Long term Trend in Rainfall over Bihar during the Period 1871-2011

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ABSTRACT

An understanding of temporal variation in rainfall distribution is key requirement for the agricultural planning and management of water resources. Bihar is an eastern state in India, where agricultural activities mainly depends on the rainfall. Any change in rainfall distribution may strongly impact the agriculture of this region. Long term rainfall (1871–2011) over the state of Bihar is analyzed for temporal variation on annual and seasonal time scales. Long term changes in rainfall are studied by parametric as well as non-parametric tests like linear regression method and Mann-Kendall test. The investigation showed a long term insignificant declining trends in annual as well as winter and monsoon rainfall, where as a significant increasing trend at 95% level of confidence in pre-monsoon season. There is no significant trend in post-monsoon rainfall during the period 1871–2011. Frequency of Normal, Excess, Deficient and Scanty rainfall over Bihar during the period 1871-2011 have also been obtained by decadal analysis of rainfall. Decadal analysis indicates that the deficient years of annual as well monsoon rainfall is maximum during last decade i.e. 2001-2010. This changing rainfall trend during monsoon months can affect the agricultural activity, hydro power generation and reservoir operation in the region.

Keywords: *Decling trend, annual and seasonal reinfall, agricaltural activity.*

1. Introduction

Bihar (22-27^{0}N, 82-88^{0}E) is located in the eastern part of the country (Fig.1). It is an entirely land–locked state, although the outlet to the sea through the port of Kolkata is not far away. Bihar lies mid-way between the humid West Bengal in the east and the sub humid Uttar Pradesh in the west which provides it with a transitional position in respect of climate. It is bounded by Nepal in the north and by Jharkhand in the south. The Bihar plain is divided into two unequal halves by the river Ganga which flows through the middle from west to east. The Himalayan Mountains in the north have a significant bearing on the distribution of monsoon rainfall over Bihar. Agriculture is the vital source of wealth in Bihar. 76% of its population is engaged in agricultural pursuits, agriculture as the primary feeder of rural economy. Agriculture in Bihar is crucially dependent on monsoon. Although around 57 percent of its gross cultivated area is irrigated, irrigation itself is crucially dependent on monsoon as it largely depends on the use of surface water. Total irrigated area in the State is 45.67 lakh hectares, of which nearly 30 percent is fed by canal water. Rainfall plays a vital role in Bihar's agriculture economy. Moreover, the state experiences floods as well as droughts almost on a regular basis.

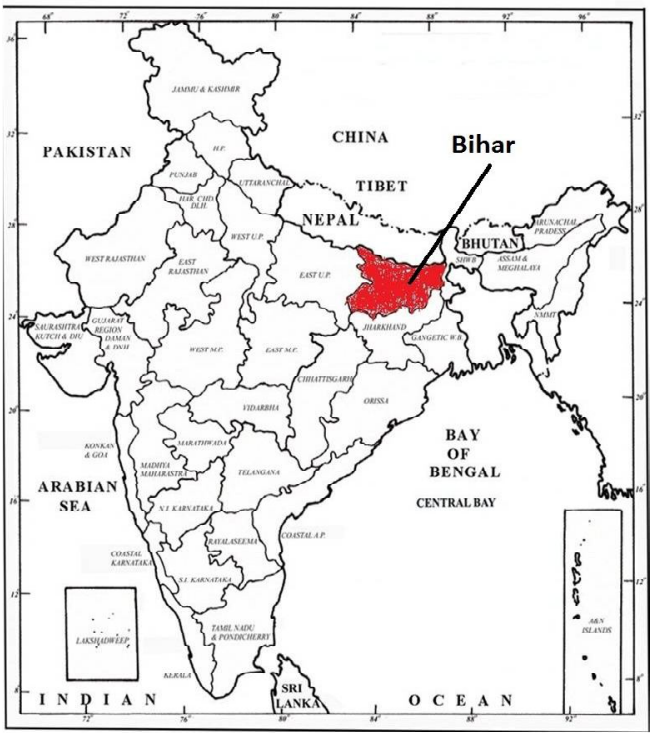

Fig.1 The geophysical location of Bihar (region of study) in sub-division map of India

Variability and trends in rainfall is one of the important aspects of climate variability studies and worldwide several attempts have been made to

study both spatial and temporal variation of the rainfall. However, a highly spatial variation has been observed at different regions of India by different researchers. Jagadish et al (2012) studied temporal variation in monthly, seasonal and annual rainfall over Orissa (Currently called as "Odisha") during the period from 1871-2006. Guhathakurta and Rajeevan (2008) performed linear trend analysis to examine the long-term trends in rainfall over different subdivisions of India and monthly contribution of each of the monsoon months to annual rainfall. Basistha et al. (2009) reported 1964 as the most probable year of change in annual as well as monsoon rainfall in the Himalayan region of India. In this region, the rainfall was in increasing trend up to 1964, followed by a decreasing trend during 1965–1980. Kumar and Jain (2010) analyzed trends in seasonal and annual rainfall and rainy days at five stations in Kashmir Valley of India. They observed decreasing rainfall at four stations and increasing rainfall at one station, but none of the observed trends in annual rainfall were statistically significant. Mohapatra et al. (2003) studied spatial variability of daily rainfall over Odisha during monsoon season for a period of 20 years (1980–1999) and reported five homogeneous regions of daily monsoon rainfall. The frequency of extreme rainfall events showed a significant inter annual and inter decadal variations in addition to a statistically significant long term trend (Rajeevan et al. 2008). Keeping in view the larger geographical area of the country, various efforts have been made towards regional and local analyses of rainfall variations (Lal et al. 1992; Sharma et al. 2000; Singh and Sontakke 2002; Singh et al. 2005, Kumar et al., 2013 and 2015).

In this paper an attempt has been made to study the long term trends in rainfall over Bihar using its monthly data for the period 1871-2011 (141 years). Seasonal, annual and decadal rainfall pattern have been studied by using linear trend of mean anomaly series of rainfall.

2. Data and Methodology

In this paper seasonal, annual and decadal rainfall pattern have been studied by using linear trend of mean anomaly series of rainfall. For the purpose the monthly rainfall data from the Indian Institute of Tropical Meteorology (IITM) for the period 1871–2011 "Homogeneous Indian Monthly Rainfall Data Sets (1871–2011)" during June to September has been used. The Mann-Kendall non-parametric test has been employed to ascertain the presence of statistically significant trend (Kendall, 1976; Kumar and Jain, 2010; Subash *et al.*, 2011, Kumar et al. 2013 & 2015). In the study, trend is considered to be significant if the confidence level is 95%.

3. Result and Discussion

3.1 Mean rainfall characteristics

The rainfall characteristics of Bihar are presented in Table-1. As seen from Table 1 the mean annual rainfall of Bihar based on 141 years data for the period from 1871 to -2011 is 1224 mm with standard deviation 218 mm and coefficient variation 17.81%. During winter the mean, standard deviation and coefficient variation are respectively 31 mm, 25 mm and 81.4%. During pre-monsoon the mean, standard deviation and coefficient variation are respectively 85 mm, 43 mm and 50.4%. During monsoon the mean, standard deviation and coefficient variation are respectively 1031 mm, 201 mm and 19.5% and during post monsoon the mean, standard deviation and coefficient variation are respectively 77 mm, 64 mm and 82.8%. it is also observed that the highest coefficient of variation is found to be during post monsoon season followed by winter, whereas coefficient of variation is found to be lowest during annual followed by monsoon. During the monsoon season the coefficient of variation is very low compared to other season which shows a dependable monsoon rainfall. About 84% of the annual rainfall occurs during monsoon season, 7% in pre-monsoon season, 6% in post-monsoon and 3% in winter season.

TABLE 1
Mean, Standard Deviation and Coefficient of Variability of rainfall over Bihar during the period from 1871 to 2011.

Seasons	Mean Rainfall (mm)	Standard Deviation (SD in mm)	Coefficient of Variability (CV in %)
Winter (Jan-Feb)	31 mm	25 mm	81.4%
Pre-Monsoon (Mar-May)	85 mm	43 mm	50.4%
Monsoon (Jun-Sep)	1031 mm	201 mm	19.5%
Post-Monsoon (Oct-Dec)	77 mm	64 mm	82.8%
Annual (Jan-Dec)	1224 mm	218 mm	17.81%

3.2 Annual rainfall trend during 1871-2011

The annual trend of rainfall over Bihar during the period 1871-2011 has been shown in Fig.2. The mean annual rainfall over Bihar showed a long term insignificant declining trend. From the data it has been observed that the highest rainfall departure (41.3%) was observed in the year 1984 followed by 40.2% in the year 1987. Similarly, we have found that the lowest rainfall departure was -47.1% in the year 1908 followed by -37.4% in the year 1972. During the period under study, the highest (173 cm) and lowest (65 cm) annual rainfall are found in the years 1984 and 1908 respectively.

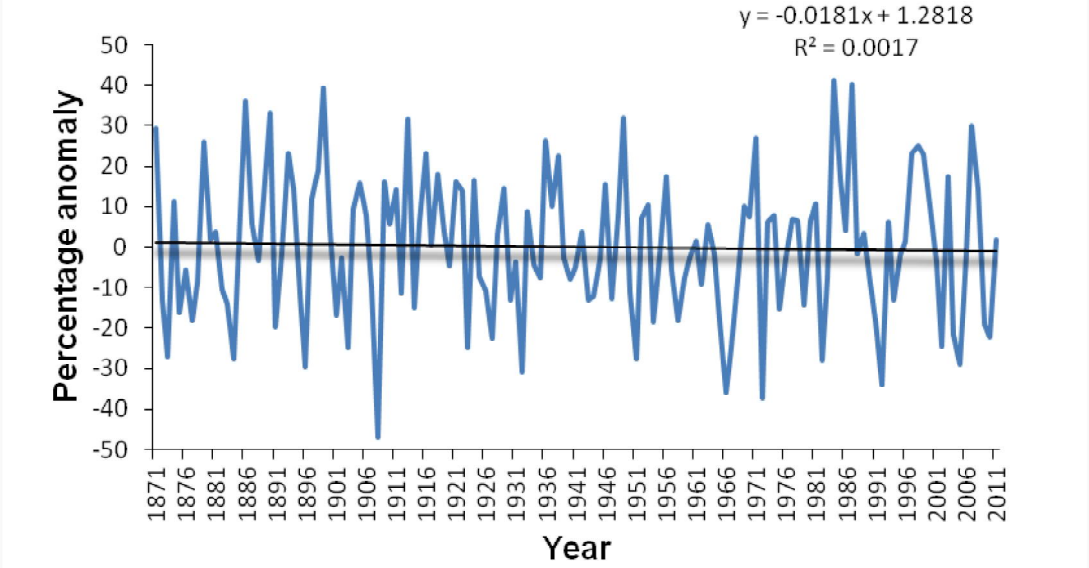

Fig.2 Annual trend of rainfall over Bihar during the period 1871-2011

3.3 Winter season

The trend of rainfall over Bihar during winter season for the period 1871-2011 has been shown the Fig.3. The mean rainfall over Bihar during winter season shows a long term insignificant declining trend. From the data it has been observed that the highest rainfall departure (283.5%) was observed in the year 1984 followed by 242.4% in the year 1957. Similarly, it is found that the lowest rainfall departure was -100.0% (no rainfall) in the year 2006 followed by -99.3% in the year 1999. The highest (120 mm) winter rainfall is found in the years 1984.

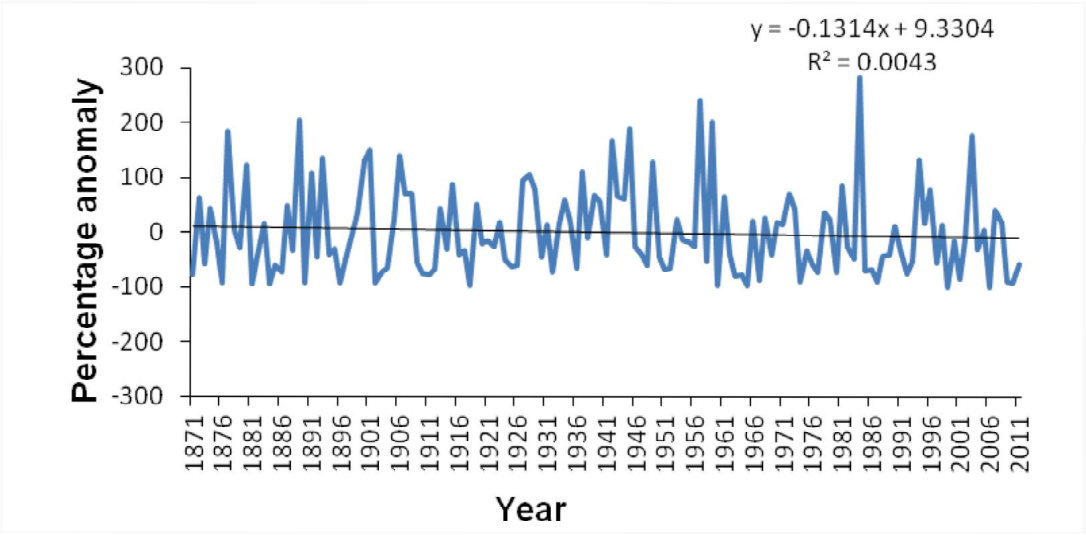

Fig.3 Trend of rainfall over Bihar during winter season for the period 1871-2011

3.4 Pre-monsoon season

The trend of rainfall over Bihar during pre-monsoon season for the period 1871-2011 has been shown the Fig.4. The mean rainfall over Bihar during pre-monsoon season shows a long term significant increasing trend. From the data it has been observed that the highest rainfall departure (208.5%) was observed in the year 1887 followed by 143.7% in the year 2000. Similarly, we have found that the lowest rainfall departure was -89.6% in the year 1972 followed by -84.1% in the year 1935. The highest (260 mm) pre monsoon rainfall is found in the year 1887. The significant increasing trend of rainfall during the pre-monsoon season could be attributed to increase in thunderstorm activity over the region particularly during the period 1961-2011 (Laskar 2009).

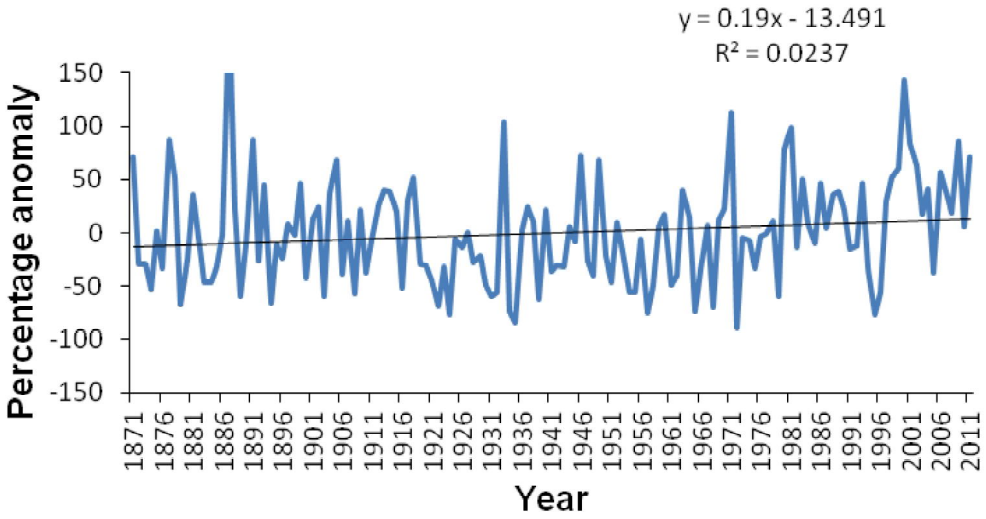

Fig.4 Trend of rainfall over Bihar during pre monsoon season for the period 1871-2011

3.5 Monsoon season

The trend of rainfall over Bihar during monsoon season for the period 1871-2011 has been shown the Fig.5. The mean rainfall over Bihar during winter season shows a long term insignificant declining trend. From the data it has been observed that the highest rainfall departure (53.6%) was observed in the year 1987 followed by 46.6% in the year 1899. Similarly, we have found that the lowest rainfall departure was -47.81% in the year 1908 followed by -37.81% in the year 1972. The highest (1580 mm) and lowest (540 mm) monsoon rainfall are found in the years 1987 and 1908 respectively.

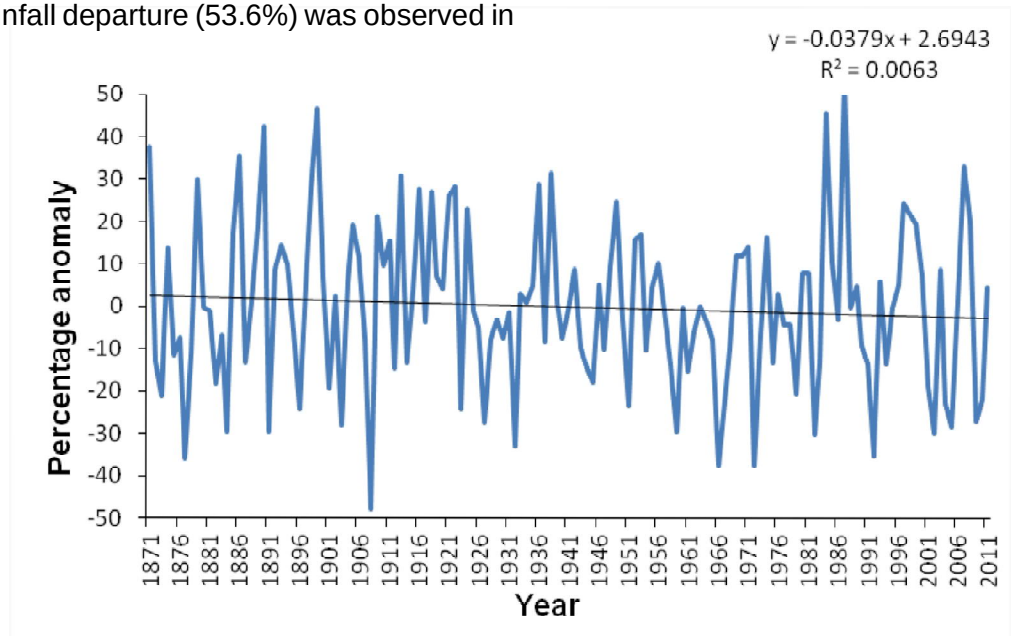

Fig.5 Trend of rainfall over Bihar during winter season for the period 1871-2011

3.6 Post-Monsoon season

The trend of rainfall over Bihar during post monsoon season for the period 1871-2011 has been shown the Fig.6. No significant trend was observed in the mean rainfall over Bihar during post monsoon season. From the data it has been observed that the highest rainfall departure (267.7%) was observed in the year 1925 followed by 255.6% in the year 1961. Similarly, we have found that the lowest rainfall departure was -99.5% in the year 1875 followed by -99.2% in the year 1935. The highest (280 mm) rainfall is found during post monsoon season in the years 1929.

As in trend analysis studies, the results significantly depend upon the period of data and the stations whose data are used as a result the study of trends using this long period data (1871-2011) may not be the correct depiction of the reality and this aspect needs to be addressed. Finally, while interpreting the results of trend analysis, the observations of Cohn and Lins (2005) are worth repeating: 'that reported trends are real yet insignificant indicates a worrisome possibility: natural climatic excursions may be much larger than we imagine.

4. Decadal, Annual and Seasonal Rainfall

To study the variability of the rainfall in more detail, decadal analysis of annual as well as seasonal rainfall has been carried out by categorizing the rainfall as normal, deficient, excess and scanty when percentage departure of rainfall from long period average (1871-2011) are +20%, -20% to -59%, +20% or more and -60% to -99% respectively and the results of the decadal analysis is summarized in Table-2.

Study reveals that during the decade 1991-2000, there were maximum numbers (3) of year with excess annual rainfall. Similarly, during the decade 2001-2010 there were maximum numbers (4) of year with deficit annual rainfall, whereas during the period 1871-2011 not a single year received scanty annual rainfall.

In winter season during the decades 1901-1910, 1931-40 and 1941-50 there were maximum number (5) of years with excess rainfall. Similarly, during the decades 1891-1890, 1911-1920 and 1941-1950 there were maximum number(4) of years with deficit winter rainfall whereas during the decades 1881-1890 and 1981-1990 there were maximum number (5) of years with scanty rainfall.

In pre monsoon season during the decades 1911-1920, 1981-1990 and 2001-2010 there were maximum number (6) of years with excess rainfall. Similarly, during the decade 1941-1950 there were maximum number(4) of years with deficit winter rainfall whereas during the decades 1931-1940

TABLE-2
Decadal frequency of Normal (N), Excess (E), Deficient (D) and Scanty (S) rainfall over Bihar during the period 1871-2011

Decade	Annual				Winter				Pre-Monsoon				Monsoon				Post-Monsoon			
	N	E	D	S	N	E	D	S	N	E	D	S	N	E	D	S	N	E	D	S
1871-1880	7	2	1	0	1	4	3	2	1	3	5	1	6	2	2	0	1	4	2	3
1881-1890	7	2	1	0	1	2	2	5	3	3	4	0	7	2	1	0	2	4	1	3
1891-1900	6	2	2	0	1	4	4	1	3	3	3	1	6	2	2	0	0	3	3	4
1901-1910	8	0	2	0	0	5	1	4	2	4	3	1	7	1	2	0	0	3	2	5
1911-1920	8	2	0	0	0	3	4	3	1	6	3	0	7	3	0	0	2	4	1	3
1921-1930	8	0	2	0	2	3	3	2	3	0	5	2	5	3	2	0	0	3	4	3
1931-1940	7	2	1	0	3	5	0	2	2	3	1	4	7	2	1	0	2	4	1	3
1941-1950	9	1	0	0	0	5	4	1	2	2	6	0	9	1	0	0	2	4	1	3
1951-1960	9	0	1	0	2	3	2	3	5	0	4	1	8	0	2	0	0	2	5	3
1961-1970	8	0	2	0	1	3	2	4	3	2	3	2	8	0	2	0	2	4	1	3
1971-1980	8	1	1	0	1	4	2	3	6	2	1	1	8	0	2	0	1	5	3	1
1981-1990	6	2	2	0	1	2	2	5	4	6	0	0	7	2	1	0	1	3	4	2
1991-2000	6	3	1	0	3	2	3	2	2	5	2	1	6	3	1	0	2	4	2	2
2001-2010	5	1	4	0	3	2	1	4	3	6	1	0	3	2	5	0	1	2	4	3

there were maximum number (4) of years with scanty rainfall.

In monsoon season during the decades 1911-1920, 1921-1930 and 1991-2000 there were maximum number (3) of years with excess rainfall. Similarly, during the decade 2001-2010 there were maximum number (5) of years with deficit winter rainfall whereas during the period 1871-2011 not a single year received scanty rainfall.

In post monsoon season during the decade 1971-1980 there were maximum number (5) of years with excess rainfall. Similarly, during the decade 1951-1960 there were maximum number(5) of years with deficit winter rainfall whereas during the decades 1901-1910 there were maximum number (5) of years with scanty rainfall.

5. Conclusion

Based on 141 years data for the period 1871-2011, it is observed that annual mean rainfall of Bihar is 122.4 cm. Its 84% rainfall occurs during monsoon, 7% in pre-monsoon, 6% in post-monsoon and 3% in winter season. The study shows decreasing trend in annual as well as in winter & monsoon season and significant increasing trend in pre-monsoon season. No trend is observed in post- monsoon rainfall. The significant increasing trend in pre-monsoon rainfall may be attributed to increase in thunderstorm activity over the region particularly during the period 1961-2011.

In decadal analysis, it is observed that maximum number of excess years in annual rainfall is during decade 1991-2000 and maximum number of deficient year in annual as well as monsoon season rainfall are during 2001-2010.

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