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Probability analysis of short period rainfall in dry farming tract in India

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सार – भारत में शुष्क खेती वाला क्षेत्र जहां वर्षा 400 से 1000 मि० मी० तक होती है 9 राज्यों के 87 जिलों से मिलकर बना है । इस क्षेत्र में वर्षा फसलों के अच्छी तरह से उगाने के लिए सीमा गुणांक मात्र है । कम वर्षा वाले वर्ष में भी फसल को एक निश्चित स्तर पर स्थिर रखने के लिए यह आवश्यक है कि कृषि के बारे में योजनाओं को क्षेत्र की संभावित जलवायु के संदर्भ में वैज्ञानिक व्यवस्था के आधार पर बनाया जाए । इसके लिए अन्य चीजों के अलावा सप्ताह दर सप्ताह होने वाली संभावित वर्षा की जानकारी आवश्यक है । इसलिये साप्ताहिक वर्षा का अपूर्ण गामा बंटन द्वारा सांख्यिक विश्लेषण कर 10 से 90 प्रतिशत तक विभिन्न प्रायिकता स्तरों में होने वाली न्यूनतम संभावित वर्षा को ज्ञात किया गया है तथा 50 प्रतिशत एवं 70 प्रतिशत वाले प्रायिकता स्तरों पर होने वाली संभावित वर्षा देखे गए प्रमुख अभिलक्षणों का विवेचन किया गया है । इस समूचे क्षेत्र को 7 समांगी वर्षा क्षेत्रों में बांटा गया है । प्रत्येक क्षेत्र की फसलावधि को भी दर्शाया गया है ।

ABSTRACT. The dry farming tract in India, where the annual rainfall varies from 400 to 1000 mm, comprises of 87 districts in 9 States. In this tract rainfall is the limiting factor for successful raising of crops. In order to stabilise the crop at a certain level even in a low rainfall year, it is essential that agricultural planning is drawn up on a rational scientific basis in terms of climatic potential of the area. For this purpose, amongst other things, it is necessary to know the minimum assured rainfall week by week. Weekly rainfall has, therefore, been subjected to statistical analysis by Incomplete Gamma distribution and minimum assured rainfall has been worked out at different probability levels from 10 to 90 per cent. Important features noticed on assured rainfall have been discussed in detail. The entire tract has been broadly divided into 7 homogeneous rainfall pattern zones. The duration of crop period in each zone has been indicated based on assured rainfall alone.

1. Introduction

India is mainly an agricultural country. The agriculture here mostly depends upon rainfed condition. The area having annual rainfall between 40 & 100 cm and practically with no irrigation facilities is known as the 'dry farming tract' and the package of agriculture practices drawn up for this area has come to be known as 'dry farming practices'. There are 105 district under this category of annual rainfall and 18 of these districts have good irrigation facilities. The Dry Farming Tract, therefore, comprises of 87 districts and is spread over Haryana, Punjab, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu (Fig. 1).

The region under this tract is more than 60 per cent of the total cultivable land in the country and about 40 per cent of the total food production of the country comes from this area. It is, therefore, but natural that increased attention is being given to the dry land agriculture.

In this tract the rainfall is limited, variability is high and evaporation is more. Agricultural production is solely dependent on rainfall and it suffers from twin problems of low production and instability. To overcome this chronic food problem, it is required to stabilise the production at a certain level. Therefore, agricultural planning in this area is called for on a scientific and rational basis in terms of basic climatology.

In this connection, studies on variability of seasonal rainfall, frequency of dry and wet spells, probabilities of occurrence of rainfall week by week will provide useful information for evaluating climatic potential for agricultural development and for evolving suitable cropping patterns. In this paper weekly assured rainfall at different probability levels from 10 to 90 per cent has been worked out. For this purpose one station has been chosen for each district. In the following paragraphs the results of the analysis are presented. It is hoped that this study will provide the necessary background material on rainfall potential for agricultural planning and management.
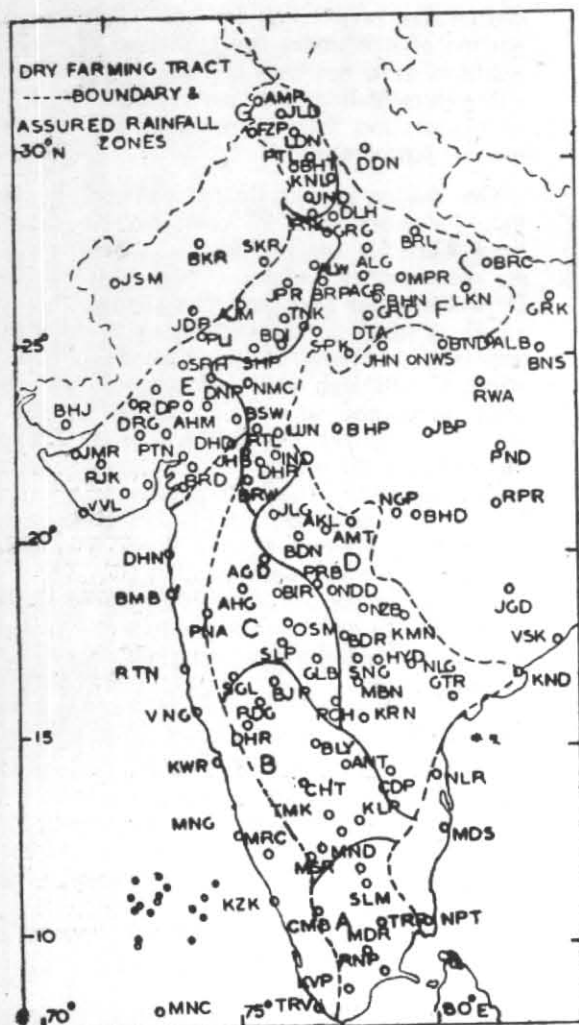
Fig. : 1. Locator map and assured rainfall (mm)
       pattern zones

Fig. 2. Assured rainfall (mm) at 50% level, week No. 26

2. Methodology

The best and easiest theoretical distribution to be fitted to the observed data is the normal distribution. But it is seen that the normal distribution does not give good fit to seasonal and annual rainfall at stations over the major portions of India (Mooley and Appa Rao 1971). It has also been seen that square root and logarithmic transformations are of limited utility in normalising the weekly rainfall. Normal distribution is a special case of Gamma distribution. Therefore, Gamma distribution probability model which covers a wide range of skewness and kurtosis can be applied to weekly rainfall. Mooley (1973) has applied Gamma distribution probability model for Asian summer monsoon monthly rainfall series. Mooley (1970) has also shown that Incomplete Gamma distribution is a good fit to the pentad rainfall at Indian stations during southwest and northeast monsoon season. Hence it can be fitted to weekly rainfall during these seasons. Weekly rainfall distribution includes zero and non-zero values of rain and Gamma
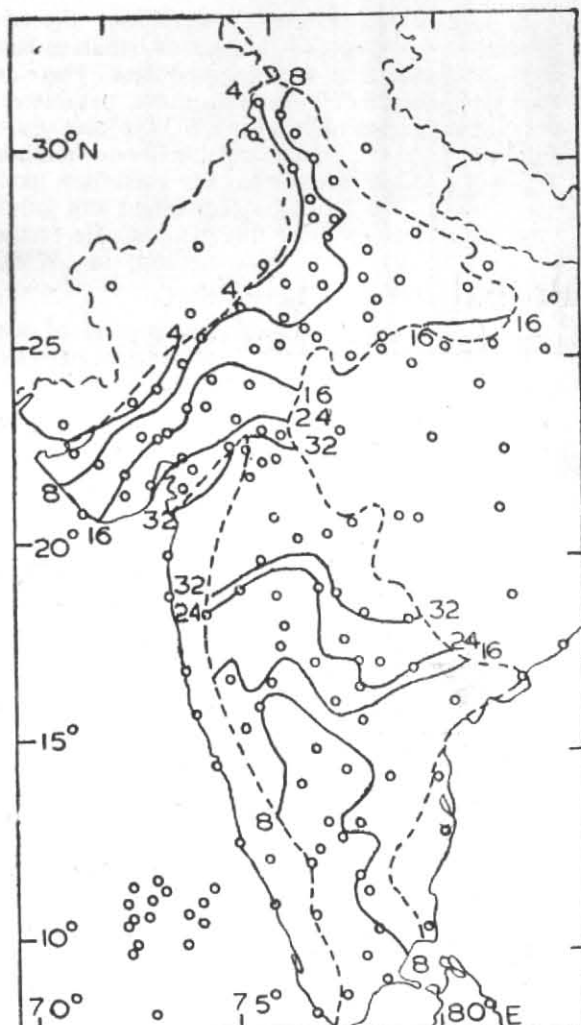
distribution is a good fit to non-zero values. Thom (1951) has given a suitable rainfall distribution for this type of data. The distribution is known as mixed Gamma distribution and is given by:

$$G(X) = q + pF(X) \qquad (1)$$

where, $F(X)$ is the Gamma distribution function, q is the probability of zero precipitation and $p = 1 - q$. We have applied the same distribution to weekly rainfall in the dry farming tract.

The distribution function $F(X)$ of the two-parameter Gamma distribution is

$$F(X) = \int_0^X \frac{x^{\gamma-1} e^{-x/\beta}}{\beta^\gamma \overline{|(\gamma)}} \, dx, \text{ where, } X, \gamma, \beta > 0 \quad (2)$$

$$F(X) = 0 \quad \text{when } X \leqslant 0 \qquad (3)$$

where γ, β are shape and scale parameters respectively of the distribution and $\overline{|(\gamma)}$ is the Gamma function of (γ). The distribution is bounded at the left side by zero. $G(X)$ is the probability of rain $< X$.

To obtain the rainfall probabilities the two parameters γ, β of the Gamma distribution have to be estimated from the observed data. There are various methods of estimating these parameters, *namely* (i) Method of moments, (ii) the least square method, (iii) the maximum likelihood method. Thom (1958) has shown that the maximum likelihood estimates are efficient, consistent and jointly sufficient. We have used this method. He further elaborately discussed this method in WMO. Technical Note No. 81 in 1966.

If $X_1, X_2 \ldots X_n$ are the non-zero values of rainfall the M.L. estimates $(\hat{\gamma}, \hat{\beta})$ of the parameters of the Gamma distribution are given by

$$\bar{X}/\beta - \hat{\gamma} = 0 \qquad (4)$$

$$\frac{\partial}{\partial \hat{\gamma}} \left[\log \overline{|(\hat{\gamma})} \right] + \log \beta - \frac{1}{n} \Sigma \log X = 0 \qquad (5)$$

log is the natural logarithm.

Thom (1966) has suggested an approximate solution of Eqn. (5)

which gives $\hat{\gamma} = \dfrac{1 + \sqrt{1 + 4A/3}}{4A} \qquad (6)$

where, $A = \log \bar{X} - \dfrac{1}{n} \Sigma \log X \qquad (7)$

$\hat{\beta}$ can be obtained from values of $\hat{\gamma}$ by using the Eqn. (4).

To get the lowest assured rainfall, the following equation has been solved on the computer by iteration process for X when $P_z = .30, .50$ and $.70$ resepctively utilising the procedure given in detail by Mooley (1973) where $z = X/\hat{\beta}$

$$P_z = 1 - \left(q + p \int_0^z \frac{z^{\hat{\gamma}-1} e^{-z}}{\overline{|(\hat{\gamma})}} \, dz \right) \qquad (8)$$

2.1. *Test of goodness of fit*

To test the fit of the Gamma distribution to the data under consideration a variance ratio test suggested by Cochran (1954) has been applied.

The test statistic is $\chi_v^2 = \dfrac{\sum\limits_{i=1}^{n} (X_i - \bar{X})^2}{\beta^2 \, \hat{\gamma}}$

n being the No. of occasions of non-zero rainfall, $\bar{X}$ the arithmetic mean of the non-zero rainfall amounts, $v (=n-1)$ being the degrees of freedom. The significance of χ_v^2 is to be seen referring to the 'chisquare' table for v degrees of freedom.

Mooley (1973) has shown the paramters $\hat{\gamma}$ & $\hat{\beta}$ are stable only when data sample is more than 50-60 years. Consequently we have applied this method for stations where data for more than 50 years are available.

3. Data

As mentioned earlier there are 87 districts in the dry farming tract. In some cases a portion of a district falls within the tract. In such cases the district has been taken for analysis, if two third portion of it is under dry land tract. Jammu and Kashmir have not been considered for the study, although rainfall in some parts is less than 100 cm, as evaporation there is not high on account of low air temperature.

One station in each district where daily rainfall data for more than 50 years are available has been taken for study (Fig. 1). Normally data of an observatory under India Meteorological Department has been preferred. In the absence of an observatory in the district or of rainfall for less than 50 years a State raingauge has been selected. Although minimum assured rainfall has been computed at all probability levels 10, 20, ..., 90 per cent. and for all the 52 weeks, the values at three levels 30, 50 and 70 per cent, during monsoon period are presented in Tables 2, 3 and 4 respectively and at 50 per cent, are depicted in different figures. Some characteristic feature of pre-monsoon rainfall over Peninsula, rainfall under the influence of northeast monsoon in south India and rainfall due to western disturbance in north India are also given in tables and figures.

4. Discussion

4.1. Annual rainfall of these 87 stations varies from 974 mm at Idar (Gujarat) to 411 mm at Pali (Rajasthan). No. of rainy days ranges from 61 to 19 days. Normally southwest monsoon sets in over Kerala on 1 June ; it gradually advances towards north and covers the whole Punjab by the first week of July. It starts withdrawing from Punjab in the 2nd week of September and leaves Tamilnadu during the 48th week (last week of November). Distribution of rainfall is not uniform. A prominent break is observed at many stations during August or early September.

4.2. Table 1 (a & b) shows that a number of stations in Karnataka and Tamilnadu receive good amount of rainfall in pre-monsoon season. About 20 mm of rainfall per week is assured in 30 per cent of the years [Table 1 (a)] at Tumkur, Bangalore and Mandya from 18th week (30 April-6 May).

4.3. *Monsoon feature*

It would have been better to give description of assured rainfall distribution for all the weeks but for the sake of brevity it has been limited to important weeks.

26th week (25 *June* - 1 *July*) — The monsoon is normally established over the whole country by this week. Rainfall has generally increased in all areas under the influence of the monsoon. The region of highest rainfall area shifts to Vidarbha and Telengana where it is more than 60 mm at 30 per cent. It reduces to 32 mm and 20 mm at 50 per cent (Fig. 2) and 70 per cent levels respectively. The zone of low rainfall is observed in south Karanataka and south Tamilnadu

R. P. SARKER et al.

TABLE 1

Assured weekly precipitation (mm) at 30% and 50% probability levels —Karnataka and Tamilnadu

Station (Abr.)	13	14	15	16	Weeks 17	18	19	20	21	No. of years
(a) 30% probability levels — Karnataka and Tamilnadu										
Bidar (BDR)	2	7	7	3	4	9	2	6	9	66
Gulbarga (GLB)	1	3	3	4	4	9	4	7	9	70
Bijapur (BJP)	—	4	3	2	8	6	3	6	16	70
Raichur ((RCH)	1	—	1	—	2	5	3	5	12	68
Bellary (BLY)	—	3	3	4	9	10	9	17	21	68
Chitradurga (CHT)	—	2	2	5	11	19	13	29	31	69
Tumkur (TMK)	—	2	9	10	13	22	17	31	31	69
Kolar (KLR)	—	—	3	9	10	9	12	28	34	69
Bangalore (BNG)	—	3	12	13	18	23	21	38	34	68
Mandya (MND)	—	3	13	17	14	25	31	51	35	69
Salem (SLM)	—	6	14	19	17	18	22	41	30	69
Coimbatore (CMB)	1	7	11	13	20	15	19	21	16	66
Tiruchirappli (TRP)	—	4	8	11	12	6	22	24	19	64
Madurai (MDR)	9	6	16	17	13	12	20	19	17	65
Kovilpatti (KVP)	10	15	30	21	17	20	13	17	8	66
Ramanathapuram (RMP)	5	7	10	10	3	3	6	5	—	66
Dharampuri (DMP)	—	2	13	14	11	17	21	34	35	69
(b) 50% probability level — Karnataka										
Bidar (BDR)	—	1	—	—	—	3	—	—	2	66
Gulbarga (GLB)	—	—	—	—	—	2	—	1	—	70
Bijapur (BJP)	—	—	—	—	2	—	—	—	5	70
Raichur (RCH)	—	—	—	—	—	—	—	1	4	68
Bellary (BLY)	—	—	—	—	3	3	3	7	8	68
Chitradurga (CHT)	—	—	—	—	4	6	4	14	14	69
Tumkur (TMK)	—	—	—	—	5	11	5	16	18	69
Kolar (KLR)	—	—	—	—	1	—	—	11	20	69
Bangalore (BNG)	—	—	2	5	7	10	7	20	18	68
Mandya (MND)	—	—	—	3	4	10	14	27	18	69

52 standard weeks with dates are : 1 (1-7 Jan), 2 (8-14 Jan), 3 (15-21 Jan), 4 (22-28 Jan), 5 (29 Jan-4 Feb), 6 (5-11 Feb), 7 (12-18 Feb), 8. (19-25 Feb), 9 (26 Feb-4 March; 8 days in leap year), 10 (5-11 Mar), 11 (12-18 Mar), 12 (19-25 Mar), 13 (26 Mar-1 Apr), 14 (2-8 Apr), 15 (9-15 Apr), 16 (16-22 Apr), 17 (23-29 Apr), 18 (30 Apr-6 May), 19 (7-13 May), 20 (14-20 May), 21 (21-27 May), 22 (28 May-3 Jun), 23 (4-10 Jun), 24 (11-17 Jun), 25 (18-24 Jun), 26 (25 Jun-1 Jul), 27 (2-8 Jul), 28 (9-15 Jul), 29 (16-22 Jul), 30 (23-29 Jul), 31 (30 Jul-5 Aug),, 32 (6-12 Aug), 33 (13-19 Aug), 34 (20-26 Aug), 35 27 Aug-2 Sep), 36 (3-9 Sep), 37 (10-16 Sep), 38 (17-23 Sep), 39 (24-30 Sep), 40 (1-7 Oct), 41 (81-4 Oct); 42 (15-22 Oct), 43 (22-28 Oct), 44 (29 Oct-4 Nov), 45 (5-11 Nov), 46 (12-18 Nov), 47 (19-25 Nov), 48 (26 Nov-2 Dec), 49 (3-9 Dec), 50 (10-16 Dec), 51 (17-23 Dec), and 52 (24-31 Dec; the last will have 8 days).

TABLE 2

Assured weekly precipitation (mm) at 30% probability

Station (Abr.)	\ Weeks																			
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Punjab																				
Amritsar (AMR)	3	10	10	17	29	52	56	66	43	46	35	41	42	29	25	2	—	—	—	—
Jullundur (JLD)	7	5	10	23	36	59	56	71	58	66	41	45	44	25	37	5	3	—	—	—
Bhartala (BHT)	3	11	10	28	44	42	43	62	51	49	38	44	34	26	44	—	—	—	—	—
Ferozpur (FZPD)	4	2	2	16	21	40	35	34	33	29	27	34	21	—	14	—	—	—	—	—
Ludhiana (LDN)	8	7	15	27	43	58	56	62	58	54	56	46	36	29	43	10	—	—	—	—
Patiala (PTL)	5	7	10	21	40	41	53	55	64	59	52	51	47	32	45	13	10	—	—	—
Haryana																				
Jind (JND)	2	7	19	23	29	50	41	60	38	42	41	37	42	20	37	—	5	—	—	—
Karnal (KNL)	6	10	15	30	46	62	69	64	66	61	65	60	44	28	40	11	14	—	—	—
Rohtak (RTK)	6	7	14	21	32	45	53	41	37	43	39	33	45	23	30	7	9	—	—	—
New Delhi (DLH)	4	12	18	28	37	50	71	56	69	62	44	46	37	33	43	18	16	—	—	—
Gurgaon (GRG)	6	16	13	25	37	50	63	55	54	50	43	49	44	34	44	13	13	—	—	—
Rajasthan																				
Bharatpur (BRP)	4	10	19	24	38	47	61	69	69	74	71	53	52	37	32	19	9	—	—	—
Alwar (ALW)	5	8	20	31	37	51	64	61	55	65	52	60	59	41	49	14	15	—	—	—
Jaipur (JPR)	6	12	14	18	32	57	63	68	53	62	52	60	45	25	27	13	10	—	—	—
Ajmer (AJM)	6	13	12	26	39	44	55	53	40	45	38	55	39	26	25	9	4	—	—	—
Pali (PLI)	—	5	12	15	28	29	32	41	37	47	27	46	62	11	16	—	—	—	—	—
Tonk (TNK)	3	18	21	22	49	72	72	82	56	55	69	69	59	27	27	10	10	—	—	—
S. Madhopur (SMP)	—	11	18	35	69	90	101	107	90	103	76	96	75	43	49	13	23	—	—	—
Bundi (BDI)	4	16	22	35	65	70	85	96	80	73	69	76	68	47	31	15	6	—	—	—
Udaipur (UDP)	6	26	21	38	59	58	53	63	60	45	43	51	60	43	27	20	18	—	—	—
Dungarpur (DNP)	7	18	27	39	78	76	67	86	77	46	43	52	57	45	38	26	8	—	—	—
Sirohi (SRH)	—	7	11	17	44	41	51	73	63	39	49	61	47	34	18	13	1	—	—	—
Shahapura (SHP)	—	23	29	27	49	51	69	70	63	71	61	65	55	33	22	19	—	—	—	—
Banswara (BSW)	5	20	34	49	83	89	80	108	110	69	70	87	95	59	44	41	6	—	—	—
Madhya Pradesh																				
Bhind (BHN)	—	6	16	23	50	67	77	81	58	83	75	69	67	57	45	29	12	—	—	—
Dhar (DHR)	15	35	55	70	77	78	78	96	77	54	50	67	76	61	63	42	32	11	—	—
Gird (GRD)	1	10	15	29	57	69	92	83	80	81	82	69	72	57	63	31	17	—	—	—
Sheopur (SPK)	—	14	20	30	61	89	87	98	78	85	79	76	73	42	34	21	8	—	—	—
Shivpuri (SVP)	3	19	30	46	57	92	93	95	86	90	73	85	79	54	44	31	15	—	—	—
Datia (DTA)	—	14	22	41	57	64	78	77	78	104	80	69	54	68	49	35	11	2	—	—
Neemuch (NMC)	6	21	32	40	69	73	75	81	79	63	61	73	65	60	35	33	14	—	—	—
Ratlam (RTL)	9	36	41	62	83	90	76	96	89	53	64	77	70	61	59	41	17	2	—	—
Ujjain (UJN)	5	37	41	57	81	87	63	99	87	58	66	70	65	67	42	42	15	1	—	—
Jhabua (JHB)	7	29	39	56	66	60	70	87	74	39	47	56	65	55	35	31	21	—	—	—
Indore (IND)	11	38	49	64	81	88	71	90	87	54	53	64	81	67	56	46	23	11	4	—
Barwani (BRW)	13	38	39	49	62	50	51	50	40	31	33	38	43	46	43	31	19	10	—	—
Gujarat																				
Deesa (DSA)	—	5	8	24	51	47	51	83	73	38	32	49	50	31	20	6	—	—	—	—
Patan (PTN)	—	—	22	37	77	70	71	65	61	51	31	36	33	35	30	13	—	—	—	—
Idar (IDR)	1	23	24	58	88	101	102	129	113	80	68	82	85	55	39	27	9	—	—	—
Dhrangadhra (DRG)	3	16	15	34	57	58	41	92	42	25	24	25	26	19	13	17	5	—	—	—
Bhuj (BHJ)	—	—	—	10	35	32	20	34	33	19	16	13	14	13	6	—	—	—	—	—
Ahmedabad (AHM)	3	15	26	50	86	79	67	101	76	55	45	46	49	50	35	22	5	—	—	—

TABLE 2 (*contd*)

Assured weekly precipitation (mm) at 30% Probability

Station	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Anand (AND)	—	22	31	59	102	78	97	105	80	66	53	46	62	56	36	33	5	—	—	—
Dohad (DHD)	2	24	39	63	66	79	62	84	71	42	57	49	56	55	49	36	23	—	—	—
Jamnagar (JMR)	—	8	11	31	50	57	41	57	30	21	25	27	18	19	6	5	—	—	—	—
Rajkot (RJK)	7	26	26	35	68	67	55	81	53	35	33	35	35	29	20	25	12	1	—	—
Baroda (BRD)	7	26	37	66	90	109	80	97	79	83	62	44	66	54	48	26	12	3	—	—
Bhavnagar (BHV)	5	22	25	47	57	65	53	66	46	25	38	33	36	35	26	28	16	—	—	—
Amreli (AML)	—	8	13	44	72	57	37	41	38	28	59	19	35	26	18	29	18	3	—	—
Broach (BRH)	6	35	44	88	98	84	78	101	67	43	45	53	53	55	40	35	27	6	—	—
Veraval (VVL)	5	23	37	43	100	65	58	47	50	33	25	20	21	18	25	10	5	—	—	—
Maharashtra																				
Jalgaon (JLG)	16	32	44	69	69	66	66	63	73	50	38	45	38	51	40	32	22	9	—	—
Amravati (AMT)	19	39	55	68	71	73	61	72	76	44	39	47	47	56	53	43	33	19	3	—
Buldhana (BDH)	21	45	68	78	64	64	67	67	72	44	36	53	49	49	51	40	29	17	—	—
Akola (AKL)	16	31	58	67	65	63	59	65	70	36	37	41	45	47	44	45	29	15	4	1
Aurangabad (AGD)	25	44	47	55	52	47	50	51	55	30	28	38	43	43	48	45	39	26	9	4
Parbhani (PRB)	27	29	59	56	64	51	57	66	57	41	46	50	54	70	54	57	58	25	8	5
Ahmednagar (AHG)	39	36	35	38	34	20	30	23	21	16	14	22	26	38	45	57	47	27	19	10
Bhir (BIR)	28	30	37	37	37	24	41	40	39	22	31	35	40	57	55	55	54	24	7	4
Nanded (NDD)	25	34	67	68	59	60	64	77	59	46	54	74	66	65	67	61	47	23	10	7
Osmanabad (OSM)	39	32	57	47	44	47	50	52	52	34	37	46	49	54	73	62	55	28	15	10
Solapur (SLP)	31	31	36	35	31	29	40	36	25	19	31	31	39	38	55	61	57	29	17	16
Sangli (SGL)	22	20	14	26	34	35	35	30	32	24	20	23	11	11	24	39	45	39	33	19
Andhra Pradesh																				
Hyderabad (HYD)	20	24	39	46	40	41	52	56	48	32	37	42	43	47	49	55	46	18	17	16
Sangareddy (SNG)	30	28	50	51	45	52	55	64	58	35	56	52	46	64	62	59	52	26	12	13
Mahbubnagar (MBN)	33	26	39	49	41	51	59	63	51	39	47	49	40	54	49	57	58	30	18	21
Kurnool (KRN)	31	18	22	24	24	30	35	43	36	23	31	35	31	33	32	52	46	19	23	25
Anantapur (ANT)	25	6	7	16	9	12	20	17	17	8	21	25	21	18	31	64	47	34	40	17
Cuddappah (CDP)	22	24	18	23	25	27	32	39	26	29	38	40	32	36	34	57	55	27	38	33
Nizamabad (NZB)	20	27	65	74	76	75	87	88	83	62	59	81	59	69	69	60	51	24	9	8
Karnataka																				
Bidar (BDR)	29	33	56	56	51	55	61	72	55	34	45	60	48	66	68	71	59	18	12	12
Gulbarga (GLB)	29	29	36	38	35	40	43	43	39	29	35	48	41	43	56	67	55	27	19	14
Bijapur (BJP)	32	16	20	19	19	16	16	25	15	9	19	19	23	24	33	57	54	32	29	15
Raichur (RCH)	26	21	30	34	34	27	35	40	31	25	38	35	39	36	40	54	53	32	24	18
Bellary (BLY)	19	8	6	11	9	14	14	13	12	8	19	18	19	15	26	51	54	41	33	27
Chitradurga (CHT)	25	12	12	16	19	19	23	25	23	16	21	27	20	15	17	34	46	39	47	29
Tumkur (TMK)	31	19	16	20	24	33	25	32	29	30	33	43	33	31	37	65	57	56	61	37
Kolar (KLR)	21	7	7	13	16	17	19	20	17	26	32	35	24	22	41	48	50	41	49	35
Bangalore (BNG)	26	18	16	18	31	29	33	31	28	38	41	45	35	33	37	56	56	56	58	34
Mandya (MND)	25	9	4	8	13	9	10	11	11	15	26	17	23	20	32	53	44	61	63	43
Tamilnadu																				
Salem (SLM)	18	27	22	23	24	28	27	31	28	45	39	48	48	33	44	43	47	59	55	55
Coimbatore (CMB)	12	9	8	10	13	12	16	14	8	10	7	6	6	5	5	13	16	25	41	53
Tiruchirapalli (TRP)	11	11	2	2	6	13	3	8	3	16	21	24	40	27	35	40	47	42	55	62
Madurai (MDR)	13	11	4	3	5	10	9	10	20	22	32	31	35	33	37	31	37	40	53	73
Ramanathapuram (RNP)	—	—	—	—	—	—	2	1	3	4	12	12	14	5	9	12	13	25	34	64
Kovilpatti (KVP)	5	—	—	—	—	—	—	—	—	2	5	5	12	9	13	15	18	26	45	59
Dharampuri (DMP)	29	17	4	9	18	18	18	20	13	18	25	26	36	27	41	50	45	57	51	50

TABLE 3
Assured weekly precipitation (mm) at 50 % probability

Station (Abr.)	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
										Weeks										
Punjab																				
Amritsar (AMR)	—	—	—	5	12	26	27	36	23	25	14	19	14	7	5	—	—	—	—	—
Jullundur (JLD)	—	—	3	8	15	32	30	40	34	36	19	21	18	6	8	—	—	—	—	—
Bhartala (BHT)	—	—	—	10	19	20	25	34	27	26	13	20	15	10	13	—	—	—	—	—
Ferozepur (FZP)	—	—	—	2	1	13	12	13	11	10	5	12	—	—	—	—	—	—	—	—
Ludhiana (LDN)	—	1	4	10	19	31	27	34	32	28	27	21	13	9	10	—	—	—	—	—
Patiala (PTL)	—	—	2	6	16	17	25	32	37	29	25	29	23	8	15	—	—	—	—	—
Haryana																				
Jind (JND)	—	—	—	6	9	24	22	26	19	21	13	15	16	—	7	—	—	—	—	—
Karnal (KNL)	—	—	4	10	19	31	35	38	35	34	31	26	18	6	11	—	—	—	—	—
Rohtak (RTK)	—	—	3	6	14	21	27	20	22	21	15	15	21	6	7	—	—	—	—	—
New Delhi (DLH)	—	3	4	7	15	24	36	28	34	33	23	22	15	9	13	—	—	—	—	—
Gurgaon (GRG)	1	5	4	8	15	24	35	28	30	25	20	23	21	9	12	—	—	—	—	—
Rajasthan																				
Bharatpur (BRP)	—	2	8	9	19	23	34	38	39	38	35	31	27	14	8	—	—	—	—	—
Alwar (ALW)	—	—	7	7	16	29	36	33	33	34	26	29	31	16	15	—	—	—	—	—
Jaipur (JPR)	—	2	5	6	16	32	33	35	29	26	23	31	18	11	8	—	—	—	—	—
Ajmer (AJM)	—	—	2	8	20	20	30	23	20	19	18	26	14	7	6	—	—	—	—	—
Pali (PLI)	—	—	—	—	9	7	10	17	16	16	4	13	18	—	—	—	—	—	—	—
Tonk (TNK)	—	3	5	6	24	36	42	40	29	25	30	34	29	5	4	—	—	—	—	—
S. Madhopur (SMP)	—	—	4	9	39	47	54	59	52	52	33	49	37	20	18	—	—	—	—	—
Bundi (BDI)	—	3	7	14	34	36	48	53	45	34	32	37	35	17	8	2	—	—	—	—
Udaipur (UDP)	—	9	8	16	33	31	29	31	30	19	20	22	29	17	9	8	3	—	—	—
Dungarpur (DNP)	—	4	8	13	43	43	38	45	40	23	20	23	23	15	8	—	—	—	—	—
Sirohi (SRH)	—	—	—	3	16	18	21	31	25	13	19	19	15	8	—	—	—	—	—	—
Shahapura (SHP)	—	5	—	9	25	28	38	41	33	32	27	31	25	9	—	—	—	—	—	—
Banswara (BSW)	—	5	11	22	46	55	46	52	55	35	35	43	40	23	12	9	—	—	—	—
Madhya Pradesh																				
Bhind (BHN)	—	—	2	6	27	35	45	47	34	44	41	41	35	23	20	5	—	—	—	—
Gird (GRD)	—	—	2	10	31	37	53	47	49	46	41	42	37	28	29	4	—	—	—	—
Sheopur (SPK)	—	—	6	10	32	47	50	53	43	43	41	41	36	17	10	1	—	—	—	—
Shivpuri (SVP)	—	7	11	15	33	51	57	59	49	51	44	47	41	29	18	9	—	—	—	—
Datia (DTA)	—	1	9	19	31	33	45	49	49	58	44	39	30	25	21	10	—	—	—	—
Barwani (BRW)	—	15	17	26	39	28	29	30	23	16	20	19	20	19	17	12	5	—	—	—
Neemuch (NMC)	—	7	10	18	39	39	40	44	38	31	29	35	34	25	12	14	1	—	—	—
Ratlam (RTL)	—	13	16	31	47	52	44	52	48	27	35	36	32	27	22	16	—	—	—	—
Ujjain (UJN)	—	13	20	29	45	47	35	56	43	29	34	32	32	29	9	12	—	—	—	—
Jhabua (JHB)	—	8	17	31	37	37	40	47	41	21	25	28	30	25	12	9	3	—	—	—
Indore (IND)	3	17	23	33	46	52	41	50	49	30	29	35	42	31	26	22	9	—	—	—
Dhar (DHR)	3	13	29	35	48	46	50	58	47	30	29	35	41	32	28	18	13	—	—	—
Gujarat																				
Deesa (DSA)	—	—	—	5	19	22	23	32	30	14	10	15	15	7	—	—	—	—	—	—
Patan (PTN)	—	—	5	11	34	32	38	30	25	24	11	10	10	8	—	—	—	—	—	—
Idar (IDR)	—	4	7	20	44	52	56	69	57	39	29	38	38	19	5	6	—	—	—	—
Dhrangadhra (DRG)	—	2	2	8	24	25	14	34	16	7	4	8	7	3	—	—	—	—	—	—
Bhuj (BHJ)	—	—	—	—	9	8	5	9	8	3	—	2	—	—	—	—	—	—	—	—
Ahmedabad (AHM)	—	3	8	25	42	39	32	48	39	23	20	20	18	15	8	—	—	—	—	—
Anand (AND)	—	—	9	27	50	54	52	63	41	25	21	22	30	17	9	8	—	—	—	—
Dohad (DHD)	—	3	11	33	39	44	35	45	36	22	31	24	23	26	17	13	—	—	—	—

TABLE 3 *(contd)*

Assured weekly precipitation (mm) at 50 % probability

Station (Abr.)	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Jamnagar (JMR)	—	—	—	5	16	22	13	20	9	—	5	6	5	—	—	—	—	—	—	—
Rajkot (RJK)	—	8	7	12	30	23	24	40	25	12	12	12	12	7	6	8	2	—	—	—
Baroda (BRD)	—	7	13	31	47	55	42	50	39	36	27	18	29	22	19	6	—	—	—	—
Bhavnagar (BHV)	—	6	8	19	28	32	27	32	22	10	13	11	15	12	9	7	—	—	—	—
Amreli (AMR)	—	—	—	16	35	23	16	20	15	11	22	4	15	7	5	—	3	—	—	—
Broach (BRH)	—	10	16	42	49	48	39	53	35	23	21	25	24	21	11	9	4	—	—	—
Veraval (VVL)	—	5	11	13	44	27	26	23	22	13	11	10	9	7	5	—	—	—	—	—
Maharashtra																				
Jalgaon (JLG)	3	12	20	37	43	41	41	37	41	30	18	23	18	25	13	12	7	—	—	—
Amravati (AMT)	7	18	28	41	46	42	38	36	45	23	19	24	24	29	25	22	13	3	—	—
Buldhana (BDH)	7	24	36	44	39	39	42	43	44	26	19	26	24	23	17	18	10	—	—	—
Akola (AKL)	5	15	30	38	40	35	36	39	40	19	17	19	22	23	19	22	9	—	—	—
Aurangabad (AGD)	10	22	27	32	31	27	31	31	31	16	14	20	21	22	19	24	16	9	—	—
Parbhani (PRB)	11	14	37	30	37	31	30	39	29	23	22	27	25	38	25	32	25	7	—	—
Ahmednagar (AHG)	21	18	17	17	16	9	15	12	9	6	5	7	9	16	18	29	21	8	4	—
Bhir (BIR)	14	15	18	16	20	12	19	19	18	10	12	15	18	27	21	31	23	8	—	—
Nanded (NDD)	10	16	39	43	39	31	37	48	42	25	29	39	37	35	33	34	22	5	—	—
Osmanabad (OSM)	16	17	31	27	25	25	28	32	31	19	19	22	26	29	37	34	26	10	—	—
Sholapur (SLP)	15	16	19	18	16	15	21	20	13	8	15	13	16	18	24	31	28	11	3	2
Sangli (SGL)	8	9	7	12	21	20	21	17	18	14	10	12	5	3	9	18	24	20	15	4
Andhra Pradesh																				
Hyderabad (HYD)	8	13	22	27	23	22	30	35	30	17	20	20	23	25	24	30	21	6	3	—
Sangareddy (SNG)	13	14	28	31	27	31	33	37	34	17	32	24	26	39	33	33	25	7	—	—
M. Nagar (MBN)	16	11	21	30	25	31	36	40	29	21	26	25	20	30	24	33	31	10	3	4
Kurnool (KRN)	15	7	12	14	12	17	20	26	22	13	15	16	15	16	15	27	26	7	10	9
Anantapur (ANT)	10	—	2	7	3	4	7	6	5	—	7	6	7	7	9	27	22	15	15	6
Cuddappah (CDP)	11	10	8	11	12	11	15	19	11	14	18	17	17	16	15	26	29	13	15	13
Nizamabad (NZB)	8	13	40	42	46	49	54	59	54	36	36	46	33	40	36	31	23	5	—	—
Karnataka																				
Bidar (BDR)	14	17	30	32	28	29	33	40	32	17	22	29	24	37	33	37	29	5	—	—
Gulbarga (GLB)	15	14	21	20	19	23	23	23	20	14	16	20	19	19	27	33	30	11	3	2
Bijapur (BJP)	17	7	8	8	8	7	7	10	5	3	6	7	7	7	14	28	32	13	10	4
Raichur (RCH)	13	11	17	18	19	16	20	22	16	12	19	15	19	16	19	28	30	13	5	3
Bellary (BLY)	7	—	—	5	4	6	6	4	4	3	6	4	5	5	10	25	29	20	11	9
Chitradurga (CHT)	12	6	6	8	11	11	13	16	13	9	1	13	10	7	8	18	21	18	23	9
Tumkur (TMK)	17	6	9	10	11	17	15	18	17	16	17	21	15	13	19	35	31	26	30	15
Kolar (KLR)	9	—	—	2	5	5	8	9	7	11	12	15	7	6	18	22	25	21	24	16
Bangalore (BNG)	14	9	9	10	18	15	19	16	15	20	23	27	19	16	18	28	27	27	28	15
Mandya (MND)	11	—	—	—	—	2	2	3	2	—	7	—	4	7	5	26	21	30	35	17
Tamilnadu																				
Salem (SLM)	9	15	9	13	13	16	15	14	15	26	22	30	30	19	23	23	26	32	31	30
Coimbatore (CMB)	3	4	3	3	6	6	5	7	3	3	2	1	—	1	1	4	6	13	20	30
Tiruchirapalli (TRP)	2	2	—	—	—	—	—	—	—	4	3	7	20	8	17	18	24	22	32	36
Madurai (MDR)	3	1	—	—	—	3	—	—	4	9	12	11	17	13	17	13	16	18	30	41
R. Puram (RNP)	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	3	4	6	10	33
Kovilpatti (KVP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	3	6	11	23	35
Dharampuri (DMP)	14	7	—	2	6	6	8	5	3	3	8	8	16	13	17	25	22	34	27	24

TABLE 4

Assured weekly precipitation (mm) at 70 % probability

Station (Abr.)	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
												Weeks								
Punjab																				
Amritsar (AMR)	—	—	—	—	—	—	9	9	16	10	11	3	5	—	—	—	—	—	—	—
Jullundur (JLD)	—	—	—	—	—	—	14	13	19	16	15	5	6	3	—	—	—	—	—	—
Bhartala (BHT)	—	—	—	—	—	—	5	11	14	9	7	—	—	—	—	—	—	—	—	—
Ferozepur (FZP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ludhiana (LDN)	—	—	—	—	—	5	13	10	16	15	11	8	5	—	—	—	—	—	—	—
Patiala (PTL)	—	—	—	—	—	3	—	8	15	19	10	9	10	7	—	—	—	—	—	—
Haryana																				
Jind (JND)	—	—	—	—	—	—	7	7	3	6	5	—	—	—	—	—	—	—	—	—
Karnal (KNL)	—	—	—	—	—	—	12	13	19	15	16	8	6	—	—	—	—	—	—	—
Rohtak (RTK)	—	—	—	—	2	6	9	7	10	5	—	3	4	—	—	—	—	—	—	—
New Delhi (DLH)	—	—	—	—	4	8	14	11	13	14	8	8	4	—	—	—	—	—	—	—
Gurgaon (GRG)	—	—	—	—	3	9	15	10	13	9	5	6	7	—	—	—	—	—	—	—
Rajasthan																				
Bharatpur (BRP)	—	—	—	—	7	8	17	16	19	15	11	15	8	—	—	—	—	—	—	—
Alwar (ALW)	—	—	—	—	4	13	17	15	18	13	5	9	11	—	—	—	—	—	—	—
Jaipur (JPR)	—	—	—	—	5	14	14	14	13	6	8	12	5	2	—	—	—	—	—	—
Ajmer (AJM)	—	—	—	—	7	5	12	6	7	2	5	7	—	—	—	—	—	—	—	—
Pali (PLI)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tonk (TNK)	—	—	—	—	8	11	20	13	11	6	—	9	9	—	—	—	—	—	—	—
S. Madhopur (SMP)	—	—	—	—	17	18	23	25	25	20	7	18	12	—	—	—	—	—	—	—
Bundi (BDI)	—	—	—	—	14	14	23	23	21	7	8	13	12	—	—	—	—	—	—	—
Udaipur (UDP)	—	—	—	3	16	12	13	12	10	5	7	6	10	4	—	—	—	—	—	—
Dungarpur (DNP)	—	—	—	—	21	21	18	17	16	10	6	6	5	—	—	—	—	—	—	—
Sirohi (SRH)	—	—	—	—	—	4	—	7	4	—	—	—	—	—	—	—	—	—	—	—
Shahapura (SHP)	—	—	—	—	9	11	17	16	12	—	5	8	3	—	—	—	—	—	—	—
Banswara (BSW)	—	—	—	6	21	30	23	19	22	14	13	16	11	5	—	—	—	—	—	—
Madhya Pradesh																				
Bhind (BHN)	—	—	—	—	12	13	21	24	16	19	17	19	13	—	—	—	—	—	—	—
Gird (GRD)	—	—	—	—	14	15	26	22	25	21	14	22	12	—	3	—	—	—	—	—
Sheopur (SPK)	—	—	—	—	11	20	25	22	17	16	13	16	8	—	—	—	—	—	—	—
Shivpuri (SVP)	—	—	—	—	15	23	30	34	23	22	22	22	15	6	—	—	—	—	—	—
Datia (DTA)	—	—	—	3	14	13	22	28	27	25	20	18	13	—	—	—	—	—	—	—
Barwani (BRW)	—	—	4	11	22	13	14	16	12	7	9	7	7	5	4	3	—	—	—	—
Neemuch (NMC)	—	—	—	5	19	17	18	19	14	12	10	12	13	6	—	3	—	—	—	—
Ratlam (RTL)	—	—	—	11	23	27	22	24	21	11	16	13	10	9	4	—	—	—	—	—
Ujjain (UJN)	—	—	2	8	21	21	17	27	17	9	13	10	12	6	—	—	—	—	—	—
Jhabua (JHB)	—	—	3	13	17	21	20	20	19	9	11	11	10	8	—	—	—	—	—	—
Indore (IND)	—	5	6	12	23	28	21	23	24	14	13	16	18	12	8	8	—	—	—	—
Dhar (DHR)	—	—	10	13	27	24	29	30	25	14	14	15	18	14	9	5	3	—	—	—
Gujarat																				
Deesa (DSA)	—	—	—	—	4	7	7	6	9	—	—	—	—	—	—	—	—	—	—	—
Patan (PTN)	—	—	—	—	10	5	15	9	6	7	—	—	—	—	—	—	—	—	—	—
Idar (IDR)	—	—	—	—	17	21	26	29	23	15	9	12	11	—	—	—	—	—	—	—
Dhrangadhra (DRG)	—	—	—	—	6	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bhuj (BHJ)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ahmedabad (AHM)	—	—	—	9	15	16	12	17	16	7	7	7	4	—	—	—	—	—	—	—
Anand (AND)	—	—	—	5	19	25	23	23	17	7	6	7	8	—	—	—	—	—	—	—

R. P. SARKER *et al.*

TABLE 4 *(contd)*

Assured weekly precipitation (mm) at 70 % probability

Station	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Dohad (DHD)	—	—	—	12	21	21	17	20	15	9	15	9	6	9	—	—	—	—	—	—
Jamnagar (JMR)	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Rajkot (RJK)	—	—	—	—	9	—	7	14	9	—	3	—	3	—	—	—	—	—	—	—
Baroda (BRD)	—	—	—	8	19	23	19	21	16	11	8	5	8	5	4	—	—	—	—	—
Bhavnagar (BHV)	—	—	—	—	10	11	9	11	8	2	—	—	3	—	—	—	—	—	—	—
Amreli (AML)	—	—	—	—	13	6	4	7	3	—	—	—	3	—	—	—	—	—	—	—
Broach (BRH)	—	—	—	13	20	24	16	24	15	10	8	9	8	5	—	—	—	—	—	—
Veraval (VVL)	—	—	—	—	13	8	9	8	8	4	4	3	3	—	—	—	—	—	—	—
Maharashtra																				
Jalgaon (JLG)	—	—	6	17	25	23	23	20	21	16	7	9	7	9	—	2	—	—	—	—
Amravati (AMT)	—	6	11	21	28	22	21	27	23	9	7	9	9	13	9	9	3	—	—	—
Buldhana (BDH)	—	11	17	22	21	21	24	25	24	15	9	10	9	9	—	6	—	—	—	—
Akola (AKL)	—	5	11	19	22	17	20	21	20	9	5	6	8	8	—	7	—	—	—	—
Aurangabad (AGD)	2	8	12	16	16	13	17	18	15	7	6	9	8	9	5	10	3	—	—	—
Parbhani (PRB)	—	5	20	13	18	16	13	21	12	12	9	12	8	17	9	15	5	—	—	—
Ahmednagar (AHG)	8	6	5	6	5	3	5	5	3	—	—	—	2	4	5	11	7	—	—	—
Bhir (BIR)	5	4	7	4	9	4	7	7	6	2	1	4	5	9	3	15	6	—	—	—
Nanded (NDD)	2	6	19	25	24	13	19	28	23	11	13	16	16	16	13	15	7	—	—	—
Osmanabad (OSM)	4	7	15	13	12	11	13	18	16	8	8	8	10	13	14	15	8	—	—	—
Solapur (SLP)	5	6	9	7	6	6	9	9	6	—	5	4	3	6	7	13	10	—	—	—
Sangli (SGL)	—	1	—	4	11	9	11	8	9	7	3	5	—	—	—	4	9	6	—	—
Andhra Pradesh																				
Hyderabad (HYD)	2	5	10	15	11	10	15	20	17	7	9	8	10	11	10	13	7	—	—	—
Sangareddy (SNG)	3	5	13	16	15	16	17	19	17	6	15	8	13	21	15	15	7	—	—	—
M. Nagar (MNB)	4	2	9	17	14	16	20	23	14	10	11	8	7	14	10	17	13	—	—	—
Kurnool (KRN)	6	2	5	7	5	8	10	15	12	6	6	5	6	5	5	11	13	—	—	—
Anantapur (ANT)	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	7	8	—	—	—
Cuddappah (CDP)	3	1	2	3	4	2	5	6	3	4	6	4	7	3	4	8	12	4	3	—
Nizamabad (NZB)	—	4	22	21	25	30	30	37	34	18	20	23	15	20	14	12	5	—	—	—
Karnataka																				
Bidar (BDR)	4	7	13	16	13	13	15	20	16	7	8	10	9	17	13	16	9	—	—	—
Gulbarga (GLB)	5	5	10	8	9	11	10	11	8	5	5	5	6	6	10	13	13	—	—	—
Bijapur (BJP)	7	1	—	1	2	1	1	3	—	—	—	—	—	—	3	11	15	3	—	—
Raichur (RCH)	4	4	8	8	8	7	9	10	7	4	8	4	7	5	7	12	15	—	—	—
Bellary (BLY)	—	—	—	1	—	1	—	—	—	—	—	—	—	—	1	8	13	7	—	—
Chitradurga (CHT)	4	2	2	3	6	5	6	9	7	4	5	5	4	2	3	7	6	6	7	—
Tumkur (TMK)	6	—	3	4	2	7	—	—	—	6	6	7	4	3	7	15	12	5	8	2
Kolar (KLR)	—	—	—	—	—	—	—	2	—	—	—	2	—	—	—	7	6	5	7	—
Bangalore (BNG)	6	3	4	4	9	6	9	7	6	9	10	13	8	6	7	12	10	10	10	4
Mandya (MND)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	3	3	10	—
Tamilnadu																				
Salem (SLM)	3	6	—	5	5	7	7	5	6	13	10	16	17	9	9	10	13	14	15	14
Coimbatore (CMB)	—	1	—	—	1	2	—	2	—	—	—	—	—	—	—	—	—	5	7	15
Tiruchirapalli (TRP)	—	—	—	—	—	—	—	—	—	—	—	—	6	—	5	5	8	9	16	19
Madurai (MDR)	—	—	—	—	—	—	—	—	—	1	—	—	5	—	—	3	4	4	14	21
R. Puram (RNP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13
Kovilpatti (KVP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	17
Dharampuri (DMP)	4	1	—	—	—	—	—	—	—	—	—	—	—	3	4	3	9	7	18	11	8

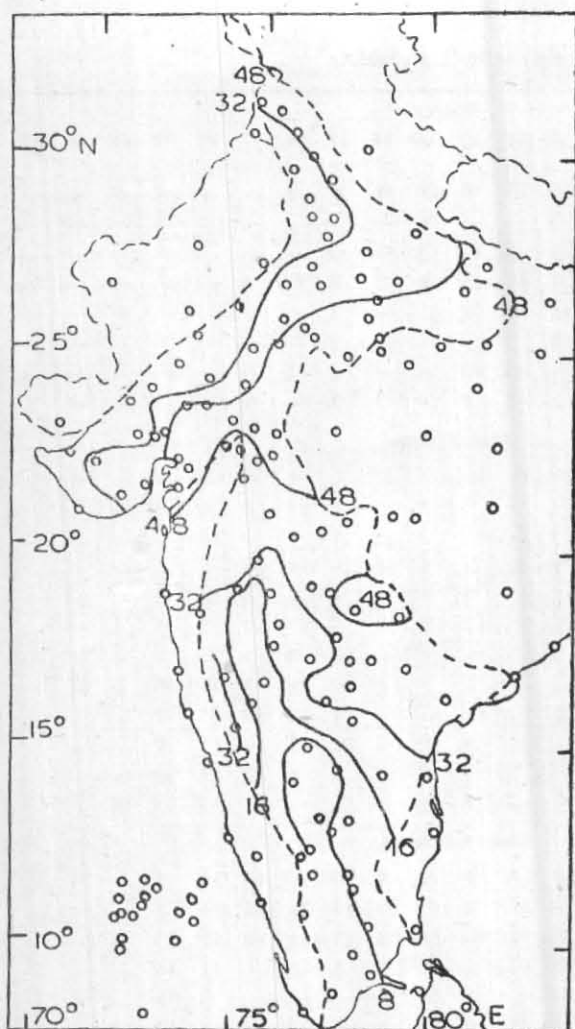Fig. 3. Assured rainfall (mm) at 50% level, week No. 30

Fig. 4. Assured rainfall (mm) at 50% level, week No. 34

where it is less than 16 mm at 30 per cent level. In the north, rainfall belt covers the entire Dry Farming Tract. In this area the assured rainfall is of the order of 25 and 10 mm at 30 and 50 per cent levels respectively. One can expect rainfall of 16 - 20 mm in Vidarbha, Marathwada and adjoining Andhra Pradesh in 7 out of 10 years.

30*th* *week* (23 - 29 *July*) — Considerable increases of rainfall is noticed after the 26th week in many parts of the country. The main rainfall belt has shifted towards north and it is more than 80 mm at 30 per cent level in Saurashtra, NE Gujarat and adjoining Madhya Pradesh. In this area one can expect more than 48 mm once in 2 years (Fig. 3). At 70 per cent level rainfall is more than 24 mm in the eastern belt of the Dry Farming Tract between Lat. 18 & 28 deg. N. The low rainfall belt from Madurai to Ahmednagar continues to be clearly seen in 50 per cent and 70 per cent level chart.
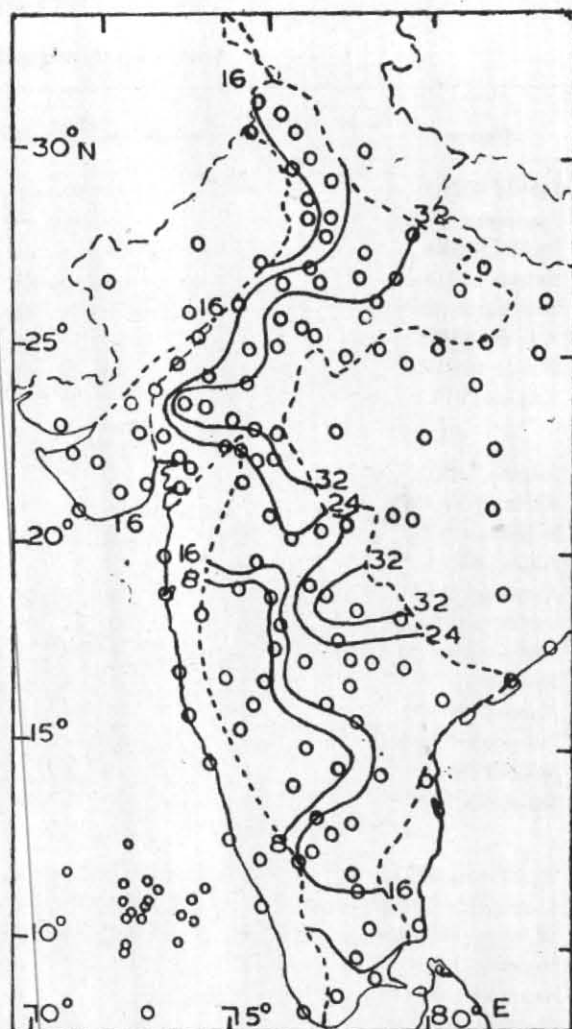
34*th* *week* (20 - 26 *August*) — The assured rainfall has decreased in north India and has increased in the south. This is clearly seen at 50 per cent level chart (Fig. 4). The minimum rainfall belt in the south has increased in extension at 70 per cent level compared to earlier week.

38*th* *week* (17 - 23 *September*) — Rainfall further decreases in the north. It increases in Andhra Pradesh, adjoining Maharashtra, Karnataka and Tamilnadu and ranges from 48 to 64 mm at 30 per cent level, from 24 to 32 mm at 50 per cent level (Fig. 5) and 8 to 16 mm at 70 per cent level. Monsoon rainfall in this area is maximum in this week. This corresponds to the second peak of monsoon rainfall in this regon.

4.4. In north India, rainfall occurs in the month of January and February due to passage of western disturbances. Table 5 gives the distribution of rainfall from 50th to 10th week at

R. P. SARKER *et al.*

TABLE 5

Assured weekly precipitation (mm) at 30 % probability level Delhi, Haryana and Punjab

Station	Weeks													
	50	51	52	01	02	03	04	05	06	07	08	09	10	No. of years
Amritsar (AMR)	1	—	1	3	9	8	5	4	6	5	5	5	6	69
Jullundur (JLD)	—	—	—	3	6	9	9	12	4	8	7	5	8	64
Bhartala (BTL)	—	—	—	8	3	—	—	5	—	—	12	—	—	54
Ferozpore (FZP)	—	—	—	—	6	2	—	3	1	4	—	—	3	59
Luchiana (LDN)	—	—	—	3	6	6	8	9	3	6	10	4	8	66
Patiala (PLT)	—	—	—	3	9	9	5	12	5	5	1	1	7	51
New Delhi (DLH)	—	—	—	4	3	5	2	4	—	4	3	—	3	70
Gurgaon (GRG)	—	—	—	1	5	2	4	4	1	4	1	—	—	64
Karnal (KNL)	—	—	—	6	5	8	4	9	3	8	4	2	4	66
Jind (JND)	—	—	—	6	5	8	4	9	3	8	4	2	4	66
Rohtak (RTK)	—	—	—	2	3	2	3	7	—	1	—	—	3	63

TABLE 6 (a)

Assured weekly precipitation (mm) at 30% probability level — Tamilnadu

Station	Weeks									
	43	44	45	46	47	48	49	50	51	52	No. of years
Salem (SLM)	42	41	32	25	21	13	14	2	—	1	69
Coimbatore (CMB)	55	49	44	29	22	21	18	4	3	1	66
Tiruchirapalli (TRP)	49	45	48	42	33	28	31	13	9	7	64
Madurai (MDR)	47	55	49	41	31	27	22	8	5	3	65
Kovilpatti (KVP)	51	63	62	46	38	30	25	14	11	5	66
Ramanathapuram (RNP)	84	89	89	63	65	67	57	26	29	14	66
Dharampuri (DMP)	39	42	39	28	26	16	16	4	—	1	69

TABLE 6 (b)

Assured weekly precipitation (mm) at 50% probability level — Tamilnadu

Station	Weeks									
	43	44	45	46	47	48	49	50	51	52	No. of years
Salem (SLM)	22	19	12	8	6	3	2	—	—	—	69
Coimbatore (CMB)	28	25	21	13	6	6	5	—	—	—	66
Tiruchirappalli (TRP)	27	23	24	19	11	12	10	2	—	—	64
Madurai (MDR)	29	29	24	18	11	10	8	—	—	—	65
Kovilpatti (KVP)	31	39	33	22	16	13	6	—	—	—	66
Ramanathapuram (RNP)	48	50	51	30	33	33	23	6	8	—	66
Dharampuri (DMP)	19	19	12	10	6	3	—	—	—	—	69
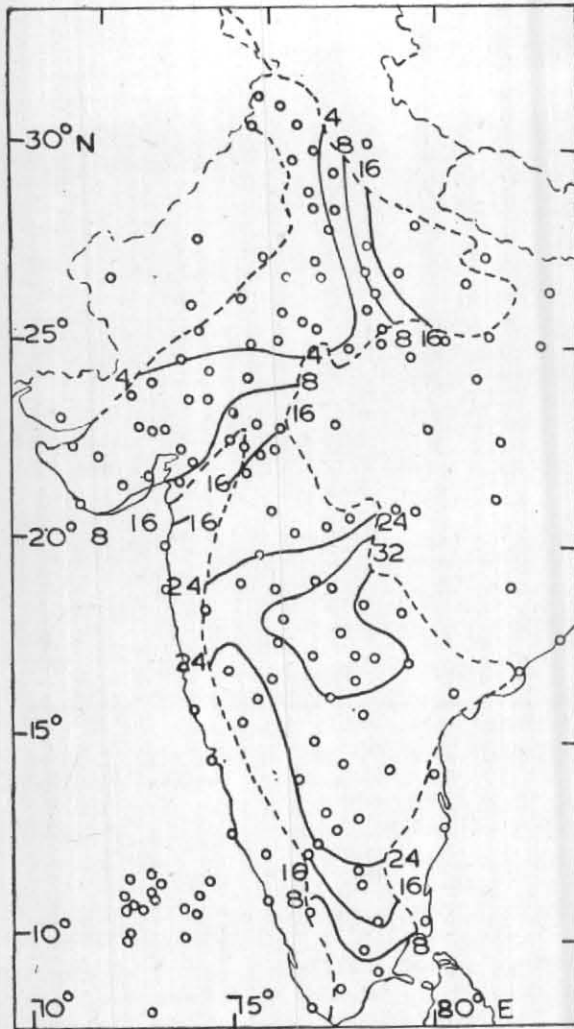
Fig. 5. Assured rainfall (in mm) at 50 per cent
week No. 38

Fig. 6. Assured rainfall at Kovilpatti
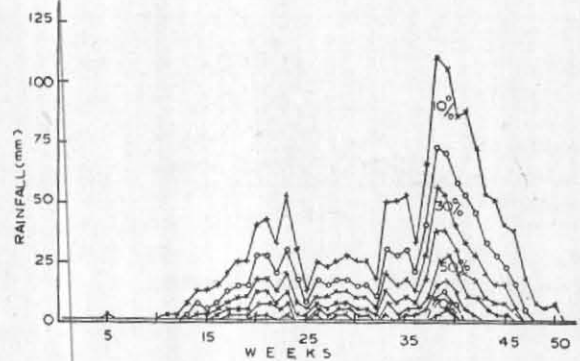
Fig 7. Assured rainfall at Bellary

30 per cent level. Rainfall varies from 5 to 15 mm per week between 2nd & 8th week (8 January - 25 February) in most of the places of Punjab.

4.5. In Tables 6 (a) and 6 (b) is given the rainfall in Tamilnadu from weeks 45 - 52 (5 November to 31 December), *i.e.,* during the NE monsoon at 30 and 50 per cent levels. Rainfall gradually decreases at all the stations from week 45 (5 - 11 November). At 50 per cent level, it becomes practically zero in 50th week (10 - 16 December).

5. Homogeneous rainfall zones

A critical examination was made of the spatial and temporal assured rainfall (A.R.) distribution to find out the homogeneous rainfall zones. A.R. values for all the probability levels have been plotted against the standard weeks for all the stations. These have been examined to find out, if there is any, typical pattern and if so, how far

this pattern is distributed. Shapes of the curves especially the time of peaks and vallies and their duration have been used to identify this pattern and classify them and then they have been used to demarcate the area with respect to their spatial distribution. We could find out that the dry farming tract comprising of 87 districts could be broadly classified into 7 homogeneous rainfall zones. We name them as A, B, C, D, E, F, and G and their demarcations are given in Fig. 1. Brief description of these zones is given below. The main crop season has also been indicated for each zone, based on assured rainfall alone.

Zone A — This zone covers Tamilnadu and adjoining parts of Karnataka. This area gets rainfall mainly from northeast monsoon and partly from southwest monsoon. A typical pattern of A.R. for thi area is given for Kovilpatti (Lat. 9 deg. 10′ N and Long. 77 deg. 52′ E) in Fig. 6. The major peak is observed during 42 - 46th week
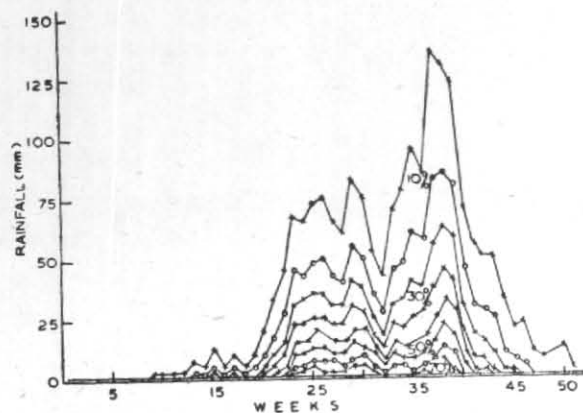
Fig. 8. Assured rainfall at Solapur
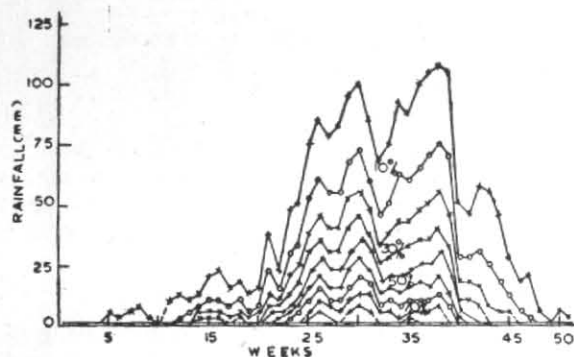
Fig. 9. Assured rainfall at Begumpet
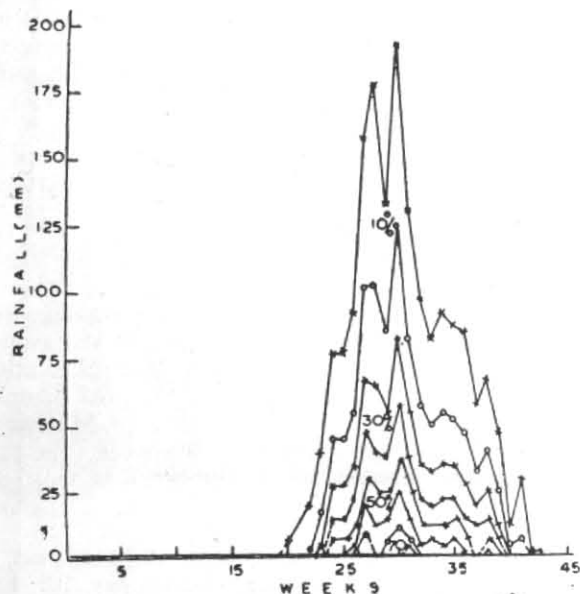
Fig. 10. Assured rainfall at Rajkot

i.e. mid-October to mid-November. During this period weekly A.R. is the order of 30 - 35 mm at 50 per cent level. A secondary peak is observed during 14-16th week, *i.e.*, 1st half of April. This is mainly due to pre-monsoon thunder activity. It appears that this area is suitable for rabi crops. The crop period may be from 40th week to 6th week (1 October - 1st week of February). A short duration summer crop may also be raised.

Zone B — Area B consists of part of Karnataka and Andhra Pradesh. Bellary (Fig. 7) depicts the typical rainfall pattern for this area. Major peak is oberved at 38 - 39th week, *i.e.*, 2nd half of September when the weekly A.R. is 25 - 30 mm at 50 per cent level. A rabi crop can be sucessfully raised in this area once in two years. The effect of pre-monsoon showers is clearly seen during mid-April to first week of June. A minor peak is observed in 22nd to 23rd week when weekly A.R. is about 20 mm at 30 per cent level. Taking advantage of this rainfall a short-duration crop may be raised with success once in 3 years.

Zone C — This zone comprises of southern and northwest part of Maharashtra. Fig. 8 gives the rainfall pattern for typical station Solapur. The main rainfall peak is in 38th week when assured rainfall is 30 mm at 50 per cent level. A secondary peak of 20 mm is noticed in 29th week (16 -22 July). The assured rainfall during 24th to 30th week is of the order of 15 - 20 mm. There is water stress period of 3 weeks from 31st to 33rd week. A short duration of kharif crop on shallow soils or a rabi crop of moderate duration in medium depth soils may be successfully raised once in 2 years.

It may be noticed that the parts of zones A, B and C comprise the low rainfall area from Madurai to Ahmednagar identified earlier. However, there is some differenes in rainfall pattern from one zone to the other in these areas.

Zone D — Most of the portions of Andhra Pradesh under Dry Farming Tract, northern and northeastern part of Maharashtra are included in zone D. Begumpet (Fig. 9) represents the assured rainfall pattern of this area. Two peaks in weekly A.R. are observed in 30th and 38th weeks. During the period 24 - 38th weeks, A.R. varies from 20 - 35 mm once in two years. Rainfall is more or less assured in this area. Duration and quantum of A.R. indicate that a kharif crop of 14 - 16 weeks can be raised in 60 per cent of the years. Once in 2 years a crop of 16 - 20 weeks or mixed crop is expected to be a success. Comparison of C and B will also reveal that but for difference in soil, Hyderabad and Solapur would have had similar crops.

Zone E — This zone covers Gujarat State and part of Rajasthan and Haryana under dry farming tract. Fig. 10 shows assured rainfall
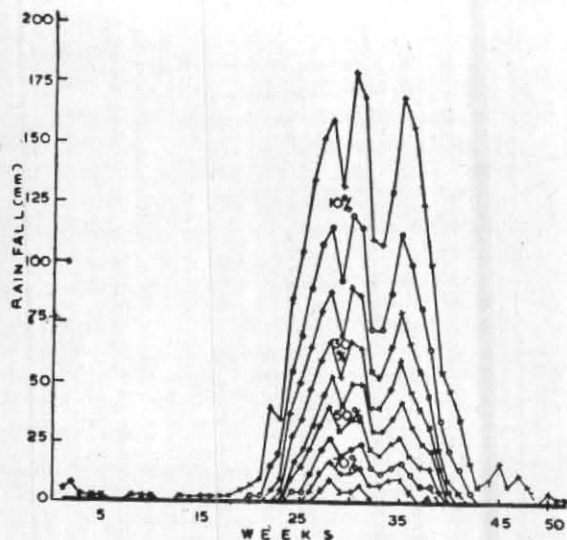
Fig. 11. Assured rainfall at Indore

Fig. 12. Assured rainfall at Ludhiana

pattern of Rajkot which is a typical station of zone E. In this area rainfall duration is short varying from 10 to 16 weeks. A peak A.R. is observed at 28, 29 or 30th week. A.R. of the order of 20 mm at 50 per cent level is observed from 27th to 35th weeks, 2 July to 2 September, the peak being 40 mm, rabi crop does not suit normally in this area. But in a few areas, where soil depth is more than 100 cm and rainfall in September is more, one may cultivate short-duration crops. A khrif crop of 11 - 14 weeks duration appears suitable in this area.

Zone F — Zone F covers part of west Madhya Pradesh and Uttar Pradesh under dry farming tract. Duration and quantum of weekly A.R. are more in this region. Fig. 11 depicts the A.R. pattern of Indore representing this region. Even in 70 per cent of the years this area gets A.R. of the order of 15mm from 26th (25 June to 1 July) to 35th (27 August to 2 September) weeks. Assured rainfall at 50 per cent is of the order of 20 - 50 mm from 25th to 39th weeks (18 June to 30 September). A long duration kharif crop in shallow soil or two crops in deep soil may be raised once in two years. Even at 70 per cent level a short duration crop may be a success.

Zone G — Ludhiana (Fig. 12) represents the pattern of A.R. in zone G which includes Haryana and Punjab under dry farming tract. Major peak in 30th (23 - 29 July) week and second peak in 35th (27 August - 2 September) week are observed. Assured rainfall is more than 20 mm from 27th (2 - 8 July) to 34th (20 - 26 August) weeks at 50 per cent of the years. Rainfall of the order of 8 mm (30 per cent level) occurs from 2nd to 20th (8 January -
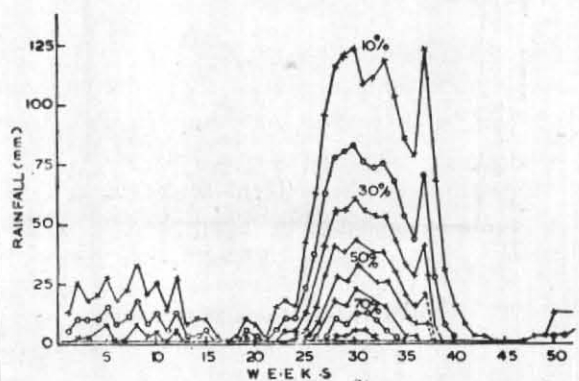
11 March) week due to western disturbances. The rainfall is very much beneficial to rabi crops. A short-duration kharif and moderate-duration rabi crop may be raised from this area.

6. Conclusion

(1) The analysis enables one to divide the dry farming tract into seven homogeneous rainfall zones which will be of help for efficient agricultural planning on the basis of the duration of crop growing period in each zone at different probability levels.

(2) A low rainfall area has been identified extending from Madurai to Ahmednagar *via* Mandya, Chitradurg, Bellary and Bijapur. In this area, the rainfall is found to increase after 35th week and peak rainfall is noticed in 38th/39th week. It is difficult to raise kharif crop in this area, but prospects of rabi crops are fairly good.

(3) The main rainfall zone during the pre-monsoon period was found in the area near Bangalore and Chitradurga in Karnataka in the 22nd week. With the progress of the monsoon, the main rainfall belt shifts towards north and it is found to be located in the area comprising of SE Gujarat, adjoining parts of Madhya Pradesh and Maharashtra in 30th week. The rainfall activity is maximum in this week in most of the dry farming tract.

(4) In the mid-season, the monsoon activity is lowest during the weeks 32 to 34 throughout the dry farming tract. It is likely that the kharif crop in Maharashtra and Gujarat will suffer water stress conditions during this period.

(5) There is a high rainfall belt in the eastern part of the dry farming tract. This belt is confined rougly between latitudes 18 & 23 deg. N and the east of longitude 75 deg. E. The kharif crop prospects in this area are very good.

(6) The information on A.R. would be very useful for identifying broad crop prospects in different areas of the dry farming tract. It is necessary to super-impose on the assured rainfall distribution, the soil characteristics and the evaporative demand of the atmosphere to suggest specific cropping pattern for different areas.

Acknowledgement

References

Cochran, .W. G., 1954, Some methods for strengthening the common chi-square tests', *Biometric*, **10**, 4, p. 417.

Mooley, D. A., 1970, Statistical distribution of pentad rain~ fall over India during Monsoon Season', *Indian J. Met. Geophys.*, **21**, pp. 219-230.

Mooley, D. A. and Appa Rao, G., 1971, Distribution function for seasonal and annual rainfall over India, *Mon. Weath. Rev.*, US Dep. of Commerce, ESSA, **99**, 10, pp. 796-799.

Mooley, D. A., 1973, 'Gamma distribution probability model for Asian Summer monsoon monthly rainfall, *Mon. Weath. Rev.*, U.S. Dep. of Commerce, NOAA **101**, 2, pp. 160-176.

Mooley, D. A., 1973, 'An estimate of the distribution of the parameters of the Gamma Probability Model applied to monthly rainfall over Southeast Asia during the summer monsoon', *Mon. Weath. Rev.*, **101**, 12, pp. 884 - 890.

Thom, H. C. S., 1951, A frequency distribution for precipitation' (Abstract) *Bull., Am. met. Soc.*, **32**, 10, p. 397.

Thom, H. C. S., 1958, A note of Gamma Distribution, *Mon. Weath. Rev.*, **86**, 4, pp. 117-122.

Thom, H. C. S., 1966, 'Some methods of climatological Analysis , WMO Tech. Note No. 81, pp. 20-22.