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Sub-divisionwise probabilistic variability and extreme rainfall analysis of the Indian summer monsoon rainfall

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सार — सामान्य/अधिक वर्षा की संभावना से संबंधित विगत आँकड़ों एवं मानसून ऋतु की अवधि के विभिन्न चरणों के दौरान अपेक्षाकृत छोटे क्षेत्रों की आगामी वर्षा की संभावना पर आधारित सांख्यिकीय विश्लेषण राज्य तथा राष्ट्रीय स्तर के उपलब्ध धरातल जल स्रोत के कुशल प्रबन्ध के लिए, उपयुक्त सूचना प्रणाली सिद्ध होगी। इस शोध-पत्र में लेखक ने इस दिशा में प्रयास किया तथा मानसून वर्षा के कुछ महत्वपूर्ण लक्षणों का पता लगाया है। यह पता लगा है कि जुलाई और अगस्त के महीने में, अधिकांश उपखण्डों में मासिक वर्षा सामान्य या अधिक होने की संभावना अधिक होती है तथा सितम्बर के महीने में इसकी संभावना सबसे कम होती है। साथ ही यह देखा गया है कि जुलाई के महीने में मानसून द्रोणी के उत्तर में, तथा अगस्त के महीने में पश्चिमी तट के किनारे दक्षिणी द्रोणी में सामान्य वर्षा की संभावना अधिक रहती है। मानसून की अवधि के विभिन्न चरणों में आगामी वर्षा की न्यूनतम सुनिश्चित मात्रा तथा अधिकतम संभावित मात्रा का पता लगाने के लिए दीर्घ अवधि की वर्षा की अधिकतम मात्रा की जानकारी उपयोगी होगी। ये सूचनाएं निर्णायकों/प्रबन्धकों आदि के लिए वास्तविक समय के आधार पर उनके निर्णय लेने की प्रक्रिया में बहुमूल्य सिद्ध होगी।

ABSTRACT. Statistical analysis based on past data on probability of normal/excess rainfall, the probable future rainfall for smaller areas at different stages of the monsoon period will serve as an appropriate information system for efficient management of available surface water resource at the state and the national levels. In this paper the author have made an attempt in that direction and have brought out some important features of the monsoon rainfall. It is found that the probability of monthly rainfall becoming normal or excess is high in maximum number of sub-divisions in July and August and is least in September. It is further observed that the normality of rainfall as highly probable to the north of the monsoon trough in July and that to the south of the trough in August besides the west coast. The rainfall extreme values over a long period will be useful in determining the minimum assured and maximum probable future rainfall at different stages of the monsoon period. These information will be valuable to decision makers, managers etc. in their decision making process on real time basis.

Key words — Aberrant, Extended forecast, Minimum assured, Maximum probable, Probabilistic, Spatial, Variability.

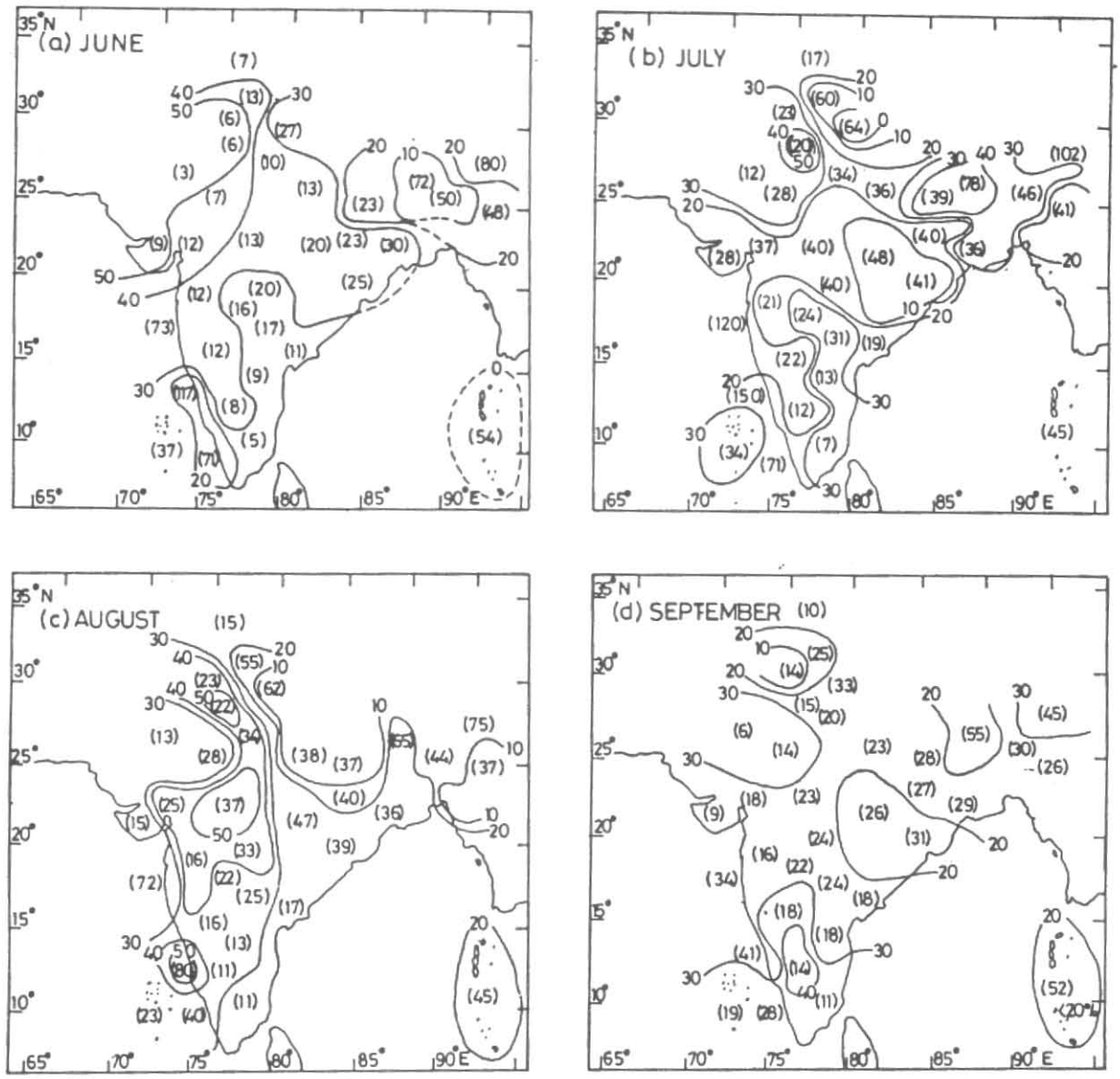
1. Introduction

For evaluation of nation's water resources, investigation and research on the availability of surface and ground water are essential. Advance information on the availability of monsoon rainfall will be extremely valuable to the planners, managers, and others in a country like India, where the principal source of surface water is the summer monsoon rainfall.

The normal duration of summer monsoon rainfall in India varies from east to west. Its duration is about 2 to 2.5 months over NW India to 4 to 4.5 months over eastern India. Moreover, the rainfall varies largely from year to year.

Summer monsoon rainfall and its vagaries have attracted the attention of the meteorological communities of the tropical countries for a long time and research on its behaviour have been carried out by many workers. As early as in 1951, Satakopan (1951) felt the usefulness of various statistical analyses with the past rainfall data base and its mapping to facilitate planners and managers for efficient surface water management. Many research workers in the field identified trends and periodicities of rainfall as an important aspect of research.

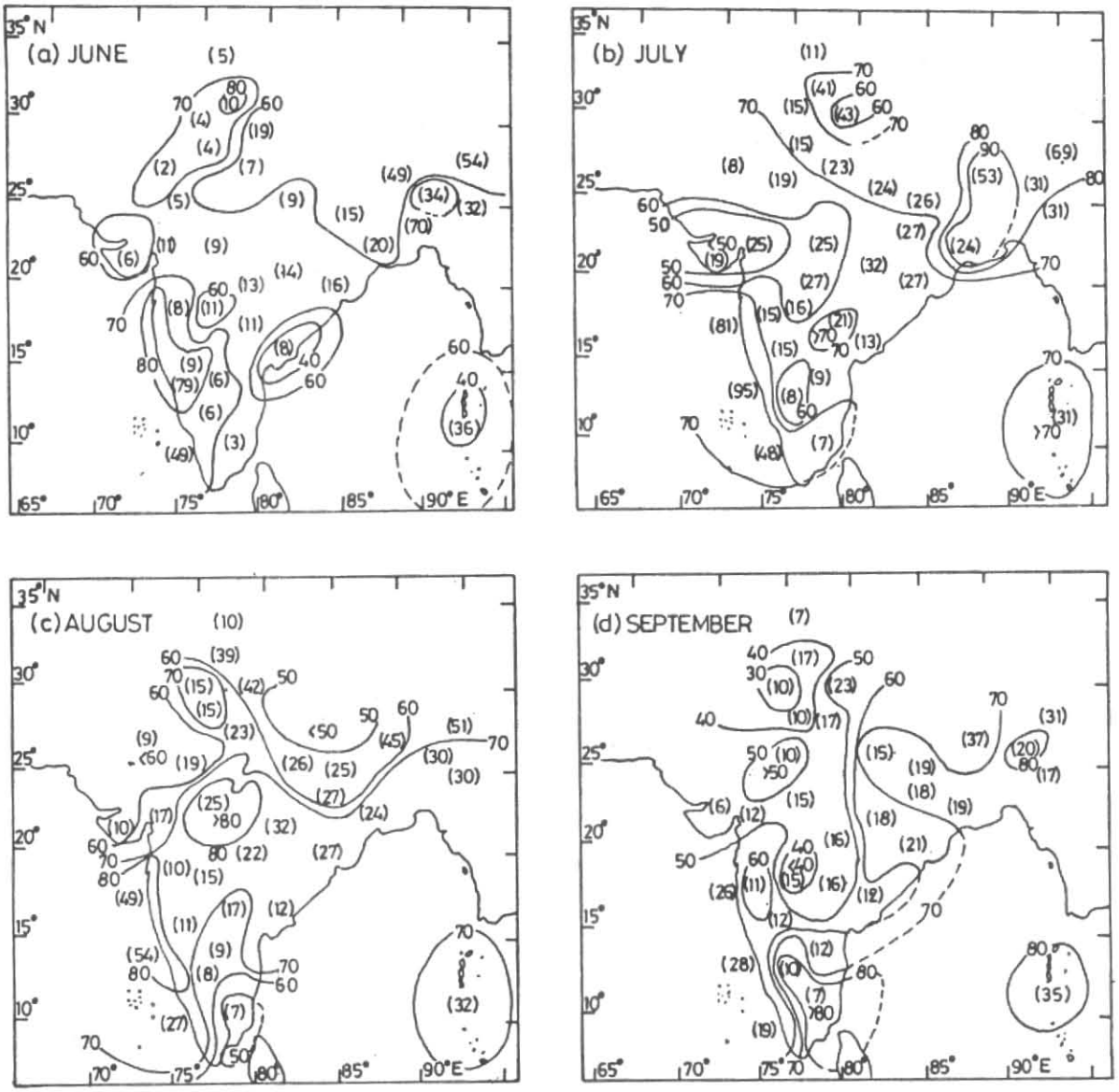
Pramanik and Jagannathan (1953) found that the probability of occurrence of deficient monsoon rainfall over arid and semi-arid region of India would be comparatively more. Rao (1958) studied the trends of rainfall over Rajasthan.



Figs.1(a-d). Monthwise probabilities of occurrence of rainfall ≥ 120% of normal rainfall. Figures in parantheses show subdivisionwise 120% rainfall amount in cm

Trends and periodicities of rainfall were studied, at west coast stations of India by Koteswaram and Alvi (1969); in sub-divisions of Maharashtra by Raghavendra (1974); in Tamil Nadu by Dhar *et al.* (1982). Rodhe and Virji (1976) analysed the trends and periodicities of seasonal rainfall of east African stations and recognised the importance of the probabilistic analysis of rainfall. Parthasarathy and Moolay (1978) investigated monsoon rainfall of five subdivisions of north India and found no significant difference in decadal mean from the long period mean. Parthasarathy *et al.* (1984, 1987) have studied the probabilities of occurrence of flood/drought over different parts of India and have found that the western parts of west Rajasthan and Gujarat are chronically drought prone areas. Biswas *et al.* (1989) and Subramanian *et al.* (1992) found a quasi periodicity of 2.5 - 3.5 years and 2.1 - 3.6 years respectively of summer monsoon rainfall in India. Raman (1990) suggested probabilistic rainfall analysis based on past data at different phases of the monsoon. De and Biswas (1994) statistically investigated sub-divisionwise rainfall probabilities upto middle of monsoon season (*i.e.* July end) and its behaviour in the later stage of monsoon period. Karmakar and Khatun (1995) studied the variability and probabilistic estimate of rainfall extremes over Bangladesh during the SW monsoon period.

In this paper, besides computation of sub-divisionwise variability and trends of monsoon rainfall, the authors have computed the sub-divisionwise monthly and seasonal



Figs.2(a-d). Monthwise probabilities of occurrence of rainfall ≥ 81% of normal rainfall. Figures in parantheses show subdivisionwise 81% rainfall amount (cm)

proabilities of occurrence of monsoon rainfall at various levels, *i.e.* probabilities of normal/excess rainfall (≥ 81 % of normal rainfall), probabilities of excess rainfall (≥ 120% of normal rainfall), probabilities of scanty rainfall (≤ 40% of normal rainfall), probabilities of the occurrence of more than twice and thrice the normal and also extreme values of rainfall. The first three features and the extreme values of rainfall have been shown area-wise in relevant figures.

2. Data and methodology

Monthly and seasonal rainfall data for the period 1965-94 (30 years) have been collected from the monsoon summary published by India Meteorological Department (IMD). The data set contain four bad monsoon years (1965, 1972, 1979 and 1987), five extremely good monsoon years (1970, 1975, 1978, 1980 and 1988) and twenty one normal/ nearly normal rainfall years. Thus the data set represent a random sample of Indian monsoon rainfall without any bias.

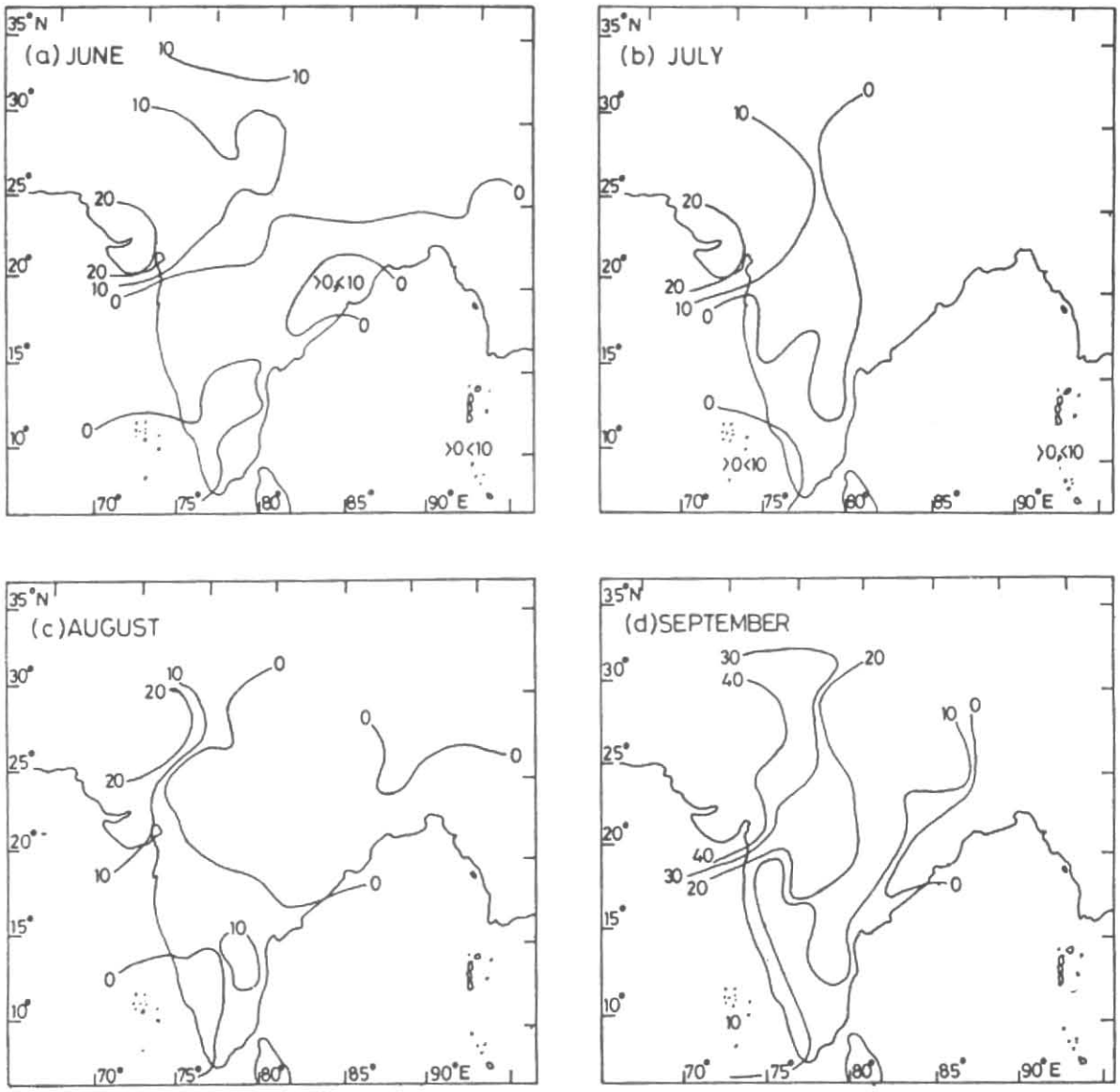
From this data set following parameters have been calculated subdivisionwise and been discussed:

(*i*) Monthly and seasonal probabilities of occurrence of excess/normal and scanty rainfall and more than twice and three times the normal rainfall.

(*ii*) Variability of monsoon rainfall.

(*iii*) Rainfall extremes (highest and lowest).

(*iv*) Spatial distribution of monsoon rainfall.



Figs.3(a-d).Monthwise probabilities of rainfall ≤ 40% of normal rainfall

The categorisation of rainfall has been done as per the IMD norms, *i.e.*

(a) Excess — rainfall 120 % or more of normal

(b) Normal — rainfall between 81 % and 119 % of normal.

(c) Deficient — rainfall between 41 % and 80 % of normal.

(d) Scanty — rainfall ≤ 40 % of normal.

3. Discussion

3.1. *Probabilistic analysis of monsoon rainfall*

Probabilities of monthly and seasonal rainfall becoming excess (R/F ≥ 120%), normal/excess (R/F ≥ 81%) and scanty (R/F ≤ 40%) have been worked out for all the Met. Sub-divisions of India and are shown in Figs.1 to 4. Probabilities are categorised as high, moderate and low as per the following norm.

Category	*Probability (%)*
(*i*) High	≥ 70
(*ii*) Moderate	Between 50 and 70
(*iii*) Low	< 50

(*i*) *Probabilities of occurrence of excess rainfall (≥ 120%)*

Areawise probabilities of monthly and seasonal occurrence of excess rainfall have been shown in Figs. 1(a-d) and Fig.4(a). It was observed that the probabilities of occur-

TABLE 1

Areawise probabilities of occurrence of > 200% rainfall

Month	Prob > 20 <30 % (6-8 occasions)	Prob> 10 < 20 % (3-5 occasions)	Prob< 10% (1-2 occasions)
June	Punjab, Himachal Pradesh, Saurashtra and Kutch	Plains of UP, Haryana, West Rajasthan and Gujarat region	GWB, Bihar, Hills of west.UP, J & K, Madhya Pradesh, Madhya Maharashtra, Rayalaseema, Tamil Nadu and Interior Karnataka
July	Nil	West Rajasthan	Haryana, Punjab, J & K, Saurashtra & Kutch, Marathwada, Telangana, Rayalaseema, Tamil Nadu & Kerala
August	Nil	J&K, Gujarat, Marathwada, Rayalaseema and coastal Karnataka	Arunachal Pradesh, Haryana, Punjab, west Rajasthan, west M.P. Telangana, NIK and LKD
September	Nil	J&K, West Rajasthan & coastal Kartnataka	Arunachal Pradesh, GWB, Bihar Plateau, UP, Haryana, Punjab, east Rajasthan, Gujarat, Konkan & Goa, Madhya Maharashtra, Marathwada, Rayalaseema, SIK, Kerala & LKD

TABLE 2

Areawise probabilities of occurrence of > 300% rainfall

Month	Probabilities < 10 % (1 - 2 occasions)
June	Haryana, Punjab, H.P., West Rajasthan and Gujarat
July	Punjab, J & K & Rayalaseema
August	J & K, Saurashtra & Kutch and Marathwada
September	Rajasthan, Konkan & Goa and Madhya Maharashtra

rence, of excess rainfall was, in general, low over all the subdivisions both on monthly as well as on seasonal scale. Further, the incidence of its occurrence was comparatively higher in the areas, where the normals were lower. However, in August its probability in coastal Karnataka was as high as in Haryana. The probabilities of its occurrence lay between 40 and 60 percent over Haryana from June to August and that was over Punjab in June and August, over Himachal Pradesh (HP). Rajasthan, Saurashtra & Kutch and north interior Karnataka (NIK) in June, over Sub-Himalayan West Bengal & Sikkim (SHWB & SKM), Bihar Plains in July, over west Madhya Pradesh (MP), Madhya Maharashtra, Vidarbha and coastal Karnataka in August and over south interior Karnataka (SIK) in September. However, the probabilities of its occurrence lay between 20 and 40 percent over maximum number of subdivisions, *i.e.* 29 in June and September followed by 27 sub-divisions in August and 23 sub-divisions in July.

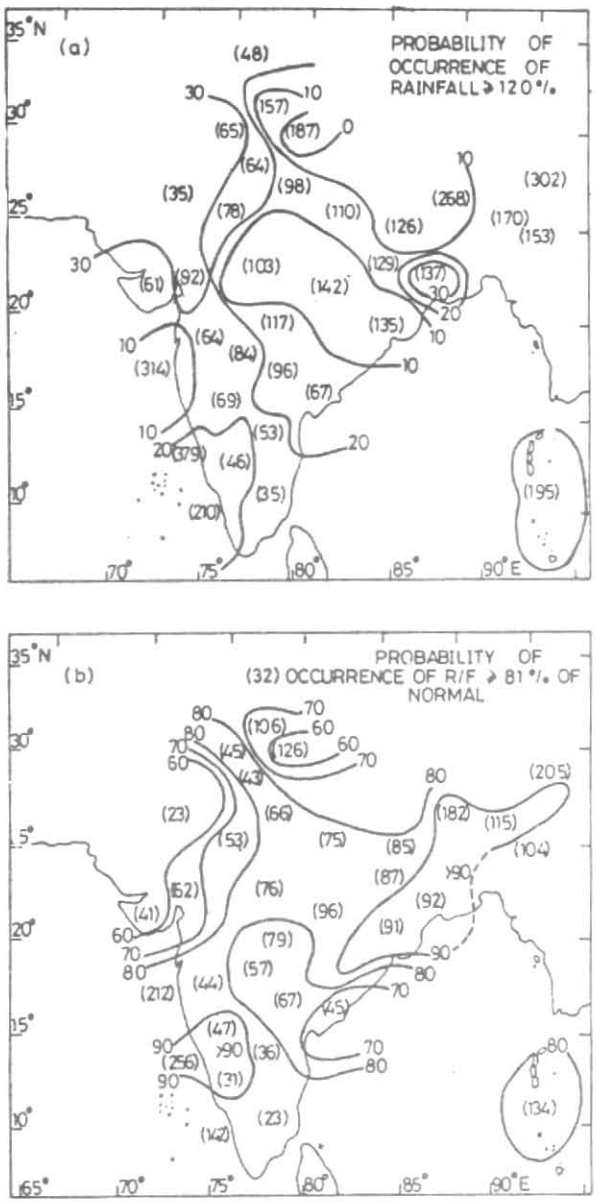
The probabilities of the seasonal rainfall becoming excess lay between 20 & 40 % in Gangetic West Bangal (GWB). Haryana, Punjab, Jammu & Kashmir (J&K) Rajasthan, Gujarat region, Madhya Maharashtra, Marathwada, Rayalaseema, Tamil Nadu, NIK and Lakshadweep (LKD) and were less than 20% elsewhere outside Andaman and Nicobar Islands (A & N Is) and hills of west Uttar Pradesh (UP), where excess seasonal rainfall hardly occurred.

(ii) Probabilities of occurrence of ≥ 81% rainfall (i.e. normal/excess)

Areawise probabilities of monthly and seasonal rainfall ≥ 81% of normal are shown in Figs.2(a -d) and Fig.4(b).

The probability of occurrence of ≥ 81% rainfall was high in 18 sub-divisions each in July and August followed by 13 sub-divisions in June and 10 sub-divisions in September. It was moderate over 20 sub-divisions in June, 17 in August, 15 in July and 13 in September and was low over 12 sub-divisions in September and 2 each in June and July. Probabilities of August rainfall becoming normal or excess was moderate to high in all the 35 Met. sub-divisions.

During the advance phase of monsoon the probability of occurrence of ≥ 81 % rainfall was high in western parts of the peninsula, Meghalaya, Haryana, Punjab and west Rajasthan and was low in coastal Andhra Pradesh. Normality of rainfall was found to be highly probable in July near and to the north of the monsoon trough (in the lower levels), West Coast and Tamil Nadu and low in Gujarat state. It appeared to have shifted to the south of the monsoon trough in the month of August. However, the probability was found in this month to be low in Tamil Nadu. It shifted in September to the east to east Uttar Pradesh and NE India and to south to Tamil Nadu and south interior Karnataka. It's probability was found to be low over NW India. Madhya Pradesh, Gujarat state, Marathwada, Vidarbha and Telangana during this month.



Figs.4(a&b). Probabilities of occurrence of seasonal (June - September) rainfall (a) ≥ 120% and (b) ≥ 81%. Figures within parantheses show (a) 120% and (b) 81% rainfall (cm)

The probability of seasonal rainfall becoming normal or excess was high over the country outside hills of west UP, HP, West Rajasthan and Gujarat, where it was moderate.

(iii) Probabilities of occurrence of scanty (≤ 40%) rainfall

Figs.3(a-d) and Fig.4(c) show the areawise probability of occurrence of monthly and seasonal scanty rainfall. In general, the probability of its occurrence was low on monthly scales and was unlikely on seasonal scale in any sub-division. However, it was comparatively higher (30-50%) over NW India and neighbourhood in September.

It was observed that most of the sub-divisions of NE India were unlikely to have scanty rainfall in any month of the season and was so in east Madhya Pradesh and coastal Karnataka during the first three months of the season. Further it was unlikely to occur in Uttar Pradesh in July and August.

(iv) Probabilities of occurrence of > 200% rainfall

The probabilities of occurrence of twice the normal or more rainfall over a sub-division were low in all the months of the monsoon period. It was observed that rainfall > 200% mainly occurred in the areas where the normal rainfall is comparatively low. Seasonal rainfall in all the sub-divisions were below 200%. Areawise probabilities of its occurrence are given in Table 1.

Areas with more than 10% probabilities of the occurrence of twice the normal or more rainfall could be a factor of consideration for any project work linked with hydrological factors.

(v) Probabilities of occurrence of > 300 % rainfall

Probabilities of monthly rainfall exceeding three times of the normal was extremely low (Prob. < 10 %) in all the months of the season. Monthwise the areas are given in Table 2.

The probabilistic information could be used advantageously for agricultural planning, irrigation and other hydrological project works.

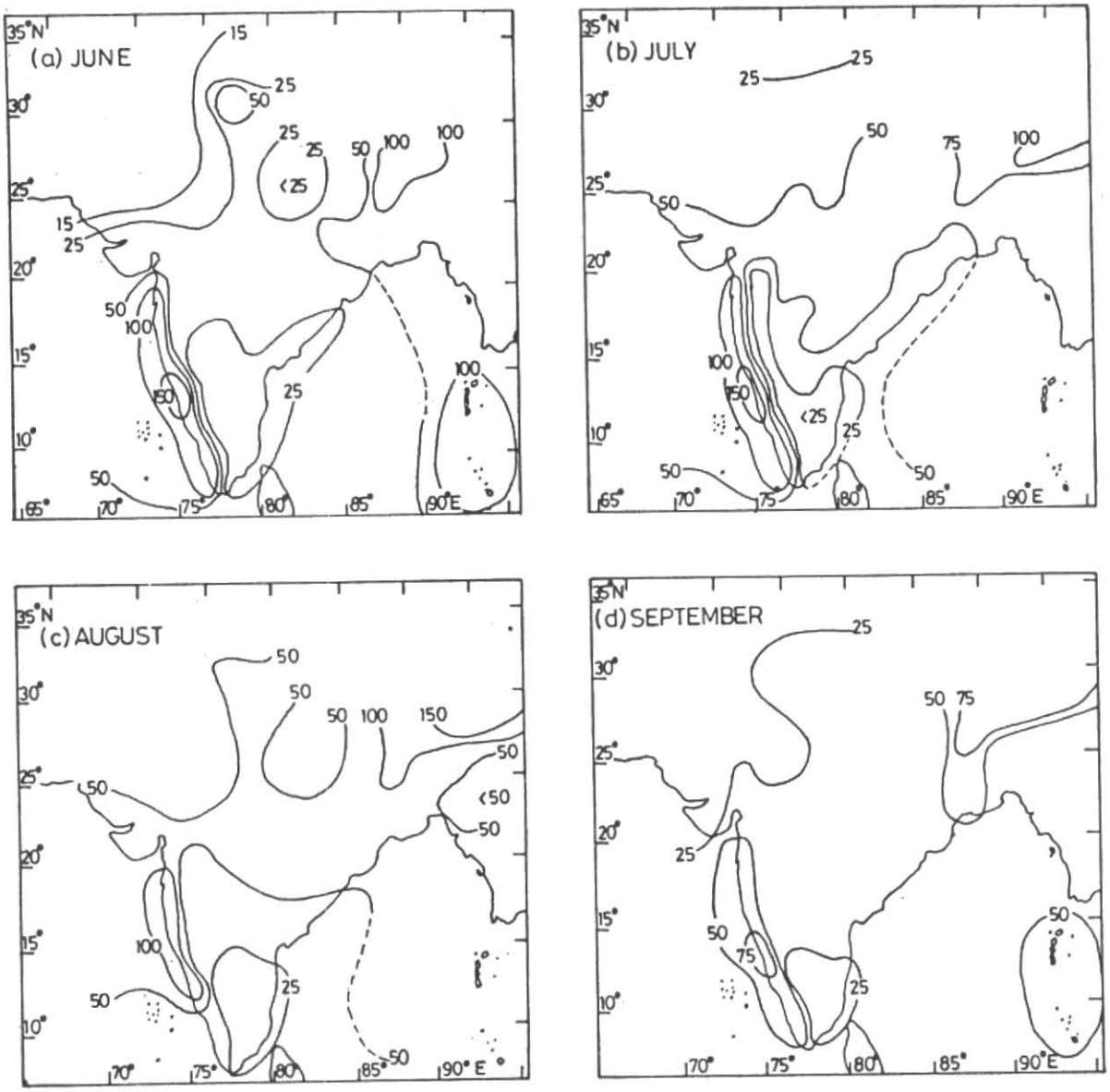
3.2. *Spatial distribution of monsoon rainfall*

Sub-divisionwise spatial distribution of monthly and seasonal rainfall has been classified into four categories namely excess, normal, deficient and scanty as per the norms of India Meteorological Deptt. Table 3 shows the averaged number of sub-divisions under each category and their standard deviations and co-efficient of variations (CVs).

It was found that on an average the rainfall in each month of the monsoon season was deficient in 10 to 11 sub-divisions. It was scanty in 1 or 2 sub-division in June, July and August which increased to 5 in September. It was found to be excess/normal in 24 sub-divisions each in July and August, 22 in June and 20 in September.

On an average, the seasonal rainfall was excess/normal in 28 subdivisions and deficient in 7 sub-divisions. However, the highest and lowest number of sub-divisions were 35 in 1978 and 16 in 1987 respectively. On the seasonal scale, no sub-division experienced scanty rainfall-a significant statistical information.

The variability of the number of sub-divisions in 'excess' & 'scanty' categories were comparatively higher than



Figs.5(a-d).Areawise highest monthly rainfall (cm)

the other categories in all the four months of the monsoon season. It could further be observed that the variability of the number of sub- division in the 'normal' category was comparatively low in June and August and that of 'deficient' category was low in July and August. In the seasonal rainfall the variability was high in 'excess' and 'deficient' categories and was low in 'normal' category.

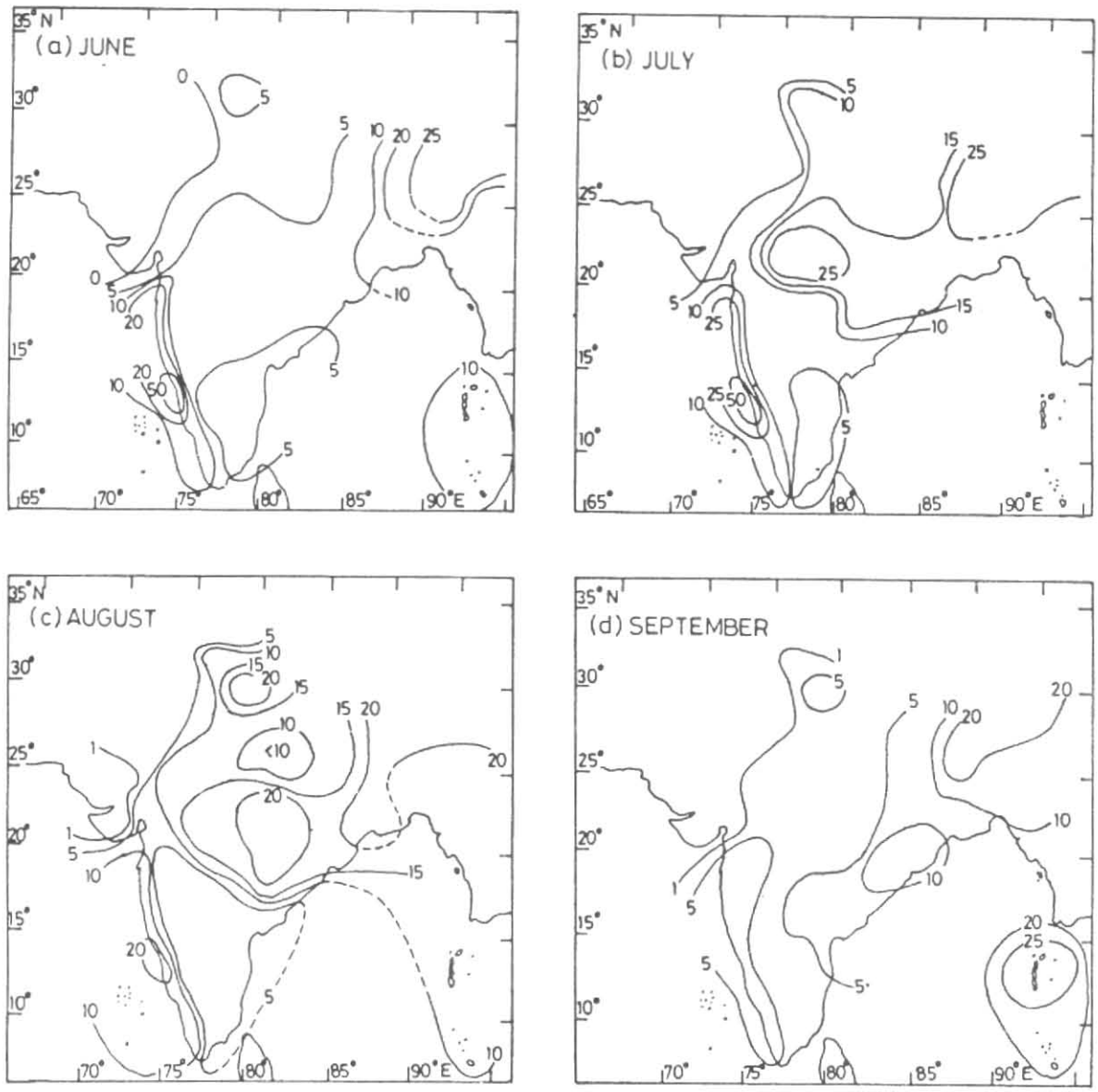
3.3. *Rainfall extremes*

Monthly and seasonal extreme amounts (highest and lowest) of southwest monsoon rainfall occured in each sub-division during the 30 years period of study are given in Tables 4 and 5. Areawise they have been shown in Figs.5(a-d), Figs.6(a-d), Fig.7 and Fig.8.

Besides the information on extreme rainfall values Tables 4 and 5 could provide significant information on the minimum assured and maximum probable future rainfall for each sub-division at different stages of the monsoon season and thus could be useful for decision makers, managers, etc. in their decision making process for smaller areas on real time basis.

Areawise following information could reasonably be obtained from these tables:

(*i*) Even in the extremely bad monsoon years rainfall in majority of sub-divisions was sufficient to



Figs.6(a-d).Areawise lowest monthly rainfall (cm)

TABLE 3

Average number of sub-divisions in each category of rainfall

Month	No. of sub-divisions				Standard Deviation (S.D.) (Figs. within parenthesis indicate CV)			
	Excess	Normal	Deficient	Scanty	Excess	Normal	Deficient	Scanty
June	10	12	11	2	6	3	5	3
					(60)	(25)	(45)	(150)
July	8	16	10	1	5	5	3	1
					(63)	(31)	(30)	(100)
August	10	14	10	1	5	3	3	2
					(50)	(28)	(30)	(200)
September	9	11	10	5	5	4	4	4
					(55)	(36)	(40)	(80)
June-Sept.	6	22	7	Nil	4	6	3	0
					(67)	(27)	(43)	

TABLE 4
Highest amount (cm) of monthly & seasonal rainfall

S.No.	Sub - division	June	July	August	September	June to September
1.	A & N Islands	106	55	53	59	189
2.	Arunachal Pradesh	98	135	175	85	338
3.	Assam & Meghalaya	81	66	51	46	222
4.	Nag., Mani., Miz. & Tripura	81	50	41	40	173
5.	SHWB & Sikkim	101	83	100	78	282
6.	Gangetic West Bengal	64	46	55	71	163
7.	Orissa	32	46	53	36	155
8.	Bihar Plateau	56	55	53	45	155
9.	Bihar Plains	38	54	57	37	155
10.	East U.P.	21	59	46	42	147
11.	Plains of west U.P.	26	41	53	36	108
12.	Hills of west U.P.	48	45	80	46	173
13.	Haryana	20	37	46	25	99
14.	Punjab	15	48	38	34	110
15.	Himachal Pradesh	57	46	72	36	185
16.	Jammu & Kashmir	15	24	31	21	63
17.	West Rajasthan	10	26	27	23	57
18.	East Rajasthan	18	40	39	10	91
19.	West Madhya Pradesh	26	57	59	31	142
20.	East Madhya Pradesh	36	58	56	39	162
21.	Gujarat Region	45	57	59	40	191
22.	Saurashtra & Kutch	32	57	69	16	93
23.	Konkan & Goa	148	134	138	60	363
24.	Madhya Maharashtra	30	23	34	33	77
25.	Marathwada	25	43	41	46	133
26.	Vidarbha	30	50	51	34	130
27.	Coastal Andhra Pradesh	22	33	25	26	85
28.	Telangana	25	52	45	35	120
29.	Rayalaseema	18	25	24	31	73
30.	Tamil Nadu	15	15	16	16	41
31.	Coastal Karnataka	167	153	143	78	470
32.	N.I. Karnataka	24	29	27	33	75
33.	S.I. Karnataka	16	17	19	24	61
34.	Kerala	108	107	49	50	166
35.	Lakshadweep	60	53	41	31	138

sustain the crops like Bajra (minimum rainfall for bajra crop is 30 cm).

(*ii*) No area could have very high rainfall in all the months of the season (Table 5).

(*iii*) From rainfall observations of the first month of the season (areawise) availability of the most probable amount of minimum and maximum rainfall during the future three months period could be obtained from Tables 4 and 5 respectively by subtracting the first month's rainfall from the seasonal ones.

(*iv*) In similar way at the end of the successive months of the monsoon period the most probable minimum and maximum future rainfall for the remaining period for smaller areas (sub- division) could be forecast.

TABLE 5
Lowest amount (cm) of monthly & seasonal rainfall

S.No.	Sub - division	June	July	August	September	June to September
1.	A & N Islands	13	7	10	25	102
2.	Arunachal Pradesh	25	31	22	20	112
3.	Assam & Meghalaya	28	34	18	12	125
4.	Nag., Mani., Miz. & Tripura	19	22	14	11	91
5.	SHWB & Sikkim	22	30	20	22	137
6.	Gangetic West Bengal	11	19	21	9	87
7.	Orissa	9	19	18	14	72
8.	Bihar Plateau	8	15	17	7	81
9.	Bihar Plains	5	13	14	7	53
10.	East U.P.	1	13	7	2	45
11.	Plains of west U.P.	0.4	12	10	2	40
12.	Hills of west U.P.	0.4	15	27	6	85
13.	Haryana	0.1	3	5	0.3	20
14.	Punjab	0.1	3	2	0	17
15.	Himachal Pradesh	5	16	14	3	59
16.	Jammu & Kashmir	1	2	3	0.4	16
17.	West Rajasthan	0	3	1	0.1	10
18.	East Rajasthan	1	5	11	1	33
19.	West Madhya Pradesh	5	29	18	2	62
20	East Madhya Pradesh	6	23	21	2	71
21.	Gujarat Region	0.1	8	5	0.2	30
22.	Saurashtra & Kutch	0	3	0.4	0.1	10
23.	Konkan & Goa	30	47	13	9	187
24.	Madhya Maharashtra	7	4	4	5	27
25.	Marathwada	6	1	4	3	35
26.	Vidarbha	8	9	17	2	60
27.	Coastal Andhra Pradesh	4	7	4	6	33
28.	Telangana	6	8	4	5	46
29.	Rayalaseema	3	3	1	2	22
30.	Tamil Nadu	2	2	2	2	18
31.	Coastal Karnataka	50	61	28	6	229
32.	North Interior Karnataka	6	8	3	4	39
33.	South interior Karnataka	2	5	4	4	24
34.	Kerala	16	19	14	5	100
35.	Lakshadweep	9	3	10	4	54

The tables could be used effectively by planners, meteorologists, and managers, on realtime basis to have an idea of the minimum assured future rainfall.

3.4. *Variability*

Areawise, co-efficient of variation (CV) of monthly and seasonal rainfall was >15% in all the 35 meteorological sub-divisions. As such the variability has been arbitrarily classified into four categories as given below:

	Category	*Range of CV (%)*
I.	Low variability	15 - 19.9
II.	Moderate variability	20 - 29.9
III.	High Variability	30 - 49.9
IV.	Very high variability	≥ 50

3.4.1. *Variability(CV) on monthly and seasonal scales*

Variability of monthly rainfall, in general, was found to be high to very high in most of the sub-divisions in all the months of the season with the following exceptions.

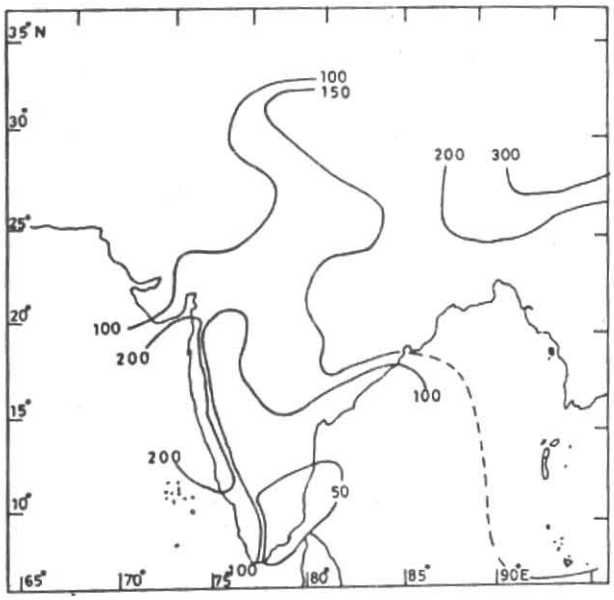


Fig.7. Areawise highest seasonal (June-September) rainfall (cm)

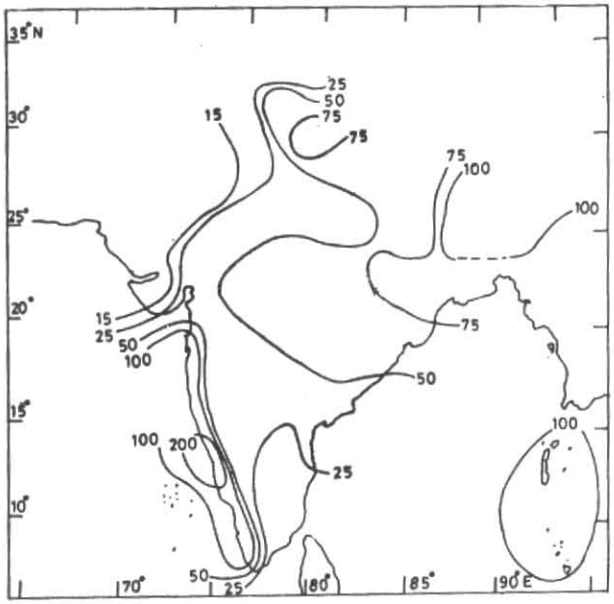


Fig.8. Areawise lowest seasonal (June-September) rainfall (cm)

(a) In June, it was found to be moderate in A & N islands, Assam and Meghalaya, SHWB & SKM, Konkan & Goa, coastal Karnataka and Kerala, where the normal rainfall was comparatively high.

(b) In July, it was low in east M.P.

(c) In August, it was moderate in A & N Islands, Assam and Meghalaya, Nagaland, Manipur, Mizorom & Tripuri (NMM & T), GWB, Orissa, Bihar Plateau, hills of west UP, and east M.P.

(d) In September, it was moderate in A & N islands and Orissa.

On seasonal (June to September) scale, the variability for most of the sub-divisions was either low or moderate. Only four sub- divisions, namely Punjab, Jammu & Kashmir and Gujarat showed high variability and west Rajasthan showed very high variability.

The low/moderate variability was the characteristics of monsoon rainfall on the seasonal scale signifying that, though the rainfall was highly variable in most of the subdivision on the monthly scale, no sub-division could have failure or partial failure of rainfall in all the months of the monsoon season.

3.5. *Periodicities (monsoon season) in sub-divisional rainfall*

The data set subjected to power spectrum analysis showed significant periodicity of seasonal rainfall of about 4 years for Gangetic West Bengal and 3 years for Haryana at 95 % significant level. Other subdivision showed no significant periodicities of seasonal rainfall.

4. Economic Value

Statistical summeries of historical data set give climate information on various time scale. Such information acquires value through its influence on the decision making of the users. Climate forecast give alternatives to decision makers at a time of uncertainty arising due to aberrant behaviour of weather / climate for improvement in decision making and can realize positive value.

Some of the climatic features emerged from the present study are given below:

(*i*) Information on the minimum assured and the maximum possible monthly and seasonal rainfall for each sub-division will be useful for hydrological projects.

(*ii*) Information computed from the Tables 4 & 5 on the availability of minimum assured and maximum probable future rainfall in each sub-division at the end of each month of the monsoon period will contribute largely towards drought and flood managements, regulation of urban water supply, irrigations, etc.

(*iii*) Areawise maps of the probabilities of the spatial distribution of monthly and seasonal rainfall will be useful for planning of agricultural operations.

5. Conclusions

(*i*) On an average, excess/normal rainfall is likely to occur in 22 sub-divisions in June, in 24 sub-divisions each in July and August and in 20 sub-divisions in September. Seasonal rainfall is unlikely to be scanty in any sub-division.

(*ii*) Areawise minimum assured and maximum probable future rainfall for the next three, two and one

month period can be predicted at the end of first, second and third month of the season from Tables 4 and 5.

(*iii*) Minimum assured rainfall is comparatively high in Assam and adjacent states and in West Bengal in all the months of the monsoon season and in West Coast during the first three months of the season.

(*iv*) The minimum assured rainfall is in excess of 15 cm/month in the sub-divisions of NE and Central India and hills of west UP during July and August. The minimum assured seasonal rainfall is in excess of 100 cm in Assam and adjacent states. West Bengal and Sikkim, Konkan and Goa and coastal Karnataka and between 50 and 100 cm in the other sub-divisions of NE India, hills of west UP, Central India and Kerala.

(*v*) Generally the probability of occurrence of excess monthly rainfall is comparatively higher in the areas where the normals are low except sub-Himalayan West Bengal & Sikkim and Bihar Plains in July and coastal Karnataka in August, where it is also comparatively higher.

(*vi*) In June probability of normal rainfall is high in western parts of the peninsular India, Meghalaya and most of NW India. In July, besides West Coast and Tamil Nadu, it is observed in the areas to the north of the monsoon trough (lower levels), whereas, in August, it appears to shift to the south of the monsoon trough. In September, it is NE India, Tamil Nadu and south interior Karnataka where the probability of normal rainfall becomes high. Its probabilities are moderate to high in all the sub-divisions in August *i.e.* in other words August rainfall is comparatively more prone to be normal than other months.

(*vii*) Both on monthly as well as on seasonal scales the probability of occurrence of scanty rainfall in any sub-division is generally low. However, during September, the subdivisions of NW India and Gujarat is more susceptible for scanty rainfall than any other areas.

(*viii*) On monthly as well as on seasonal scales the probability of occurrence of excess rainfall (≥ 120 %) is generally low. Seasonal rainfall becoming excess is unlikely in A & N Islands and hills of west UP.

(*ix*) No sub-divisions of the Indian sub-continent may have partial/total failure of rainfall in all the months of the monsoon season.

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