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Some characteristics of intra-seasonal variability of southwest monsoon rainfall

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सार - हमारे देश की अर्थव्यवस्था पर दक्षिण-पश्चिमी मॉनसून वर्षा और क्षेत्रीय पैमाने पर उसकी परिवर्तिता, स्थानिक और कालिक दोनों ही, का महत्वपूर्ण प्रभाव रहता है। योजनाकारों, अर्थशास्त्रियों और कृषि विशेषज्ञों को इस जानकारी की आवश्यकता है कि दक्षिण पश्चिम मॉनसून ऋतु के पूर्वार्द्ध के चार महीनों के दौरान ऋतु के आगे बढने के साथ क्षेत्रीय पैमाने पर विसंगतियां कम होंगी या नहीं। जून और जुलाई के पहले दो महीनों तथा पूरी ऋतु (जून - सितम्बर) के संबंध में 60 वर्षों (1951-2010) की अवधि की ऋतु की वर्षा का अध्ययन किया गया है। इस शोध पत्र में इसकी जांच की गई है कि क्या ऋतु के दौरान वर्षा के पैटर्न में परिवर्तन आता है तथा क्या मॉनसून के विफल होने की कोई स्थानिक संबद्धता है। अल-निनो की घटना तथा मॉनसून की विफलता की भी जांच की गई है। परिणाम दर्शाते हैं कि, सामान्यत: दक्षिण-पश्चिम मॉनसून ऋतु के वितरण में ऋतु के अंत में मॉनसून की कमी वाले क्षेत्रों में भरपाई की प्रवृत्ति और मॉनसून की अधिकता वाले क्षेत्रों में कमी की प्रवृत्ति देखी गई है।

ABSTRACT. Southwest monsoon rainfall and its variability on regional scale, both spatial and temporal, have significant impact on the economy of our country. Whether the anomalies on the regional scale during the earlier half of the four-month SW monsoon season would be reduced or not as the season progresses is needed by planners, economist and agriculturist. Seasonal rainfall for a period of 60 years (1951-2010) have been studied for the first two months of June and July and the whole season (June-September). Whether the rainfall pattern changes within the season and or whether there is any spatial coherence in the failure of monsoon have been examined. Occurrence of El-Nino and failure of monsoon has also been examined. The results show that, in general, there is a tendency for a late season recovery in the distribution of southwest monsoon rainfall in the areas of deficiency and reduction in areas in excess category at the end of the season.

Key words – El-Nino, Epochal variation, Spatial coherence, Area-weighted, Southern oscillation, Drought, Clustering.

1. Introduction

Indian summer monsoon is an annual phenomenon with noticeable regularity. But, its onset, activity during the season, its withdrawal and quantum of seasonal rainfall (Fig. 1) are all subject to variations that are often large. Any aberration in the normal behaviour of southwest monsoon like late onset, rainfall deficiency in certain months, prolonged breaks, early withdrawal etc. has a severe impact on the agricultural oriented Indian economy (Gadgil *et al.*, 1999). Year to year variation of southwest monsoon rainfall in different homogenous areas has been a matter of scientific investigations by many workers (Banerjee and Raman (1976); Bhalme and Mooley (1980); Mooley and Parthasarathy (1984). Normand (1953) observed that India is large enough to be treated as single unit and some areas like Bengal and Assam are negatively correlated with Mumbai and Central India monsoon rains. The Long Period Average (LPA) of All India Summer Monsoon Rainfall (AISMR) based on the period 1941-1990 is found to be 890 mm and the standard deviation of the seasonal rainfall is about 10 per cent. Years with seasonal rainfall in excess of one standard deviation over LPA have been referred to as "Flood years" and those with less than one standard deviation below the LPA as "Drought Years". AISMR displays multi-decadal variations in which there is clustering of wet and dry Years. Several other studies (Thapliyal and Kulshreshtha 1991; Pant and Kumar 1997; Rupakumar *et.al.*, 1992; Rajeevan *et al.*, 2006) have also indicated a highly variable behaviour of AISMR with a prominent epochal nature of variability. Kripalani and Kulkarni (1997) have discussed the epochal variation of monsoon rainfall and ENSO-AISMR relationship. They have shown that the impact of El-Nino on AISMR is more severe during below normal epochs than during the above normal epochs.

Efforts have been made to find out whether the anomalies during the earlier part of the four-month SW monsoon season would be recovered as the season progresses and if so what are their chances. How the first

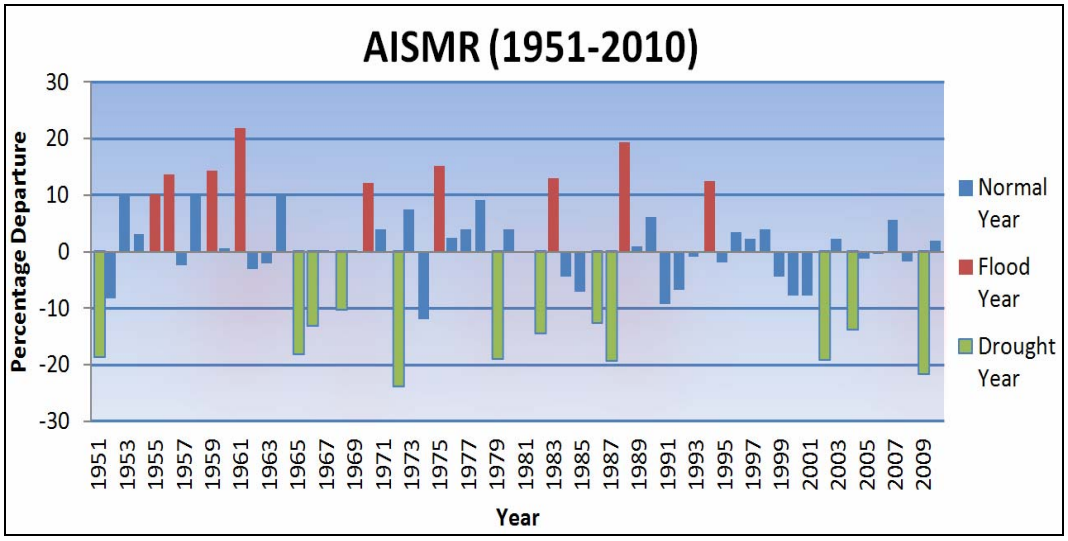

Fig. 1. Interannual variability of AISMR during the period from 1951 to 2010

two months of monsoon performance is related to the total seasonal performance has been examined by Subramanian (1994). De and Biswas (1994) have examined the probabilities of failure of monsoon during June and July for various subdivisions. They also looked into the probability as to how the failure in the first two months is made up in the later half of the season. In the present study rainfall during June and July and for the whole season for a period of 60 years (1951-2010) has been studied. An attempt has been made to see how the rainfall pattern changes within the season and whether there is any spatial coherence in the failure of monsoon. Occurrence of El-Nino and failure of monsoon has also been examined.

2. Data and methodology

Weekly rainfall departures for meteorological sub-divisions for June to September have been utilized for the period 1951-2010. The rainfall departures are given under four categories Excess (≥ 20% of the normal); Normal (lying between -19% and +19% of the normal); Deficient (lying between -20% and -59% of the normal) and Scanty (less than -60% of the normal). During each year the southwest monsoon season is divided into two parts, the first part comprising of June and July and the second of complete season, *i.e*., June-September.

Table 1 gives the number of sub-divisions and the total area which received Deficient and Scanty (D-S) rains during June + July and during whole season for a period of 60 years (1951-2010). Similarly Table 2 gives the number of sub-divisions and the corresponding area which received excess rainfall. Earlier a similar study was carried out by De and Vaidya (1996) for 31 meteorological sub-divisions of India using data for a period of 35 years (1960-1994).

3. Results and discussion

SW monsoon covers almost the whole of the country except some parts of Rajasthan by 1st July. It covers Rajasthan during the first fortnight of July. The rainfall received in the first two months (June-July) of the southwest monsoon season constitutes about 65% of the seasonal rainfall for the sub-divisions of west coastal peninsula, about 52% for sub-divisions of northeast India and about 48% for the sub-divisions falling under northwest, central India and rest peninsula. It is therefore natural that the deficiency in rainfall during the first half of the season becomes a cause of concern and an advance information as to whether the rainfall deficiency in a given region of interest gets wiped out with the realisation of some extra rainfall during August and September becomes important. This aspect of monsoon rainfall has been studied using 60 years data at sub-divisional level and the country as a whole.

The average number of sub-divisions falling under deficient and scanty category works out to be 9 (8.80) which comprises of 26.2% of the total area of India during the first half of the season while at the end of the season the average becomes 6 (6.37) and 18.3% area of the country. Thus in general there appears to be a tendency for a late season recovery in the distribution of SW rainfall in conformity (De and Vaidya, 1996). The average number of sub-divisions under Excess category works out to be 8 (7.67) covering 22.2% of the total area of India during the first half of the season while at the end

TABLE 1

Year wise number of Sub-divisions and area of India which received Deficient and Scanty rainfall during June + July and that at the end of the Southwest Monsoon Season

Year	No. of Sub-div. in D/S category at the end of July	Area and its % of the total area of the country which received D/S rainfall till the end of July		No. of Sub-div. in D/S category till the end of the season	Area and its % of the total area of the country which received D/S rainfall till the end of season	
		Area (km^2)	%		Area (km^2)	%
1951	17	1878753	57.1	16	1717183	52.2
1952	8	720503	21.9	9	716852	21.8
1953	5	694583	21.1	0	0	0.0
1954	4	652398	19.8	1	45821	1.4
1955	9	1293747	39.4	1	79638	2.4
1956	1	32	0.0	2	38896	1.2
1957	4	459167	14.0	4	416607	12.7
1958	11	1045338	31.8	2	66260	2.0
1959	4	383350	11.7	2	240747	7.3
1960	5	379623	11.5	1	86597	2.6
1961	5	288035	8.8	1	83578	2.5
1962	14	1436708	43.7	2	219126	6.7
1963	13	1223687	37.2	2	305076	9.3
1964	6	378090	11.5	1	50362	1.5
1965	14	1299716	39.5	17	1756228	53.4
1966	9	891097	27.1	13	1186541	36.1
1967	8	849636	25.8	0	0	0.0
1968	6	593199	18.0	11	1097713	33.4
1969	11	1006737	30.6	6	708255	21.5
1970	6	458852	14.0	0	0	0.0
1971	6	554182	16.9	5	568067	17.3
1972	21	2203786	67.0	19	1709637	52.0
1973	7	777600	23.7	1	146509	4.5
1974	13	1330908	40.5	12	1262715	38.4
1975	5	447521	13.6	2	95152	2.9
1976	10	980642	29.8	6	361877	11.0
1977	2	352785	10.7	1	222236	6.8
1978	1	130549	4.0	2	159473	4.9
1979	14	1543739	47.0	13	1346405	41.0
1980	3	201028	6.1	5	460639	14.0
1981	5	523403	15.9	3	321206	9.8
1982	19	2189264	66.6	12	1312516	39.9
1983	11	988637	30.1	2	149911	4.6
1984	10	1282125	39.0	8	484953	14.8
1985	9	849082	25.8	12	1173026	35.7
1986	12	854512	26.0	12	1012477	30.8
1987	23	2149639	65.4	20	2158974	65.7
1988	0	0	0.0	0	0	0.0
1989	5	593084	18.0	5	391807	11.9
1990	8	812914	24.7	5	250340	7.6
1991	12	1369924	41.7	9	1062151	32.3
1992	17	1620850	49.3	5	423696	12.9
1993	9	1003550	30.5	5	573052	17.4
1994	6	456438	13.9	10	784698	23.9
1995	7	648703	19.7	3	215304	6.5
1996	4	283631	8.6	3	304441	9.3
1997	5	450268	13.7	3	255107	7.8
1998	3	512910	15.6	2	290674	8.8
1999	5	497138	15.1	8	755119	23.0
2000	6	389798	11.9	7	850447	25.9
2001	8	432753	13.2	6	492221	15.0
2002	26	2347691	71.4	20	1776639	54.0
2003	5	435885	13.3	5	286441	8.7
2004	13	1218785	37.1	13	1158627	35.2
2005	4	345335	10.5	4	345335	10.5
2006	11	969198	29.5	9	719339	21.9
2007	6	448055	13.6	5	383530	11.7
2008	11	897616	27.3	3	304862	9.3
2009	20	1766338	53.7	22	2284249	69.5
2010	7	803214	24.4	5	487625	14.8

TABLE 2

Year wise number of sub-divisions and area of India which received excess rainfall during June + July and that at the end of the southwest monsoon season

Year	No. of sub-div. in Excess category at the end of July	Area and its % of the total area of the country which received Excess rainfall till the end of July		No. of sub-div. in Excess category till the end of the season	Area and its % of the total area of the country which received Excess rainfall till the end of season	
		Area (Km^2)	%		Area (Km^2)	%
1951	7	444094	13.5	3	176655	5.4
1952	5	707262	21.5	0	0	0.0
1953	15	1234043	37.5	11	1182443	36.0
1954	7	388244	11.8	10	663009	20.2
1955	5	448922	13.7	8	810888	24.7
1956	20	2290934	69.7	13	1427813	43.4
1957	2	291279	8.9	1	222236	6.8
1958	9	767061	23.3	12	1180613	35.9
1959	14	1148493	34.9	18	1646569	50.1
1960	7	574565	17.5	3	213050	6.5
1961	20	1930241	58.7	18	1878983	57.2
1962	0	0	0.0	3	258133	7.9
1963	2	120198	3.7	3	195402	5.9
1964	11	901169	27.4	11	895357	27.2
1965	5	393783	12.0	2	99371	3.0
1966	4	217793	6.6	2	352785	10.7
1967	8	702203	21.4	4	308266	9.4
1968	5	397807	12.1	1	38864	1.2
1969	1	70447	2.1	3	354214	10.8
1970	5	358685	10.9	13	1066511	32.4
1971	10	1131194	34.4	7	541029	16.5
1972	0	0	0.0	0	0	0.0
1973	4	395500	12.0	6	758579	23.1
1974	6	597878	18.2	4	264517	8.0
1975	12	1241206	37.8	20	1853419	56.4
1976	10	958390	29.2	8	865016	26.3
1977	13	1175837	35.8	7	714622	21.7
1978	13	1173176	35.7	13	965048	29.4
1979	4	372934	11.3	3	286729	8.7
1980	14	1445224	44.0	5	506564	15.4
1981	10	1079748	32.8	6	499885	15.2
1982	0	0	0.0	0	0	0.0
1983	7	686041	20.9	15	1347338	41.0
1984	9	813244	24.7	5	421015	12.8
1985	6	383989	11.7	1	130549	4.0
1986	5	691079	21.0	1	66228	2.0
1987	3	278828	8.5	5	373980	11.4
1988	15	1395331	42.4	18	1682905	51.2
1989	13	1269577	38.6	7	500760	15.2
1990	8	812073	24.7	9	940307	28.6
1991	12	803460	24.4	6	342399	10.4
1992	1	38864	1.2	2	233950	7.1
1993	6	580667	17.7	1	70447	2.1
1994	17	2021089	61.5	12	1609385	49.0
1995	5	654490	19.9	7	594665	18.1
1996	6	704335	21.4	10	1041471	31.7
1997	5	494423	15.0	8	897570	27.3
1998	9	667547	20.3	10	664900	20.2
1999	4	263102	8.0	3	240104	7.3
2000	11	1201754	36.6	5	478276	14.5
2001	10	1274236	38.8	1	155782	4.7
2002	1	28924	0.9	1	222236	6.8
2003	11	920570	28.0	8	955165	29.1
2004	1	94238	2.9	0	0	0.0
2005	11	1061084	32.3	8	702813	21.4
2006	3	311893	9.5	6	884997	26.9
2007	11	787531	24.0	13	1053303	32.0
2008	9	957596	29.1	2	206144	6.3
2009	2	265772	8.1	3	283046	8.6
2010	11	1287938	39.2	14	1418976	43.1

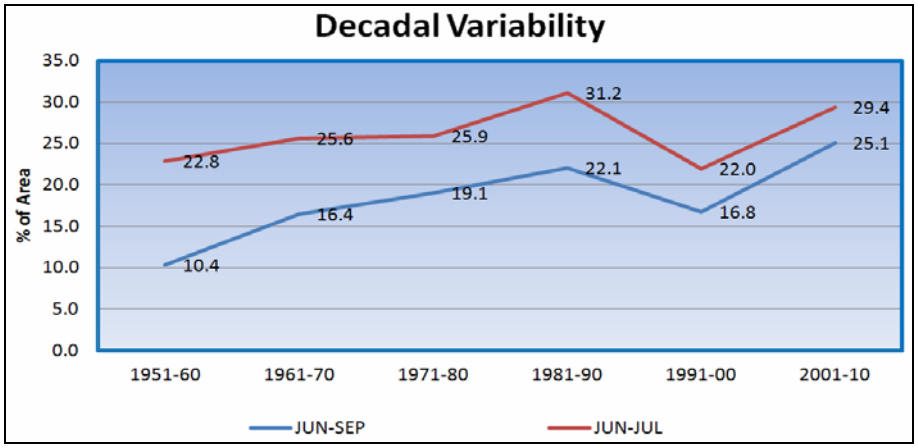

Fig. 2. Percentage of total area of India under Deficient/Scanty (D/S) category rainfall

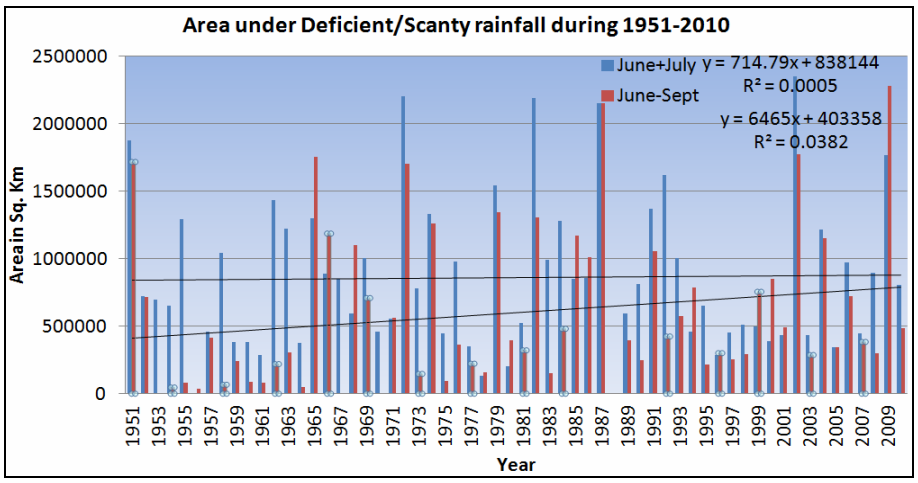

Fig. 3. Area under Deficient/Scanty (D/S) rainfall during 1951-2010

of the season the average becomes 7 (6.65) comprising of 19.2% area of country. This shows that there is deterioration in the area in excess category at the end of the season. However, the average number of sub-divisions receiving Excess rainfall is maintained (De and Vaidya, 1996).

3.1. *Inter-annual variability*

There are large year to year variations in the area as well as the number of sub-divisions coming under the D/S category (Fig. 3). Some of the significant features of the analysis are discussed below:

3.1.1. *First half of the season*

(a) The year 2002 ranks as the worst year in which 71 % of the total area of India (26 sub-divisions) was under the D/S category. This was followed by 1972 (67%), 1982 (66.6%), 1987 (65.4%), 1951 (57.1%) and 2009 (53.7%) with 21, 19, 23, 17 and 19 sub-divisions respectively under D-S category. But even during these six years of major failure of southwest monsoon, there was improvement during the second half of the season in five years with respect to both the area as well as the number of sub-divisions under D/S category decreasing at the end of the season except in 2009.

(b) During the years 1965, 1966, 1968, 1980, 1985, 1986, 1994, 1999, 2000 and 2009 the area under D/S category increased during second half of the season. In the remaining 50 years there was a decrease in the number of sub-divisions as well as the area at the end of the season. Out of these ten years, 1965, 1966, 1968 and 2009, were drought years.

(c) Table 3 gives subdivision-wise statistics of number of occurrences rainfall falling under Deficient / Scanty

TABLE 3

Sub-divisionwise statistics of number of occurrences of Deficient/Scanty rainfall during June - July and its recovery/deterioration during August-September

S. No.	Name of Sub-division	No. of years of Deficient/Scanty rainfall till the end of July	No. of years of no Recovery in D/S rainfall till the end of season	No. of years of Late seasonal recovery till the end of season	No. of years of Deterioration from June- July to the end of season	No. of years of Deficient/Scanty rainfall in Jun-Sep
1.	Andman & Nicobar	18	11	7	3	14
2.	Arunachal Pradesh	10	7	3	0	7
3.	Assam & Meghalaya	6	4	2	2	6
4.	NMMT	18	8	10	0	8
5.	SHWB & Sikkim	8	6	2	2	8
6.	Gangetic WB	15	5	10	1	6
7.	Orissa	14	2	12	2	4
8.	Bihar	16	8	8	3	11
9.	Jharkhand	18	10	8	1	11
10.	East U.P.	18	10	8	4	14
11.	West U.P.	19	10	9	3	13
12.	Uttarakhand	15	10	5	2	12
13.	HAR CHD & Delhi	15	9	6	6	15
14.	Punjab	11	8	3	4	12
15.	Himanchal Pradesh	16	11	5	6	17
16.	J & K	18	8	10	4	12
17.	West Rajasthan	18	10	8	10	20
18.	East Rajasthan	22	10	12	5	15
19.	West M.P.	20	6	14	4	10
20.	East M.P.	21	8	13	4	12
21.	Gujrat Region	21	10	11	7	17
22.	Saurastra & Kutch	25	16	9	2	18
23.	Konkan & Goa	5	2	3	3	5
24.	Madhya Maharashtra	9	4	5	3	7
25.	Marathwada	14	5	9	1	6
26.	Vidarbha	16	13	3	2	15
27.	Chattisgarh	14	6	8	4	10
28.	Coastal A.P.	12	5	7	4	9
29.	Telangana	16	9	7	2	11
30.	Rayalaseema	11	5	6	4	9
31.	Tamil nadu	13	6	7	1	7
32.	Coastal Karnataka	8	3	5	2	5
33.	North Interior Karnataka	7	2	5	2	4
34.	South Interior Karnataka	11	5	6	2	7
35.	Kerala	18	12	6	2	14
36.	Lakshadweep	14	8	6	3	11

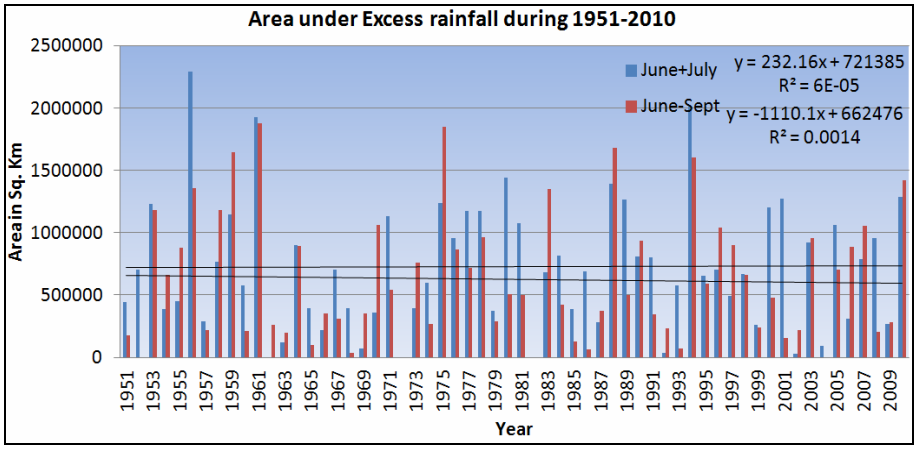

Fig. 4. Area under excess rainfall during 1951-2010

(D/S) rainfall category during June-July and its recovery/deterioration during August-September. It follows from Table 3 that there were 22 years out of 60 when the area under D/S category was low (<10 sub-divisions).

(d) The years 1956, 1978 and 1988 appear to be the best monsoon years during the 60 year period (1951-2009) with near zero area coming under D/S category during the first half or entire season. 1961 and 1975 are two 'Flood' years in this period. In the present study also these years rank as very good monsoon years with areas receiving Deficient and Scanty rainfall being less than 10,000 sq km (Fig. 4).

3.2. *Second half of the season*

(a) As mentioned above there is, in general, an improvement in the rainfall distribution (decrease in the area under D/S category) in the later half of the season. This holds good for drought years also.

(b) The years 1958, 1962, 1963 1976, 1983, 1992 and 2008 showed remarkable improvement in the second half of the season. In all these years except 1982, the number of sub-divisions under D/S category decreases from 10 or more (897616 sq km) in the first half of the season to 5 or less (423696 sq km) at the end of the season. While in 1982 it decreased from 19 sub-divisions under D/S category during the first half to 12 at the end of the season.

(c) During some of the years, *e.g.*, 1951, 1955, 1991 and 2002 breaks occurred during June and/ or middle of July causing substantial decrease in rainfall in the first two months of the season whereas there was improvement in rainfall activity due to increased number of lows, depressions and storms in August and September, *e.g.*, rainfall in the years, 1962, 1976 and 1982.

3.3. *Decadal variability*

There were 44 years, out of 60 years when monsoon could be termed as good. They had less than 1/3 of the area coming under Deficient/ Scanty (D/S) category. Two decades, *i.e.*, 1951-1960 and 1991-2000 had only one year and other four decades 1961-1970, 1971-1980, 1981-1990 and 2001-2010 had three years each when less than 1/3 of the area of the country came under D/S category. During these 44 years the number of sub-divisions under Excess category ranged between 2 to 20. More than 50% of the total areas came under Excess category at the end of the season in 1959, 1961, 1975, 1988 and 1994.

Average percentage of area under D/S category for two decade, 1951-60 and 1991-2000 are 22.8 and 22.0 respectively during the first half of the season which is less than the average percentage area of the study period (26.2). This shows good rainfall in first half and good seasonal recovery at the end of the season (Fig. 2). Despite three drought years each in the decades 1961-70 and 1971-80, the percentage area in first half of the season is close to average of the study period whereas in the decade of 1961-70 seasonal recovery is better than in the decade of 1971-80. For the two decades, 1981-90 and 2001-10, percentage area under D/S category in first half of the season are 31.2 and 29.4 respectively which is much higher than the entire study period average suggesting poor rainfall in the first half of the season and poor late seasonal recovery. In the decade 1981-90 despite poor rainfall in the first half, there is remarkable late seasonal recovery whereas in the decade 2001-10 there was poor late recovery with 25.1 per cent of total area of India coming under D/S category.

3.4. *ENSO linked drought and flood years*

Several workers [Sikka (1980), Krishnakumar *et. al.* (2006)], have established that the probability of having positive departure in seasonal rainfall on all India scale is very small during El-Nino years. Most of the drought years are concentrated in El-Nino years. The concurrent El-Nino years since 1951, noted by Rasmusson and Carpenter (1983) and Fredric and Miller (1992) are 1957, 1965, 1969, 1972, 1976, 1982, 1986, 1991, 1994, 1997, 2002, and 2009 while the events with cold temperatures are 1954, 1955, 1956, 1964, 1970, 1973, 1975, 1988, 1998, 1999, 2007 and 2010. Of these 1951, 1965, 1972, 1982, 1987, 2002 and 2009 El-Nino years were associated with years of major failures of monsoon though the area and intensity of the D/S rainfall were different.

3.4.1. *Drought years*

(a) 1982 is the drought year during which improvement is seen in 34% and simultaneously deterioration in 7% of the area of the country at the end of the season, followed by 1972, 22% and 7%; 2002, 17% and 5%; 1979, 16% and 10%; and 1974, 15% and 13% respectively. The worst late season recovery was seen during the drought years of 1968 and 2009 in 6% of the area was under improvement then the deterioration 22% followed by years 1965, 7% and 21% and 1966, 9% and 18% within the season.

(b) During the ENSO linked drought years like 1965, 1966, 1968, 1986 and 2009, except 1987, the number of sub-divisions which were in Deficient/Scanty category till the end of July was less than the number at the end of the season. The corresponding areas of sub-divisions under D-S category also showed similar variation. Years 2002 and 1972 showed remarkable late seasonal recovery.

(c) Failure of monsoon rainfall during the years 1974, 1979 and 2004 recurred even when there was no El-Nino either in the preceding or in the subsequent years. There was no significant change in area as well as number of sub-divisions in D/S category at end of the season.

(d) 1985 was followed by El-Nino year 1986. Both years showed poor rainfall in the later half of the season.

3.4.2. *Flood years*

(a) For all La-Nina years during the study period, the ISMR was positive except for the year 1999. During the year 1999 there was deterioration from 15% to 23% in area under D/S category from the first half till the end of the season.

(b) During the years 1956 and 1988 there was no area under D/S category in the first half as well as for the season.

(c) The good monsoon years 1955, 1954 and 1973 can be categorised as years of remarkable recovery in the second half of the season.

4. Spatial pattern

The year to year deficiency pattern reveals a kind of clustering of the areas under D/S category. Joshi *et.al.*, (1981), De and Joshi (1993) and De and Vaidya (1996) had also reported similar type of clustering in the sub-divisions which showed close association among them in the weekly, monthly rainfall departures during the southwest monsoon season.

There appears to be some preferred zones of deficient-scanty pattern in the rainfall on the seasonal/sub-seasonal scale (June-July). These are:

I. A zone extending from Orissa, Bihar, Uttar Pradesh to Punjab and Haryana. Punjab has shown good rainfall in the first half in recent decades.

II. A zone extending from Chattisgarh, Madhya Pradesh to East Rajasthan through Vidarbha and Gujarat.

III. Interior Maharashtra, Andhra Pradesh and Karnataka.

There is consecutive yearly deficient rainfall seen in some sub-divisions, *e.g.*, Chattisgarh, Telangana, Coastal Karnataka and Kerala in recent decades. During years of major failures of monsoon 2009, 2002, 1987, 1982, 1979, 1974, 1972 and 1965 the deficient and scanty area extended into all the three zones cited above. In 1966 it was confined to the first two zones, in 1968 to zones II and III and in 2004 it was confined to zones I and III.

Since the areas of meteorological sub-divisions are not uniform, the total area which comes under D/S category may be taken as a better index of rainfall deficiency in a given year. Using these criterion, the very poor monsoon years can be ranked as: 2009, 1987, 2002, 1965, 1951, 1972, 1979, 1982, 1974 and 1966 when the area under D/S category exceeded 12,00,000 sq km (approximately little less than 40% of the total area of the country). There is significant increasing trend in the areas coming under Deficient and Scanty category for whole of the season but no trend for the first half (June-July) of the season is seen Fig. 3.

During the above mentioned years either there was late onset of monsoon or a number of spells of break

occurred inspite of development of good number of lows or cyclonic disturbances during the season, *e.g*., 1972, 1966 and 1965. Years when the area under D/S category was between 10,00,000 and 12,00,000 sq km, can be ranked moderately poor monsoon years such as 1985, 2004, 1968, 1991 and 1986. In the sample of 60 years there were in all 16 years under above mentioned two categories. In the remaining 44 years the country had less than one third of its area (≤10,00,000 sq km) under the D/S category. This is an important feature of southwest monsoon and could be of use in providing climate related information.

5. Conclusions

(*i*) In general there appears to be a tendency for a late season recovery in the distribution of southwest monsoon rainfall.

(*ii*) The average number of sub-divisions and the total area receiving Excess rainfall get reduced from the first to second half of the season. This implies that there is deterioration in the area in Excess category at the end of the season. In other words, monsoon rainfall tends to become normal by the end of season.

(*iii*) There was a deterioration in D/S category in the later half of the season during the years 1965, 1966, 1968, 1985, 1986, 1994, 1999, 2000 and 2009. Only 1986, 1994 and 2009 were El-Nino years. On the other hand during the remaining 51 years there was an improvement in rainfall which included years of very poor and moderately poor monsoon as well.

(*iv*) The normal monsoon years 1953, 1960, 1962, 1963, 1967, 1976, 1992, 1993 and 2008 had remarkable recovery during the later half of the season. However, the corresponding increase in the Excess category was not noticeable. Incidentally 1953 was an El-Nino year.

(*v*) During 1951, 1952, 1956, 1960, 1965, 1968, 1971, 1974, 1977, 1978, 1980, 1981, 1984, 1985, 1986, 1989, 1991, 1993, 1994, 2000, 2005 and 2008 there was deterioration in the number of sub-divisions receiving excess rain as well as area coming under this category.

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