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SOME CHARACTERISTICS OF THE INTER-RELATIONSHIP IN MONTHLY AND SEASONAL MONSOON RAINFALL OVER ORISSA

1. Indian summer monsoon rainfall shows large scale intra-seasonal and inter-annual variabilities. Any advance information on the availability of monsoon rainfall will be immensely helpful to the planners, managers and others, as the principal source of surface water is the summer monsoon rainfall. Satakapan (1951) has felt the usefulness of various statistical analyses with the past rainfall data base to facilitate planners and managers for efficient surface water management. Pramanik and Jagannathan (1953) have found that the probability of occurrence of deficient monsoon rainfall over arid and semi-arid regions of India would be comparatively more. Parthasarathy *et al*. (1984 and 1987) have studied the probabilities of occurrence of flood/drought over different parts of India. Raman (1990) has suggested probabilistic rainfall analysis based on past data at different phases of monsoon. De and Biswas (1994) have statistically investigated subdivision-wise rainfall probabilities upto middle of monsoon season (up to July end) and its behaviour in the later stage of monsoon period.

2. Orissa state, which lies adjacent to north Bay of Bengal, also lies adjacent to but to the south of the eastern

TABLE 1

Statistical characteristics of monsoon rainfall over Orissa

Period	Jun	Jul	Aug	Sep	Season (JJAS)
Long period average (cm) based on data of 1901-70	22.1	35.6	35.5	24.4	117.6
Mean rainfall departure (%) during 1960-2000	-3.7	-10.8	3.5	-5.1	-4.4
Lowest rainfall departure (%) (year of occurrence)	-66 (1964)	-51 (1974)	-46 (1987)	-57 (1996)	-40 (1974)
Highest rainfall departure (%) (year of occurrence)	64 (1986)	27 (1994)	60 (1983)	126 (1961)	32 (1961, 1994)

end of normal position of monsoon trough over Indian main land. As most of the synoptic disturbances develop over the north Bay of Bengal and move west-northwestwards along the monsoon trough and most intense rainfall takes places over the region, a little south of the monsoon trough (Raghavan, 1973; Pathan, 1993), the monsoon rainfall over Orissa largely depends on the activity and location of monsoon trough and the characteristic features like, region of formation, intensity and movement etc. of the synoptic disturbances developing over Bay of Bengal and moving along the monsoon trough. The rainfall over Orissa is contributed mainly by the interaction of these synoptic disturbances with the basic monsoon flow and the orography in Orissa due to eastern Ghat hill range over south Orissa and other hill peaks in different parts of Orissa. The variations in the characteristics of monsoon trough and the synoptic disturbances over Bay of Bengal contribute largely to the intra-seasonal variability of monsoon rainfall over Orissa.

3. The monthly and seasonal monsoon rainfall departures from long period average over Orissa during the period 1960-2000 are collected from India Meteorological Department (IMD). These data are used to find out the different seasons with above average, below average, normal, excess and deficient rainfall. If the rainfall departure from the long period average is positive (> 0) the rainfall is considered as above average rainfall. If the rainfall departure from the long period average is negative (< 0), it is considered as below average rainfall. If the rainfall departure from the long period average is within –19% to + 19%, it is considered as normal rainfall. If the rainfall departure from the long period average is ≤-20%, it is considered as deficient rainfall. If the rainfall departure is ≥ 20%, it is considered as the excess rainfall. The long period average is calculated based on the rainfall data during 1901-70. The above mentioned classification of rainfall into excess, deficient and normal rainfall categories is based on the IMD norms.

The correlation coefficients (CC) of seasonal monsoon rainfall with the rainfall during different monsoon months are calculated and analysed. The stability of the CC is tested by calculating the CC between above average seasonal rainfall and the corresponding monthly rainfall, CC between below average seasonal rainfall and the corresponding monthly rainfall and CC between extreme (excess/deficient) seasonal rainfall and corresponding monthly rainfall. The probabilities of occurrence of different categories of rainfall during different monsoon months, bi-monthly periods and the monsoon season are calculated and analysed based on the data of 1960-2000.

4. According to the long period average calculated from the data of 1901-70, Orissa receives about 117.6 cm of rainfall during the monsoon season. It receives about 22.1 cm, 35.6 cm, 35.5 cm and 24.4 cm respectively during June, July, August and September (Table 1). From Table 1, the mean rainfall departures over Orissa are found to be –3.7%, –10.8%, 3.5%, –5.1% and –4.4% during June, July, August, September and the season respectively. Considering the seasonal rainfall, the data set (1960-2000) consists of two excess rainfall years (1961, 1994), four deficient rainfall years (1974, 1987, 1996 and 1998) and 35 normal rainfall years. The frequencies of years with below average rainfall, above average rainfall and average rainfall are 25, 14 and 2 respectively. The negative mean departure of seasonal rainfall and

TABLE 2

Correlation coefficients between seasonal rainfall and corresponding monthly rainfall over Orissa during monsoon season

Corresponding monthly rainfall	Whole period seasonal rainfall	Above average seasonal rainfall	Below average seasonal rainfall	Excess/deficient seasonal rainfall
June	**0.44**	0.41	**0.56**	**0.92**
July	**0.52**	0.29	0.09	**0.87**
August	**0.56**	0.08	**0.63**	**0.66**
September	**0.63**	**0.69**	0.26	**0.82**
June-July	**0.69**	**0.49**	**0.6**	**0.95**
July-August	**0.76**	0.29	**0.69**	**0.89**
August-September	**0.81**	**0.6**	**0.73**	**0.93**

Correlation coefficients, significant at 95% level of confidence are shown in bold figures

Above average rainfall : Rainfall > long period average
Below average rainfall : Rainfall < long period average
Excess rainfall : Rainfall ≥ 120% of long period average
Deficient rainfall : Rainfall ≤ 80% of long period average
Normal rainfall : Rainfall ≥ 81% and ≤ 119% of long period average

significantly higher negative departure during July may be due to the fact that the monsoon rainfall over Orissa depends significantly on the frequency, intensity and movement of the monsoon depressions developing over north Bay of Bengal and moving west-northwestwards along the monsoon trough. The frequency of these monsoon depressions is significantly less during the period under study than the long period average, specially during July (Mohapatra and Gupta, 2000). The rainfall departure ranges from –66% to 64% during June, from –51% to 27% during July, from –46% to 60% during August, from –57% to 126% during September and from –40% to 32% during the monsoon season (Table 1). The information on extreme rainfall can provide significant information on the minimum assured and maximum probable future rainfall at different stages of monsoon season and thus can be useful for decision makers, water resource managers and others.

5. Considering the CC between seasonal rainfall departures and the corresponding monthly rainfall departures from the long period averages over Orissa, the seasonal monsoon rainfall is directly correlated with the rainfall in all the individual monsoon months (Table 2). However, the CC is maximum between seasonal rainfall and rainfall in September .Also the bi-monthly rainfall in June-July, July-August and August-September are directly correlated with the rainfall during the season with the CC in each case being significant at least at 0.95 level of confidence. However the CC between bi-monthly rainfall in August-September and seasonal rainfall is maximum. It may be due to the fact that the frequencies of cyclonic disturbances and total synoptic disturbances are higher during August- September than during June-July or July-August. According to Mohapatra and Gupta (2000), during the period of 1960-98, the frequency of monsoon depressions crossing the coast between Vishakhapatnam and Kolkata, which generally affects rainfall over Orissa during monsoon season, is maximum in August followed by September, June and July. As the rainfall over Orissa largely depends on the frequency of the synoptic disturbances including the cyclonic disturbances and monsoon lows, the seasonal rainfall is more correlated with the rainfall in the months associated with higher frequencies of synoptic disturbances. So the correlation between seasonal rainfall and bi-monthly rainfall during August and September is higher than that between seasonal rainfall and bi-monthly rainfall during July-August or June-July.

6. Considering different categories of seasonal rainfall, it is found that there is direct correlation between the above average rainfall during the season and corresponding rainfall in all individual monsoon months (Table 2). However, the seasonal rainfall is significantly correlated only with the rainfall in September. The above

TABLE 3

Probabilities (%) of occurrence of different categories of monsoon rainfall over Orissa

Period	Category of monsoon rainfall					
	Above average	Below average	Normal	Excess	Deficient/scanty	Excess/deficient/scanty
Jun	37	63	39	29	32	61
Jul	27	71	56	7	37	44
Aug	51	49	49	27	24	51
Sep	50	49	51	15	34	49
Jun-Sep	34	61	**85**	5	10	15
Jun-Jul	27	73	**76**	7	17	24
Jul-Aug	44	56	71	10	20	30
Aug-Sep	46	54	66	17	17	34

The high probabilities (>75%) are shown in bold figures

average rainfall during the season is also directly correlated with corresponding bi-monthly rainfall during June-July, July-August and August-September being most significantly so with rainfall during August-September followed by that during June-July. Here again it indicates that the rainfall during August and September has more influence on seasonal rainfall which may be due to the higher frequency of synoptic disturbances affecting rainfall over Orissa during the months of August and September. Though the nature of the CC remains same, the significance of CCs in July and August are very less for the above average seasonal rainfall than for the whole period rainfall (1960-2000).

Considering the below average seasonal rainfall and the corresponding monthly rainfall, there is also direct correlation between seasonal rainfall and the monthly rainfall over Orissa (Table 2). However the seasonal rainfall most significantly increases with increase in rainfall during August followed by that in June. The seasonal rainfall most significantly increases with increase in bi-monthly rainfall during August-September followed by July-August. Like the previous cases, it may be attributed to the higher frequency of synoptic disturbances affecting rainfall over Orissa during August-September. Unlike the whole period rainfall, the CC is not significant between below average seasonal rainfall and the rainfall in July and September.

Considering the excess/deficient seasonal rainfall and the corresponding monthly and bi-monthly rainfall, the CCs are positive and highly significant for all individual months, June-July, July-August and August-September (Table 2). The relation between the excess/deficient seasonal rainfall and the corresponding monthly/bi-monthly rainfall differs significantly from the relation between below average seasonal rainfall/above average seasonal rainfall and the corresponding monthly and bi-monthly rainfall. Though the nature of the CCs remains same, the CCs are more significant between excess/deficient seasonal rainfall and corresponding monthly rainfall.

Comparing the CCs between the different categories of seasonal rainfall and corresponding monthly rainfall, the correlation between seasonal rainfall and rainfall in June is significant and most stable with minimum variation in its significance. The rainfall in July shows maximum instability in its relationship with different categories of seasonal rainfall. Similarly, the correlation of seasonal rainfall with bi-monthly rainfall is more stable for bi-monthly rainfall during August-September followed by June-July.

7. The probabilities of monthly and seasonal rainfall becoming excess, normal, deficient and scanty etc.

are worked out and the results are shown in Table 3. The probabilities are categorised as per the following.

Category	*Probability (%)*
High	> 75
Moderate	50-75
Low	≥ 20, < 50
Very low	< 20

The probability of occurrence of normal rainfall is moderate during July, September, July-August and August-September and low during June and August. It is high during the season and June-July. The analysis further indicates that though the probability of occurrence of normal rainfall is less in individual months, it is high in the monsoon season as a whole and first half (June-July) of the season. The probability of the above average rainfall is moderate in August and September and low in all other monthly and bimonthly periods and the season as a whole. The probability of the below average rainfall is low in August and September and moderate in all other monthly and bimonthly periods and the season as a whole.

The probability of occurrence of excess rainfall is very low during all the months and the season except June and August, when it is low. The probability of occurrence of deficient/scanty rainfall is low for all the monsoon months, being maximum during July (37%) and very low during the season (10%). Comparing the probabilities of excess rainfall and deficient rainfall, the probabilities of deficient rainfall are significantly higher during July and September. The scanty rainfall (rainfall departure from long period average ≤ -60%) is unlikely during all monsoon months and the season except June, when the probability is only about 2%. Considering the probability of occurrence of extreme (excess/deficient/scanty) rainfall, the probability is moderate during June and August and low during July and September. During the season as a whole, the probability is only 15%.

8. The following conclusions may be drawn out of this study.

(*i*) The seasonal monsoon rainfall over Orissa is more significantly dependent on the rainfall during August-September due to higher frequency of synoptic disturbances affecting Orissa during these months.

(*ii*) The rainfall in June shows significant and more stable correlation with the seasonal monsoon rainfall, considering different categories of seasonal rainfall. Hence, the rainfall in June may be used as a precursor for seasonal monsoon rainfall over Orissa.

(*iii*) The probability of occurrence of extreme (excess/deficient) seasonal monsoon rainfall is very low (15%). The probabilities of occurrence of below average rainfall are significantly higher than those of above average rainfall during the season. It indicates that the seasonal monsoon rainfall over Orissa has decreased in recent years compared to the long period average.

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