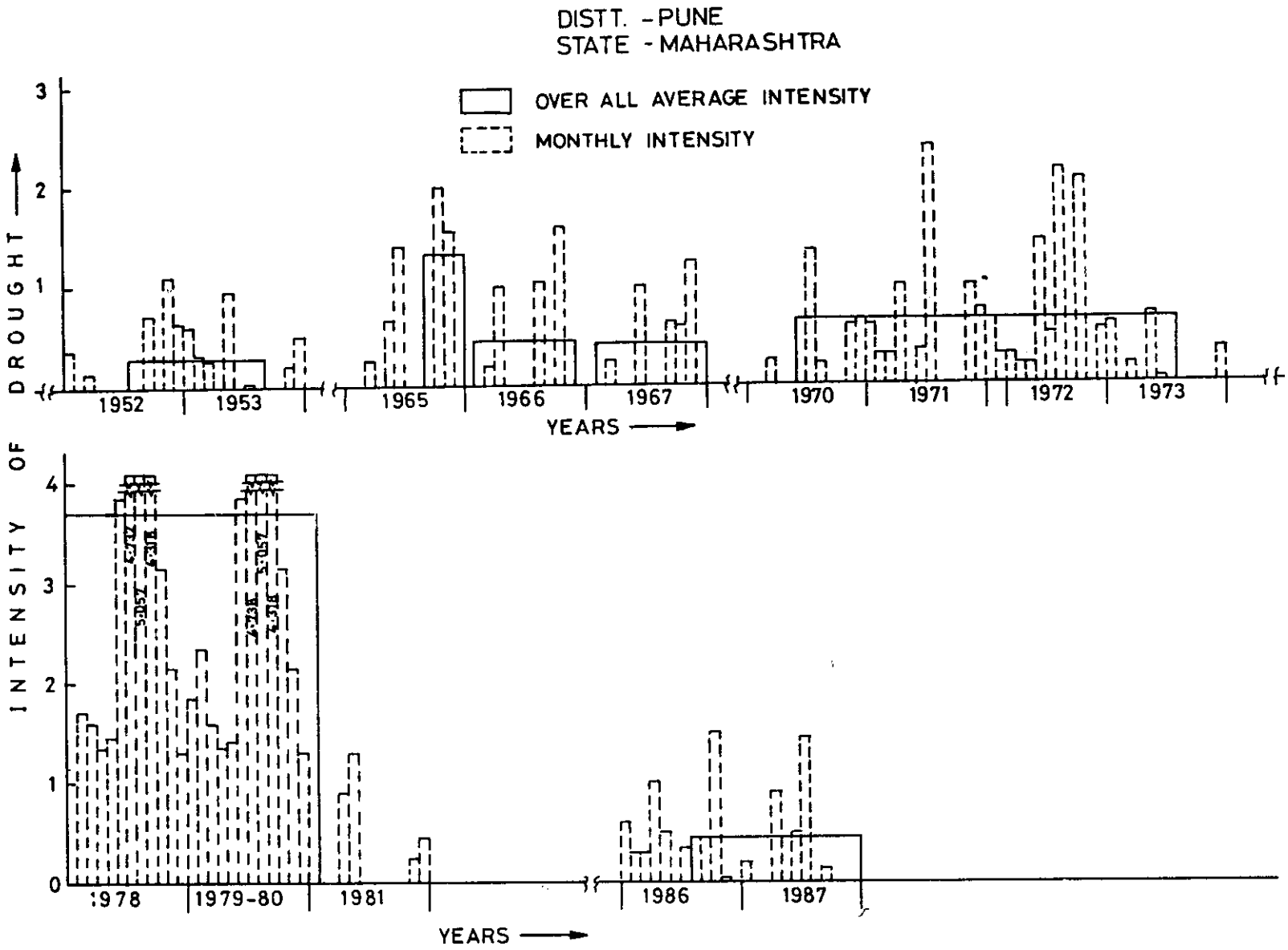


FIG. 3-4 OVER ALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

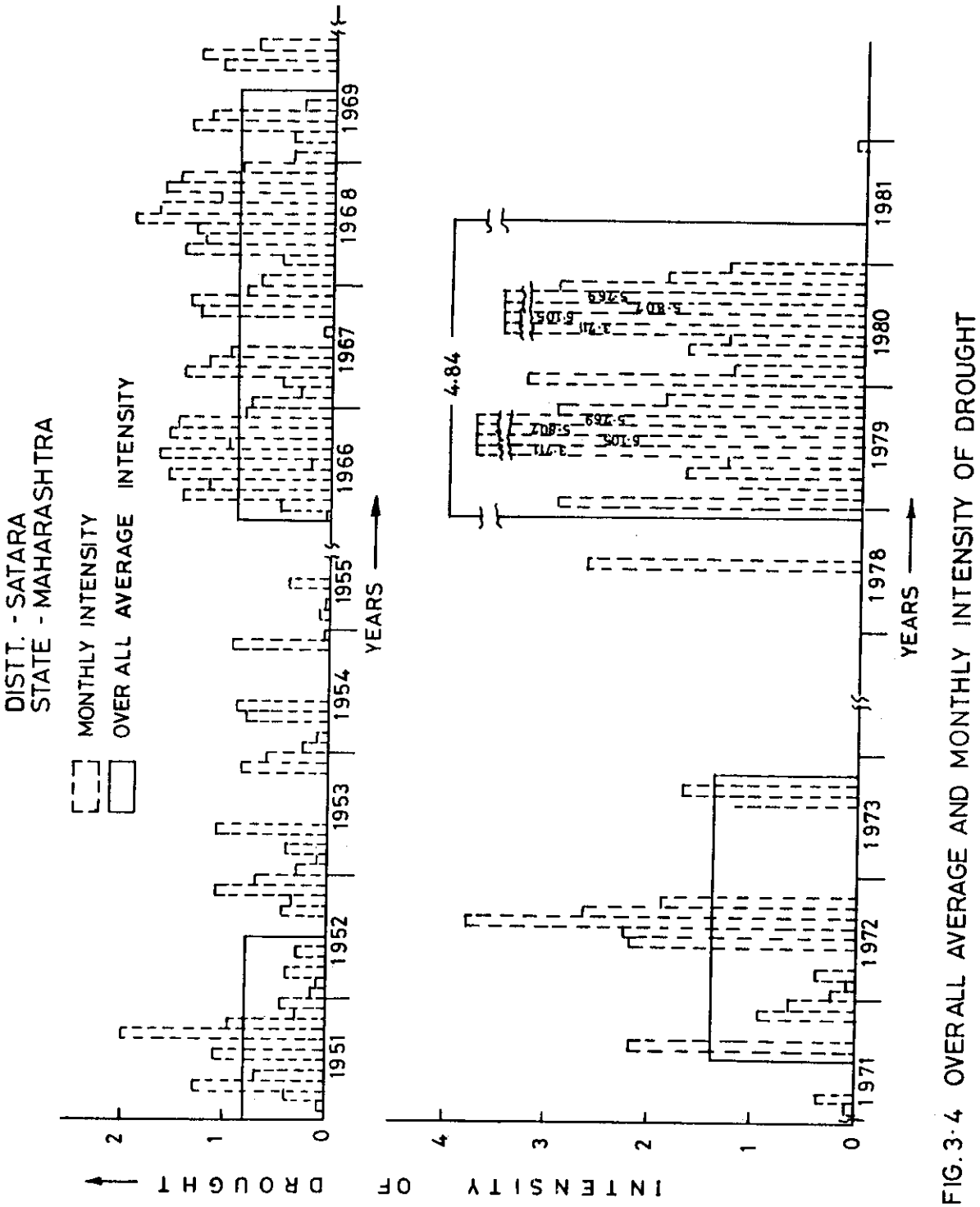


FIG. 3·4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

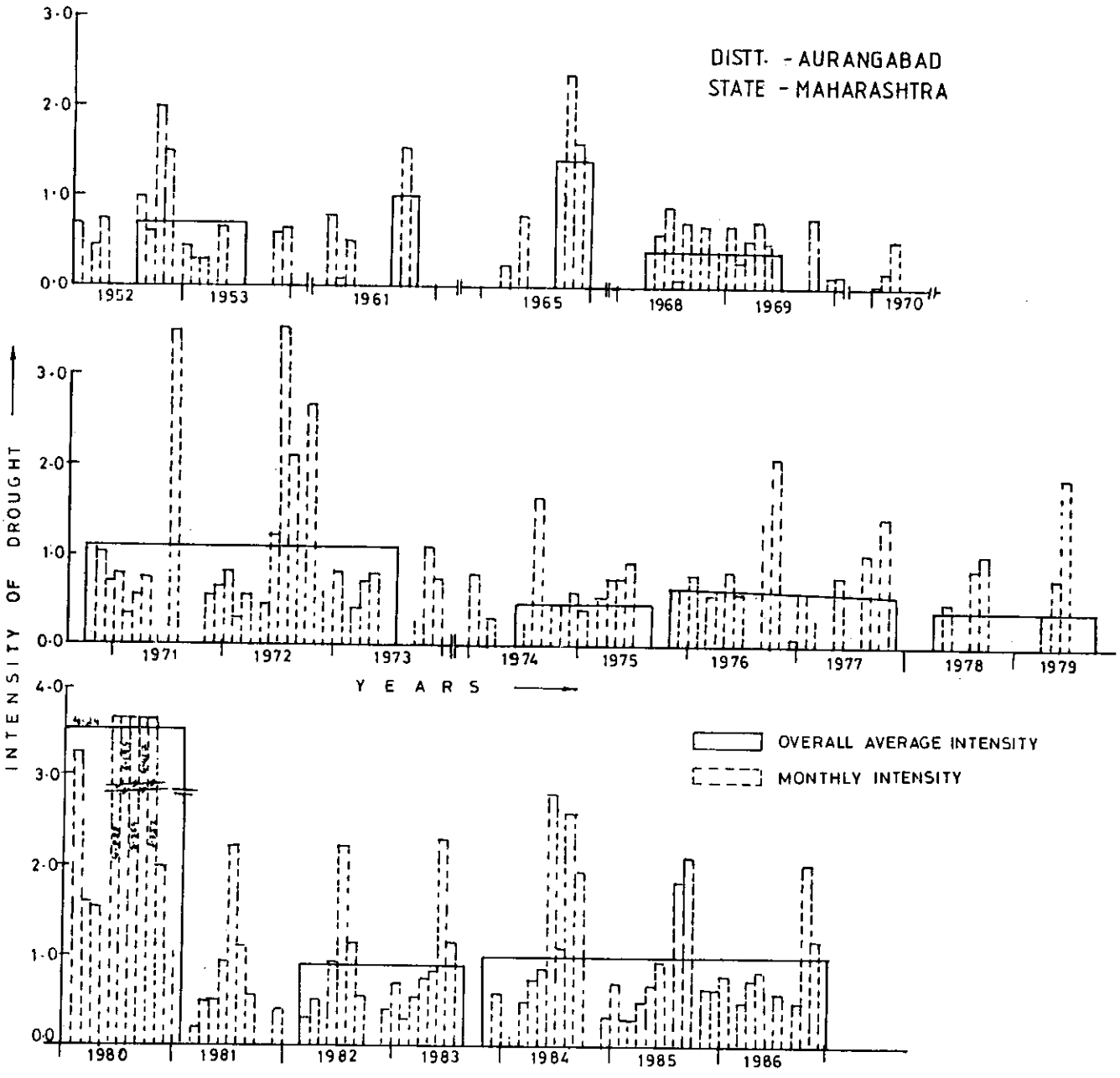


FIG. 3.4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

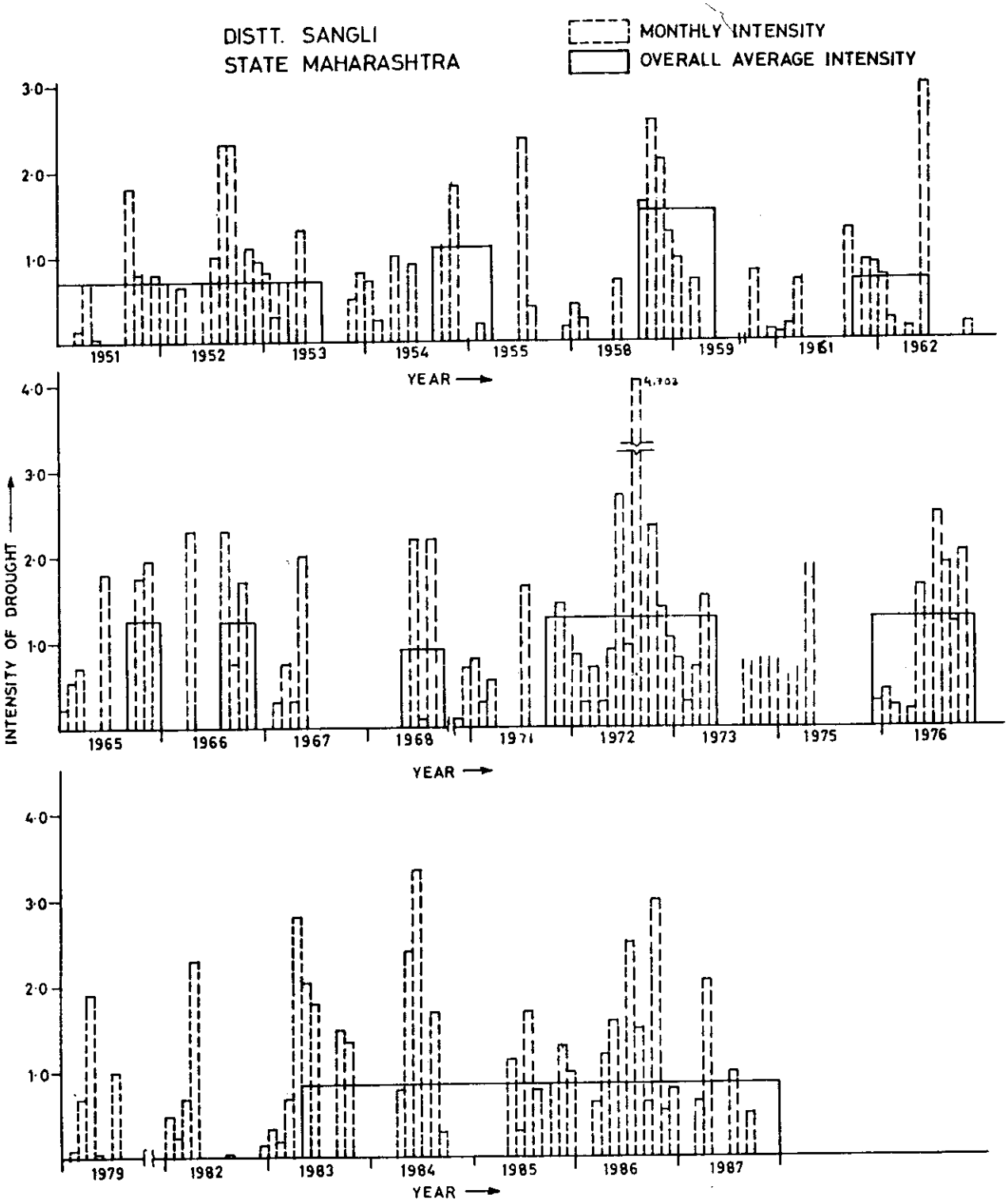


FIG. 3·4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

of the spells of drought was not matching in various districts. The approach has yielded comparable results of drought analysis and has further scope for improvement taking into account the revision 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 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 ($\geq$ 2 weeks) within monsoon season has importance 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 districts of state Maharashtra.

The criteria for selection of dry spell 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 atleast 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 districts of state Maharashtra 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 no. 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 no. of spells occurring from 1981-1987 and cummulative percentage was obtained starting from the maximum duration of dry spell group downwards adding successive percentage (Appendix III-4(B). The probability curves have been drawn showing range of duration of dry spells on the abscissa and cummulative percentage of no. 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. It can be observed from the table that at 75% probability, the duration of dry spell ranges from 21-28 days for all the six taluks selected for all the six districts respectively.

This 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.

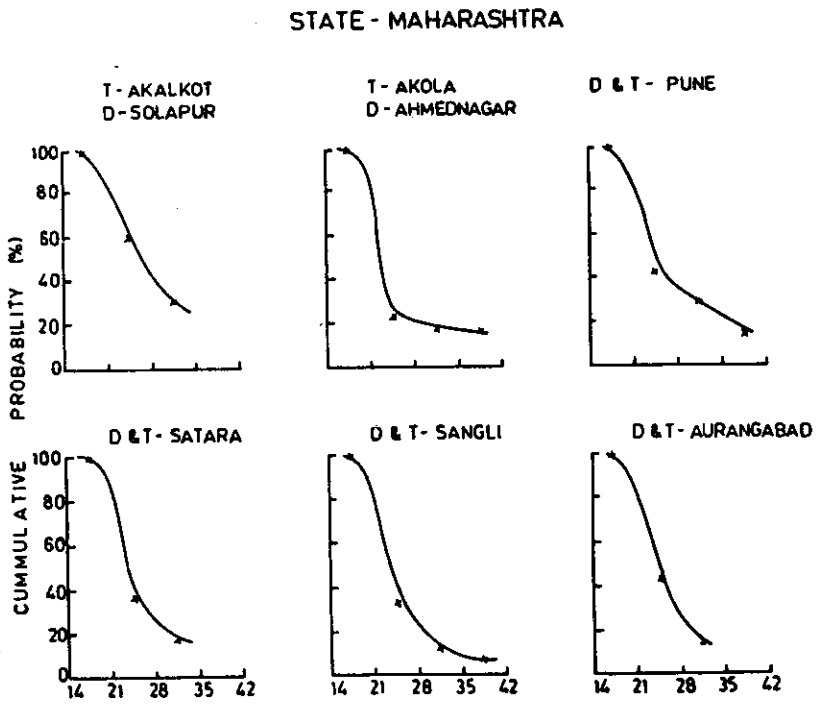


Fig. 3.5 : Probability Distribution of Dry Spells

Table 3.4 : RANGE OF DURATION OF DRY SPELLS FOR 75% PROBABILITY

S.No.	Taluk (Distt.)	State	At 75% Probability, duration of dry spells (in days)
1.	Akolkot (Sholapur)	Maharashtra	21-28
2.	Akola (Ahmednagar)	-do-	21-28
3.	Pune (Pune)	-do-	21-28
4.	Satara (Satara)	-do-	21-28
5.	Sangli (Sangli)	-do-	21-28
6.	Aurangabad (Aurangabad)	-do-	21-28

4.0 GROUND WATER DEFICIT

4.1 General

The main objective of groundwater management is to ensure that groundwater will be available at an appropriate time and in an appropriate quantity and quality to meet the most important demands of society. The measurement of groundwater levels and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table reflect the effects of infiltration, precipitation and discharge of groundwater 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 of rains or droughts, more dependence comes on ground water storages and steep decline in groundwater levels are experienced. Because of improper management of groundwater aquifers after development, numerous undesirable consequences such as the depletion of aquifers and groundwater 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 groundwater should be restricted to average annual recharge. This will conserve water from over exploitation during drought periods.

Therefore, there is a long standing need to better understand the relationship between precipitation and groundwater

levels. The relationship can be developed by carrying out statistical analysis of precipitation data and well level observations. Besides, 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 groundwater regime, statistical analysis of groundwater level data vis a vis precipitation has been carried out for all the 6 districts chosen in the state of Maharashtra. However, 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 groundwater level fluctuations were collected in respect of observation wells in all the six districts, namely Ahmednagar, Sholapur, Pune, Satara, Aurangabad & Sangli of state Maharashtra. The information 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 Groundwater Data of State Maharashtra

Sl. No.	Name of districts	Data available (four time in a year)	No. of wells taken	Source of data availability
1.	Ahmednagar	1976-88	7	G.W.Survey & Dev.Agency
2.	Pune	1976-88	8	-do-
3.	Satara	1976-88	8	-do-
4.	Sholapur	1976-88	8	-do-
5.	Aurangabad	1977-88	10	-do-
6.	Sangli	1976-88	10	-do-

As is evident from table 4.1, about 7-10 wells were chosen in each district for evaluating impacts on groundwater regime. It was kept in mind that these wells are evenly distributed within the district. The locations of the wells on the district map have already been shown in the figures presented in chapter 2.

The groundwater level analysis was attempted with the help of quarterly/seasonal data depending upon the frequency of the data collected from the central & state Govt. agencies of the state. Appendix IV-1 gives the details of various observation wells spread over 6 selected district prone districts of Maharashtra state with their latitude and longitude. The analysis has been carried out for ground water level data from 1976-88.

The water levels 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 groundwater level calculated with respect to mean sea level, multiplied by Thiessen weight, gave average ground water level for the district. Based on the values of water levels in wells, computed with respect to MSL, average ground water level for the district was obtained. The values so obtained were plotted against each year to derive trend in ground water fluctuation. The trend was established for two periods namely, pre-monsoon and post-monsoon. In order to see the trend in the rainfall, the seasonal rainfall was also plotted in the same graph showing the ground water level fluctuations. For this purpose, the seasonal rainfall from June to September was used. A simple regression line was fitted to show the trend of rainfall in order to see the effect of deficit ground water levels. The plots

showing trends of seasonal rainfall and average ground water fluctuations for all the districts are shown in figures 4.1 to 4.6. As has already been mentioned that due to non-availability of abstraction data, the effects caused due to over exploitation of ground water during drought periods could not be introduced in the study and it is presumed that decline in the ground water level is caused solely due to failure of rainfall. Also a district has been taken as a unit for analysing drought impacts on ground water levels. Ideally, a hydrogeological boundary will need to be established for such an analysis. However, it has been presumed that the district has no inflow or outflow of ground water into/from its aquifer. Based on the analysis, following inferences can be drawn:

The seasonal rainfall figures for year 1987-88 show deficient picture in all districts except Sholapur. The seasonal deficiency has been in the range of 9-60%. The rainfall trends for all the districts have shown declining trend over years except in case of Satara district. The rate of decline has increased in case of Pune and Solapur, however, the district of Ahmednagar experienced relatively less decline rate as compared to previous years. The water table analysis has indicated that the water table (post-monsoon) has been falling for the districts of Satara, Pune, Aurangabad and Sangli. However, the districts of Ahmednagar and Sholapur showed rather positive trend in post monsoon water table positions, indicating rise in the post monsoon water table levels over years. The pre-monsoon water table levels have shown declining trend for all the six districts with the rate of decline being little less than the previous year. The analysis of ground water levels based on the water-table fluctuation data of post 10-12 years has yielded in knowing the groundwater level trends (pre & post) as a result of seasonal rainfall departure. In most

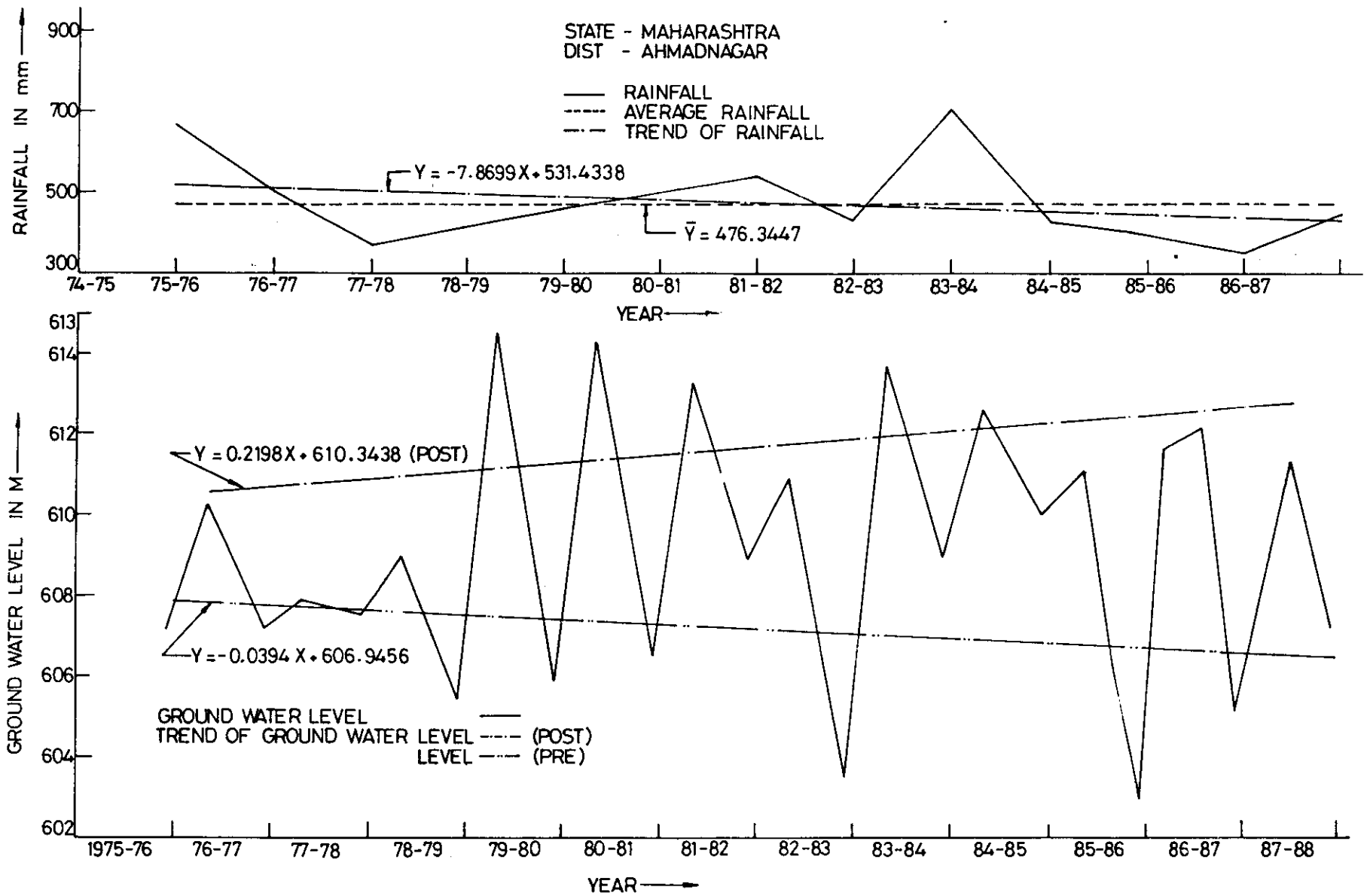


FIG. 4.1: GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

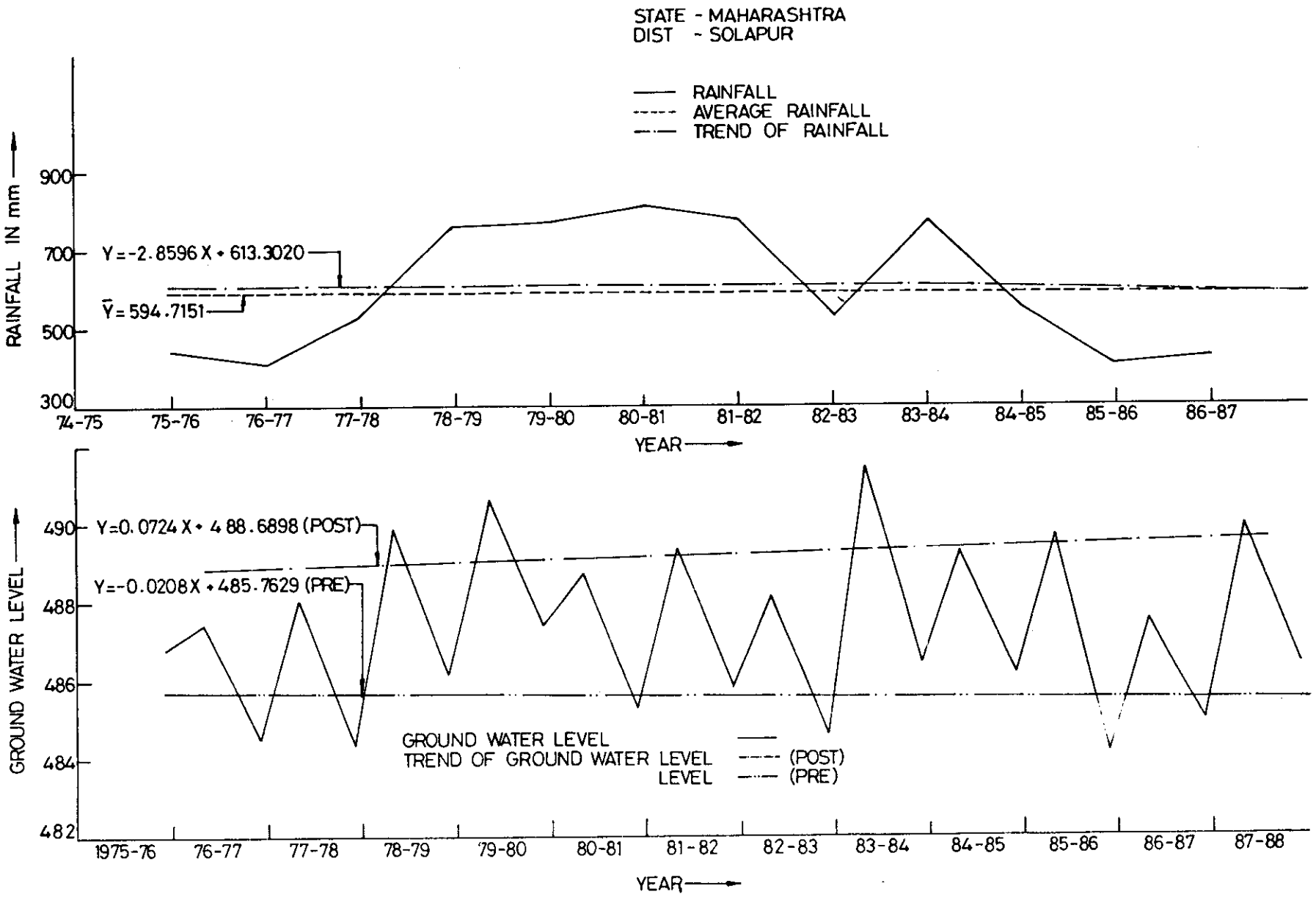


FIG -4.2 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

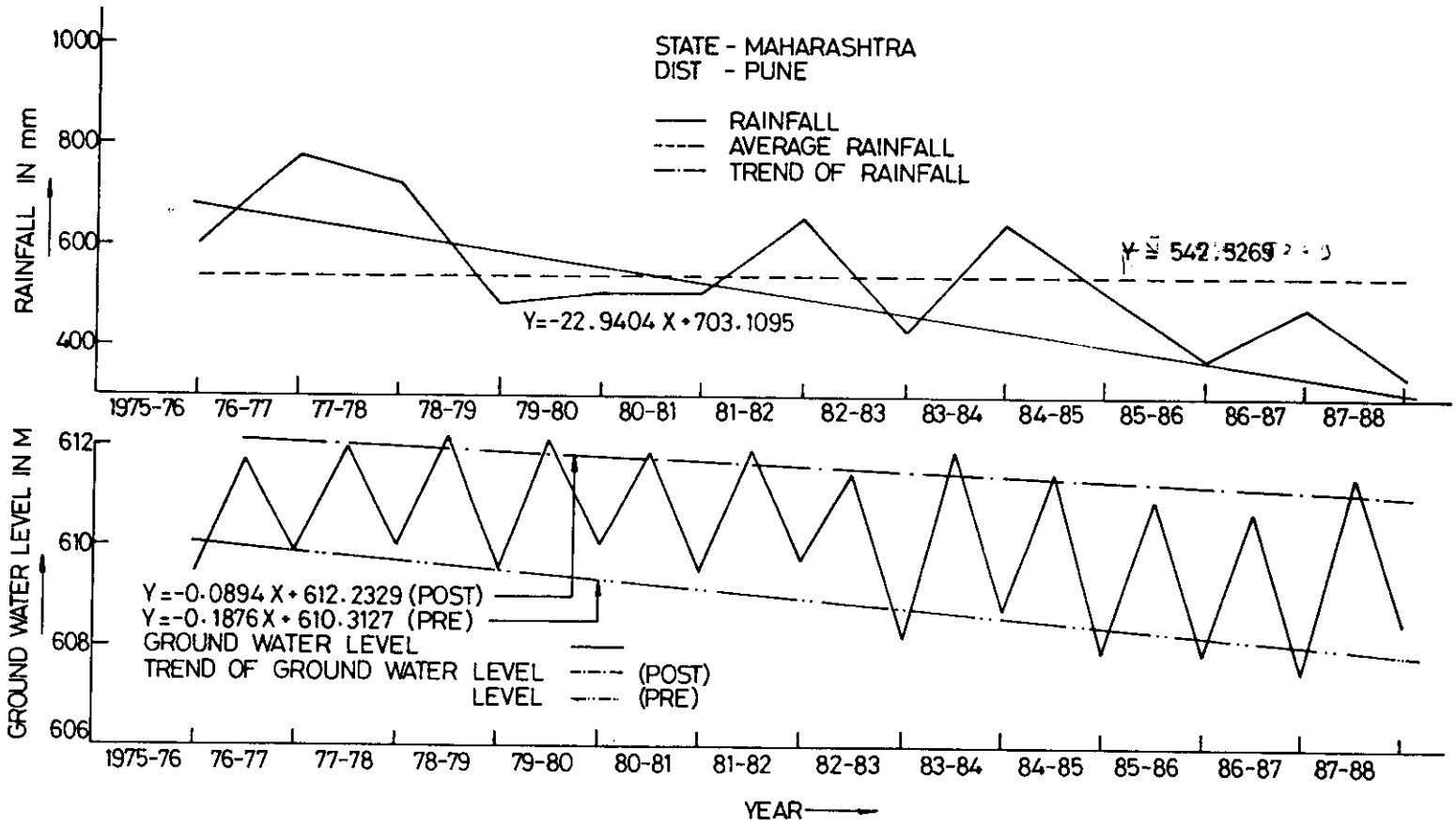


FIG 4.3: GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

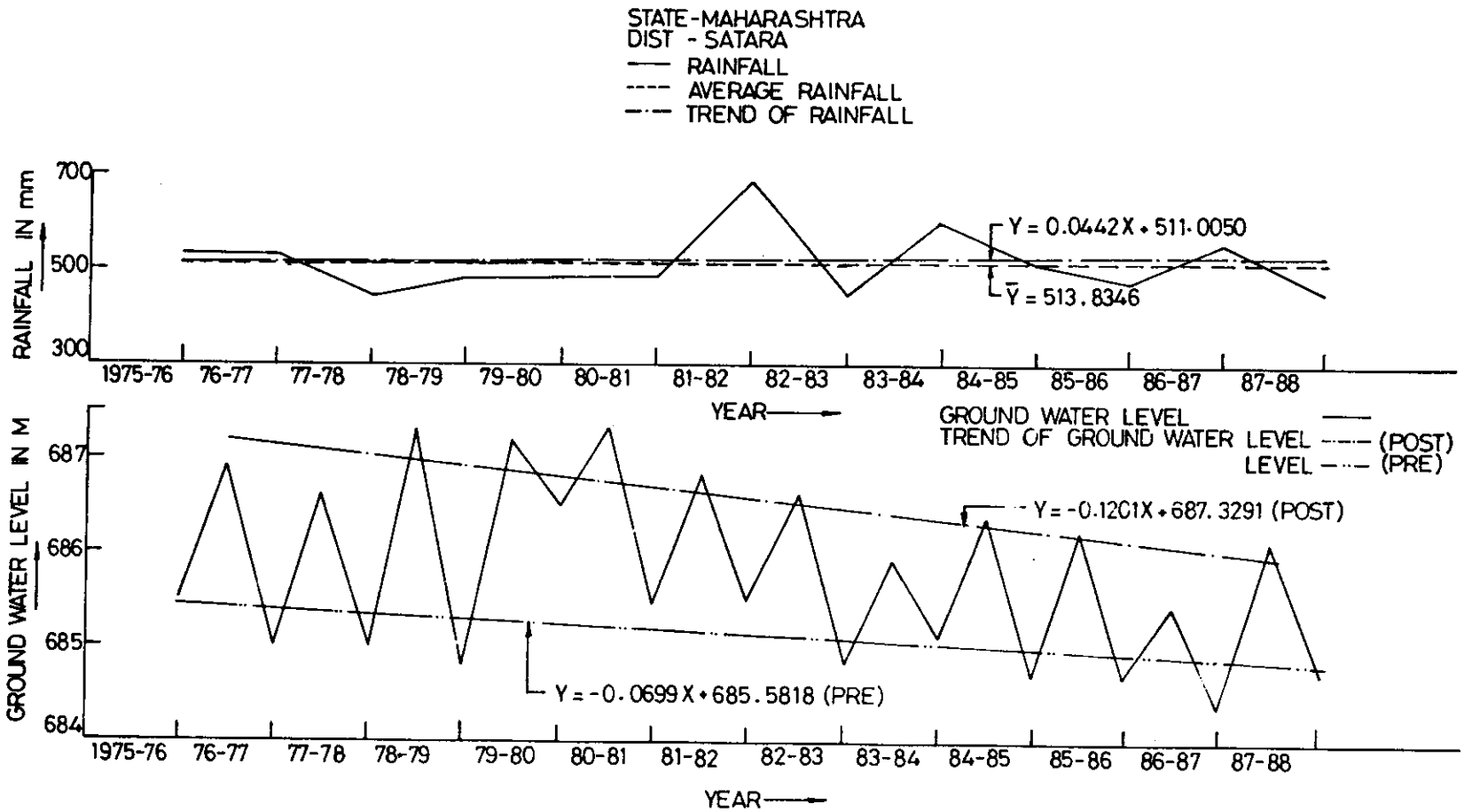


Fig. 4.4 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

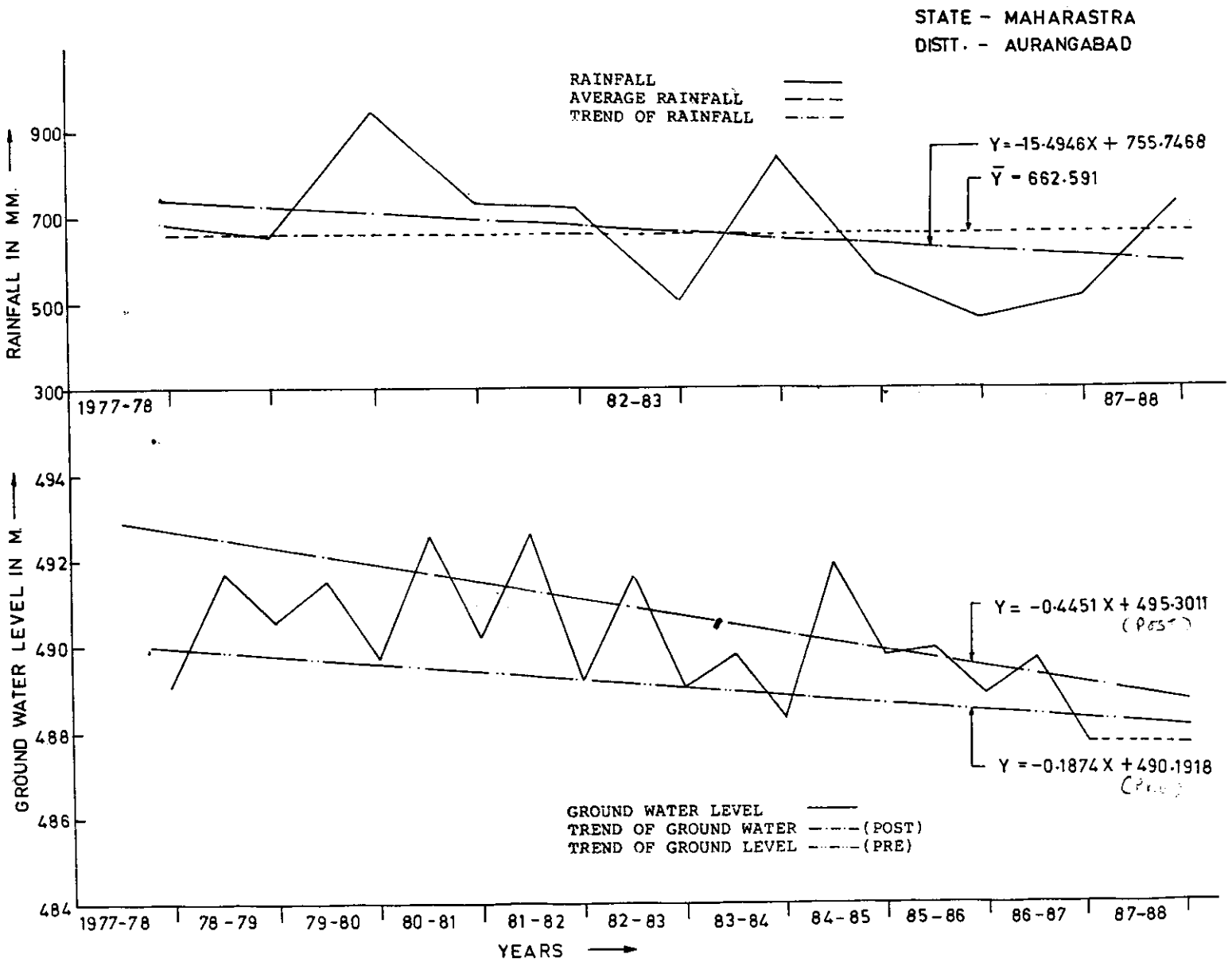


FIG. 4.5 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

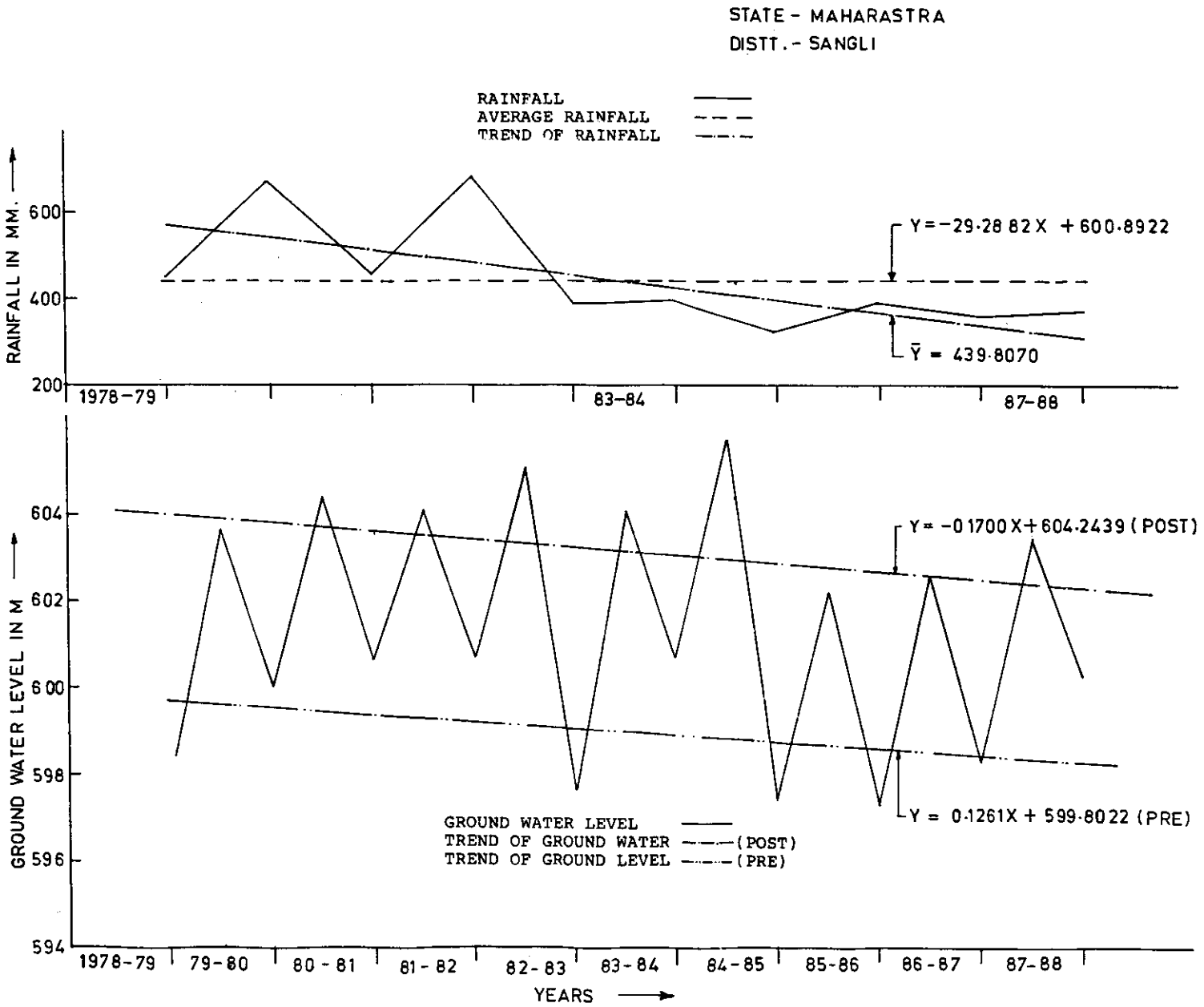
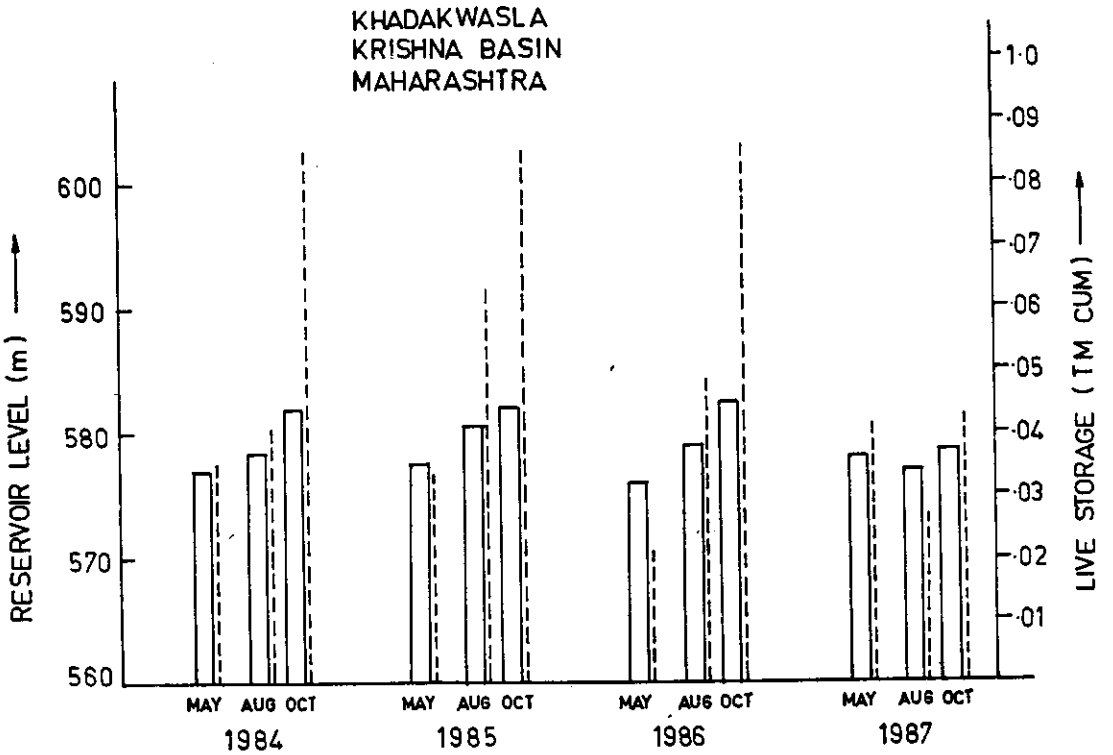


FIG. 4.6 -GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

cases the water table has been recorded falling and 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 groundwater imbalances created by surface water irrigation projects. Better analysis to correlate rainfall failure and groundwater regime can be done by taking into account the well abstraction data, which has not been done in the present case due to non-availability of relevant data.

5.0 ANALYSIS OF RESERVOIR STORAGE

In order to illustrate the impact of failure of monsoon on storage reservoirs, an attempt has been made to compare the storages only for four selected reservoirs (i) Jayakwadi, Godavari, (ii) Khadakwasla, Krishna (iii) Koyana, Krishna & (iv) Bhima, Krishna. For this purpose, the live storages & corresponding reservoir level in some selected months have been plotted against time. The weekly reservoir level data as supplied by Central Water Commission from 1984-1987 have been used for this analysis. As can be observed from figures 5.1 & 5.2 that all the reservoirs showed more deficient storages during year 1987 as compared to previous 2-3 years, except Jayakwadi reservoir. The Koyna reservoir showed worst impact of drought on storages as compared to previous years out of all the four reservoirs. The live storages in Koyna, Khadakwasla, Bhima & Jayakwadi during mid Oct.'87 were 80%, 49%, 92% and 152% respectively to previous years storages.



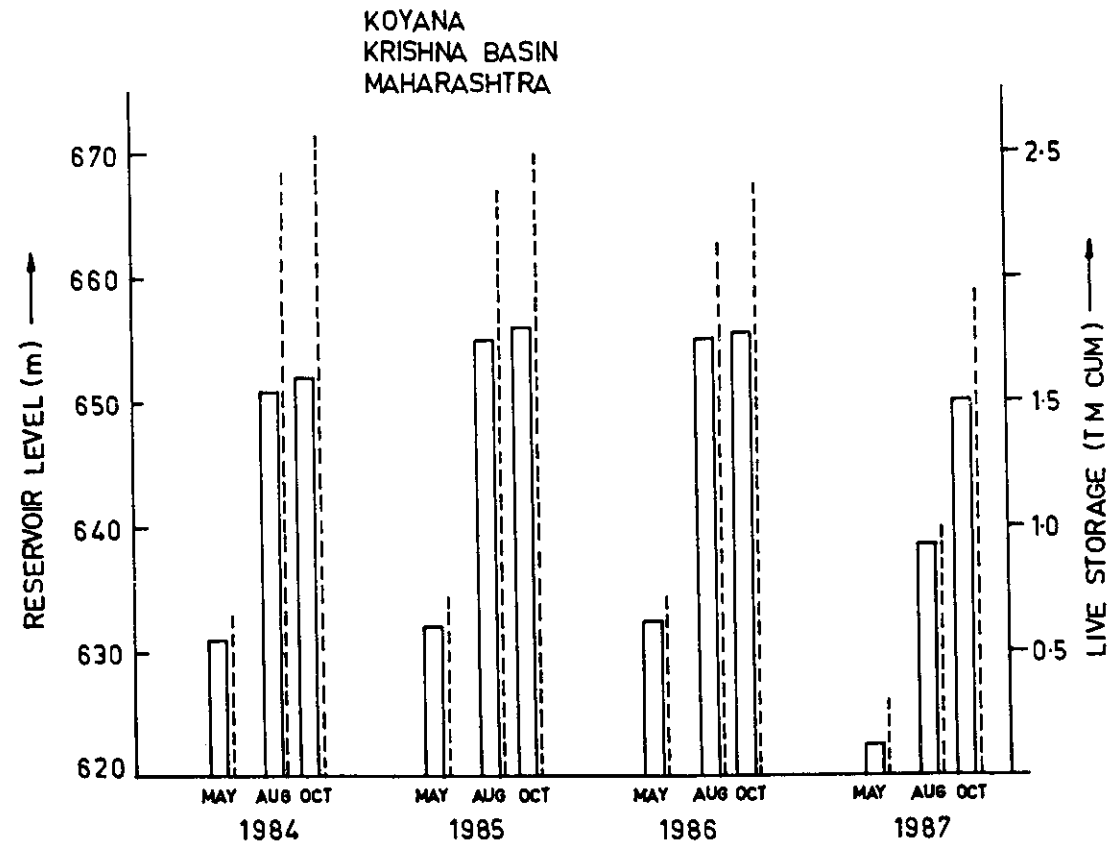


Fig. 5.1 : Reservoir Levels and Storages for Khadakwasla & Koyna Reservoirs.

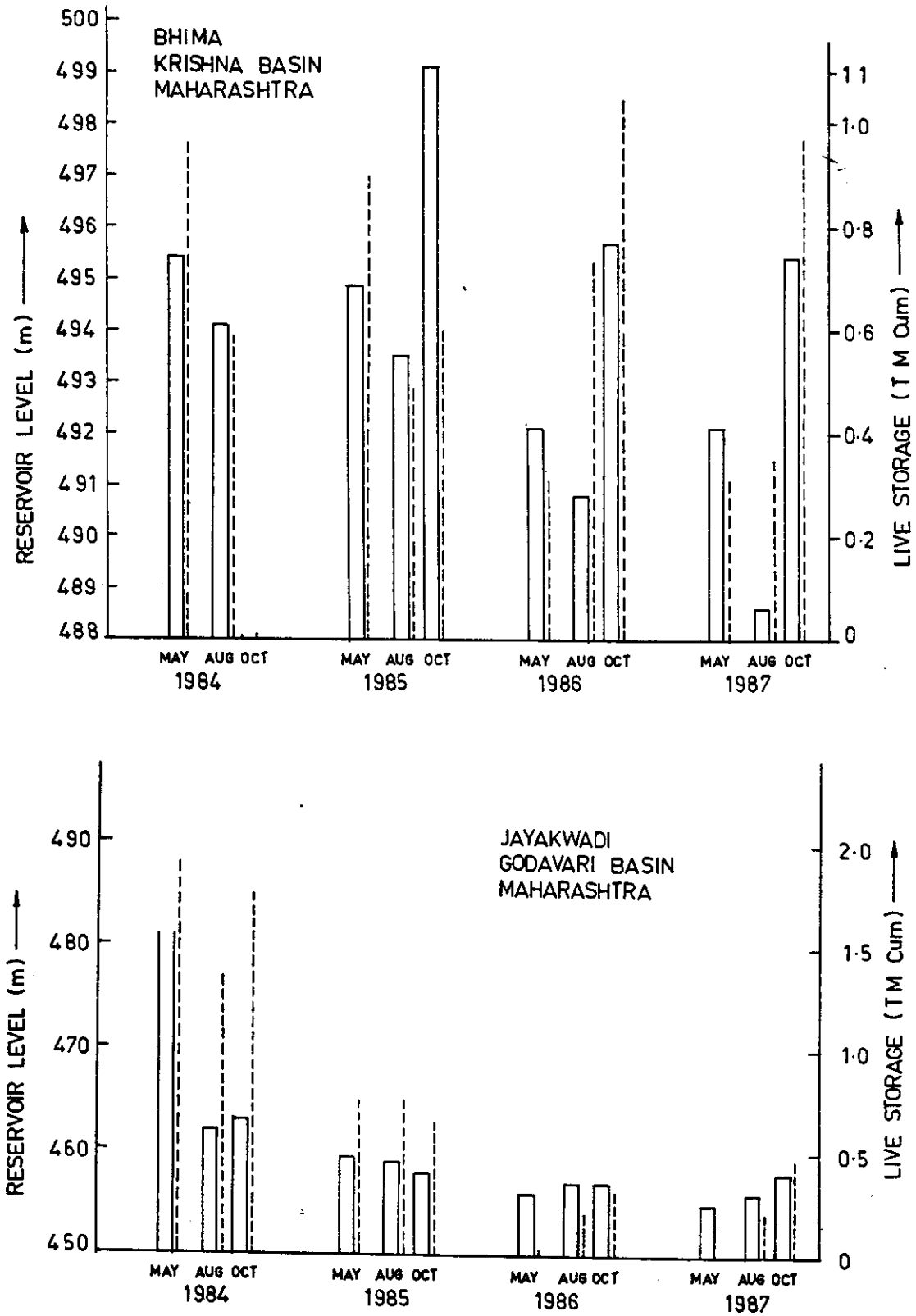


Fig. 5.2 : Reservoir Levels and Storages for Bhima and Jayakwadi Reservoir

6.0 CONCLUSIONS & RECOMMENDATIONS

1. The report presents analysis of rainfall & groundwater data for year 1987 on the hydrologic regime. For this purpose, six districts in the state namely Sholapur, Satara, Pune, Aurangabad, Ahmednagar and Sangli were selected for the analysis. The evaluation of structures of drought have been done using field data which have been obtained by carrying out field trips and information extracted from the published reports.

2. The rainfall analysis done on seasonal basis indicates that during year 1987-88 all districts have recorded deficiency in seasonal rainfall. It has been further observed that in most of the districts, the seasonal rainfall has been observed since '84 with the deficiency lying in the range of 50-60%.

3. Monthly deficiency of rainfall has been worked out in the water year 1987-88 for all the districts which have been chosen for analysis. The results indicated that in most of the months, the rainfall deficiency has been of the order of 10-79%, in most of the districts. Few months have however recorded slightly excess rainfall.

4. Probability analysis of monthly rainfall has been carried to work out the group range of annual rainfall at 75% level of the probability. For this purpose data from 1901-87 have been used. It has been found that most of the districts have a group range of 500-600 mm of rainfall at 75% probability level. However, districts of Pune and Satara have shown this range of 900-1000 mm using this analysis, the probability of occurrence of 75% of normal rainfall of various districts has also been worked

out. The results indicate that the districts of Pune & Sholapur have the probability level below 80% indicated that in 20 years out of 100 years these districts have chances of getting less than 75% of the normal rainfall. In case of Satara, the probability value was worked out as 84%.

5. The monthly rainfall data have been used for using Herbst Approach during the period of analysis and their duration. It has been found that all the districts recorded drought spells during the period 1984-87 except Satara and Ahmednagar. However, the intensity of spells during the period of spells was found maximum in case of Satara and in general 4-11 no. of drought spells were observed in various districts during the period of analysis. The district of Sangli experienced the longest spell of drought during 1983-84.

6. In order to work out the probability of getting a dry spell and its duration, dry spell analysis was carried out for the district. A dry spell was assumed to be of the period atleast 14 days long during which rain in one single day does not exceed 5 mm. The analysis results have found duration of dry spells for various districts and it has been found that for most of the districts, the duration of dry spells at 75% of probability work out to be 21-28 days.

7. Analysis of ground water data as obtained from ground water wells has been carried out for assessing impacts on ground water regime. For this purpose, 7-10 wells were chosen in all the districts and average ground water level (pre and post monsoon) have been worked out. Based on the allocation of pre and post monsoon reports as recorded in the last 10-12 years, inferences

have been made on impacts of water regime. It was observed that post monsoon level were declining in Pune, Satara and however the districts of Ahmednagar and Sholapur showed a trend in the monsoon indicating a rise in the post monsoon level.

REFERENCES

1. Agriculture Bulletin No.574, Deptt. of Agriculture, Maharashtra.

2. 'A Glimpse into Groundwater Resources of Maharashtra and its Development Programmes' May 1983, Directorate of Groundwater Survey and Development Agency, Govt. of Maharashtra, Pune.

3. Central Water Commission (1982), 'Report on Identification of Drought Prone Areas for 99 districts', New Delhi.

4. Epitome of Agriculture, Directorate of Agriculture, Maharashtra, 1987.

5. Herbst, pH, D.B. Bredenkamp and M.H.G. Barker (1966), 'A Technique for the evaluation of Drought from Rainfall Data' Journal of Hydrology, 4, pp. 264-272.

6. 'Hydrological Aspects of Drought 1985-86' - A case study prepared by NIH (CS-21).

7. 'Hydrological Aspects of Droughts (1986-87)' - A case study prepared by NIH (CS-24).

8. Institute of Hydrology, Wallingford, OXON, (1980) Research Report, Low Flow Studies.

9. Linsley, R.K. Kohler, M.A. and Paulhus, J.L.H., Hydrology for Engineers 1975, Second Edition, McGraw Hill Publications.

10. McMohan T.A. and Arenas A.D. (1982) Method of Computation of Low stream flow, UNESCO, Paris.

11. Sampath, T.V. (1989), 'Effect of Drought on Indian Agriculture' paper presented in International Symposium on Ground Water Resources Management in Drought Prone Areas', 27 Nov. to 1 Dec. 1990, New Delhi.

12. Singh, R.D. (1987) Hydrological Aspects of Drought RN-37, National Institute of Hydrology.

13. Water Resources of India, Central Water Commission (CWC) 1988.

14. Upadhyaya, D.S. & Gupta, D.K. (1989), 'Droughts in India'- A historical review Paper presented in international Symposium on Ground Water Resources Management in Drought Prone Areas', 27 Nov. to 1 Dec. , New Delhi.

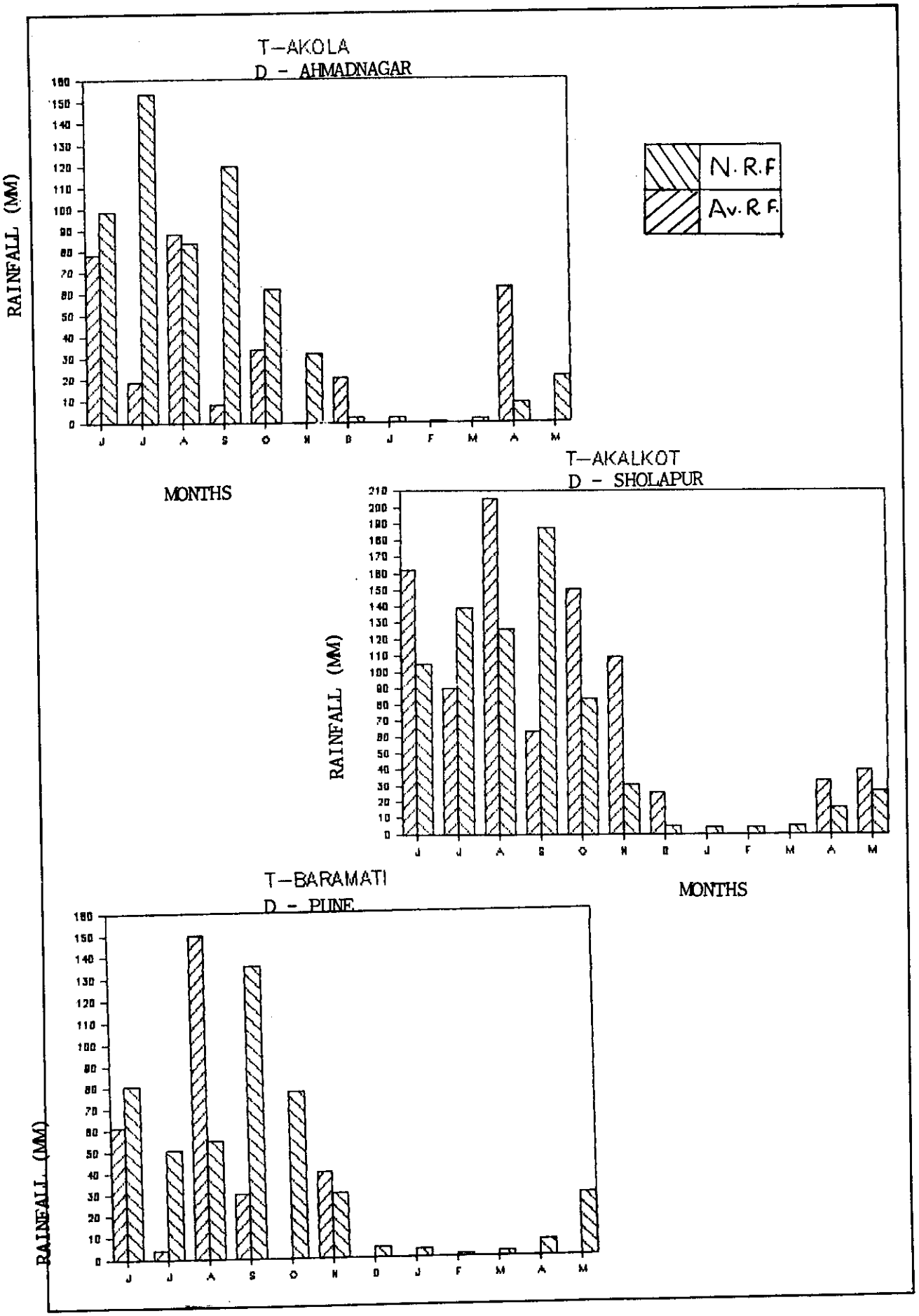
LIST OF OFFICES AND PLACES FROM WHERE DATA AND INFORMATION WERE COLLECTED

MAHARASHTRA

PLACE	
Bombay	Irrigation Department, Maharashtra
	Deptt. of Forest and Revenue
	Secretary, Rural Development Department of Agriculture
Pune	Asstt. Director, Ground Water Survey and Development Agency under Deptt. of Rural Development
	Met. Gr.I., Drought Research Unit, IMD
	Superintending Engineer, Poona
	Directorate of Agriculture
	C.E.(Irrigation), Zilla Parishad
	Pune Gauging Division, C.W.C.
Aurangabad	Chief Engineer, Aurangabad, Irrigation Circle
	Executive Engineer, Aurangabad Irrigation Circle
	Superintending Engineer Jayakwadi Project, Stage-I, Aurangabad Irrigation circle Deptt.,
Sholapur	Krishi Vidhyapeeth, under All India Coordinated Dry Land Farming Project of ICAR, Solapur

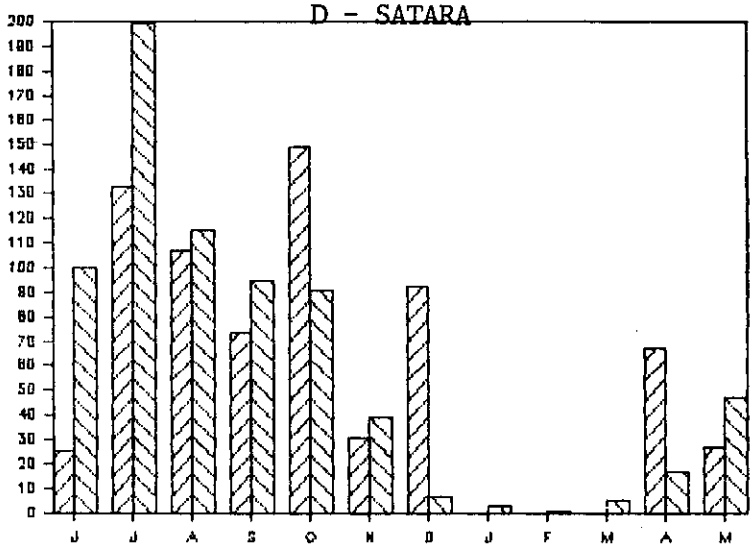
	Zilla Parishad
	DRDA
	Chief Geologists
	Agronomist & Agricultural Meteorologist N.A.P.P.Scarcity Zone, Mahatma Phule Krishi Vidhyapeeth
Beed	Senior Geologist
	GSDA
	Collector's office
	Zilla Parishad
	E.E. Irrigation Department
Parbhani	Agriculture Meteorology Deptt., Marathwada Agricultural University, Collector's office & Zilla Parishad
Ahmad Nagar	Zilla Parishad, Collector's Office
Satara	Collector's Office,GSDA,Zilla Parishad
Sangli	Collector's Office, Zilla Parishad.

STATE - MAHARASHTRA



STATE - MAHARASHTRA

T–KARAD
D - SATARA



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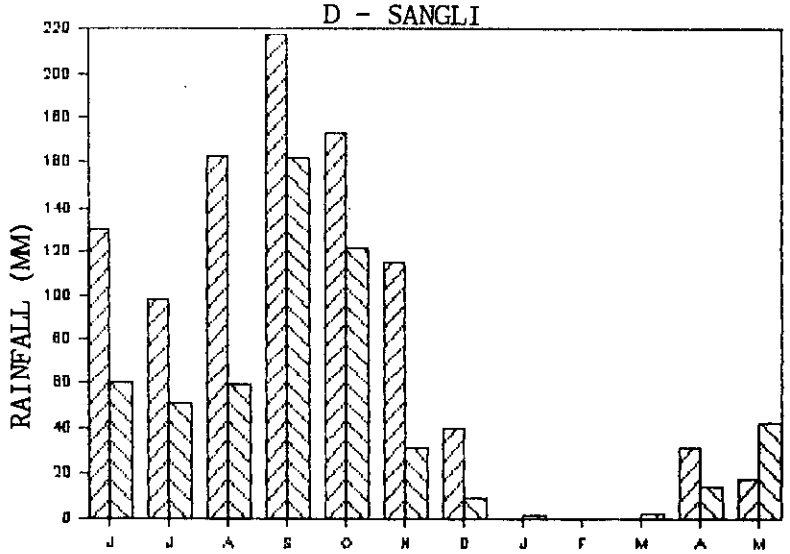
D - SANGLI



T–GANGAPUR
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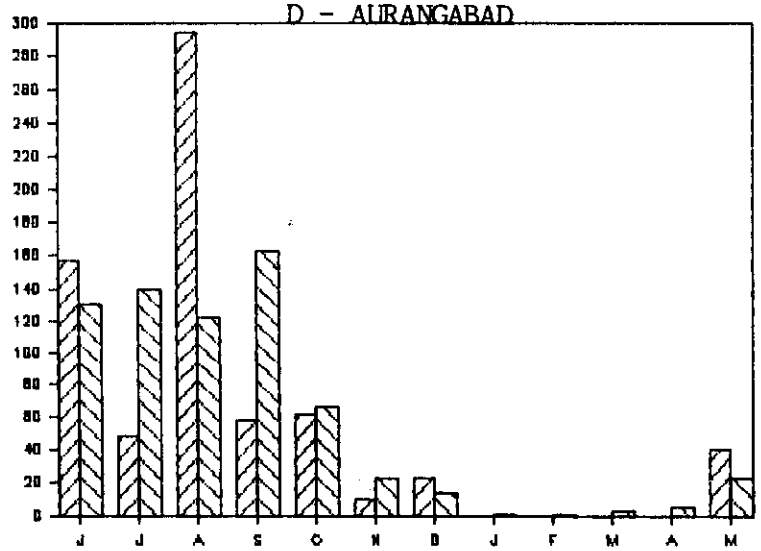

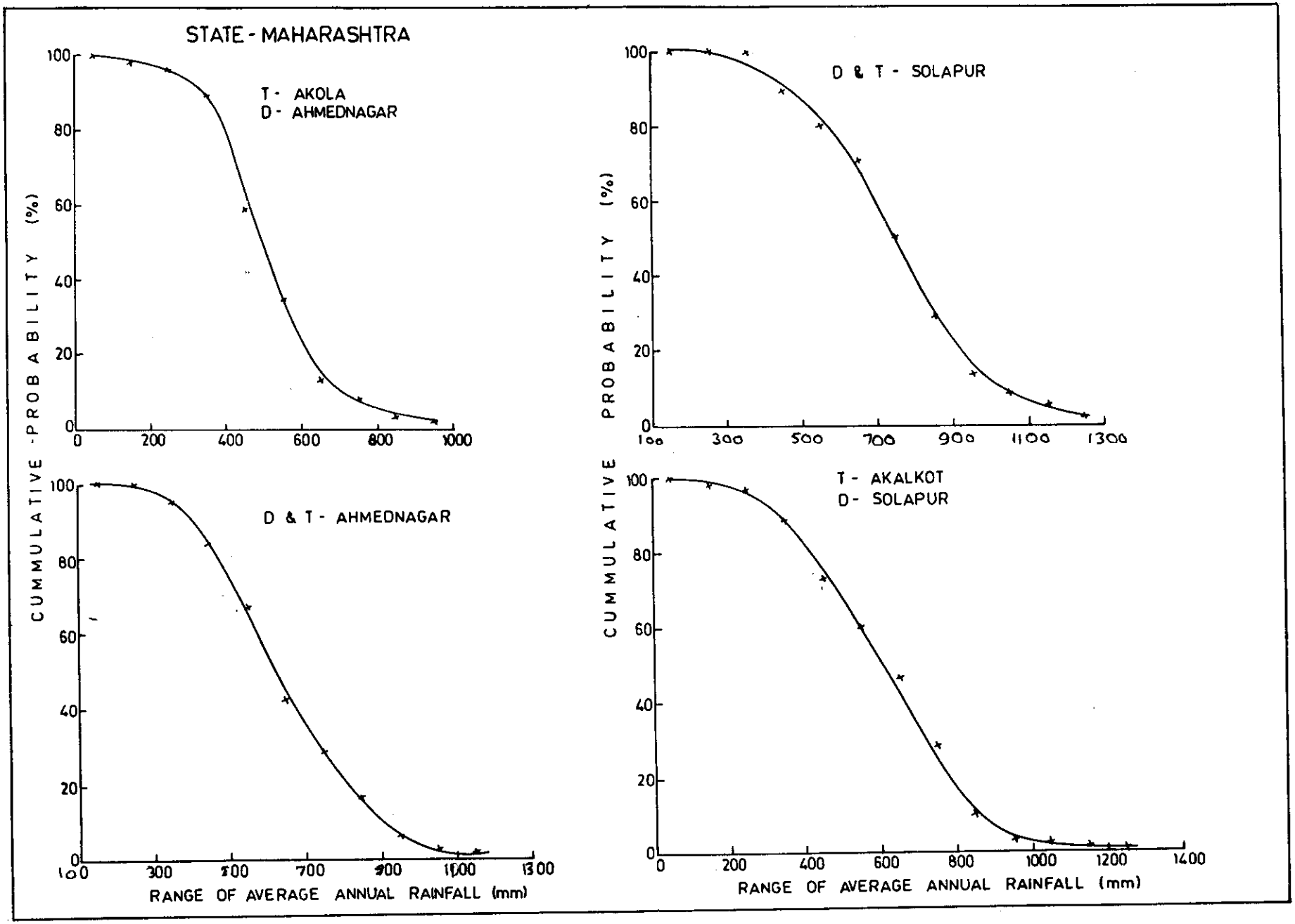
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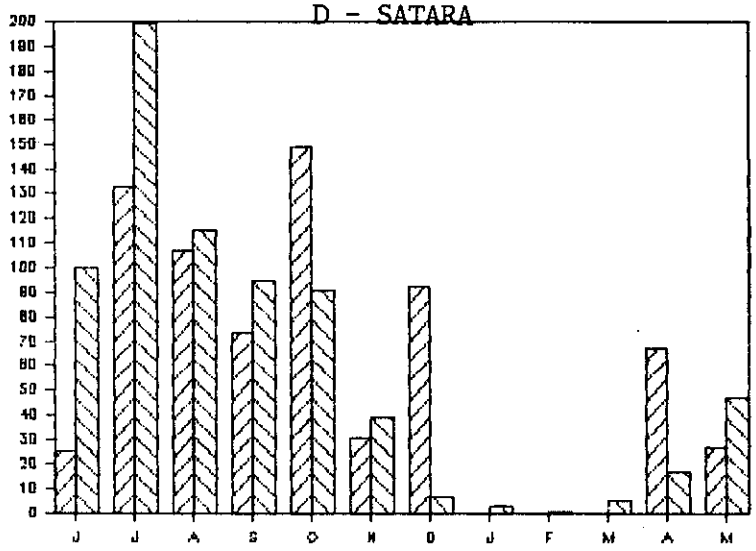
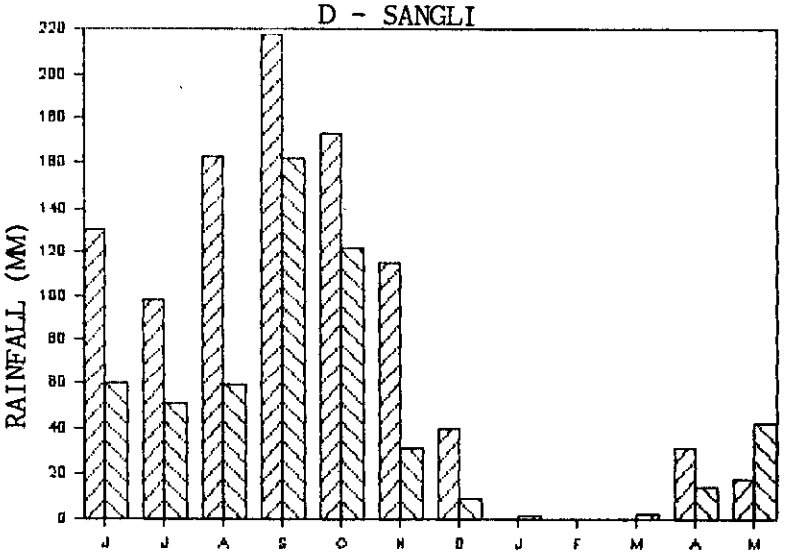
T - AKOLA
D - AHMEDNAGAR
D & T - SOLAPUR
D & T - AHMEDNAGAR
T - AKALKOT
D - SOLAPUR
CUMMULATIVE - PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)

STATE - MAHARASHTRA

T--KARAD
D - SATARA



T--ATAPADI
D - SANGLI



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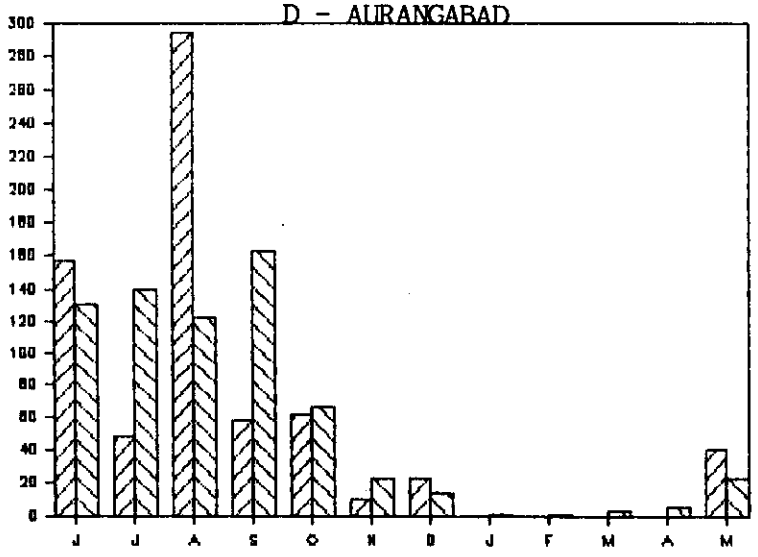
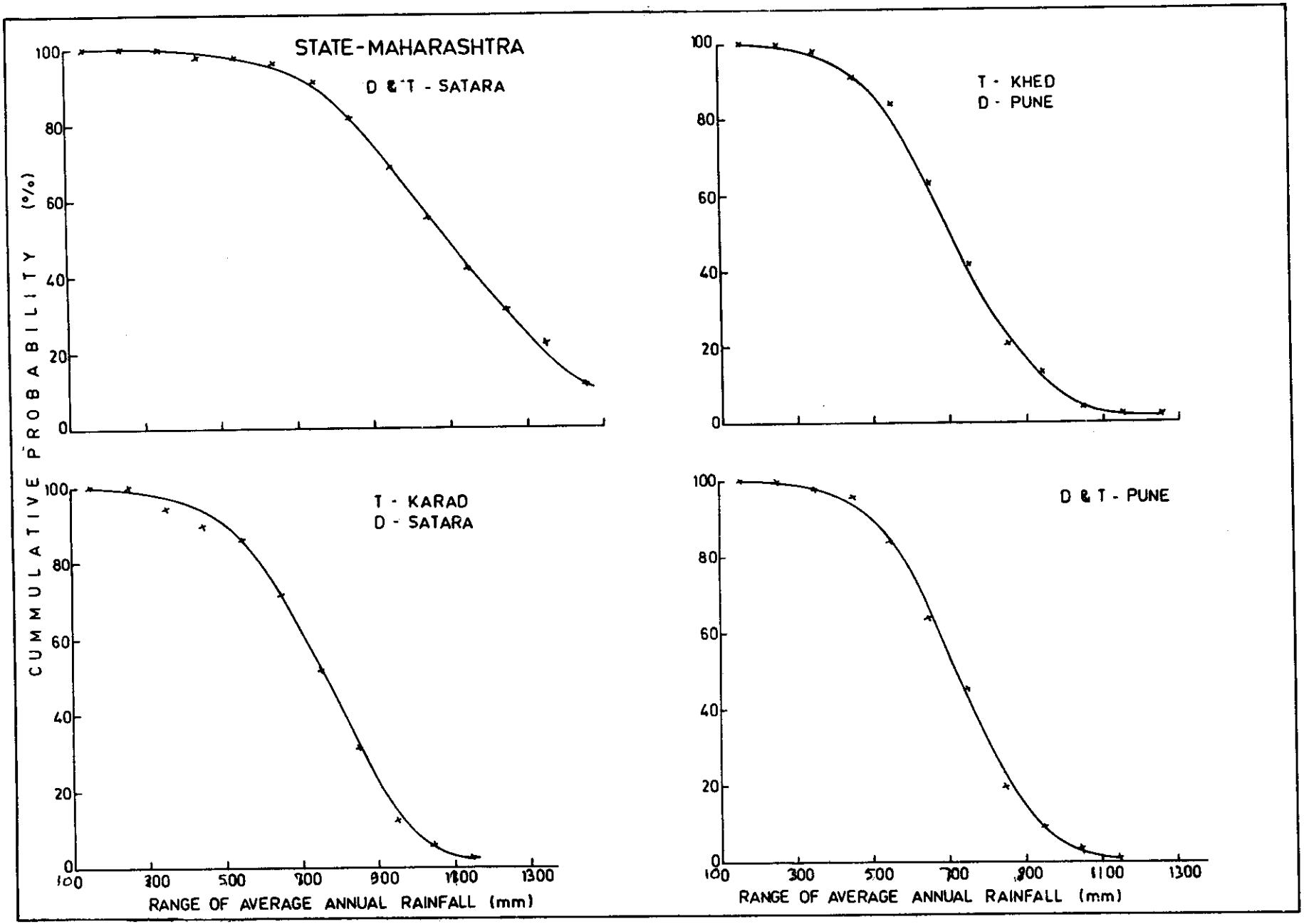
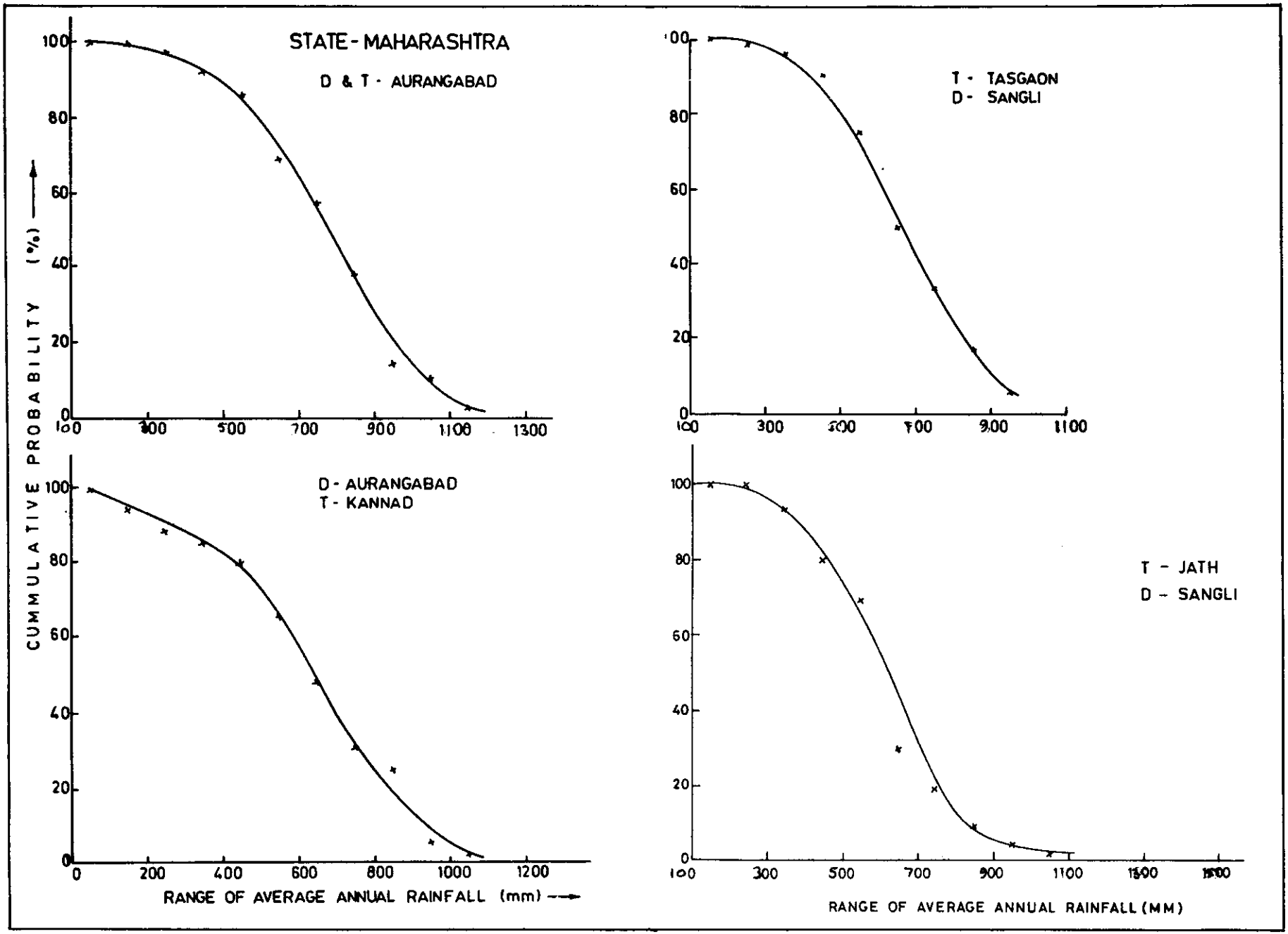



STATE - MAHARASHTRA
D & T - SATARA
T - KHED
D - PUNE
T - KARAD
D - SATARA
D & T - PUNE
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)
0
20
40
60
80
100
100
300
500
700
900
1100
1300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D & T - AURANGABAD
T - TASGAON
D - SANGLI
D - AURANGABAD
T - KANNAD
T - JATH
D - SANGLI
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (mm)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT AHMEDNAGAR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.147	0.000	0.000	0.000	0.000	0.000	0.000	1.436	0.000	0.000	0.00
1952	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.600	1.430	0.104	0.870	0.2
1953	0.543	0.329	0.621	0.000	0.497	0.000	0.000	0.000	0.000	0.000	0.037	0.511
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.278	0.976	0.00
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.736	0.000	0.000	0.000	0.000	0.1
1956	0.492	0.365	0.621	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1957	0.000	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.49
1958	0.000	0.000	0.000	0.000	0.000	1.340	0.000	0.000	0.000	0.000	0.000	0.00
1959	0.000	0.172	0.613	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.192	0.302	0.419	0.520	0.000	0.000	0.000	1.654	0.000	0.000	0.000	0.261
1961	0.540	0.526	0.621	0.000	0.000	0.000	0.000	0.000	2.205	0.000	0.000	0.00
1962	0.000	0.435	0.000	0.000	0.000	0.907	1.671	0.000	0.000	0.000	0.000	0.00
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.343	0.000	0.599	0.704
1964	0.830	0.351	0.622	1.015	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.12
1965	0.000	0.000	0.430	0.000	0.968	2.188	0.000	0.000	0.548	1.799	0.774	0.00
1966	0.000	0.000	0.527	1.039	0.000	1.588	0.584	1.767	0.762	1.918	0.000	0.00
1967	0.000	0.225	0.000	0.000	0.166	1.015	0.000	0.000	0.000	0.000	0.185	0.00
1968	0.000	0.000	0.000	0.000	0.783	1.933	0.126	0.673	0.000	0.000	0.000	0.00
1969	0.239	0.305	0.620	0.640	1.102	0.000	0.000	0.000	0.000	0.214	0.000	0.12
1970	0.157	0.297	0.619	0.000	0.000	0.000	0.339	0.000	0.000	0.000	0.553	0.67
1971	0.613	0.349	0.622	0.776	0.000	1.109	3.765	0.000	0.000	0.000	0.771	0.74
1972	0.659	0.555	0.622	0.000	0.173	2.176	3.204	2.039	1.625	2.016	1.109	0.85
1973	0.751	0.000	0.000	0.740	1.106	0.524	0.000	0.000	0.000	0.000	0.260	0.56
1974	0.751	0.345	0.000	0.511	0.000	0.066	0.795	0.000	0.000	0.000	0.000	0.25
1975	0.537	0.525	0.621	1.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.47
1976	0.679	0.559	0.000	0.516	1.058	0.000	0.000	0.000	0.601	1.799	0.000	0.00
1977	0.000	0.258	0.000	0.276	0.000	0.000	0.696	1.121	1.915	0.545	0.000	0.00
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.607	1.423	2.190	0.000	0.000	0.00
1979	0.000	0.213	0.613	1.015	1.117	0.000	0.356	0.856	1.210	2.103	1.427	0.961
1980	0.999	0.564	0.623	1.015	1.117	0.000	0.358	1.199	0.000	1.643	1.313	0.925
1981	0.974	0.562	0.623	1.015	1.117	0.000	0.585	1.368	0.000	0.479	1.026	0.851
1982	0.973	0.557	0.622	1.015	1.117	0.045	1.994	1.281	0.000	1.545	1.289	0.917
1983	0.969	0.561	0.623	1.015	1.117	1.846	0.000	0.000	0.000	0.000	0.577	0.66
1984	0.616	0.550	0.622	1.015	1.117	2.874	0.000	1.917	0.773	1.947	1.388	0.94
1985	0.998	0.563	0.623	1.015	1.117	0.569	1.296	2.471	1.615	2.248	1.463	0.97
1986	1.000	0.564	0.623	1.015	0.950	0.000	0.481	0.213	0.669	1.696	1.194	0.000
1987	0.000	0.000	0.000	0.174	0.000	0.855	2.309	0.000	1.558	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
5	1952	8	1954	23	0.31	7.12
5	1966	11	1966	9	1.06	9.50
5	1968	8	1969	14	0.42	5.90
8	1971	8	1971	5	1.62	4.35
10	1971	2	1973	17	1.54	26.14
7	1977	11	1977	5	1.06	5.29
7	1978	7	1983	61	0.84	51.30

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT SHOLAPUR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.533	0.347	0.07
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.094	1.175	1.113	0.528	0.10
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.298	0.000	0.000	0.000	0.00
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.165	0.04
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1956	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.01
1958	0.000	0.000	0.000	0.000	0.000	5.070	0.418	0.000	0.000	0.000	0.156	0.04
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.518	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.288	2.767	2.118	0.841	0.16
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.258	1.165	0.544	0.11
1964	0.000	0.000	0.000	0.000	0.000	0.751	0.000	0.000	0.000	0.000	0.000	0.00
1965	0.398	0.506	1.655	1.581	0.221	1.374	0.000	0.000	0.000	0.110	0.304	0.21
1966	0.000	0.000	0.000	0.000	0.000	1.111	0.000	0.000	0.000	0.175	0.236	0.05
1967	0.075	0.000	0.000	0.000	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.05
1968	0.000	0.000	0.000	0.000	0.000	1.248	0.000	2.265	0.000	0.000	0.153	0.04
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	1.133	3.334	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	1.364	3.081	3.321	2.041	1.660	0.698	0.137
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1974	0.000	0.000	0.000	0.000	0.000	0.000	1.149	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	1.339	0.000	0.000	0.000	0.000	0.000	0.00
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.063	1.043	0.506	0.10
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.553	1.352	0.602	0.12
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1979	2.229	16.666	16.461	9.641	1.097	4.138	4.738	4.113	4.247	3.171	1.524	0.83
1980	2.572	16.622	16.483	9.643	1.097	4.139	4.738	4.113	4.247	3.171	1.524	0.83
1981	0.234	0.000	0.000	0.000	0.000	0.000	0.178	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.625	0.000	0.096	0.211	0.05
1983	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	2.801	0.000	0.000	0.000	0.369	0.296	0.067
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.746	1.361	1.626	1.398	0.616	0.12
1986	0.000	0.000	0.000	0.000	0.000	0.000	2.223	0.466	0.824	0.647	0.000	0.00
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.789	0.000	0.268	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
4	1952	2	1953	11	0.95	10.45
4	1958	2	1959	11	0.52	5.75
8	1961	2	1962	7	1.74	12.17
4	1968	2	1969	11	0.70	7.67
4	1972	2	1973	11	2.33	25.60
8	1977	2	1978	7	0.94	6.58
10	1978	2	1981	29	3.92	113.68
4	1984	11	1986	32	0.79	25.34

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT PUNE

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.116	0.265	0.000	0.000	0.000	0.000	0.000	0.531	0.000	0.000	0.01
1952	0.344	0.000	0.139	0.000	0.000	0.000	0.000	0.000	0.720	0.000	1.112	0.6
1953	0.613	0.287	0.275	0.000	0.955	0.000	0.032	0.000	0.000	0.000	0.185	0.51
1954	0.359	0.274	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.483	1.266	0.0
1955	0.000	0.000	0.000	0.000	0.243	0.000	1.408	0.000	0.000	0.000	0.000	0.2
1956	0.426	0.245	0.272	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
1958	0.000	0.000	0.000	0.000	0.000	1.152	0.000	0.000	0.336	0.609	0.464	0.6
1959	0.596	0.265	0.274	0.253	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
1960	0.000	0.000	0.241	0.000	0.000	0.000	0.000	0.639	0.000	0.000	0.000	0.0
1961	0.506	0.418	0.271	0.000	0.000	0.000	0.000	0.000	1.350	0.571	0.035	0.4
1962	0.559	0.270	0.000	0.000	0.000	1.028	0.000	0.000	0.000	0.000	0.000	0.0
1963	0.000	0.000	0.000	0.000	0.000	0.213	0.000	0.000	0.121	0.000	0.527	0.6
1964	0.604	0.265	0.274	0.757	0.864	0.044	0.127	0.000	0.000	0.000	0.000	0.0
1965	0.000	0.000	0.242	0.000	0.663	1.396	0.000	0.000	0.839	1.995	1.549	0.0
1966	0.000	0.000	0.213	1.017	0.000	0.000	0.000	1.081	0.000	1.614	0.000	0.00
1967	0.000	0.000	0.239	0.000	0.000	1.002	0.000	0.000	0.641	0.617	1.245	0.00
1968	0.000	0.000	0.000	0.000	0.945	0.000	0.000	0.377	0.000	0.000	0.000	0.19
1969	0.418	0.245	0.272	0.000	0.789	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1970	0.000	0.000	0.251	0.000	0.000	0.000	1.343	0.226	0.000	0.000	0.039	0.65
1971	0.619	0.288	0.275	1.019	0.000	0.358	2.426	0.000	0.000	0.000	0.976	0.76
1972	0.665	0.295	0.275	0.226	0.188	1.462	0.509	2.254	0.773	2.085	0.333	0.5
1973	0.579	0.000	0.196	0.000	0.702	0.046	0.000	0.000	0.000	0.000	0.000	0.34
1974	0.486	0.258	0.273	0.000	0.000	0.000	0.486	0.000	0.000	0.000	0.000	0.2
1975	0.501	0.217	0.000	1.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.3
1976	0.460	0.257	0.000	0.603	1.286	0.000	0.000	0.000	0.000	1.244	0.000	0.0
1977	0.067	0.164	0.000	0.920	0.000	0.000	0.000	0.248	0.856	0.000	0.000	0.00
1978	0.000	1.753	1.535	1.349	1.418	3.866	4.732	5.057	4.318	3.170	2.164	1.31
1979	1.862	2.356	1.619	1.350	1.418	3.866	4.732	5.057	4.318	3.170	2.164	1.31
1980	1.862	2.356	1.619	1.350	1.418	3.866	4.732	5.057	4.318	3.170	2.164	1.31
1981	0.000	0.000	0.000	0.695	1.299	0.000	0.000	0.000	0.000	0.000	0.253	0.4
1982	0.000	0.000	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.000	0.00
1983	0.229	0.200	0.270	1.019	1.305	0.717	0.000	0.000	0.000	0.000	0.614	0.7
1984	0.643	0.000	0.000	0.998	1.304	0.000	0.000	0.600	0.000	0.000	0.000	0.0
1985	0.000	0.000	0.000	0.972	1.304	0.000	0.000	0.681	1.063	0.000	0.858	0.6
1986	0.629	0.290	0.275	1.019	0.508	0.000	0.367	0.000	0.000	1.513	0.052	0.00
1987	0.193	0.000	0.000	0.924	0.000	0.525	1.954	0.000	0.137	0.000	0.000	0.0

DROUGHT BEGAN MONTH	DROUGHT BEGAN YEAR	DROUGHT TERMINATED MONTH	DROUGHT TERMINATED YEAR	DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
8	1952	8	1953	13	0.27	3.51
9	1965	12	1965	4	1.33	5.31
2	1966	11	1966	10	0.46	4.59
2	1967	12	1967	11	0.43	4.78
8	1970	7	1973	38	0.66	24.99
1	1976	1	1981	37	3.71	137.39
8	1986	12	1987	17	0.45	7.66

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT SATARA

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.068	0.400	1.291	0.721	0.000	1.108	0.966	2.002	0.953	0.323	0.474
1952	0.165	0.117	0.403	0.000	0.308	0.000	0.000	0.000	0.446	0.362	1.131	0.707
1953	0.298	0.125	0.403	0.000	1.123	0.000	0.000	0.000	0.000	0.000	0.860	0.629
1954	0.253	0.122	0.000	0.784	0.870	0.000	0.000	0.000	0.000	0.000	0.963	0.034
1955	0.000	0.102	0.068	0.000	0.393	0.000	0.000	0.000	0.000	0.000	0.000	0.240
1956	0.035	0.109	0.402	0.000	0.000	0.235	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.096	0.402	0.977	0.730	0.000	0.000	0.000	0.340	0.000	0.000	0.000
1958	0.000	0.099	0.270	0.000	0.016	0.642	0.000	0.000	0.000	0.278	0.705	0.584
1959	0.228	0.120	0.403	0.493	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013
1960	0.000	0.101	0.268	0.000	0.000	0.000	0.000	0.000	0.000	0.379	0.235	0.441
1961	0.151	0.116	0.403	0.000	0.000	0.000	0.000	0.000	0.000	0.294	0.273	0.459
1962	0.157	0.116	0.241	1.164	0.000	2.468	0.000	0.000	0.000	0.055	1.050	0.000
1963	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.722	0.584
1964	0.251	0.121	0.000	0.020	0.609	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.006	0.140	0.419	0.000	0.455	0.000	0.000	0.000	0.084	1.360	0.341	0.000
1966	0.000	0.042	0.499	1.456	1.239	1.572	0.227	1.732	1.005	1.615	1.480	0.862
1967	0.013	0.508	0.515	1.457	1.239	0.974	0.000	0.122	0.000	1.334	1.405	0.841
1968	0.729	0.324	0.537	1.464	1.244	1.351	1.944	1.725	1.104	1.645	1.489	0.873
1969	0.391	0.130	0.404	1.410	1.213	0.310	0.000	0.000	0.000	1.119	1.331	0.765
1970	0.350	0.126	0.403	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.092	0.371	0.000	0.000	0.000	0.465	2.209	0.000	0.000	0.950	0.655
1972	0.268	0.125	0.403	0.000	0.000	2.197	2.234	3.801	2.671	1.901	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.223	1.728	0.000	0.000	0.000
1974	0.000	0.071	0.000	0.000	0.000	1.278	1.136	0.455	0.000	0.000	0.000	0.171
1975	0.000	0.107	0.402	1.410	0.000	0.000	0.141	0.000	0.000	0.000	0.000	0.172
1976	0.000	0.107	0.000	0.000	0.456	0.000	0.000	0.057	1.349	0.065	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.770	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	2.646	0.000	0.000	0.000	0.000	0.000
1979	2.745	1.180	1.004	1.673	1.336	3.711	6.105	5.870	5.769	2.949	1.905	1.275
1980	4.217	1.255	1.00	1.673	1.336	3.711	6.105	5.870	5.769	2.949	1.905	1.275
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.085
1982	0.000	0.104	0.404	0.030	0.000	0.202	0.412	0.000	0.000	0.000	0.000	0.000
1983	0.000	0.000	0.000	1.317	1.014	0.000	0.000	0.000	0.000	0.000	0.212	0.000
1984	0.000	0.000	0.000	0.000	1.116	1.588	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.043	0.398	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.052	0.247	0.529	0.000	0.000	0.000	0.000	0.000	0.766	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.247	0.000	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	5	1952	18	0.81	14.62
2	1966	7	1969	42	0.93	39.16
7	1971	10	1973	28	1.33	38.55
12	1978	4	1981	29	4.84	140.45

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT AURANGABAD

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.164	0.000	0.000	0.000	0.000	0.000	0.000	0.739	0.000	0.000	0.35
1952	0.083	0.000	0.446	0.737	0.000	0.000	0.000	1.024	0.578	2.002	1.510	0.00
1953	0.459	0.282	0.325	0.000	0.669	0.000	0.000	0.000	0.000	0.000	0.639	0.65
1954	0.228	0.243	0.000	0.000	0.407	0.009	0.000	0.000	0.000	0.000	0.997	0.00
1955	0.000	0.000	0.000	0.000	0.366	0.000	0.000	0.000	0.000	0.000	0.070	0.54
1956	0.000	0.000	0.519	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1957	0.324	0.259	0.000	0.000	0.000	0.000	0.433	0.000	0.000	0.000	0.000	0.00
1958	0.506	0.290	0.296	0.000	0.627	0.000	0.000	0.000	0.000	0.000	0.000	0.00
1959	0.000	0.000	0.519	0.000	0.659	0.000	0.000	0.000	0.000	0.000	0.000	0.22
1960	0.479	0.285	0.084	0.708	0.000	0.000	0.000	0.813	0.000	0.000	0.548	0.65
1961	0.778	0.075	0.530	0.000	0.000	0.000	0.000	0.965	1.555	0.000	0.000	0.00
1962	0.376	0.268	0.000	0.000	0.000	0.000	0.000	1.032	0.000	0.000	0.000	0.00
1963	0.000	0.000	0.000	0.426	0.000	0.000	0.000	0.000	0.000	0.000	0.340	0.54
1964	0.764	0.334	0.000	0.000	0.078	0.000	0.000	0.000	0.000	0.000	0.367	0.60
1965	0.000	0.000	0.265	0.000	0.761	0.051	0.000	0.000	1.079	2.347	1.587	0.00
1966	0.000	0.015	0.458	0.785	0.000	2.123	0.000	0.000	0.000	1.703	0.000	0.00
1967	0.000	0.000	0.000	0.534	0.833	0.000	0.000	0.000	0.000	1.332	1.360	0.00
1968	0.000	0.000	0.000	0.000	0.604	0.931	0.118	0.762	0.000	0.679	0.000	0.39
1969	0.696	0.522	0.552	0.746	0.524	0.000	0.000	0.000	0.000	0.785	0.000	0.12
1970	0.052	0.213	0.543	0.000	0.000	0.000	0.000	0.000	0.000	0.021	1.068	0.75
1971	0.615	0.542	0.554	0.746	0.000	0.000	4.045	0.000	0.000	0.000	0.560	0.65
1972	0.779	0.336	0.554	0.257	0.446	1.237	4.116	2.146	1.708	2.643	0.503	0.62
1973	0.775	0.000	0.397	0.735	0.789	0.000	0.000	0.000	0.000	0.254	1.115	0.74
1974	0.517	0.000	0.523	0.000	0.000	0.239	0.000	1.665	0.470	0.000	0.469	0.62
1975	0.424	0.276	0.546	0.746	0.000	0.950	0.000	0.000	0.000	0.000	0.652	0.65
1976	0.785	0.537	0.554	0.746	0.841	0.000	0.000	0.000	1.410	2.180	0.000	0.07
1977	0.584	0.505	0.000	0.000	0.519	0.000	0.000	1.073	0.559	1.479	0.000	0.00
1978	0.000	0.000	0.000	0.000	0.497	0.000	0.000	0.903	1.046	0.000	0.000	0.00
1979	0.000	0.000	0.000	0.554	0.814	1.928	0.000	0.000	0.000	0.000	0.000	0.00
1980	0.565	4.151	1.610	1.544	0.984	4.888	5.194	5.364	4.417	3.753	1.981	1.07
1981	0.000	0.000	0.200	0.717	0.000	0.815	1.053	0.000	0.000	0.000	0.000	0.00
1982	0.000	0.000	0.272	0.505	0.000	0.952	2.238	1.176	0.568	0.000	0.000	0.39
1983	0.696	0.522	0.552	0.746	0.841	2.309	1.155	0.000	0.000	0.000	0.525	0.57
1984	0.073	0.034	0.526	0.744	0.841	2.792	0.111	2.587	1.945	0.000	0.000	0.35
1985	0.581	0.520	0.514	0.501	0.699	0.950	0.000	1.864	2.163	0.000	0.655	0.65
1986	0.785	0.000	0.495	0.742	0.841	0.000	0.576	0.000	0.498	2.063	1.192	0.00
1987	0.000	0.000	0.000	0.585	0.000	0.000	0.000	0.000	1.297	0.030	0.000	0.00

DROUGHT BEGAN MONTH	DROUGHT BEGAN YEAR	DROUGHT TERMINATED MONTH	DROUGHT TERMINATED YEAR	DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
8	1952	7	1953	12	0.69	8.29
8	1961	10	1961	3	1.01	3.03
9	1963	12	1965	4	1.37	5.50
4	1966	6	1969	15	0.38	5.73
10	1970	7	1973	34	1.12	38.06
6	1974	8	1975	15	0.44	6.59
11	1975	11	1977	25	0.57	14.31
4	1978	9	1979	18	0.40	7.23
1	1980	1	1981	13	4.24	55.17
3	1982	8	1983	18	0.89	16.02
11	1985	12	1986	38	0.98	37.40

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE FOR DISTRICT Sangli

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.000	0.172	0.683	0.048	0.000	0.000	0.000	1.837	0.773	0.000	0.449	0.781
1952	0.689	0.000	0.649	0.000	0.000	0.687	1.006	2.279	2.313	0.000	1.099	0.964
1953	0.787	0.275	0.686	0.000	1.293	0.000	0.000	0.000	0.000	0.000	0.474	0.775
1954	0.686	0.265	0.000	1.074	0.000	0.887	0.000	0.000	1.138	1.116	1.790	0.000
1955	0.626	0.201	0.000	0.000	0.000	0.000	2.350	0.416	0.000	0.000	0.000	0.172
1956	0.562	0.000	0.670	0.051	0.000	0.977	0.000	0.000	0.157	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.422	1.187	0.000	0.000	0.000	0.292
1958	0.427	0.240	0.000	0.000	0.000	0.673	0.000	0.000	1.590	2.554	2.083	1.262
1959	0.947	0.291	0.687	0.000	0.000	0.000	0.000	0.000	0.000	0.771	0.000	0.120
1960	0.334	0.231	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.100	0.208	0.684	0.000	0.000	0.000	0.000	0.000	1.283	0.000	0.928	0.912
1962	0.760	0.273	0.000	0.167	0.000	2.946	0.000	0.000	0.000	0.000	0.207	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.011	0.000	0.000	0.521
1964	0.550	0.252	0.000	0.000	2.052	0.813	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.224	0.563	0.715	0.000	0.000	1.807	0.000	0.000	0.793	1.745	1.947	0.000
1966	0.000	0.000	0.000	2.298	0.000	0.000	0.000	2.326	0.745	1.689	0.000	0.000
1967	0.000	0.283	0.769	0.339	1.973	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.856	2.203	0.091	2.239	0.000	0.000	0.104	0.676
1969	0.633	0.260	0.000	0.113	1.057	1.986	0.000	0.000	0.000	0.953	0.239	0.000
1970	0.000	0.157	0.682	0.000	0.000	0.485	0.000	0.000	0.000	0.000	1.083	0.959
1971	0.785	0.275	0.632	0.000	0.000	0.000	1.669	0.000	0.000	0.000	1.450	1.070
1972	0.845	0.281	0.686	0.281	0.898	2.705	0.968	4.703	0.000	2.360	1.399	1.055
1973	0.636	0.280	0.686	1.550	0.000	0.000	0.000	0.000	0.767	0.000	0.799	0.779
1974	0.688	0.266	0.000	0.000	0.000	0.040	0.812	0.000	0.000	0.000	0.064	0.651
1975	0.619	0.259	0.685	1.896	1.769	0.000	0.000	0.000	0.000	0.000	0.000	0.312
1976	0.437	0.241	0.000	0.209	1.651	0.000	2.516	1.874	1.239	2.074	0.000	0.000
1977	0.000	0.161	0.000	0.000	0.000	0.000	0.000	0.650	1.608	0.000	0.000	0.000
1978	0.000	0.000	0.515	0.000	0.000	0.000	1.012	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.116	0.681	1.908	0.045	0.000	1.058	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.171	0.682	0.000	0.000	0.000	0.000	0.000	0.573	2.215	0.000	0.000
1981	0.000	0.000	0.470	0.000	0.997	0.000	0.000	0.884	0.000	0.000	0.000	0.432
1982	0.502	0.247	0.685	2.272	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.167
1983	0.360	0.233	0.685	2.779	2.012	0.000	1.786	0.000	0.000	1.565	1.354	0.000
1984	0.000	0.000	0.000	0.859	2.419	3.357	0.000	1.710	0.292	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	1.169	0.273	1.738	0.779	0.859	0.000	1.284	1.020
1986	0.000	0.000	0.643	1.218	1.598	0.000	2.508	1.482	0.655	2.932	0.553	0.799
1987	0.000	0.000	0.663	2.049	0.000	0.000	0.997	0.000	0.537	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	7	1953	31	0.70	21.80
9	1954	3	1955	7	1.10	7.73
9	1955	5	1959	9	1.47	13.23
9	1961	8	1962	12	0.70	8.45
9	1965	12	1965	4	1.25	4.99
8	1966	11	1966	4	1.23	4.91
5	1968	9	1968	5	0.90	4.49
10	1971	5	1973	20	1.27	25.35
12	1975	11	1976	12	1.32	15.78
5	1983	12	1987	56	0.85	47.56

Duration and Number of Dry Spells during Monsoon (4th June to 15th Sept.)

Akalkot (Sholapur)

First day of monsoon	Date of beginning of dry spell	Duration of dry spells (2 weeks in days)	Total no. of dry spells in a year
1	2	3	4
4.6.81	8.7.81	16	1
14.6.82	15.6.82	14	3
	16.7.82	14	
	24.8.82	24	
4.6.83	NIL	NIL	NIL
3.7.84	4.6.84	29	2
	10.8.84	31	
9.6.85	3.7.85	21	2
	17.8.85	23	
4.6.86	29.6.96	23	2
	14.8.86	22	
11.6.87	-	-	-
			10

Akola (Ahmednagar)

1	2	3	4
13.6.81	17.7.81	20	3
	7.8.81	16	
	24.8.81	14	
17.6.82	18.6.82	36	3
	26.7.82	17	
	26.8.82	21	
22.6.83	4.6.83	18	2
	17.8.83	22	
7.6.84	18.6.84	14	4
	20.7.84	15	
	8.8.84	21	
	28.8.84	14	
25.6.85	4.6.85	21	4
	26.6.85	21	
	18.7.85	20	
	8.8.85	39	
5.6.86	24.6.86	24	2
	19.7.86	59	
17.6.87	9.7.87	38	2
	27.8.87	20*	
			21

Satara (Satara)

1	2	3	4
5.6.81	-	-	-
19.6.82	4.6.82	15	2
	26.8.82	21	
14.6.83	17.8.83	27	1
8.6.84	20.7.84	14	2
	28.8.84.	15	
9.6.85	13.8.85	34	1
7.6.86	1.7.86	17	3
	23.7.87	14	
	14.8.86	33	
5.6.87	21.7.87	26	2
	27.8.87	18	
			11

Pune (Pune)

1	2	3	4
5.6.81	9.8.81	20	1
19.6.82	4.6.82	15	3
	5.7.82	16	
	26.8.82	21	
16.6.83	24.6.83	1	
8.6.84	20.7.84	15	2
	13.8.84	30	
8.6.85	10.6.85	18	
	29.6.85	18	
	3.8.85	44*	
4.6.86	20.7.86	17	2
	13.8.86	34	
5.6.87	9.7.87	39	2
	27.8.87	20*	
			14

Sangli (Sangli)

1	2	3	4
6.6.81	8.7.81	16	3
	26.7.81	18	
	14.8.81	23	
18.6.82	4.6.82	14	4
	24.7.82	24	
	20.7.82	15	
	31.8.82	16	
14.6.83	21.7.83	19	1
1984	Date not available		
10.6.85	28.6.85	18	2
	11.8.85	36*	
4.6.86	28.6.86	20	3
	19.7.86	18	
	14.8.86	33	
17.6.87	9.7.87	27	2
	27.8.87	20	
			15

Aurangabad (Aurangabad)

1	2	3	4
9.6.81	NIL	-	-
25.6.82	4.6.82 22.8.82	21 25	2
14.6.83	18.8.83	14	1
1984	Date not available		
15.6.85	12.8.85	21	1
4.6.86	23.6.86 13.8.86	25 34*	2
6.6.87	27.8.87	15	1
			7

Probability Analysis of Dry Spells

Taluk/Station (Distt.)	Class Interval (in day)	No. of Spells	Percentage	Cummulative Probability
Akkalkot (Sholapur)	14-21	4	40	100.0
	22-28	3	30	60.0
	29-35	3	30	30.0
	> 35	-	-	-
		10		
Akola (Ahmednagar)	14-21	14	77.7	100.0
	22-28	1	5.5	22.1
	29-35	-	-	16.6
	> 35	3	16.6	16.6
		18		
Pune (Pune)	14-21	8	57.1	100.0
	22-28	2	14.3	42.9
	29-35	2	14.3	28.6
	> 35	2	14.3	14.3
		14		
Satara (Satara)	14-21	7	63.6	100.0
	22-28	2	18.2	36.4
	29-35	2	18.2	18.2
	> 35	-	-	-
		11		
Sangli (Sangli)	14-21	10	66.6	100.0
	22-28	3	20	33.2
	29-35	1	6.6	13.2
	> 35	1	6.6	6.6
		15		
Aurangabad (Aurangabad)	14-21	4	57.1	100.0
	22-28	2	28.6	42.8
	29-35	1	14.2	14.2
	> 35	-	-	-
		7		

LIST OF OBSERVATION WELL

STATE-MAHARASTRA
DISTT-AURANGABAD

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	GP-10	NIPANI	19 49 30	75 27 14	555.96		0.1404
2.	GV-45	MANJRI	19 43 05	74 57 01	571.52		0.0731
3.	GV-40	PALASWADI	20 03 30	75 03 05	522.31		0.1011
4.	GV-44	KANNAD	20 15 20	75 06 30	520.42		0.1011
5.	GV-52	AKATWADE	19 50 17	75 26 30	432.10		0.0562
6.	TE-156	AMKHEDA	20 05 35	75 30 45	376.52		0.0506
7.	GP-5	SILLOD	20 10 00	75 57 06	515.90		0.1011
8.	GV-550	VAIJAPUR	19 55 42	74 43 50	533.50		0.0731
9.	GP-108	MANDI	20 37 40	75 52 45	516.59		0.1348
10.	GV-55	TALEGAON	19 50 05	75 54 51	472.56		0.1095

STATE-MAHARASTRA
DISTT-SANGLI

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	KR-52	PALUS	17 05 15	74 27 25	566.41		0.1122
2.	KR-54	ALTE	17 04 59	74 32 50	580.04		0.1225
3.	KR-57	KUCHI	17 05 40	74 51 50	553.10		0.1020
4.	KR-57	RANJANI	19 5 1	74 56 55	549.75		0.1055
5.	KR-43	SHIRALA	19 57 05	74 07 40	503.55		0.1020
6.	KR-46	TANDULWADI	19 55 55	74 17 20	550.40		0.0476
7.	SM-105	UMBARGAON	17 32 55	74 57 45	571.54		0.0544
8.	SM-115	KHANDUNGI	17 27 55	74 46 40	707.51		0.1225
9.	SM-105	ANTRAJ	17 11 10	75 13 00	505.55		0.1225
10.	SM-121	UTAGI	17 11 51	75 40 15	515.76		0.1088

LIST OF OBSERVATION WELLS

STATE-MAHARASHTRA
DISTT-PUNE

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	BK-1	UTTUR	18 18 01	73 59 05	661.40	1578	0.1009
2.	BM-20	KHED (RAJGURU-NAGAR)	18 51 10	73 52 [illegible]	609.76	1871	0.1196
3.	BM-16	BHAMBURDI	18 47 [illegible]	74 05 30	640.24	2351	0.1503
4.	BM-40	BAVDHAN	18 43 [illegible]	73 50 11	591.46	1972	0.1261
5.	BM-35	KATRAJ	18 28 30	73 51 [illegible]	607.08	1838	0.1175
6.	BM-[illegible]	WARJESANI	18 11 01	73 4[illegible] [illegible]	673.76	1916	0.1225
7.	BM-75	PANDARE	18 [illegible] [illegible]	74 [illegible] 35	550.10	2987	0.1910
8.	BM-[illegible]	[illegible]PUR	18 [illegible] 05	73 01 40	515.24	1126	0.0721

STATE-MAHARASHTRA
DISTT-SATARA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	BM-[illegible]C	NAIGON	18 [illegible] [illegible]	73 [illegible] 00	625.[illegible]	725	0.0694
2.	AK-[illegible]	MAHABALE-SHWAR	17 55 51	73 39 40	1[illegible]5.71	725	0.0694
3.	BM-[illegible]4	KARAD-II	17 [illegible] 44	74 1[illegible] [illegible]	5[illegible] 2[illegible]	1455	0.1387
4.	AK-[illegible]	KOREGAON	17 41 [illegible]	74 [illegible] 45	655.96	1152	0.1098
5.	KK-4	SATARA	17 41 00	73 [illegible] [illegible]	712.50	1273	0.1214
6.	BM-107	PALSHI	17 40 20	74 41 00	626.52	1819	0.1734
7.	AK-25	CHAILALA	17 25 02	74 30 00	657.01	1152	0.1098
8.	AK-1[illegible]	YERAPHAL	17 22 [illegible]	73 5[illegible] [illegible]	608.25	2183	0.2081

LIST OF OBSERVATION WELL

STATE-MAHARASTRA
DISTT-AHMADNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	GM-15	SUPA	1 [illegible]	7[illegible] 20	71[illegible]	5951	0.3497
2.	GV-22A	SHRIRAMPUR	1[illegible]	74 55 15	55[illegible]	1291	0.0758
3.	GV-29C	TELEGAON	1[illegible]	74 17 45	594.91	1071	0.0629
4.	GD-31B	TAKALI	1[illegible]	74 25 00	594.14	355	0.0208
5.	GV-34D	ARFGAON	1[illegible]	74 27 30	581.84	489	0.0287
6.	GV-13C	BOTA	1[illegible]	74 35 30	[illegible]13	2122	0.1246
7.	GV-16B	KOKANA	1[illegible]	74 24 00	4[illegible]1	3391	0.1246
8.	GV-19D	MALI-[illegible] SHEVGAON	1[illegible]	74 36 1	592.37	1759	0.1032

STATE-MAHARASTRA
DISTT-SOLAPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	M.S.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	SM-112	MADDEWADI	17 20 30	75 14 15	456.20	1801.51	0.1066
2.	SM-111	SAKHAL	17 24 45	75 31 45	474.06	1508.45	0.1004
3.	SM-40	KANDALGAON	17 40 55	75 17 15	466.46	1186.81	0.0790
4.	SM-102	MUSTI	17 40 45	75 04 30	460.16	2311.29	0.1539
5.	SM-35	KALMAN	17 35 45	75 40 45	495.90	1239.32	0.0825
6.	SM-20	PENJE	17 14 30	75 14 00	542.66	2065.54	0.1375
7.	SM-27	KUSLAM	17 18 30	75 40 45	502.50	1505.10	0.1002
8.	SM-106	SOLA	17 25 30	75 10 30	440.54	1795.57	0.1195
9.	SM-29	UPLAI	17 31 00	75 29 30	495.90	1807.32	0.1204