Probabilities of excess and deficient southwest monsoon rainfall over different meteorological sub-divisions of India

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Temporal distribution of southwest monsoon (June – September) rainfall is very useful for the country's agriculture and food grain production. It contributes more than 75% of India's annual rainfall. In view of this, an attempt has been made here to understand the performance of the monthly rainfall for June, July, August and September when the seasonal rainfall is reported as excess, deficient or normal. To know the dependence of seasonal rainfall on monthly rainfall, the probabilities of occurrence of excess, deficient and normal monsoon when June, July, August and also June + July and August + September rainfall is reported to be excess or deficient, are worked out using the long homogenous series of 124 years (1871–1994) data of monthly and seasonal rainfall of 29 meteorological sub-divisions of the plain regions of India.

In excess monsoon years, the average percentage contribution of each monsoon month to the long term mean (1871–1994) seasonal rainfall (June – September) is more than that of the normal while in the deficient years it is less than normal. This is noticed in all 29 meteorological sub-divisions. From the probability analysis, it is seen that there is a rare possibility of occurrence of seasonal rainfall to be excess/deficient when the monthly rainfall of any month is deficient/excess.

1. Introduction

Abnormalities in performance of the southwest monsoon marked as excess or deficient have definite effects on agriculture, industry and the generation of hydro-electric power, causing a severe strain to the national economy. Almost every year some part or other of the country suffers from such calamities. The Government of India spends large sums of money on providing relief in these affected parts. In view of the great impact of excess and deficient rainfall on the Indian economy, many research workers have studied fluctuations in southwest monsoon rainfall over the Indian regions. Parthasarathy *et al* (1984) have studied probabilities of droughts and floods over India during the southwest monsoon period and noted that the areas which are prone to drought and flood are nearly the same. Further Mooley and Parthasarathy (1984) have done detailed statistical analysis of the all-India monsoon rainfall during the period 1871–1978. Parthasarathy *et al* (1987) have studied droughts/floods in the summer monsoon seasonal rainfall over different meteorological sub-divisions of India for the period 1871–1984 and observed larger number of droughts/floods in Saurashtra and Kutch, Punjab, west Rajasthan and a lower frequency along the west coast and northeast India. Subramanian (1994) examined the possibility of various meteorological sub-divisions to recover the June + July rainfall deficiency during the latter half of the southwest monsoon period. He found that recovery of June + July rainfall deficiency by August + September is highest (60% and more) in the northeast part of India and lowest (about 40%) in the west coast peninsula.

The purpose of the present paper is to study the probability of the occurrence of seasonal rainfall to be excess, deficient and normal, whenever the rainfall in June, July and August is in one of three categories (excess, deficient and normal).

2. Data and methodology

In the present study the monthly and seasonal (June – September) area weighted rainfall series of 29

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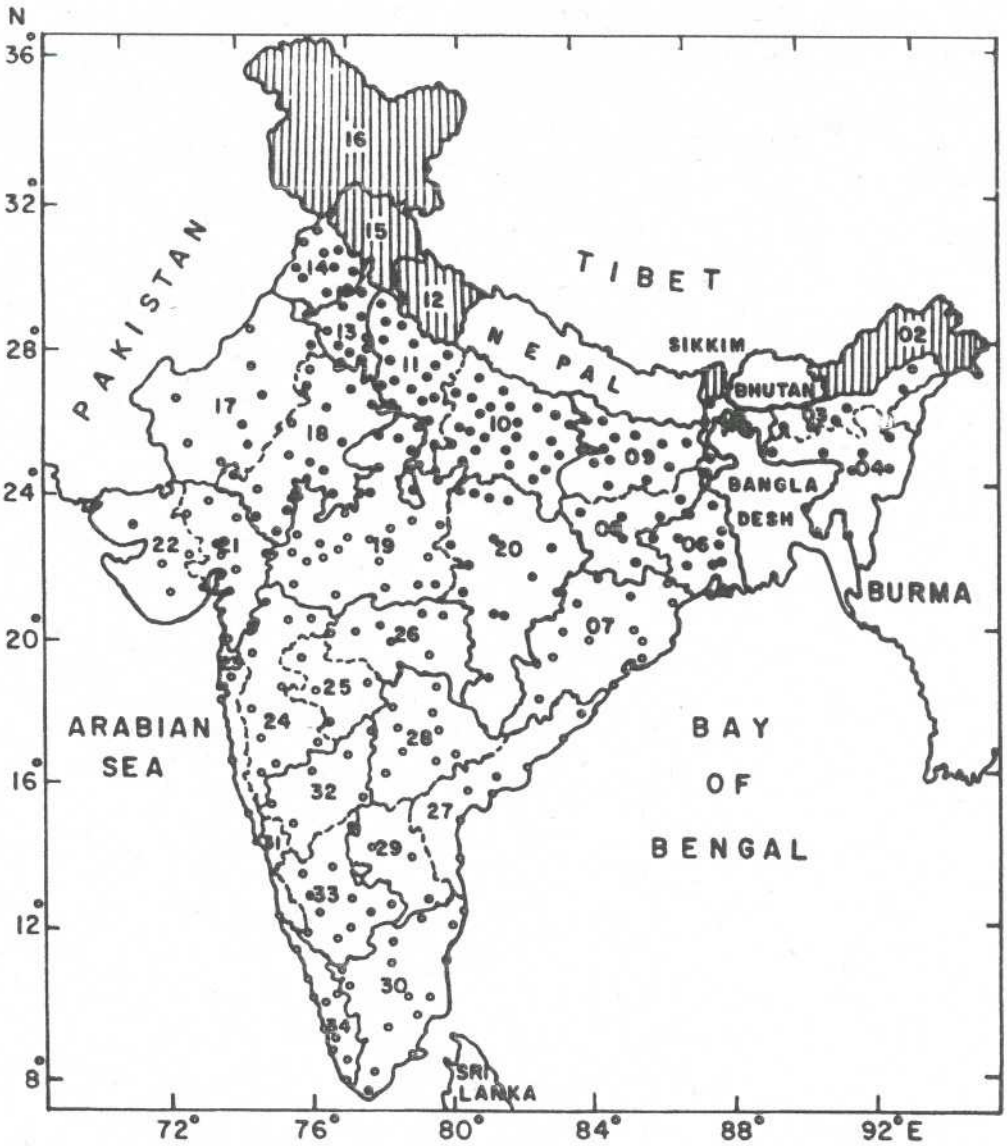


Figure 1. Meteorological sub-divisions of India and locations of rain gauge stations. Hatched areas are not considered.

meteorological sub-divisions for the period 1871–1994 is used. For details refer to Parthasarathy *et al* (1995). The meteorological sub-divisions in hilly regions (see figure 1) (viz., Arunachal Pradesh, Hills of West U.P, Himachal Pradesh and Jammu and Kashmir) and the two Island sub-divisions

namely Bay Island and Arabian Sea Island are not considered.

The probability of the occurrence of seasonal excess/deficient rainfall whenever the individual month's (June, July and August) rainfall is excess/deficient is calculated. From monthly rainfall series, the excess/deficient years for the particular month are identified and further corresponding to these excess/deficient years, the seasonal excess/deficient years are counted. The probability (%) is the ratio of the number of seasonal excess/deficient rainfall years to the number of monthly excess and deficient years.

To examine the relationship between monthly and seasonal rainfall, the correlation coefficient between monthly rainfall with the monsoon (June–September) rainfall has been calculated for 29 subdivisions.

3. Discussion

3.1 *Percentage contribution of monthly rainfall to the seasonal mean in normal, excess and deficient monsoon year*

From the point of view of agriculture and other planning purposes the percentage contribution of monthly (June, July, August and September) and seasonal (June–September) rainfall to seasonal normal rainfall, in excess, deficient and normal monsoon years are very important. The seasonal percentage contribution of rainfall in excess, deficient and normal monsoon years, for all the sub-divisions is shown in table 1.

3.1.1 *Normal years*

The percentage contribution of the monthly rainfall of June, July, August and September to the seasonal

Table 1. *Percentage contribution of seasonal (June to September) rainfall in excess and deficient years.*

		Normal	Excess years			Deficient years		
No.	Sub-divisions	rainfall	No. years	(%)	Range (mm)	No. years	(%)	Range (mm)
03	North Assam	1454	16	121	1631–2054	21	90	1015–1282
04	South Assam	1444	22	121	1636–1892	22	83	1032–1258
05	S.H.W. Bengal	1994	21	125	2316–2739	19	78	1205–1680
06	G.W.Bengal	1148	24	124	1320–1601	22	80	837–966
07	Orissa	1171	19	122	1339–1583	20	78	755–1010
08	Bihar Plateau	1098	23	122	1259–1505	21	81	695–937
09	Bihar Plains	1032	18	133	1252–1502	19	70	642–832
10	East U. P.	906	18	138	1114–1433	18	65	309–699
11	West U. P	763	20	132	945–1131	17	59	165–572
13	Haryana	458	21	148	600–897	23	57	142–316
14	Punjab	496	17	165	700–1012	16	54	151–320
17	West Rajasthan	258	18	167	359–573	15	38	34–156
18	East Rajasthan	637	19	138	813–1119	20	58	195–466
19	West M. P.	920	20	127	1096–1288	22	74	519–753
20	East M. P.	1200	17	126	1397–1837	20	76	708–1001
21	Gujarat	867	19	146	1141–1363	21	51	211–580
22	Sau. and Kutch	431	20	173	623–1080	17	38	63–238
23	Konkan and Goa	2385	18	131	2855–3754	19	62	1052–1828
24	Madhya Maharashtra	580	17	134	702–942	20	67	211–457
25	Marathawada	691	24	143	888–1300	18	61	244–490
26	Vidarbha	950	21	129	1136–1372	20	70	383–756
27	Coastal A. P.	506	21	137	619–780	18	71	315–392
28	Telangana	718	22	137	892–1186	20	68	371–549
29	Rayalseema	421	21	148	541–791	22	64	197–300
30	Tamilnadu	308	20	137	384–466	19	68	170–237
31	Coastal Karnataka	2860	22	128	3367–4623	16	74	1601–2319
32	N. I. Karnataka	600	16	134	729–904	16	69	340–472
33	S . I. Karnataka	504	20	132	606–776	23	75	265–402
34	Kerala	1944	19	132	2318–3115	22	74	1150–1573
	All-India	852	18	113	940–1020	22	83	604–768

Table 2(a). *Probabilities (%) of seasonal excess (Ex) and deficient (Def) rainfall of different sub-divisions when monthly rainfall is reported as excess.*

		June			July			August		
No.	Sub-division	Ex.	Def.	Nor.	Ex.	Def.	Nor.	Ex.	Def.	Nor.
03	North Assam	29	05	67	42	00	58	36	00	59
04	South Assam	56	00	44	55	05	41	47	00	53
05	Sub H. W. Bengal	45	00	55	45	00	55	41	00	51
06	Gangetic W. Bengal	53	00	47	33	00	67	52	00	48
07	Orissa	59	00	41	38	00	62	42	00	58
08	Bihar Plateau	59	00	41	42	00	58	47	00	53
09	Bihar Plains	32	00	68	43	05	52	39	00	61
10	East Uttar Pradesh	43	05	52	50	00	50	45	00	55
11	West Uttar Pradesh	35	00	65	29	00	71	46	00	54
13	Haryana	21	16	63	40	00	60	44	00	56
14	Punjab	17	00	83	36	00	64	50	00	50
17	West Rajasthan	29	00	71	29	00	71	47	00	53
18	East Rajasthan	42	08	50	30	00	70	55	00	45
19	West Madhya Pradesh	25	10	65	32	00	68	26	00	74
20	East Madhya Pradesh	38	00	63	39	00	61	26	00	68
21	Gujarat	35	10	55	43	00	57	24	00	76
22	Saurashtra and Kutch	32	05	64	43	00	53	57	00	43
23	Konkan and Goa	19	00	81	47	00	53	47	00	53
24	Madhya Maharashtra	36	00	64	27	00	73	30	00	70
25	Marathawada	46	00	54	38	00	63	45	00	55
26	Vidharbha	47	06	47	35	00	65	25	00	75
27	Coastal A. P.	45	00	55	50	00	50	57	00	43
28	Telangana	44	00	56	44	00	56	65	00	35
29	Rayalseema	25	00	75	41	00	59	53	00	47
30	Tamil Nadu	29	00	71	61	00	39	43	00	57
31	Coastal Karnataka	41	00	59	57	00	43	40	00	60
32	N. Int. Karnataka	45	00	55	39	00	61	32	00	68
33	S. Int. Karnataka	39	00	61	77	00	23	32	00	68
34	Kerala	50	00	50	39	00	61	59	06	35
	All-India	35	00	65	40	00	60	32	00	68

rainfall of each year is computed first and the average of these values over the entire period (1871–1994) considered as the normal monthly percentage contribution.

Monthly normal percentage contribution of rainfall to the seasonal amount in each subdivision is found to be higher in the months of July and August excepting the sub-divisions of Marathawada, coastal Andhra Pradesh, Rayalseema, Tamil Nadu where the September contribution is the highest of all the four months. The rainfall along the west coast (Kerala, coastal Karnataka, and Konkan and Goa) is more in June and July, with the values ranging between 30 and 35% of the seasonal normal and decreases gradually in August and September. A similar type of phenomenon is observed in north Assam, south Assam and Sub-Himalayan West Bengal. In these sub-divisions, the percentage contribution of rainfall in June and July is almost the same. They are in the range of 25 to 30%. The rainfall of June and September is almost the same as for all-India as one unit.

3.1.2 *Excess years*

The seasonal rainfall has been classified as excess when the seasonal rainfall is greater than $R + S$ and deficient if it is less than $R - S$, (Parthasarathy *et al* 1992a) where R and S are the mean and standard deviation of the series. The percentage contribution of monthly rainfall to the long term (1871–1994) mean seasonal rainfall is calculated for all the excess rainfall years and the average of these for the individual month is the representative value of the monthly percentage contribution in excess rainfall years.

Table 2(b). *Probabilities (%) of seasonal excess (Ex) and deficient (Def) rainfall of different sub-divisions when monthly rainfall is reported as deficient.*

No.	Sub-division	June			July			August		
		Ex.	Def.	Nor.	Ex.	Def.	Nor.	Ex.	Def.	Nor.
03	North Assam	0	57	43	0	38	62	0	35	65
04	South Assam	0	41	59	0	45	55	0	48	52
05	Sub H.W. Bengal	06	50	44	00	25	75	05	40	55
06	Gangetic W. Bengal	05	33	62	10	50	40	07	36	57
07	Orissa	00	42	58	00	33	62	05	30	65
08	Bihar Plateau	05	16	79	07	29	64	00	59	41
09	Bihar Plains	00	44	56	00	29	67	00	50	50
10	East Uttar Pradesh	00	32	68	00	50	50	00	56	44
11	West Uttar Pradesh	06	18	76	14	38	48	00	50	50
13	Haryana	16	11	74	00	61	39	00	45	55
14	Punjab	00	00	100	00	52	48	10	45	45
17	West Rajasthan	06	33	61	05	41	55	00	58	42
18	East Rajasthan	05	25	70	11	63	26	00	35	65
19	West Madhya Pradesh	10	15	75	00	48	52	00	41	59
20	East Madhya Pradesh	00	14	86	00	48	52	00	48	52
21	Gujarat	10	30	60	00	65	35	10	48	43
22	Saurashtra and Kutch	07	43	50	06	50	44	00	36	64
23	Konkan and Goa	12	32	56	00	53	47	00	37	63
24	Madhya Maharashtra	00	28	72	00	53	47	05	45	50
25	Marathawada	00	25	75	00	72	22	00	25	75
26	Vidharbha	09	27	64	00	44	56	00	43	57
27	Coastal A. P.	04	30	65	00	32	68	00	40	60
28	Telangana	00	39	61	00	67	33	00	50	50
29	Rayalseema	07	27	67	00	27	73	11	39	50
30	Tamilnadu	10	43	48	00	50	50	00	33	67
31	Coastal Karnataka	06	19	75	00	50	50	06	28	67
32	N. Int. Karnataka	00	31	69	05	23	73	00	38	63
33	S. Int. Karnataka	05	37	58	00	44	56	00	20	80
34	Kerala	00	32	68	00	61	39	00	36	64
	All-India	05	32	64	06	65	29	00	45	55

The percentage contribution of rainfall in the excess monsoon years for each monsoon month (June, July, August and September) is more than that of the normal and deficient year. It indicates that in the excess monsoon years, from the beginning of the season, the rainfall of each month is above normal. Rupa Kumar *et al* (1992) have shown that for all-India, the rainfall of each of the months (June, July, August and September) is well correlated with the seasonal rainfall. We have calculated the correlation coefficients (CCs) between monthly and seasonal rainfall of all 29 sub-divisions. The correlation coefficients (CCs) values are significant at 1% level. These monthly CCs values suggest that when the monthly rainfall is above normal then the seasonal rainfall is also above normal and vice-versa. Also, the correlation coefficients are calculated within the monsoon months (June – July, July – August and August – September) for all 29 subdivisions. CC values are not found statistically significant for most of the sub-divisions. The significant correlations are observed between the June and July rainfall for Marathawada, coastal A.P. and Telangana sub-divisions; and between the August and September rainfall for Kerala.

Though the July month is the peak month of the monsoon season, all sub-divisions do not receive maximum rainfall during this month. Out of 29 sub-divisions, 16 sub-divisions receive maximum rainfall in July whereas 7 and 4 sub-divisions get maximum rainfall in August and September respectively. The rainfall activity in the month of September is strong in madhya Maharashtra, Marathawada, coastal A.P., Rayalseema and Tamil Nadu. Kerala and south Assam receive maximum rainfall in June. It is observed from table 1 that the seasonal rainfall of Haryana, Punjab, west Rajasthan, Gujarat, Saurashtra and Kutch and Rayalseema is

Table 3(a). *Probabilities (%) of seasonal excess (Ex) and deficient (Def) rainfall of all-India when monthly rainfall of sub-divisions is reported as excess.*

		June			July			August		
No	Sub-divisions	Ex.	Def.	Nor.	Ex.	Def.	Nor.	Ex.	Def.	Nor.
03	North Assam	10	10	81	16	16	68	18	23	59
04	South Assam	22	22	56	23	23	55	21	11	68
05	Sub H.W. Bengal	15	05	80	10	15	75	12	35	53
06	Gangetic W. Bengal	29	24	47	06	28	67	05	19	76
07	Orissa	06	18	76	19	10	71	11	05	84
08	Bihar Plateau	12	29	59	16	21	63	12	12	76
09	Bihar Plains	16	11	74	10	24	67	11	33	56
10	East Uttar Pradesh	29	10	62	6	11	83	15	00	85
11	West Uttar Pradesh	20	10	70	24	14	62	19	12	69
13	Haryana	16	16	68	25	15	60	33	06	61
14	Punjab	17	11	72	14	00	86	33	00	67
17	West Rajasthan	29	00	71	14	05	81	16	00	84
18	East Rajasthan	21	08	71	10	05	85	20	00	80
19	West Madhya Pradesh	30	05	65	16	16	68	05	11	84
20	East Madhya Pradesh	21	12	67	26	04	70	11	16	74
21	Gujarat	25	00	75	24	10	67	24	10	67
22	Saurashtra and Kutch	27	14	59	24	06	71	36	07	57
23	Konkan and Goa	10	14	76	27	07	67	35	06	59
24	Madhya Maharashtra	27	09	64	18	05	77	20	10	70
25	Marathawada	15	00	85	31	00	69	36	05	59
26	Vidharbha	06	12	82	15	05	80	20	10	70
27	Coastal A. P.	27	05	68	38	12	50	33	05	62
28	Telangana	26	00	74	28	11	61	39	04	57
29	Rayalseema	33	17	50	29	00	71	42	05	53
30	Tamilnadu	29	00	71	22	00	78	19	10	71
31	Coastal Karnataka	27	09	64	19	10	71	30	05	65
32	N. Int. Karnataka	35	15	50	22	06	72	26	00	74
33	S. Int. Karnataka	33	11	56	23	00	77	21	00	79
34	Kerala	18	14	68	17	22	61	35	06	59

more than 150% of the normal. The normal rainfall of these sub-divisions is in the range of 400 to 500 mm. In excess monsoon years, these sub-divisions receive substantial rainfall of normal rain. Out of 29 sub-divisions, maximum excess years (24) are observed in Marathawada and S.H.W. Bengal and minimum excess years (16) are observed in north Assam and N.I. Karnataka for the period 1871–1994.

3.1.3 *Deficient rainfall years*

In deficient rainfall years, the monthly rainfall of June, July, August and September is less than that of normal and excess year rainfall. It is observed that from the beginning of the season, rainfall is below normal in each sub-division for all monsoon months. In the deficient years, the seasonal rainfall is significantly reduced in east Uttar Pradesh, west Uttar Pradesh, Haryana, Punjab, west Rajasthan, east Rajasthan, Gujarat and Saurashtra and Kutch and vice-versa in excess rainfall years. The seasonal rainfall contribution in the above sub-divisions are 40 to 60% of the normal (table 1). These are the regions well known for low rainfall and high rainfall variability over the Indian sub-continent. Parthasarathy *et al* (1984) have also shown that the sub-divisions of Punjab, Haryana, Rajasthan and the adjoining areas, a large part of Uttar Pradesh, Gujarat and Saurashtra and Kutch are drought prone areas. Further, the northeast part of India (north Assam, south Assam, sub-Himalayan West Bengal, Gangetic West Bengal, Orissa and Bihar Plateau) receive more rainfall than that of the rest of the sub-divisions, where the seasonal rainfall of these sub-divisions in deficient years is about 80 to 90% of the normal value (table 1).

Table 3(b). *Probabilities (%) of seasonal excess (Ex.) and deficient (Def.) rainfall of all-India when monthly rainfall of sub-divisions is reported as deficient.*

		June			July			August		
No	Sub-divisions	Ex.	Def.	Nor.	Ex.	Def.	Nor.	Ex.	Def.	Nor.
03	North Assam	22	17	61	24	14	62	05	25	70
04	South Assam	27	18	55	10	30	60	14	10	76
05	Sub H.W. Bengal	17	22	61	10	10	80	15	20	65
06	Gangetic W. Bengal	10	24	67	30	15	55	21	14	64
07	Orissa	05	26	68	19	29	52	15	30	55
08	Bihar Plateau	11	42	47	07	36	57	12	35	53
09	Bihar Plains	06	38	56	12	25	63	11	28	61
10	East Uttar Pradesh	05	32	63	00	50	50	00	38	63
11	West Uttar Pradesh	06	24	71	05	43	52	06	44	50
13	Haryana	00	16	84	11	44	44	09	27	64
14	Punjab	14	29	57	14	38	48	10	25	65
17	West Rajasthan	06	28	67	05	41	55	00	37	63
18	East Rajasthan	05	25	70	05	53	42	00	26	74
19	West Madhya Pradesh	05	30	65	10	33	57	00	36	64
20	East Madhya Pradesh	05	27	68	14	52	33	00	43	57
21	Gujarat	05	40	55	05	50	45	05	38	57
22	Saurashtra and Kutch	07	57	36	06	50	44	00	45	55
23	Konkan and Goa	04	28	68	11	42	47	00	37	63
24	Madhya Maharashtra	06	39	56	12	47	41	05	36	59
25	Marathawada	05	30	65	06	44	50	06	25	69
26	Vidharbha	05	23	73	06	56	39	10	29	62
27	Coastal A. P.	09	17	74	05	53	42	05	30	65
28	Telangana	06	17	78	00	56	44	00	44	56
29	Rayalseema	13	07	80	07	53	40	00	22	78
30	Tamilnadu	19	19	62	12	38	50	11	44	44
31	Coastal Karnataka	19	12	69	00	56	44	00	28	72
32	N. Int. Karnataka	00	25	75	05	41	55	00	25	75
33	S. Int. Karnataka	05	11	84	06	50	44	05	35	60
34	Kerala	11	11	79	17	50	33	00	36	64

3.2 *Probabilities of occurrence of excess, deficient and normal seasonal rainfall when monthly (June, July and August) rainfall is excess/deficient*

Probabilities of occurrence of seasonal rainfall to be excess/deficient and normal are computed when monthly (June, July and August) rainfall is excess. Here, September rainfall is not considered because by the end of this month, the total amount of seasonal rainfall is known. It is observed that when the June rainfall of Kerala, south Assam, Gangetic West Bengal, Bihar Plateau and Orissa is excess, there is more than 50% probability of seasonal rainfall to be excess (table 2a). These sub-divisions are under the same southwest monsoon branch. When the June, July and August rainfall is deficient, the number of sub-divisions for which the probability of occurrence of seasonal rainfall to be deficient is 50% or more are 2, 14, 6 and 7 respectively. The deficient rainfall in July leads more sub-divisions towards the seasonal rainfall to be deficient. This situation may happen because out of the four monsoon months, the maximum rain is in July, the amount of rainfall in July is about 35% of it's seasonal (June through September) rainfall (Parthasarathy *et al* 1995, RR 651). When the rainfall of any monsoon month is excess for any sub-division, the probability of seasonal rainfall to be deficient is almost nil and seasonal rainfall is either excess or normal (table 2a). If deficient rainfall occurs in any monsoon month for any sub-division then the season's rainfall may be either normal or deficient but not excess (table 2b). All the above mentioned statistical information could be used for extended forecast of monsoon rainfall for different meteorological sub-divisions.

A similar attempt has been made for computing probabilities of seasonal rainfall of all-India excess and

deficient when monthly sub-divisional rainfall is excess/deficient. From table 3(b), the sub-divisional rainfall of July except the sub-divisions in northeast part of India is deficient, then the probability of occurrence of seasonal all-India rainfall to be deficient is about 50%. When the monthly rainfall of some particular sub-divisions is excess/deficient, the probability of occurrence of all-India rainfall to be deficient/excess is very less. However, when the monthly rainfall of northeast India is excess, the all-India rainfall has an equal chance of occurring excess and deficient (table 3a and 3b).

3.2.1 *Probabilities of seasonal rainfall to be excess, deficient and normal when June + July and August + September rainfall is excess/deficient*

Rainfall received in the first two months of the monsoon season (June + July) constitutes about 50% of the seasonal total for all the sub-divisions excepting Konkan and Goa, coastal Karnataka, madhya Maharashtra and Kerala which receive more than 60% of seasonal rainfall while Tamil Nadu and Rayalseema receive only 35 to 40% of seasonal rainfall. The deficiency in rainfall during the first half of the southwest monsoon period may recover in the subsequent August and September. When the total rainfall of June + July is deficient, there is more than 60% probability of occurrence of seasonal deficient rainfall in the sub-divisions of north Assam, south Assam, G.W. Bengal, Punjab, east Rajasthan, Gujarat, Telangana, S. Int. Karnataka and Kerala. These sub-divisions have a very rare chance of occurrence of excess monsoon when June + July rainfall is deficient, the contribution of August + September rainfall makes the seasonal rainfall to be normal or deficient. The percentage of recovery of June + July rainfall deficiency by August + September rainfall is maximum for Orissa, Bihar plains, Haryana, east M.P., coastal A.P, Rayalseema, Tamil Nadu and coastal Karnataka (50 to 60%) and minimum for east Rajasthan and Punjab (20%). If the total rainfall of June + July is excess, there is nearly 60% probability of occurrence of seasonal rainfall to be excess in the sub-divisions of south Assam, S.H.W. Bengal, G. W. Bengal, Orissa, Bihar plateau, east Uttar Pradesh, Saurashtra and Kutch, coastal Karnataka and Kerala. In these sub-divisions, there is a very rare possibility of occurrence of seasonal rainfall to be deficient and the contribution of August and September rainfall leads the total rainfall to be excess or normal.

3.3. *Conditional probabilities*

Conditional probabilities are computed for the observed rainfall of June, June + July and June+ July + August in one of the two categories (excess and deficient), then what would the rainfall of every future month of the monsoon season be?

3.3.1 *June excess/deficient rainfall*

Figure (2a) shows that when the June rainfall of all-India is excess, the July rainfall may be either excess or normal. The possibility of occurrence of deficient rainfall is only 4%. It is also seen that the July rainfall of Rayalseema, Tamil Nadu, S.I. Karnataka and Kerala is either excess or normal when the June rainfall of these sub-divisions is excess. It shows that strong monsoon current may persist for two months consecutively for the above sub-divisions. The details of probabilities for sub-divisional rainfall of July, August and September to be excess, deficient and normal when the June rainfall is excess/deficient is shown in figure 2(a and b).

If the June rainfall of all-India is deficient the probability of occurrence of July, August and September rainfall to be normal is 73, 68, and 59%, to be excess is 9, 14 and 14% and to be deficient is 18, 18 and 14% for the respective months.

3.3.2 *June+July excess/deficient rainfall*

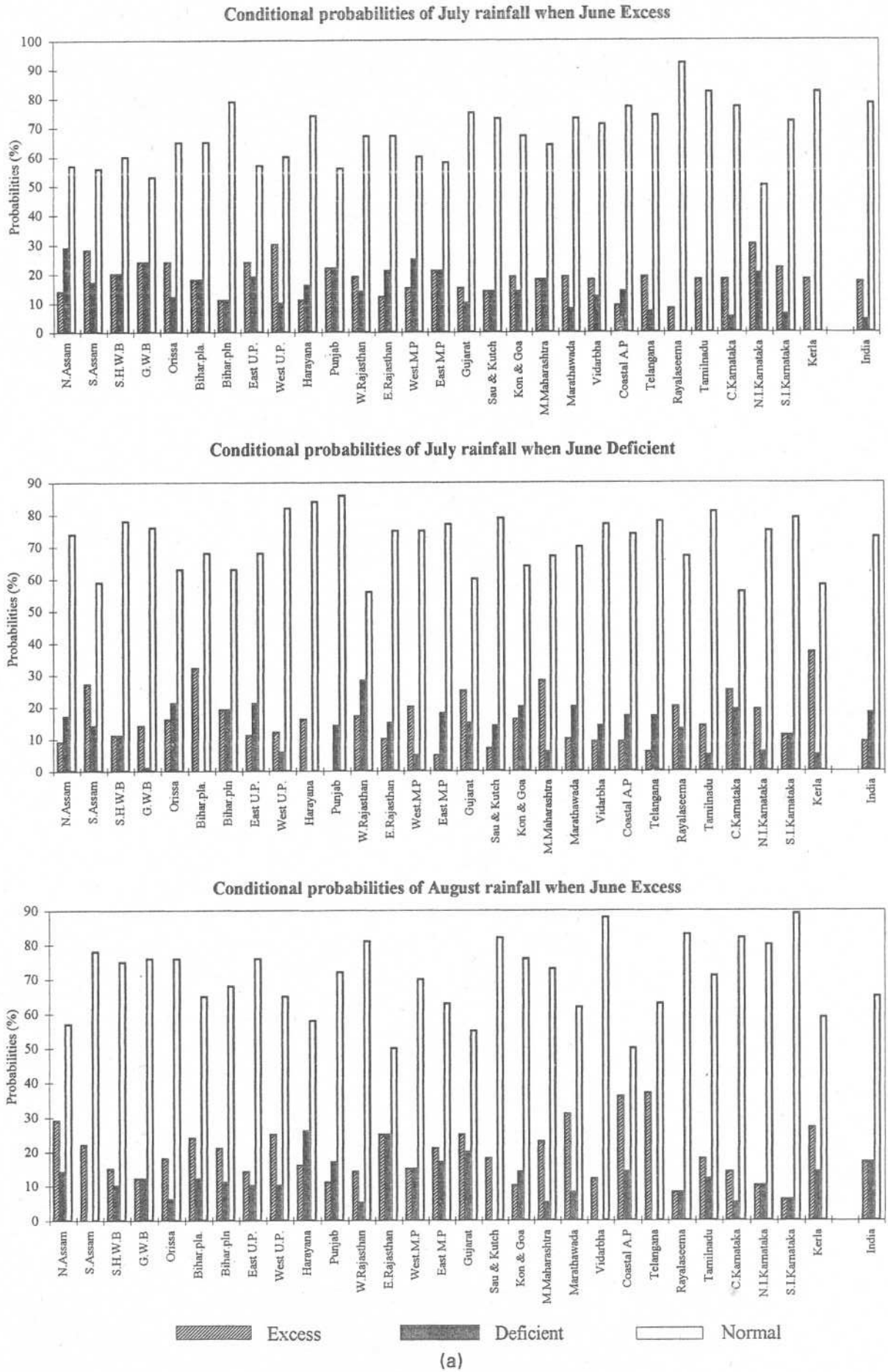
If the rainfall for any sub-division for the month June + July is excess, the rainfall for future months (August and September) for that sub-division may be normal or excess and the probability of getting deficient rainfall is comparitively less than that of excess rainfall. Similarly for any sub-division, when the June + July rainfall is deficient the probability of August and September rainfall being normal is about 70%, and for all-India is about 65% (figures 2c and d).

3.3.3 *June + July + August excess/deficient rainfall*

During the period June through August all-India as one unit receives rainfall about 80% of seasonal rainfall. When the rainfall of all-India for the months June + July + August is excess, the probability of occurrence of September rain to be normal is 78% or to be excess is 17%. There is very less possibility of September rainfall being deficient (figure 2d). When the total rainfall of these three months is deficient, the probability of rainfall of all-India to be excess or to be deficient is about 20% and to be normal is 60%. The details of probability analysis for individual sub-divisions is shown in figure 2(d).

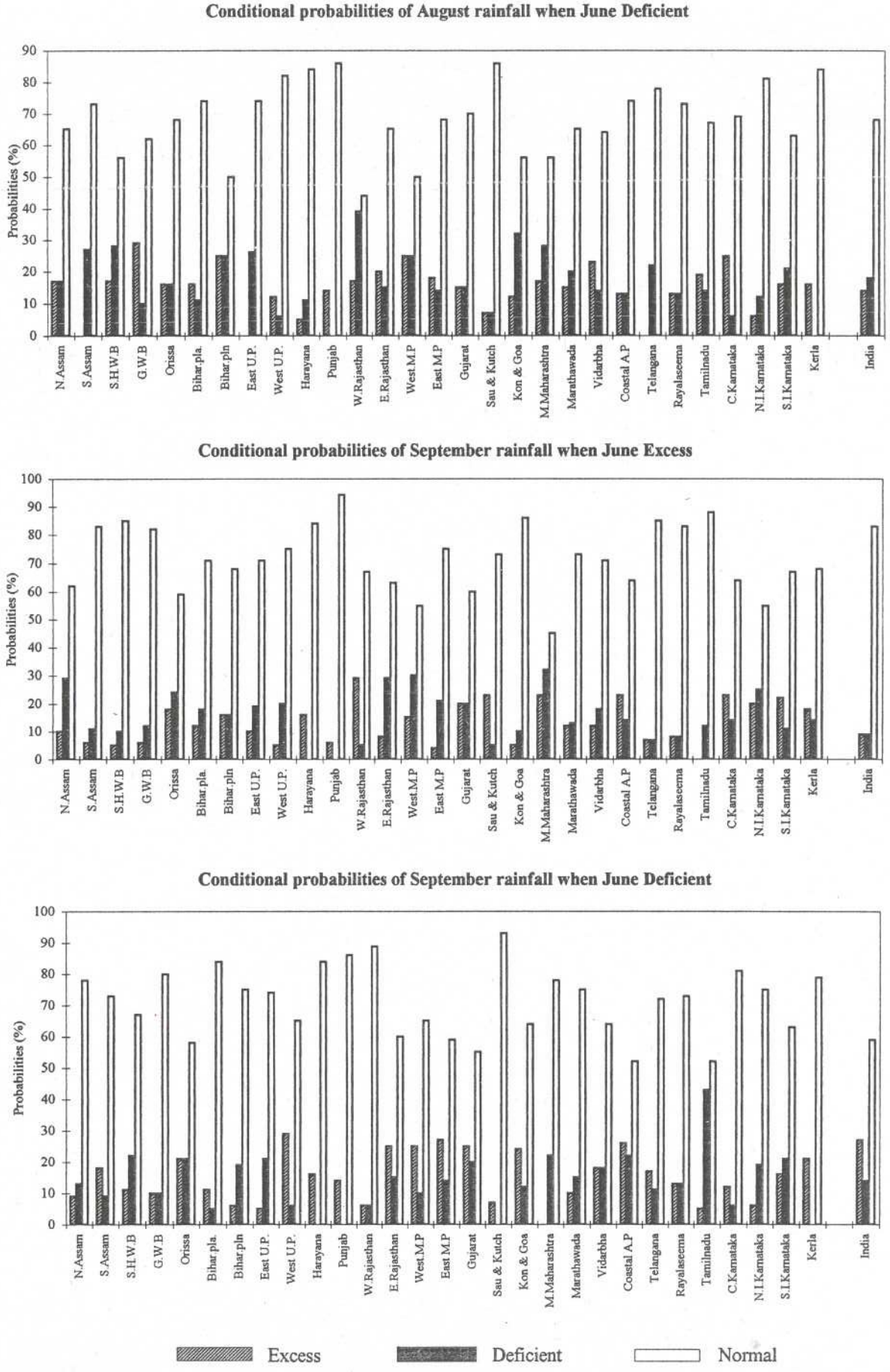
4. Summary

- In excess monsoon years, the average percentage contribution of rainfall of each monsoon month to the long term mean (1871–1994) seasonal rainfall is more than that of normal while in deficient years it is less than normal. In general, it indicates that in excess monsoon years, from the beginning of the season, the rainfall of each month is above normal and a reverse situation is observed in deficient years.



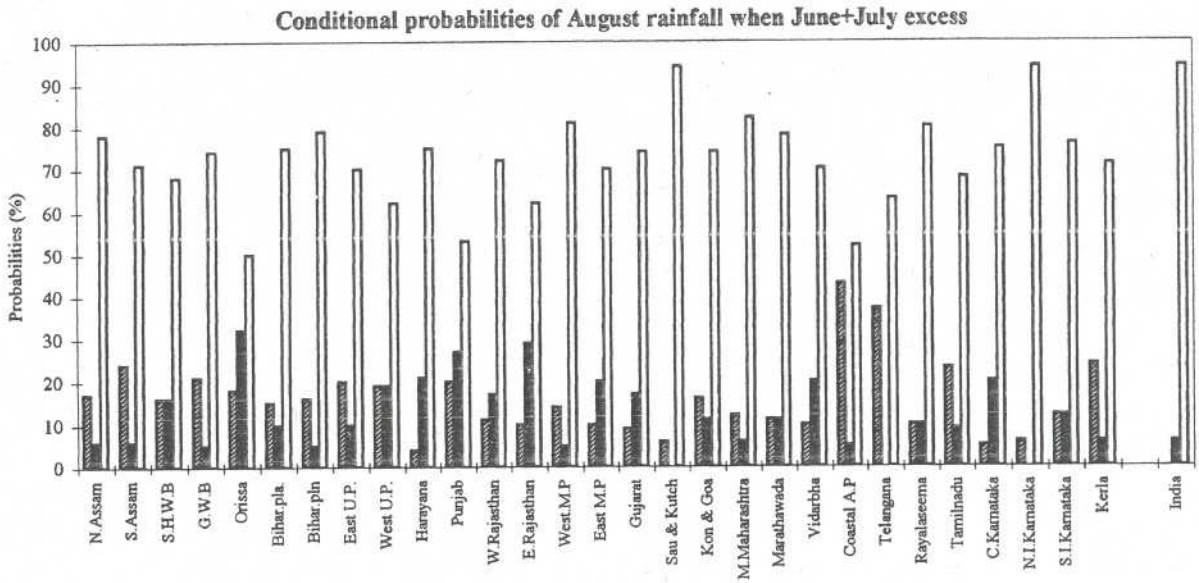
(a)

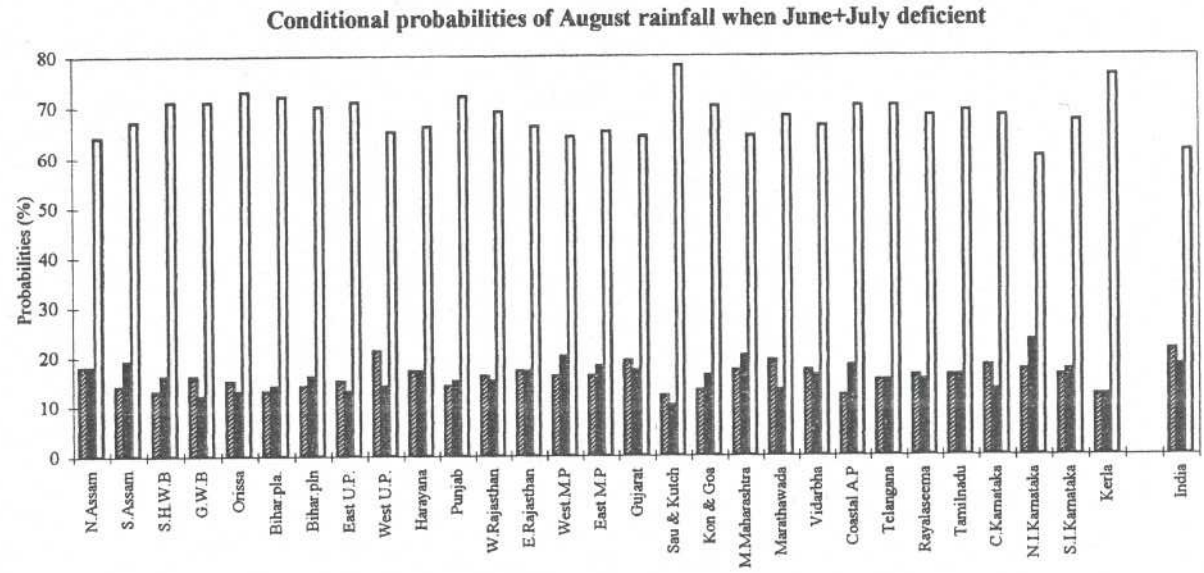
Figure 2(a). (*Continued*)

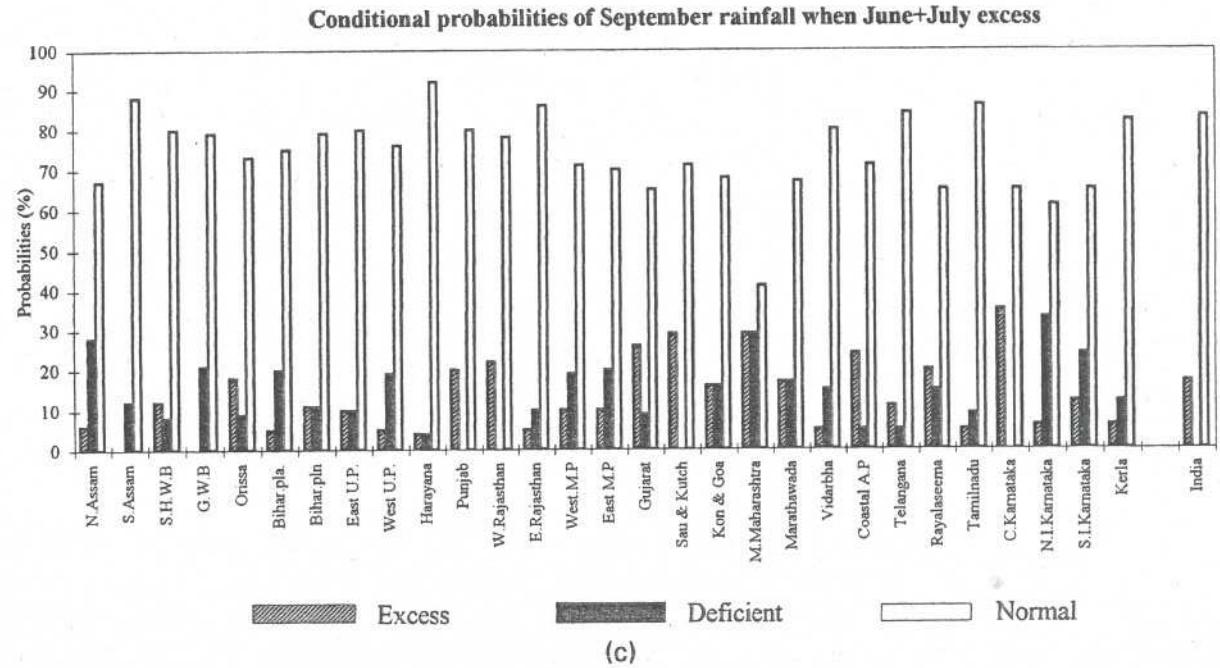


(b)

Figure 2(b). (*Continued*)







(c)

Figure 2(c). (*Continued*)

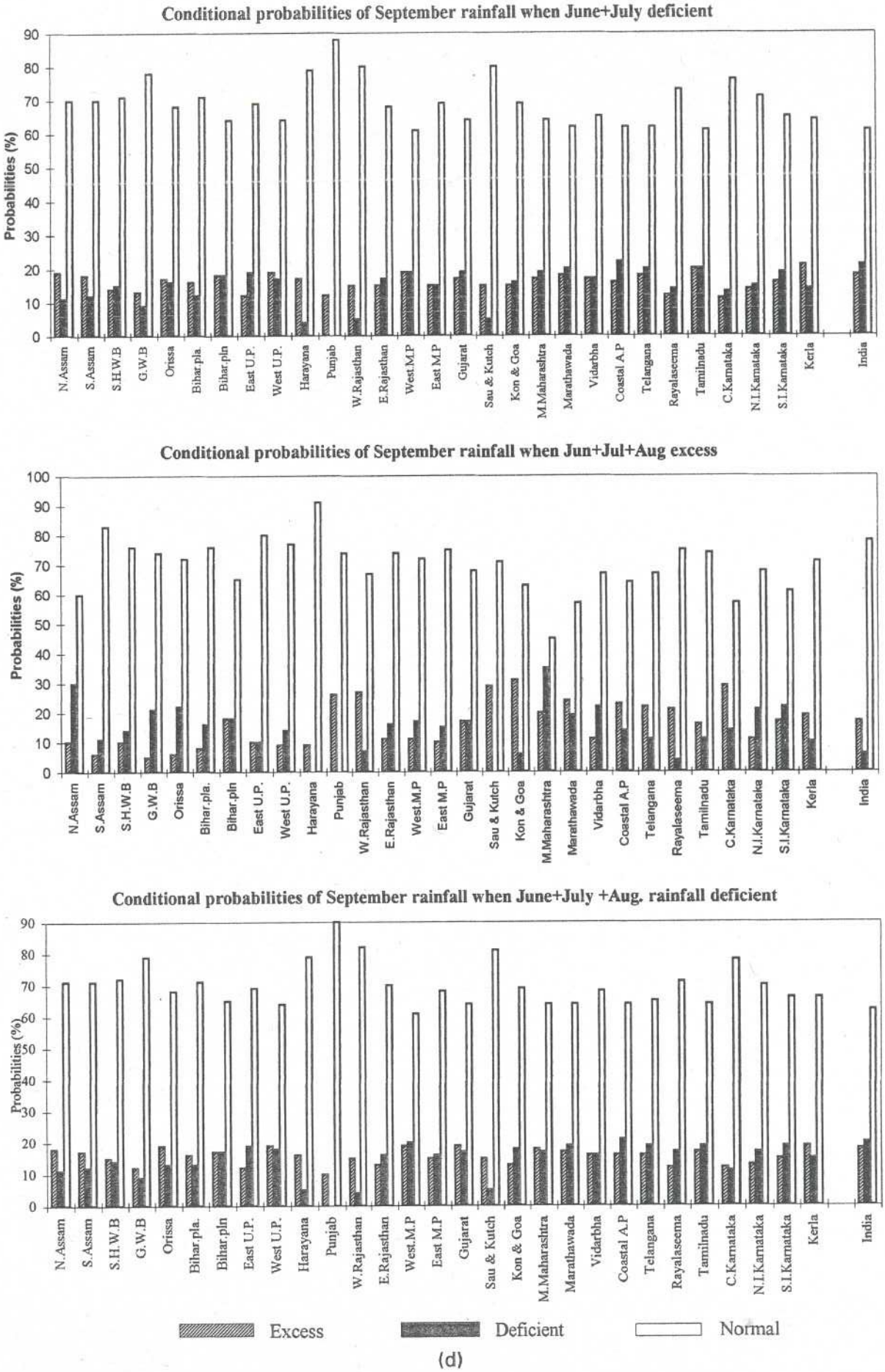


Figure 2(a–d). Conditional probabilities of July, August and September rainfall when June, June + July, June + July + August is in one of the two categories (excess and deficient rainfall).

- Significant correlations are found between monthly (June, July, August and September) and seasonal rainfall in all the 29 sub-divisions.
- Inter-correlation within the monsoon months is not statistically significant for most of the sub-divisions, the monthly rainfall behaviour is independent.
- When the rainfall of any monsoon month is excess for any sub-division, the probability of seasonal rainfall to be deficient is almost nil and the seasonal rainfall is either excess or normal.
- When the rainfall of any monsoon month is deficient for any sub-division, the probability of seasonal rainfall to be excess is almost nil and the seasonal rainfall is either deficient or normal.

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