TREND ANALYSIS OF RAINFALL OVER ORISSA REGION OF INDIA

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ABSTRACT

The present study is mainly focused historical spatiotemporal variability and trend of rainfall on the annual and seasonal time series state of Orissa over a period of 60 years (1954–2013). The state of Orissa showed abrupt variation in rainfall intensity due to reoccurring cyclonic disturbances, throughout the study period. El Nino event during summers led to drier conditions and deficient monsoons (droughts noted during years 2000, 2002, 2004, 2009 and 2010). La-Nina event in year 1995 (September - December) leading to formation of severe cyclonic storms in BOB region. In post-monsoon season, major increase in rainfall was observed in year 1999, with increased rainfall anomaly (+1.78) due to coinciding super cyclone event. A similar cyclonic event (Phailin) in October 2013 positive anomaly (+3.01) in rainfall intensity. Extreme rainfall event was observed over the state of Orissa adjacent to Bay of Bengal; which in turn influenced the rainfall.

KEYWORDS: Rainfall, Mann-Kendall Test, Sen's slope estimator, Cramer Test, Standardized Anomaly Index.

1. INTRODUCTION

Global climate changes have been responsible in influencing the long-term rainfall and temperature patterns of a region. Hence, it becomes imperative to attempt for investigating the trend of climatic variables like rainfall and temperature for a country at regional level as well as at the individual stations. The amount of rainfall received over an area is an important factor in assessing availability of water to meet various demands for agriculture, industry, irrigation, generation of hydroelectricity and other anthropogenic activities. Similarly, changes in temperature may affect other hydrological processes including rainfall and such processes, in turn may lead to temperature variability (Jain and Kumar, 2012). It has been emphasized by several researchers that in developing countries, the economy is heavily dependent on low-productivity rain fed agriculture. As a result, rainfall trends and variability are important factors adopted to analyze socioeconomic problems such as food insecurity (Cheung *et. al.,* 2008). As a result, investigation of the temporal dynamics of meteorological variables is imperative to provide necessary input to policymakers and practitioners for making informed decisions. Similarly, characterization of the intra- as well as inter-annual temporal trends of meteorological variables, in the context of a changing climate, is vital for assessment of climate-induced changes and thereby suggest feasible adaptation strategies and agricultural practices (Asfaw *et.al,* 2018).

In order to identify the trends, the rainfall series was divided into 10-year non- overlapping sub-periods from 1954-2013 and the Cramer's test was then used to compare the means of the sub-period with the mean of the whole recorded period.

For the investigation of the trends analysis of rainfall in the data series of monthly, seasonal and annual rainfall of Orissa region using standardized rainfall anomaly. Aim of the present study was to identify the trend of rainfall in Orissa region of India, to achieve this, analyse of historic data is carried out.

2. MATERIAL AND METHOD.

In this study, the observed annual/seasonal January-February (J-F), March-April-May (MAM), June-July-August-September (JJAS), October-November-December (OND)and monsoonal month June, July, August, September rainfall are used. Daily gridded rainfall data set (0.25° × 0.25°, latitude × longitude) procured from National Data Centre, Indian Meteorological Department (IMD), Pune.

2.1 Mann-Kendall Trend Analysis

The Mann (1945)-Kendall (1975), test, is a non-parametric approach, has been widely used for detection of trend in different fields of research including hydrology and climatology. It is used for identifying trends in time series data. If the data do not confirm to a normal distribution, the Mann-Kendall test can be applied.

To perform a Mann -Kendall test, compute the difference between the later-measured value and all earlier-measured values, (yj-yi), where j>i, and assign the integer value of 1,0, or −1 to positive differences, no differences, and negative differences, respectively. The test statistic S, is then computed as the sum of the integers:

n-1 n

Σ Σsign(y_i-y_j)

i=1 j=i+1

Where sign(y_i-y_j), is equal to +1, 0, or -1 as indicated above.

When S is a large positive number, later-measured values tend to be larger than earlier values and an upward trend is indicated. When S is a large negative number, later values tend to be smaller than earlier values and a downward trend is indicated.

Where *xi* and x_j the annual values in years *i* and *j*, i>*j*, respectively, and

1 if x_i-x_j>0

sign(y_i-y_j) ={ 0 if x_i-x_j=0

-1if x_i-x_j<0

It has been documented that when n ≥ 8, the statistic S is approximately normally distributed with the mean. E(s)=0

The variance statistic is given as-

q

Var(s)=[n(n-1) (2n+5)-Σt_p(t_p-

P=1

1)(2t_p+5)]/18.......Eqn(1)

Here *q* is the number of tied groups and *tp* is the number of data values in the P^{th} group.

The values of *S* and *VAR(S)* are used to compute the test statistic *Z* as follows-

S-1/[Var(s)]$^{1/2}$ if S>0

Z={0 if S=0

S+1/[Var(s)]$^{1/2}$ if S<0

The presence of a statistically significant trend is evaluated using the *Z* value. A positive (negative) value of *Z* indicates an upward (downward) trend. The statistic *Z* has a normal distribution. To test for either an upward or a downward monotone trend (a two-tailed test) at α level of significance, *H0* is rejected if the absolute value of *Z* is greater than Z1-α/2, where Z1-*α/2* is obtained from the standard normal cumulative distribution tables.

2.2 Sen's slope estimator test

The Sen's estimator predicts the magnitude of trend. Here, the slope (T_i) of all data pairs is computed as (Sen,1968). The estimate for the magnitude of the slope of trend *b* is calculated using non-parametric Sen's method, which is the median of slopes of all data value pairs.

b= median[X_j-X_i/j-i]for all i<j……..Eqn(2)

where *b* is the slope between data points X_j and X_i measured at times j and i respectively.

2.4 Cramer Test

For analyzing the sub-periodical means significantly alter from the average of the 60-year period (the long term normal or period normal) of sub-periodical divisions were employed to rainfall series 10-year redundant sub-periods (1954-1963, 1964-1973, 1974-1983, 1984-1993, 1994- 2003, 2004-2013), Then Cramer's test was applied to all rainfall series and the test data, t_k, was used by Nath and Mwchahary, (2013) it was calculated as:

t_k=√(n(N-2)/N-n(1+$Ʈ_k^2$))× τ_k … Eqn. (1)

where, $Ʈ_k$ = standardized measure of difference between the means of sub-period and total period and N = number of years constituting the sub-period and the entire period and. For significance of Cramer's t-value at 5% level, the required t_k value is ±1.96 or more. Significant positive and negative values of tk indicated a shift towards wet and dry conditions of rainfall respectively.

2.5 Standardized rainfall Anomaly

To study the variation of the nature of the trends, the Standardized Anomaly Index (SAI) is then used. It provides an area average index of relative rainfall yield based on the standardization of rainfall totals used by Abaje *et. al*, (2010). It was calculated as:

Z =x-$\bar{x}$/S … Eqn (2)

where $\bar{x}$ and *S* are the mean and standard deviation of the entire series respectively and x is mean of sub period.

3. RESULT AND DISCUSSION

3.1 Mann Kendall Trend Analysis

The annual, seasonal and monsoonal time series of rainfall is studied by subjecting them to non-parametric Mann-Kendall test and increasing or decreasing slope of trends in the time series is determined by using Sen's method (Sen, 1968). This is a statistical method which is being used for study the spatial variation and temporal trends of hydro-climatic series. Table 1. shows that for pre-monsoon (MAM) season increasing trend in rainfall is observed for the period of 1914-2013, positive trends have been also observed for central India (Parthasarathy and Dhar,1974). In winter season, rainfall has shown decreasing trends for Orissa (-0.33 mm/year). Rainfall showed increasing trend in the month of June. In pre-monsoon season, Orissa shows increasing trend (1.9mm/year) and statistically significant (0.1level) for the period of 1954-2013 as presented in Table 2. Rainfall show increasing trend and statistically significant (0.1 level) in the pre-monsoon season, may be due to cyclonic disturbances discussed in details in following section.

3.2 Rainfall Pattern

Table 3. shows the results of10-year non-overlapping decadal sub-periodical variation analysis (Cramer's test) for the seasonal, annual and monsoonal months of rainfall. In monsoon season, rainfall increases (1.049mm) from mean value (3074 mm). Results of Cramer's test on 30-year sub-periodical variation were as presented in Table 4. During the last 30-year sub-period of 1984-2013 in monsoon season t_k values were increased in comparison to other sub periods.

3.3 Decadal variation in rainfall

In winter season, maximum variation in rainfall (-8 mm/decade) was observed for decade VI with respect to decade V (Figure 1). This coincided with an increase in SSN during decade VI. For monsoon season, maximum rainfall intensity increase was 245 mm/decade during decade VI, in comparison to decade V. The increase in rainfall intensity may be due to cyclonic events.

3.4 Result of Seasonal and Annual Rainfall Standardized Anomalies

Rainfall showed decreasing trend after decade III, in winter (J-F) and post-monsoon (OND) season. While, rainfall in annual, pre-monsoon (MAM) and monsoon(JJAS) season showed increasing trend after decade III, as shown in figure 2. In pre-monsoon (MAM) season, maximum increased rainfall anomaly was (+5.45) in year 1995. Satyamorothy *et. al,* (2010) reported that the atmospheric temperature has increased over north/northwestern parts of the Indian summer monsoon region in May, with enhancement in meridional pressure gradient, and possibly causing more rain during 1979–2009.Whereas, Lee *et. al,* (2009) mentioned that increased pre monsoon rainfall over India may be a

consequence of increased pre monsoon irrigation and increased vegetation. The increased pre-monsoon rainfall intensity was followed by a delayed onset of monsoon in the same year. Samanta *et. al,* (2020) observed an increase in rainfall over central and northeast India, during the pre-monsoon, suggesting decreased land-sea thermal contrast and reduced monsoon rainfall. In the monsoon season(JJAS), in year 2002 and 2004, rainfall anomaly was negative (-1.3 and – 1.0). During the year 2002, the development of a moderate El Nino in the summer season, led to monsoon drought as reported by various researchers (McPhaden, 2004; Krishnan *et. al*, 2006, Mujumdar *et. al*, 2007). A similar trend in monsoon rainfall was observed due to El Nino in the year 2004. Also, there was a halt in the progress of monsoon due to anomalous July wind patterns showing anti-cyclonic circulation at the 850 hPa level over central India and a strong easterly wind anomaly over Arabian Sea. This led to curtailed duration of the established phase causing a deficit monsoon in the country (Basu and Iyengar, 2007). In post-monsoon season maximum increased rainfall anomaly was (+3.01) in year 2013 as shown in Figure 3. The severe cyclonic storm Phailin originating in October 2013 caused excess rainfall in Orissa and the adjoining areas. In year 1999, positive anomaly value of (+) 1.78 indicated increased rainfall intensity in Orissa due to the super cyclone event in month of October.

In decadal trend analysis of rainfall, increasing trend was observed after decade III in month of June, July and August as shown in figure 3. However, in month of September, rainfall showed decreasing trend after decade III as shown in figure 4. In month of June, rainfall anomaly was (+) 2.92, in year 2001 and (+) 3.23 in month of August, for year 2006 (as shown in Figure 5). Both years have had severe flood condition. Also observed rainfall anomaly (-1.36) coincided with severe drought condition during monsoon season, in the year 2002.

4.CONCLUSION

In Orissa winter season, maximum variation in rainfall (-8 mm/decade) was observed for decade VI with respect to decade V. For monsoon season, maximum rainfall intensity increase was observed to be 199 mm/decade in decade V, in comparison to decade IV. Throughout decade I-VI (1954-2013), for winter (J-F) and pre-monsoon (MAM) season, the maximum temperature showed decreasing trend. In Orissa overall shift (decreased) of rainfall in this study period decreases from 1984 or from decade III onwards in winter and post-monsoon season. Extreme rainfall in pre-monsoon season is in decade V, in year 1995 periodicity is 3-8 years noticed here due to La-Nina (-0.33) formation of cyclone in Bay of Bengal maximum wind 190Km/hr and lowest pressure is 956 hPa. In post-monsoon season, major increase in rainfall was observed in year 1999, with increased rainfall anomaly (+1.78) due to coinciding super cyclone event.

Rainfall trend in monsoonal month (June, July, August, September) is seen to increase after decade III. Maximum rainfall anomaly was (+2.92) in July 2001. Maximum rainfall anomaly (+3.23) observed in 2006 (August). La-Nina effect is found in year 2008 (July), 2009 (August) in Orissa, winter rainfall showed a decreasing trend (-0.33 mm/year) in the study period (i.e. 1954-2013), indicating prevalence of relatively cooler winters. An increasing (2.31mm/year) trend of rainfall was noted in the monsoon season (JJAS), due to increase in rainfall in the month of June (7.52 mm/year).

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ABBREVIATION

El-Nino Southern Oscillation	ENSO
January-February	J-F
June-July-August-September	JJAS
March-April-May	MAM
October-November-December	OND

Table 1: Trend analysis of rainfall data for Orissa region of India (1914-2013)

Seasonal/Annual/ Monthly	Test Z	Significance	Q
JF	-1.02		-0.40
MAM	1.54		0.85
JJAS	-1.56		-2.16
OND	-0.39		-0.40
Annual	-0.75		-0.52
June	-0.05		-0.21
July	-1.36		-5.13
August	-0.31		-0.89
September	-0.29		-0.72

Table 2 : Trend analysis of rainfall data for Orissa region of India(1954-2013)

Seasonal/ Annual/ Monthly	Test Z	Significance	Q
JF	-0.39		-0.33
MAM	1.82	+	1.96
JJAS	0.82		2.31
OND	-1.40		-3.08
Annual	1.20		1.59
June	1.34		7.52
July	0.08		0.51
August	0.50		2.70
September	-0.46		-3.82

+ Statistically significant 0.1 level

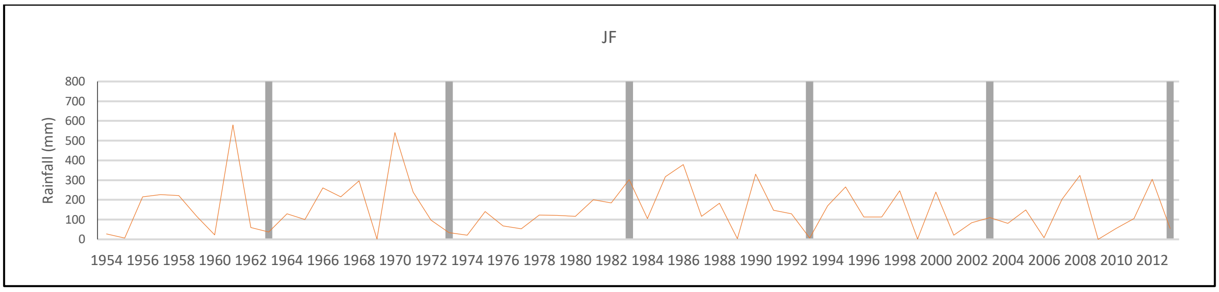
Table 3: Cramer's test (t_k value) Result of Decadal Rainfall Data for State of Orissa

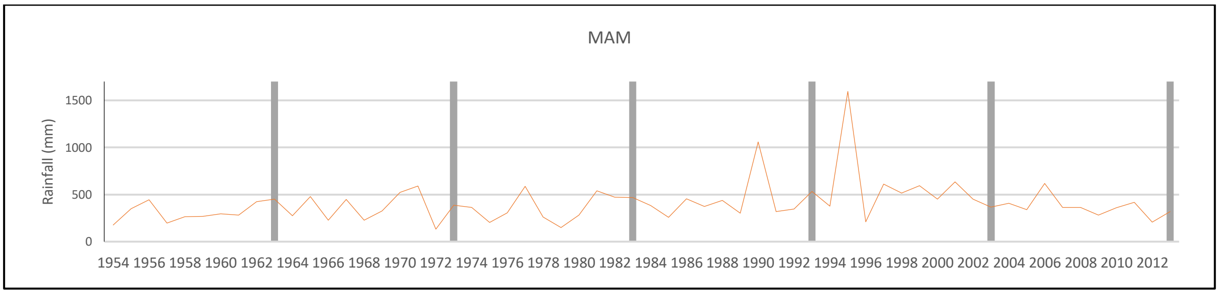
Annual/Seasonal/ Monthly	1954-1963 (I)	1964-1973 (II)	1974-1983 (III)	1984-1993 (IV)	1994-2003(V)	2004-2013 (VI)
Annual	0.81	-0.60	-1.54	0.20	0.66	0.84
JF	-0.06	0.70	-0.34	0.36	-0.29	-0.43

MAM	-0.90	-0.47	-0.45	0.43	1.48	-0.40
JJAS	0.67	-0.63	-1.32	0.52	-0.15	1.04
OND	1.28	0.12	-0.97	-1.32	0.51	0.46
June	-0.15	-0.67	-0.93	0.79	0.70	0.29
July	0.08	0.64	-1.33	0.37	-0.41	0.84
August	-0.20	-0.65	0.08	0.47	0.17	0.14
September	1.45	-0.69	-0.68	-0.65	-0.71	0.95

Table 4: Cramer's test (t_k value) Result of 30 Years Overlapping Rainfall Data for Orissa

Annual/Seasonal/Monthly	**1954-1983**	**1964-1993**	**1974-2003**	**1984-2013**
Annual	-0.75	-1.00	-0.49	0.75
JF	0.16	0.32	-0.11	-0.16
MAM	-0.80	-0.21	0.78	0.79
JJAS	-0.65	-0.71	-0.51	0.65
OND	0.25	-1.02	-0.87	-0.25
June	-0.78	-0.37	0.24	0.78
July	-0.36	-0.24	-0.69	0.36
August	-0.34	-0.04	0.31	0.34
September	0.17	-0.87	-0.89	-0.17





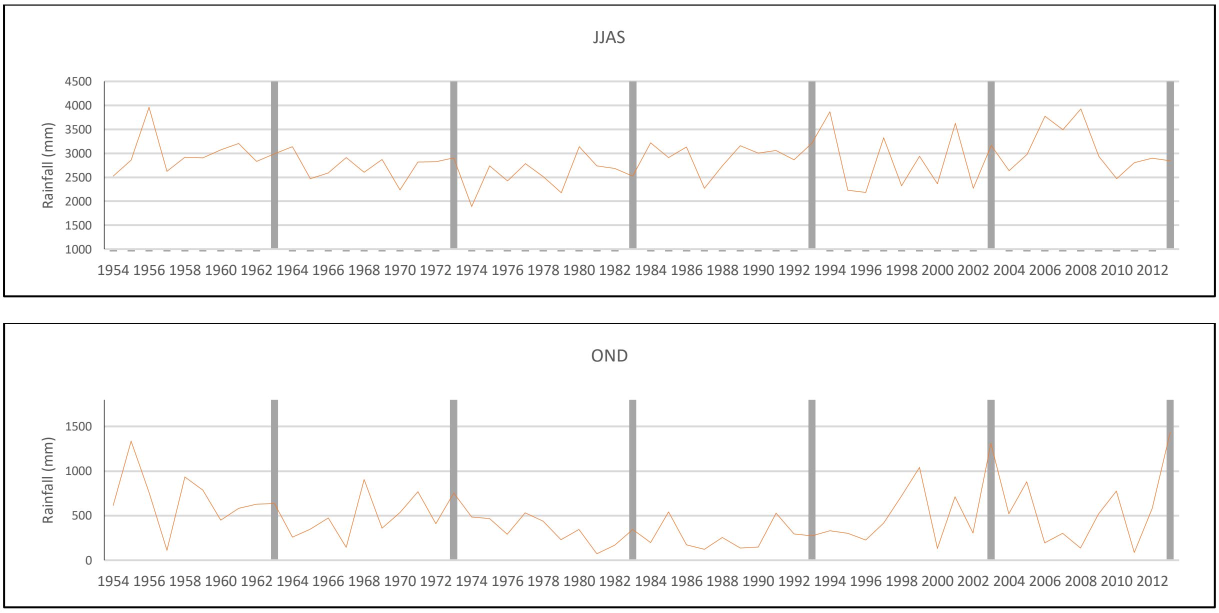
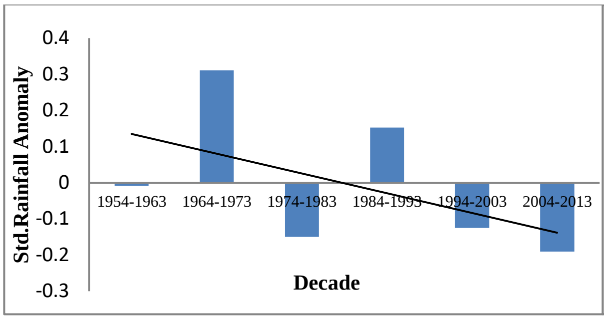
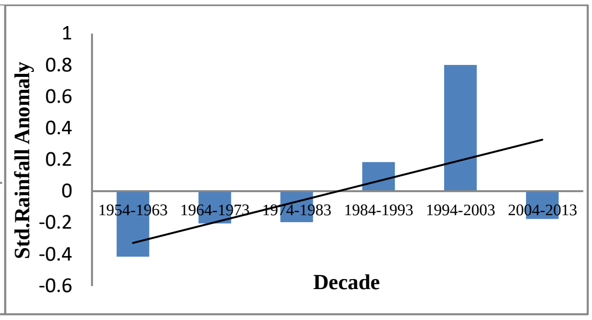
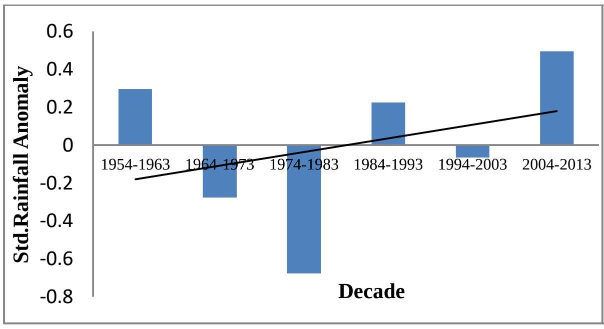


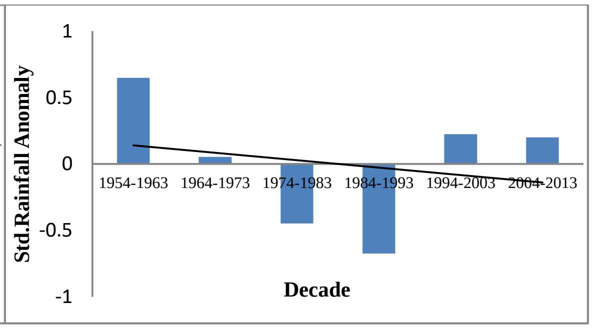
Figure 1: Decadal rainfall variation (JF, MAM, JJAS, OND) of Orissa



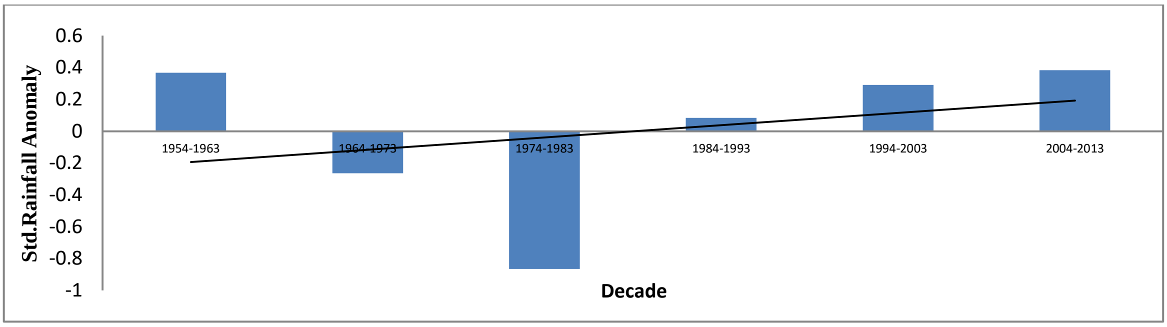


a) J-F **b) MAM**



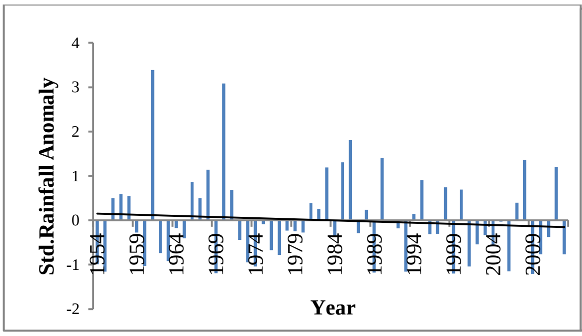


C) JJAS **d) OND**

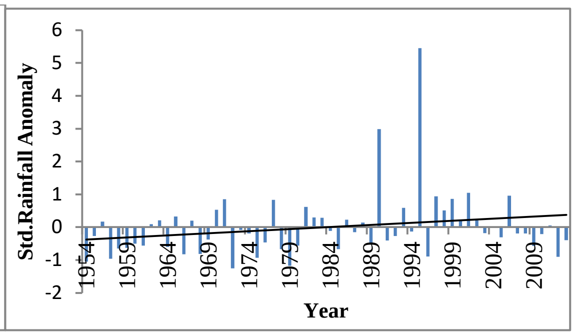


e) Annual

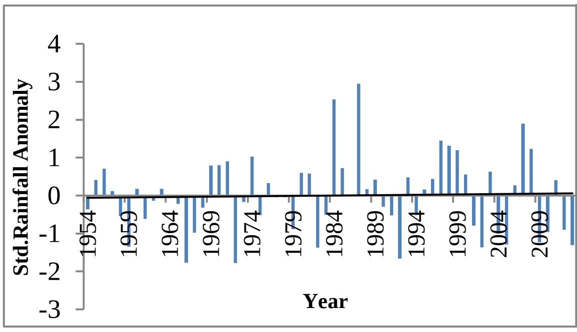
Figure 2: Decadal Rainfall Standardized anomalies of Orissa (a-J-F, b-MAM, c-JJAS, d-OND, e- annual)



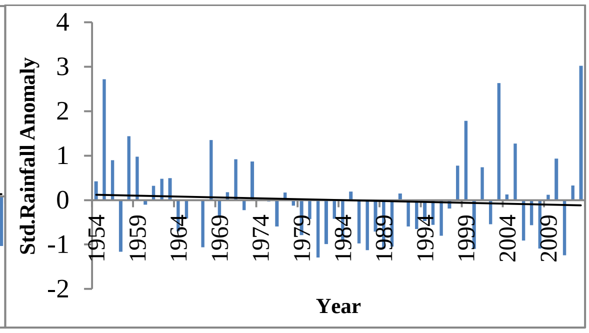
a) J-F



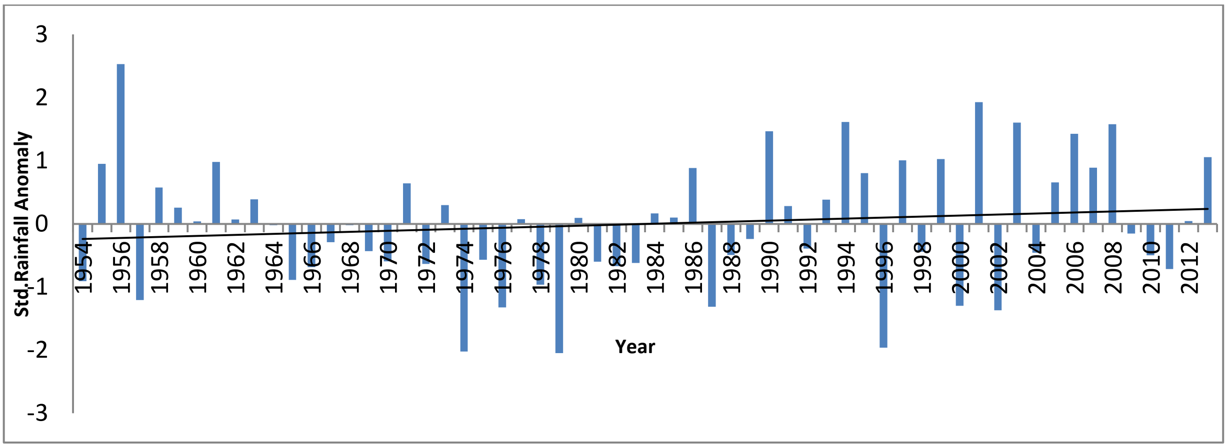
b) MAM



c) JJAS

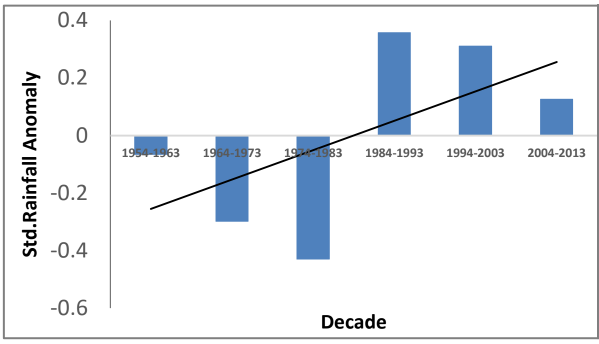


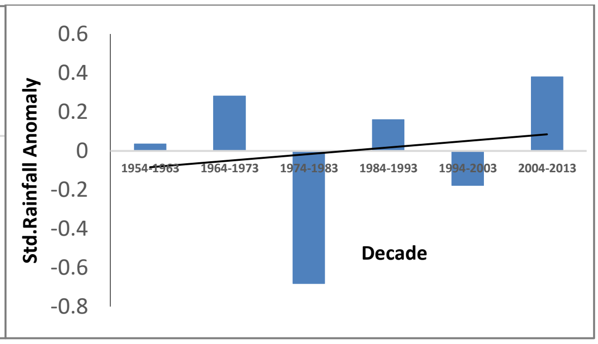
d) OND



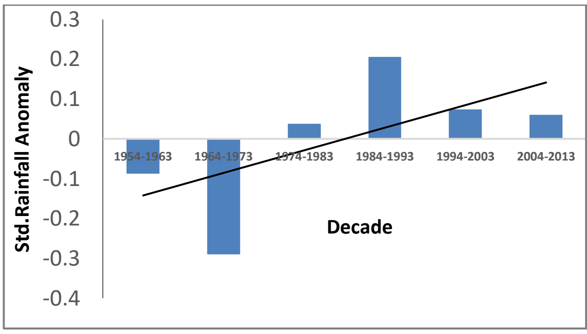
e) Annual

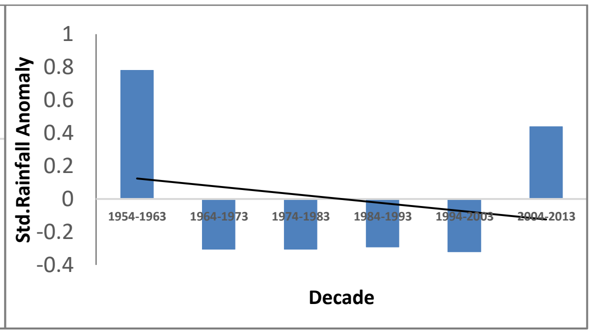
Figure 3: Annual rainfall anomalies of Orissa (a-J-F, b-MAM, c-JJAS, d-OND, e-Annual)





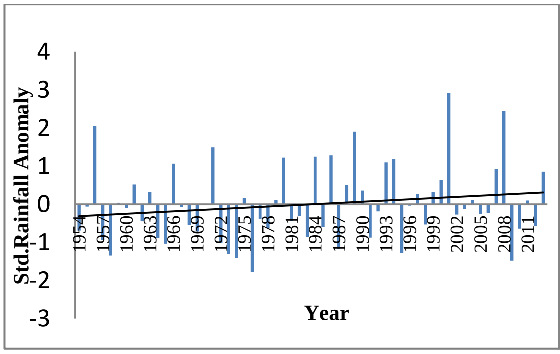
a) June b) July

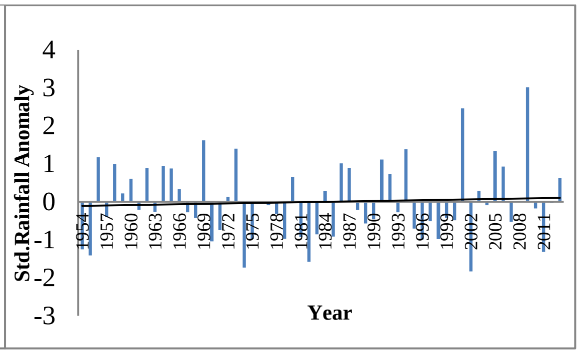




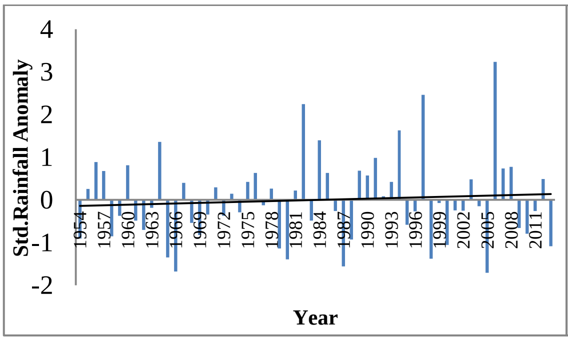
c) August d) September

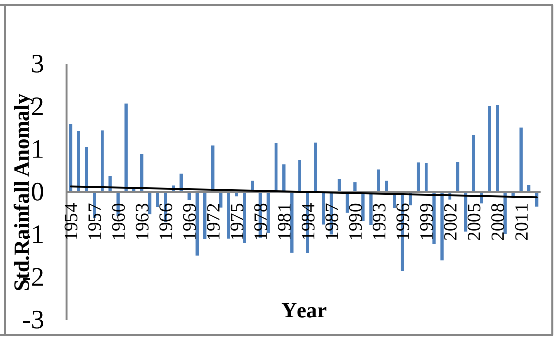
Figure 4: Decadal Rainfall standardized anomalies of Orissa a-June, b-July, c-August, d-September)





a) June b) July





c) August d) September

Figure 5: Annual Rainfall standardized anomalies of Orissa