

Persistence, intensification and recession of meteorological drought over India during 1987

RAJENDRA PRASAD, HARI SINGH and B. LAL

Meteorological Office, New Delhi, India

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सार – दक्षिणी पश्चिमी मानसून ऋतु (जून-सितंबर) के दौरान भारत के 355 जिलों की सामान्य से संचयी साप्ताहिक वर्षा की कमियों (प्रतिशत) का उपयोग करते हुए वर्ष 1987 के दौरान भारत में जिलेवार मौसम विज्ञान से संबंधित सूखे की अवस्थिति, उसके भीषण होने और अपगमन का अध्ययन किया गया है। उत्तरपूर्वी, उत्तर और प्रायद्वीपीय भारत में दक्षिणी पश्चिमी मानसून वर्षा ऋतु की तीन विभिन्न अवस्थाओं, जैसे मानसून की प्रगति (9 सप्ताह) उसका सक्रिय होना (6 सप्ताह) और वापसी की अवस्था के दौरान (3 सप्ताह) की विशेषताओं का विश्लेषण किया गया है।

प्रमुख मौसम तंत्रों के अभाव के परिणामस्वरूप अगस्त के मध्य तक उत्तरी पश्चिमी भारत के विस्तृत क्षेत्रों में वर्षा की कमी के दौर के लंबा होने से भीषण सूखे की स्थितियाँ उत्पन्न हुईं। पूरी मानसून वर्षा ऋतु में 65 जिलों में मिली जुली मोड अवस्था विद्यमान रही। भारत के विभिन्न भागों के 209 जिलों में भीषण तीव्रता से एकबहुल अवस्थिति उत्पन्न हुई। उत्तर भारत में सूखे की तीव्रता अधिक प्रधान थी जिसने 67 प्रतिशत जिलों को प्रभावित किया। उत्तरी पूर्वी और प्रायद्वीपीय भारत के 40 प्रतिशत और उसके अधिक जिलों में सूखे का अवगमन रहा।

ABSTRACT. The persistence, intensification and recession of districtwise meteorological drought over India during 1987 have been studied using cumulative weekly rainfall deficiencies (%) from the normal during the southwest monsoon season (June-September) for 355 districts of India. These features have been analysed in northeast, North and Peninsular India during three distinct phases of southwest monsoon, *viz.*, progress (9 weeks), active (6 weeks) and retreat phase (3 weeks).

A prolonged dry spell emerged over a vast region of northwest India up to mid August due to the absence of major weather systems, leading to intense drought conditions. Mixed mode persistence prevailed throughout monsoon season over 65 districts. Unimode persistence of severe intensity occurred in 209 districts over different parts of India. Intensification of drought was more prominent in north India affecting 67% districts. Recession of drought occurred in 40% and more districts in northeast and Peninsular India respectively.

Key words – Monsoon, Persistence, Intensification, Recession, Drought, Unimode, Mixed mode.

1. Introduction

About 80% of the average annual rainfall in India is received during the four months of southwest monsoon season from June to September. The agricultural production, water resources, hydro-power generation *etc.* mainly depend on the monsoon rainfall. Therefore, the national economy of our country largely banks upon the success or failure of monsoon during a particular year.

Drought is one of the worst natural calamities that affects India due to deficient rainfall during the summer

monsoon season (June – September). Abnormally deficient monsoon rainfall in some years leads to large scale drought over India thereby adversely affecting the food production and water resource management of the country. Prolonged drought conditions persisting over a large area create innumerable socio-economic problems. Therefore, a spatial and temporal analysis of drought provides useful information to the planners, decision makers, agricultural scientists *etc.*

During 1875 to 1999, India has been affected by large scale drought several times. Although monsoon

TABLE 1

Sub-divisionwise list of districts under mixed mode persistence of 18 weeks' duration

S.No.	Met. sub-division	Districts
1	Arunachal Pradesh	—
2	Assam & Meghalaya	K & J Hills
3	Naga, Mani., Mizo. & Tri. (NMMT)	Manipur, Mizoram
4	Gangetic West Bengal	—
5	Sub-Himalayan West Bengal & Sikkim	N & S Dinajpur
6	Orissa	Kalahandi, Mayurbhanj
7	Bihar Plateau	Dumka, Chaibasa
8	Bihar Plains	—
9	East Uttar Pradesh	Bahraich, Barabanki Basti, Faizabad Gazipur, Gonda Kheri, Banda
10	Plains of west U.P.	Agra, Aligarh Hamirpur, Jalaun Jhansi, Mainpuri Mathura
11	Hills of west U.P.	—
12	Haryana, Chandigarh & Delhi	Delhi, Sirsa Rohtak
13	Punjab	Jalandhar, Ludhiana
14	Himachal Pradesh	Mandi
15	Jammu & Kashmir	—
16	West Rajasthan	Jalore
17	West M.P.	Betul, Datia Gwalior, Seoni
18	East M.P.	Bilaspur, Durg Jabalpur, Raigarh Rewa, Satna Sidhi
19	Gujarat region	Ahmedabad, Kaira Mehsana, Panchmahal, Sabarkantha
20	Saurashtra & Kutch	Jamnagar, Rajkot Junagarh
21	Konkan & Goa	—
22	Madhya Maharashtra	Pune
23	Marathwada	—
24	Vidarbha	Chanderpur, Wardha
25	Coastal A.P.	Guntur, West Godavari Krishna
26	Telengana	Mehaboobnagar
27	Rayalaseema	—
28	Tamil Nadu & Pondicherry	Coimbatore, Thanjavur
29	Coastal Karnataka	—
30	North interior Karnataka	—
31	South interior Karnataka	—
32	Kerala	Palakkad, Kollam Kottayam

rainfall displays inter-annual variability, yet the occurrence of drought is a random phenomenon. Uniquely, 1987 was one of the worst drought year when

the monsoon rains failed over vast areas of the country. About 47% area of the country was affected by drought during 1987 and it ranked 4th in order of spatial extent

during the past 125 years. However, 1918 was the worst drought year since 1875 when 70% area of the country was affected by drought. The period of three consecutive years from 1985 to 1987 has been unique in the history of monsoon rainfall as it has witnessed successively increasing deficit in all India area-weighted seasonal rainfall percentage departures of -7%, -13% and -19% in 1985, 1986 and 1987 respectively.

A number of workers in India have carried out drought studies by using different types of indices (George and Kalyansundaram, 1969; Bhalme and Mooley, 1980; Mooley and Parthasarathy, 1983; Appa Rao and Vijayaraghavan, 1983 and Choudhary and Abhyankar, 1984).

The severity of drought during 1987 necessitated a detailed study of meteorological aspects which led to the failure of monsoon rainfall. Consequently, the Director General of Meteorology, India Meteorological Department (IMD), constituted a Committee to look into the scientific aspects of the performance of the monsoon season of 1987 (Monsoon-87). The Committee carried out a detailed study of rainfall distribution, onset/advance of monsoon season, drought intensity, synoptic conditions and regional and global scale meteorological parameters associated with monsoon failure. The Committee found that several unfavourable atmospheric circulation parameters, which persisted during June to September 1987, were responsible for the failure of monsoon rains which could not be anticipated from the antecedent conditions prevailing over India and neighbourhood up to May 1987. Some of the important parameters are: persistent above normal surface pressure, particularly over 15° N - 28° N, persistence of anomalous anticyclone vorticity in the lower troposphere over India, northward position of the monsoon trough over India for a major part of the season, continuation of ENSO phenomenon which had begun in 1986 and reached its peak in June-July 1987 and absence of MTC over Arabian sea. However, other aspects pertaining to the behaviour of meteorological drought of 1987, like persistence, intensification and recession have not been investigated so far by using any specific criterion.

Prasad (1987) first suggested the concept of intensification and recession of drought in a dry farming region of India by using the percentile ranks of monthly rainfall and later Prasad and Datar (1989) carried out a detailed analysis of intensification and persistence of agricultural drought over India during 1987 by using weekly aridity anomaly index based on Thornthwaite's Water Balance technique. In the present study, authors have made an attempt to analyse critically the persistence, intensification and recession of meteorological drought

during 1987 on districtwise scale by using cumulative weekly rainfall data. Areas and periods of drought conditions of varying intensities have also been identified.

2. Data & method

Cumulative weekly rainfall data of 355 districts of India, for which requisite data for 1987 was available, has been utilised in the present study. The data was obtained from the Hydromet Division of IMD at New Delhi. These districts were covered under the Districtwise Rainfall Monitoring Scheme (DRMS) of IMD. Cumulative weekly rainfall deficiencies (%) from the normal during the southwest monsoon season (June-September) have been used to identify meteorological drought of different intensities over the districts under study.

The classification of meteorological drought (hereafter mentioned as drought) of mild, moderate and severe intensity is based on the criteria followed by IMD (1971), depicted by seasonal (June - September) rainfall deficiencies 1-25%, 26-50% and >50% respectively.

In order to identify the persistence and intensification of meteorological drought, the criteria employed by Prasad and Datar(1989) have been adopted. Recession of drought is identified when the intensity of drought recedes from severe to moderate and then mild during atleast three consecutive weeks.

The names of 32 meteorological sub-divisions considered for the present study is given in Table 1. The serial numbers of sub-divisions refer to the subdivision numbers shown in the figures. northeast, north and Peninsular India comprise of the sub-divisions at serial numbers 1- 8, 9-17 and 18-33 respectively.

3. Monsoon activity

3.1. Phases of monsoon

In order to carry out an analytical study of week-wise drought conditions in various regions of India, the southwest monsoon period has been split into three main parts (Prasad and Datar 1989) as follows:

Phase - I

Progress Phase – From onset (2 June) to complete progress (27 July).

Phase - II

Active Phase – From complete progress to start of withdrawal (12 September).

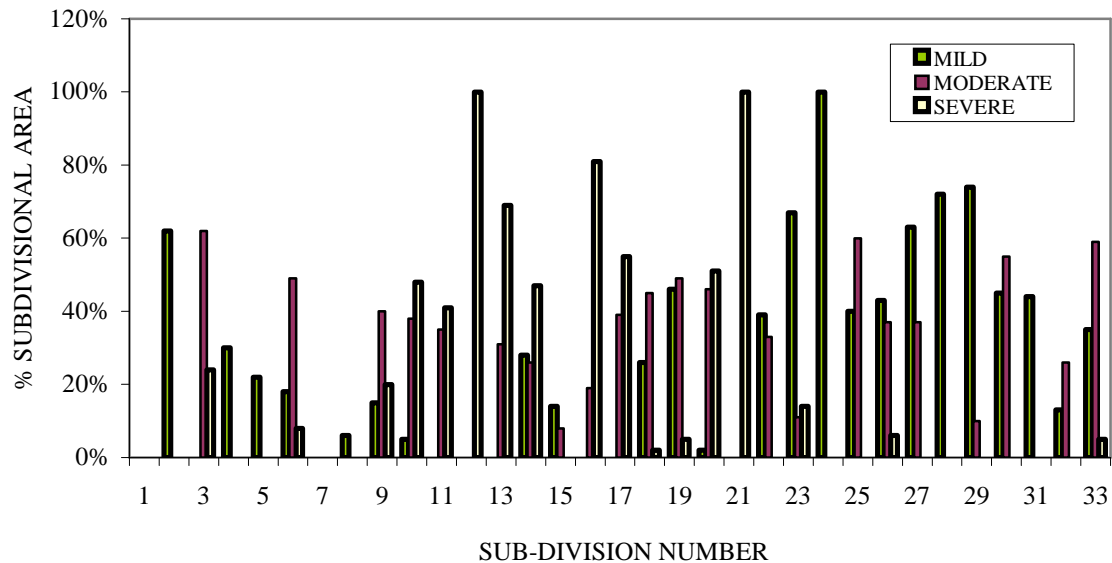


Fig. 1. Sub-divisional percentage area of districts affected by mild, moderate and severe drought during monsoon season

Phase - III

Retreat Phase – From start of withdrawal to the end of monsoon season (30 September).

3.2. Onset and advance of monsoon

The onset of monsoon occurred over Kerala close to the normal date on 2 June when a deep depression formed in central Bay of Bengal, intensified into a cyclonic storm and moved into Bangladesh by 6 June. Also simultaneously, a well marked low pressure area formed over central Arabian Sea. These synoptic systems led to the onset of monsoon over Tamil Nadu, Karnataka, Goa, Konkan, Assam, Sub-Himalayan West Bengal and parts of Gangetic West Bengal during 4-10 June. Another low pressure area formed over NW Bay on 9 June, which crossed Orissa coast on 11 June and dissipated on 13 June. It led to the advance of monsoon over Orissa and Bihar. Monsoon advance was close to the normal in the first surge (2-13 June) of monsoon activity.

There was a lull in the advance of monsoon to Gujarat and along Gangetic valley. It took nearly 10 days for the next surge.

Under the influence of cyclonic circulations in lower and mid-tropospheric levels, the second surge of monsoon activity pushed monsoon current from Bihar Plateau to

Bihar Plains on 25 June nearly two weeks behind the normal. It was a short-lived, weak surge not accompanied with an active monsoon disturbance. Thereafter, monsoon activity remained weak for nearly a month. This was a major abnormality which proved unfavourable to the progress of monsoon (IMD 1988) and consequently led to large-scale spread of drought conditions over India.

The next phase of advance of monsoon occurred during 5-15 July, when monsoon current covered Uttar Pradesh (UP) and Rajasthan under the influence of a weak low pressure area / cyclonic circulation.

Another lull period followed for about 2 weeks before the monsoon covered Delhi, Punjab and other parts of India during 24-28 July under the influence of weak upper air cyclonic circulations over north Gujarat and neighbourhood (20-26 July) and southwest Uttar Pradesh and adjoining northwest Madhya Pradesh (27-29 July), arriving late by about a month and broke all records of delayed onset over Delhi, Haryana, Plains of west U.P. and parts of Rajasthan. A general lack of cyclogenesis in the monsoon trough region noticed in July also persisted upto September (IMD 1988).

3.3. Rainfall distribution

In order to obtain realistic distribution of rainfall over various places, India has been divided into 35 meteorological sub-divisions. Various categories of

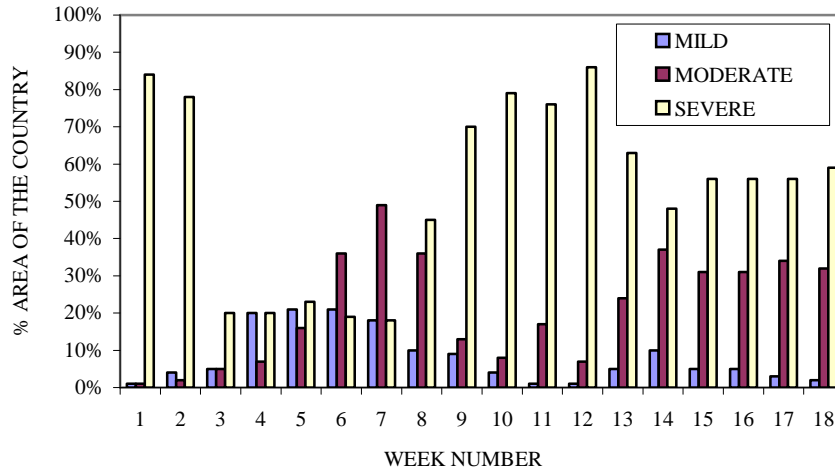


Fig. 2. Week-by-week progressive distribution of the percentage of total area of the country affected by mild, moderate and severe drought

rainfall distribution (excess, normal, deficient and scanty) described in this paper, are based on well known criteria followed by IMD.

In 1987, all India area-weighted seasonal rainfall departure was -19% . In the past, there were only four years when percentage departures of all India area weighted seasonal rainfall fell below -19% (IMD 1988). These are, 1877(-31%), 1899(-29%), 1918(-26%) and 1972(-25%).

The seasonal rainfall was excess, normal, deficient and scanty in 10, 33, 42 & 15 percent districts respectively. Thus, seasonal rainfall was excess or normal in 43% and deficient or scanty in 57% districts respectively. In northeast, north and Peninsular India the number of districts with deficient or scanty rainfall was 17%, 90% and 51% respectively. The seasonal rainfall in the remaining districts was excess or normal. Weekly progress of rainfall revealed a prolonged dry spell over a vast region in NW India during mid June to mid August. Cumulative weekly rainfall was, exceptionally, below normal during all weeks ending from 3 June to 30 September. Lowest amounts of rainfall during 30 June to mid August had adverse impact on cumulative seasonal rainfall figures.

4. Results and discussion

4.1. Areal & temporal spread of drought

Fig. 1 shows the sub-divisional percentage areas of districts under mild, moderate and severe seasonal drought. In northeast India, maximum areas were affected

by mild drought ($>60\%$) in Assam & Meghalaya and by moderate ($>60\%$) and severe ($>20\%$) drought in NMMT. In north India, severe drought appeared in all sub-divisions except Jammu & Kashmir and covered 100% area of Haryana. It spread over 40% to 70% areas of Plains & Hills of west Uttar Pradesh, Punjab, Himachal Pradesh and west and east Rajasthan. In Peninsular India, severe drought was prominent in only two sub-divisions, viz., Gujarat region (50%) and Saurashtra & Kutch (100%). Moderate drought spread over 40% to 60% areas in Vidarbha, Coastal Andhra Pradesh, Telengana, Coastal Karnataka and Kerala. Mild drought persisted over most of the sub-divisions covering 100% area of Marathwada and 60% to 70% areas of Madhya Maharashtra, Telengana, Rayalaseema and Tamil Nadu.

A week-by-week progressive distribution of the percentage of total area of the country affected by mild, moderate and severe drought is shown in Fig. 2. It reveals that more than 75% area was under severe drought in the first two weeks when there were no major weather systems. Subsequently, monsoon advanced under the influence of a trough (12-17 June) extending from Gujarat coast to Kerala-Karnataka coast, a well marked low pressure area (7-10 June) over east central Arabian Sea and cyclonic circulations in lower and mid/upper tropospheric levels during 5-24 June. Consequently, the area under severe drought decreased to 20% by the end of Phase I due to the increased rainfall activity with the advance of monsoon. Thereafter, from 8th week onwards, the areal spread of severe drought increased gradually attaining a peak (85%) in the 12th week ending on 13th August. During this period, mostly in situ cyclonic circulations were seen in the lower and mid tropospheric

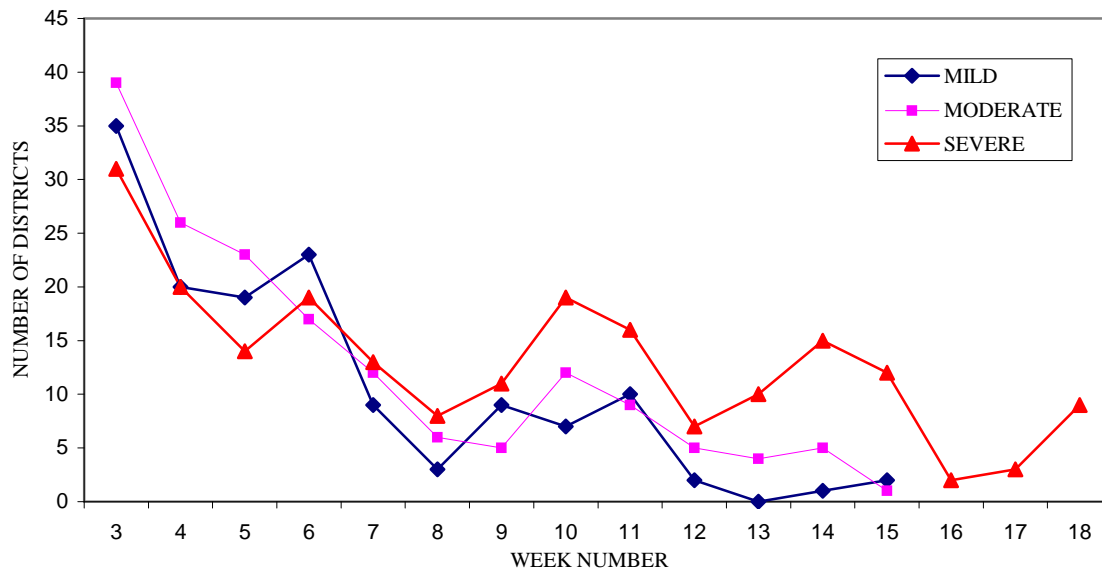


Fig. 3. Distribution of districts under unimode persistence of mild, moderate and severe drought for different durations (3 to 18 weeks)

levels over Gujarat, Bihar, Punjab and neighbourhood, southwest Bay of Bengal and southeast Arabian Sea. Monsoon activity, however, remained weak during this period.

The percent area of the country affected by severe drought decreased to about 60% in the 13th week ending on 26 August and remained nearly so thereafter till the end of monsoon.

4.2. Persistence

4.2.1. Mixed mode persistence

Analysis of mixed mode persistence of various durations, viz., 3-7, 8-12, 13-17 and 18 weeks was also carried out to identify areas of prolonged persistence. In NE India, mixed mode persistence covered 60% districts of Arunachal Pradesh for 8-12 weeks, 50% districts of NMMT for 13-17 and 18 weeks each and 60% districts of each Gangetic West Bengal and Orissa for 13-17 weeks. Mixed mode persistence of longer duration was more prominent in north India where it covered more than 60% districts in each of the sub-divisions, viz., Hills of west Uttar Pradesh, Haryana, Punjab and Himachal Pradesh and more than 50% districts in each of west and east Rajasthan for 13-17 weeks. In Peninsular India, mixed mode persistence prevailed throughout monsoon season in more than 45% districts of east Madhya Pradesh and Gujarat region reaching a maximum of 75% in Saurashtra

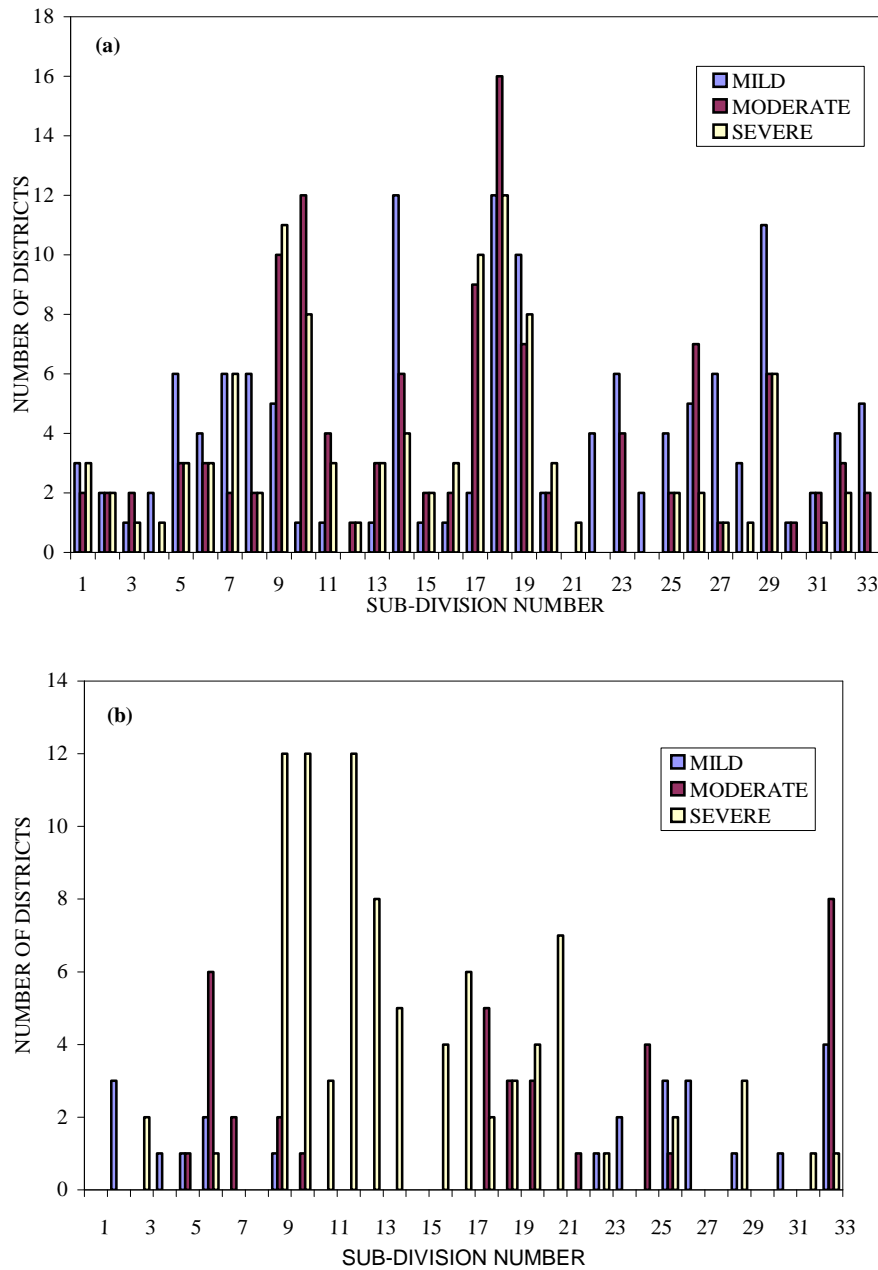
& Kutch. The number of districts under mixed mode persistence of 13-17 weeks was 45% and 50% in Coastal Andhra Pradesh and Coastal Karnataka respectively rising upto 65% in Kerala.

Table 1 gives the sub-divisionwise list of districts covered by mixed mode persistence of drought throughout the monsoon season (18 weeks). It shows the severity of drought over different parts of India during 1987.

The mixed mode persistence of drought commenced in the beginning of Phase-I in almost all sub-divisions except Punjab, Himachal Pradesh and Jammu & Kashmir where it began in the middle of Phase-I. It terminated in the middle of Phase-I in all sub-divisions of NE India. It continued upto the end of Phase-III in most sub-divisions of North India as well as east Madhya Pradesh, Gujarat region, Saurashtra & Kutch, Konkan & Goa and Kerala in Peninsular India. Mixed mode persistence was short-lived in the remaining sub-divisions in Peninsular India.

4.2.2. Unimode persistence

Fig. 3 shows the distribution of districts under unimode persistence of mild, moderate and severe drought of different durations ranging from 3 to 18 weeks. More than 30 districts were affected by unimode persistence of each category of drought, viz., mild (35), moderate (39) and severe (31) for a duration of 3 weeks and their number declined gradually with the increasing duration of drought



Figs. 4(a&b). Sub-divisionwise number of districts affected by unimode persistence of mild, moderate and severe drought for (a) ≤ 9 weeks and (b) >9 weeks

persistence. Following districts remained under severe drought persistence for duration of 16 or more weeks:

- (a) 16 weeks : Jalaun, Jalandhar
- (b) 17 weeks : Mainpuri, Sirsa, Pune
- (c) 18 weeks : Fatehpur, Kanpur, Lucknow, Etawah, Dhaulpur, Banaskantha, Bhavnagar, Diu, Kutch.

Figs. 4 (a&b) show sub-divisionwise number of districts under unimode persistence of mild, moderate and severe drought for (a) ≤ 9 weeks and (b) >9 weeks. The unimode persistence of mild and moderate drought upto 9 weeks was more prominent in almost all sub-divisions than that exceeding 9 weeks. In north India, maximum 12 districts were affected by unimode persistence of mild, moderate and severe drought upto 9 weeks' duration in each of the sub-divisions, viz., Himachal Pradesh, Plains of west Uttar Pradesh and east Uttar Pradesh

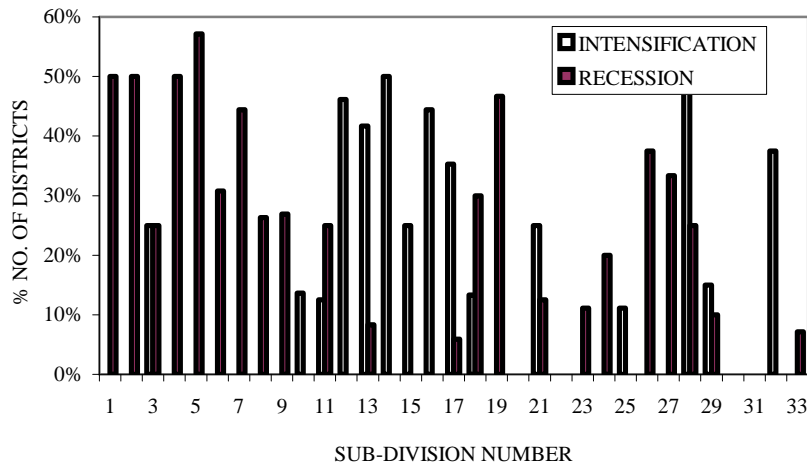


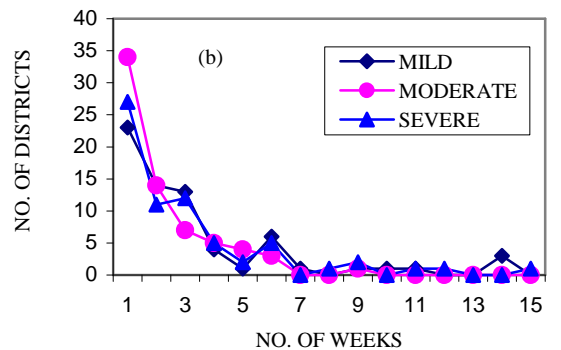
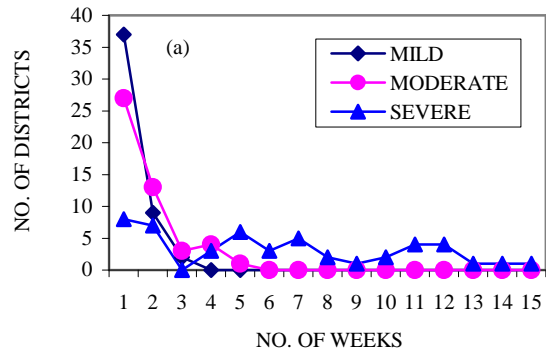
Fig.5. Sub-divisionwise distribution of percent number of districts under intensification and recession of drought

respectively. In Peninsular India, highest number of districts were affected by unimode persistence of mild(12), moderate(16) and severe(12) drought in west Madhya Pradesh.

The influence of unimode persistence of severe drought of more than 9 weeks' duration was less prominent in northeast and Peninsular India as compared with North India where almost all sub-divisions displayed unimode persistence of severe drought. The highest number of districts emerged in east Uttar Pradesh, Plains of west Uttar Pradesh and Haryana (12 each). In Peninsular India, maximum seven districts were affected by persistence of severe drought in Saurashtra & Kutch. The maximum number of districts (8) were affected by unimode persistence of moderate drought in Kerala.

4.3. *Intensification*

The sub-divisionwise percent distribution of districts under intensification and recession is shown in Fig. 5. In NE India, intensification occurred only in Tripura in NMMT. However, north India was widely affected by intensification. Out of the total number of districts under intensification, 67% pertained to north India. In Haryana, Punjab, Himachal Pradesh and west Rajasthan, the number of districts under intensification ranged from 35% to 50%. The areal spread of intensification was much less in Peninsular India, where it occurred in about 25% districts in Saurashtra & Kutch and south interior Karnataka. Maximum 50% districts remained under



Figs. 6(a&b). Number of districts under mild, moderate and severe drought of different durations during the course of (a) intensification and (b) recession

intensification in Rayalaseema only and did not exceed 25% in any other sub-division.

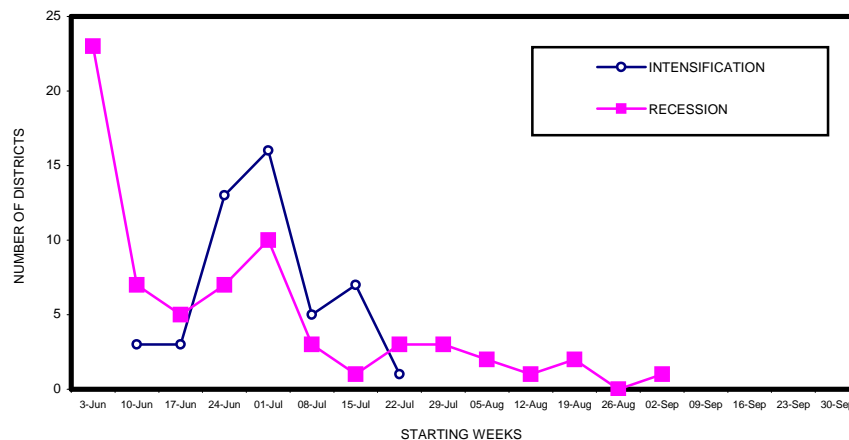


Fig. 7. Number of districts in which intensification /recession commenced in different weeks

An attempt was made to find out the duration of mild, moderate and severe drought in different districts during the course of intensification [Fig. 6(a)]. The maximum number of districts were affected by drought of different intensities during one to two weeks. The maximum duration of moderate and severe drought was 15 weeks. However, the number of districts under severe drought of any duration did not exceed 10.

Severe drought appeared for 9 weeks in Jaisalmer, 10 weeks in Karnal and Chikmagalur, 11 weeks in each Hissar, Faridkot, Nagaur and Jaipur, 12 weeks in Bulandshahar, Jind, Kurukshetra and Surendranagar, 13 weeks in Hamirpur, 14 weeks in Manali and a maximum period of 15 weeks in Rohtak.

The number of districts in each of the weeks, when the process of intensification commenced, is shown in Fig. 7. The maximum number of districts were affected by intensification during the weeks ending on 24 June and 1 July. The number of districts emerged as 13 and 16 respectively together amounting to 60% of the total number (48) of districts influenced by intensification.

The commencement of widespread intensification apparently corresponds to the periods of lull (14-24 June), weak surge (25-30 June) and weak monsoon activity (1-4 July). A second maxima, during the week ending on 15 July, corresponds to the beginning of a second lull period.

4.4. Recession

Fig. 5 shows the sub-divisionwise percent number of districts affected by recession of drought. Recession was most prominent in NE India, where it occurred in all sub-

divisions. Arunachal Pradesh, Assam & Meghalaya, Gangetic West Bengal, Sub-Himalayan West Bengal and Bihar Plateau each displayed recession in 30% to 50% districts. Recession of drought was insignificant in north India where it occurred in 25% - 30% districts in east Uttar Pradesh and Hills of west Uttar Pradesh. It appears that little rainfall activity associated with *in situ* cyclonic circulations over north India failed to wipe out or weaken drought conditions significantly. In Peninsular India, a number of sub-divisions had recession of drought affecting maximum about 50% districts in east Madhya Pradesh and about 30% districts in each west Madhya Pradesh, Coastal Andhra Pradesh and Telengana.

Fig. 6(b) shows the number of districts under mild, moderate or severe drought of different durations during the course of recession. The maximum number of districts were under drought of different intensities during one to three weeks. The maximum duration of severe drought was 14 weeks.

Severe drought appeared for 9 weeks in Rae Bareilly, 10 weeks in Varanasi, 11 weeks in Pratapgarh and 14 weeks in Allahabad, Sidhi and Satna.

It is seen from Fig. 7 that the recession commenced in maximum number of districts in the first week of monsoon season, which supports the fact that the drier conditions get humid as the monsoon gets established over the country. The phase of recession and absence of intensification was marked by the active surge of monsoon during 2-13 June when monsoon current extended over greater part of Peninsular India. Second maxima of recession appeared in NE India in the week ending on 1 July. However, recession commenced in a number of

districts upto the week ending on 19 August. A land depression and three low pressure areas developed over the Indian sub-continent and adjoining sea areas during the month of August in addition to three western disturbances which moved eastwards across the extreme north India yielding rainfall which resulted in the conditions of recession over a number of districts.

5. Conclusion

The salient features of the present study are enlisted below :

(i) The prolonged dry spell over a vast region in NW India during mid June to mid August caused severe drought conditions. In north India, 90% districts received deficient or scanty rainfall during monsoon season, where about 50% districts covering more than 40% area in each sub-division except Jammu & Kashmir came under the impact of severe drought.

(ii) Mixed mode persistence of longer duration was more prominent in north India. However, it prevailed throughout monsoon season in more than 45% districts of east Madhya Pradesh and Gujarat region and maximum 75% districts of Saurashtra & Kutch in Peninsular India. 65 districts remained under mixed mode persistence throughout the monsoon season.

(iii) Unimode persistence of moderate drought exceeding 9 week's duration occurred in maximum 6 districts of Orissa in northeast India and 8 districts of Kerala in Peninsular India. It was severe in 12 districts of each east Uttar Pradesh and Plains of west Uttar Pradesh and Haryana in north India. Nine districts remained under severe drought persistence throughout the monsoon season.

(iv) Intensification of drought was most prominent in North India affecting 67% districts. northeast India was least affected, where only Tripura suffered from intensification. Generally, the commencement of intensification corresponded to the lull period.

(v) Recession of drought occurred in 44% districts of Peninsular India followed by 40% districts in northeast India. It took place in only 16% districts in 4 sub-divisions of north India.

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