https://doi.org/10.36375/prepare_u.iiche.a395

Trend analysis of precipitation under climate change scenario

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Abstract

The climate change is a natural phenomenon. But it has been hastened by anthropogenic activities. As an obvious consequence, extreme weather events like cyclones, heavy rainfall, and floods have increased. On the contrary, desertification also taking place in other parts of the country. So, disaster management and water management are essential for each part of the country even in the areas not affected still now. This paper analyses the June-July-Aug-Sep (JJAS) rainfall pattern over 117 years (1901-2017) for six meteorological subdivisions in East & North-East India. A rainfall trend with polynomial curve fitting has been shown for individual regions. The descriptive analysis was also done to compare the overall rainfall and variations over the periods.

Keywords: Climate change; JJAS Rainfall; Trend analysis; Descriptive analysis

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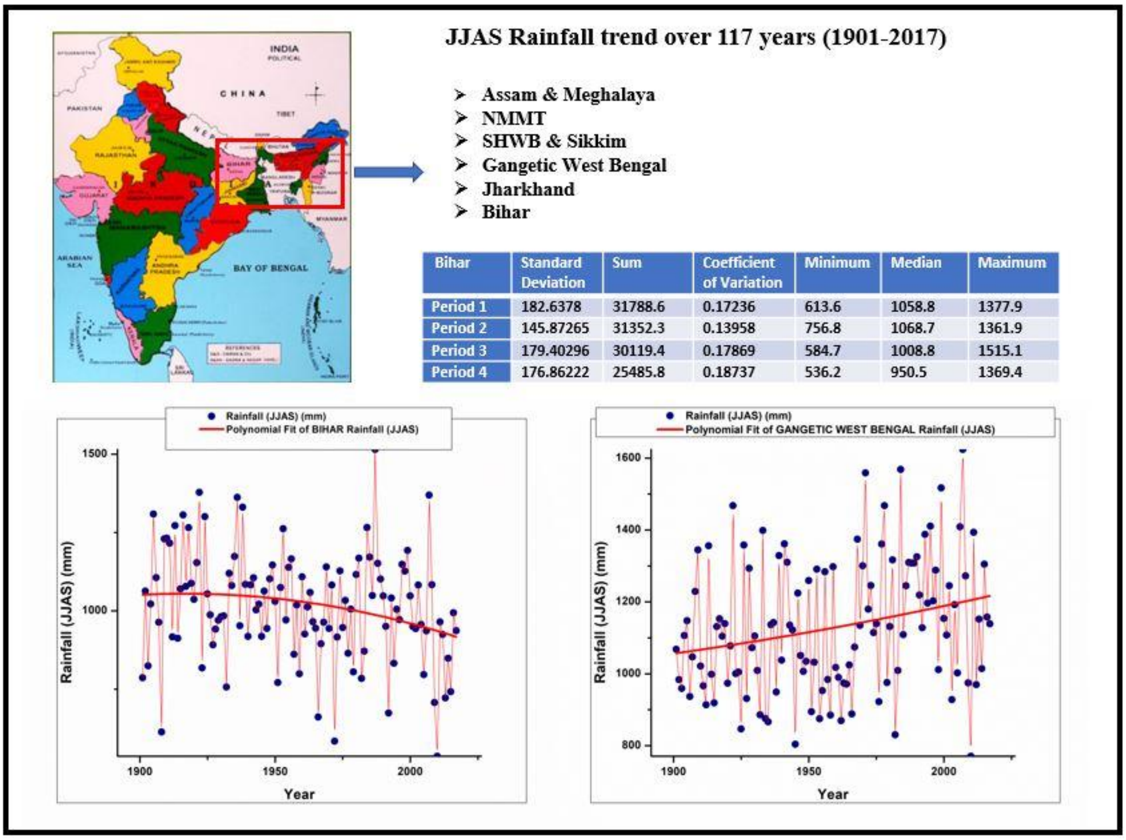
Graphical Abstract



Bihar	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	182.6378	31788.6	0.17236	613.6	1058.8	1377.9
Period 2	145.87265	31352.3	0.13958	756.8	1068.7	1361.9
Period 3	179.40296	30119.4	0.17869	584.7	1008.8	1515.1
Period 4	176.86222	25485.8	0.18737	536.2	950.5	1369.4

1. Introduction

In the latest years, large-scale economic loss, lives & property damage took place due to the inconsistent and unpredictable nature of the monsoons. Also, the destruction caused to the farmlands and environment. For example, the economy and life loss in major metro cities like Mumbai, Bangalore, and Chennai happened in 2005 for heavy rainfall (Goswami et al. 2006; Rajeevan et al. 2008). Additionally, the unpredictable nature of rainfall generates food insecurity issues. Thus, the prediction of monsoon rainfall patterns got important in many Asian countries (Reuter et al. 2013).

Not only that, the non-uniform variation in rainfall, is also a major concern of recent decades. Even the variation is not dependent on Latitude-longitude. Such as whether most of the locations in Gujrat (11 from 16) getting increased Summer Monsoon Rainfall (SMR), the Jharkhand getting decreased rainfall although it is in the same latitude.

Furthermore, the monsoon core zone is currently showing a decreasing trend in SMR rainfall (Kulkarni 2012; Guhathakurta et al. 2015). Northeast India, popular for homogeneous and huge rainfall, also experienced a notable rainfall reduction after 1950 (Guhathakurta et al. 2015). The "dry becomes drier and wet becomes wetter" paradigm is not universal. Rather the High Rainfall Zone (HRZ) experiencing less rainfall and Low Rainfall Zone (LRZ) experiencing higher rainfall (Barde et al. 2021a). The Indian Monsoon Sparse Zone (IMSZ) is showing a Counter-clockwise epochal shift (Barde et al. 2021b).

In this regard, the rainfall trend analysis is very important to predict flood-prone or drought-prone areas which can reduce agricultural loss,

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water stress, and economic loss as well. This paper observed the Indian summer monsoon (ISM) which is highly crucial for India as a larger part of employment is agriculture based (Gadgil et al. 2019; Ministry of Finance 2018). Generally, the duration of monsoon in India is from June to September (Wang et al. 2006). Even a small variation in the amount and timing of rainfall brings a significant impact on agricultural productivity and the economy as well.

In this study, the researchers observed the century-long trend (1901-2017) for six meteorological subdivisions in East & North-East India. The regions are Assam & Meghalaya; Nagaland Manipur Mizoram and Tripura (NMMT); Sub Himalayan West Bengal (SHWB) & Sikkim; Gangetic West Bengal; Jharkhand and Bihar respectively. From the descriptive statistics the Mean; Median; Standard Deviation; Maximum; Minimum; Coefficient of Variation were also analyzed to understand changing patterns properly. This is highly essential to take preventive measures for extreme weather events.

2. Data & Methodology

In this study the rainfall data considered from 1901 to 2017. The kharif, the monsoon crop of India requires a lot of water along with hot and humid weather. In this study the investigators considered Monsoon season, June-July-August-September (JJAS) for east and North-east India. The study includes six stations Assam & Meghalaya; Madhya Maharashtra; Sub Himalayan West Bengal & Sikkim; Gangetic West Bengal; Jharkhand and Bihar. The data was collected from Open Government Data (OGD) Platform India (OGD 2021).

Starting from year 1901, JJAS rainfall data in mm unit considered for 117 years. The polynomial curve fitting done for individual zone. The duration 1901-1930, 1931-1960, 1961-1990 and 1991-2017 represented as period 1; period 2; period 3; and period 4 respectively. For each zone, mean, median, maximum, minimum, sum, Standard Deviation (SD), and Coefficient of Variation (CV) have been calculated for the individual period.

3. Results and Discussions

Assam & Meghalaya:

In case of Assam & Meghalaya, overall rainfall trend is slightly decreasing, shown in Fig. 1. The overall JJAS rainfall gradually decreased from period 1 to period 4, as sum decreased from 52909.6 mm to 44172.8 mm [table 1]. Highest Maximum rainfall and highest minimum rainfall both observed highest in period 1 respectively 2442.5 mm and 2169 mm. The average deviation from the mean value is lowest in period 2 (147.70323) and Coefficient of Variation is close to zero (0.08524).

Nagaland Manipur Mizoram and Tripura (NMMT):

In case of NMMT the JJAS rainfall has a decreasing trend over the years as shown in Fig.2. The overall rainfall decreases gradually from 49572.7 mm to 37661.4 mm. The lowest value for mean, median, minimum, maximum observed in period 4. Rainfall variation increasing and notable rainfall fluctuations observed during period 3 [table 2].

Sub Himalayan West Bengal & Sikkim (SHWB & Sikkim):

In case of Sub Himalayan West Bengal & Sikkim (SHWB & SIKKIM) the JJAS rainfall has a decreasing trend over the years (Figure 3). The sum of rainfall is maximum in period 1 (64989.8 mm) and minimum in period 4 (54432.7 mm) as shown in table 3. Average deviation from the mean value over the periods varies up to around 331 mm. The highest rainfall variation takes place in period 4 as the coefficient of variation observed highest (0.16419) in this duration.

Gangetic West Bengal:

In the case of Gangetic West Bengal JJAS rainfall has an increasing trend over the years, shown in Figure 4. Although the overall rainfall

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was reduced in period 4, but the mean, median, and maximum rainfall was observed highest in period 4. Maximum rainfall fluctuation was observed in period 3 [Table 4].

Jharkhand:

In case of Jharkhand the JJAS rainfall has a decreasing trend as observed in figure 5. Overall rainfall is decreasing gradually from 33809.4 mm to 27796.3 mm. Additionally the rainfall fluctuations observed highest for period 4. That creates problems for overall management in all sectors including agriculture [table 5].

Bihar:

In case of Bihar the JJAS rainfall showing a decreasing trend over the periods as shown in fig. 6. Overall rainfall decreasing gradually over the periods from 31788.6 mm to 25485.8 mm. The mean, minimum, median, maximum observed lowest for period 4. Moreover, the highest rainfall fluctuations observed in 4th period which requires shift in planning in all sectors including agriculture [table 6].

Table 1. Descriptive Statistics of Assam & Meghalaya from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	1763.65333	206.33952	52909.6	0.117	1465	1714.9	2442.5
Period 2	30	1732.82333	147.70323	51984.7	0.08524	1424.6	1705.65	2001
Period 3	30	1728.91333	73.63629	51867.4	0.15827	1261.7	1693.7	2356.3
Period 4	30	1636.02963	254.01362	44172.8	0.15526	1172.9	1683.9	2169

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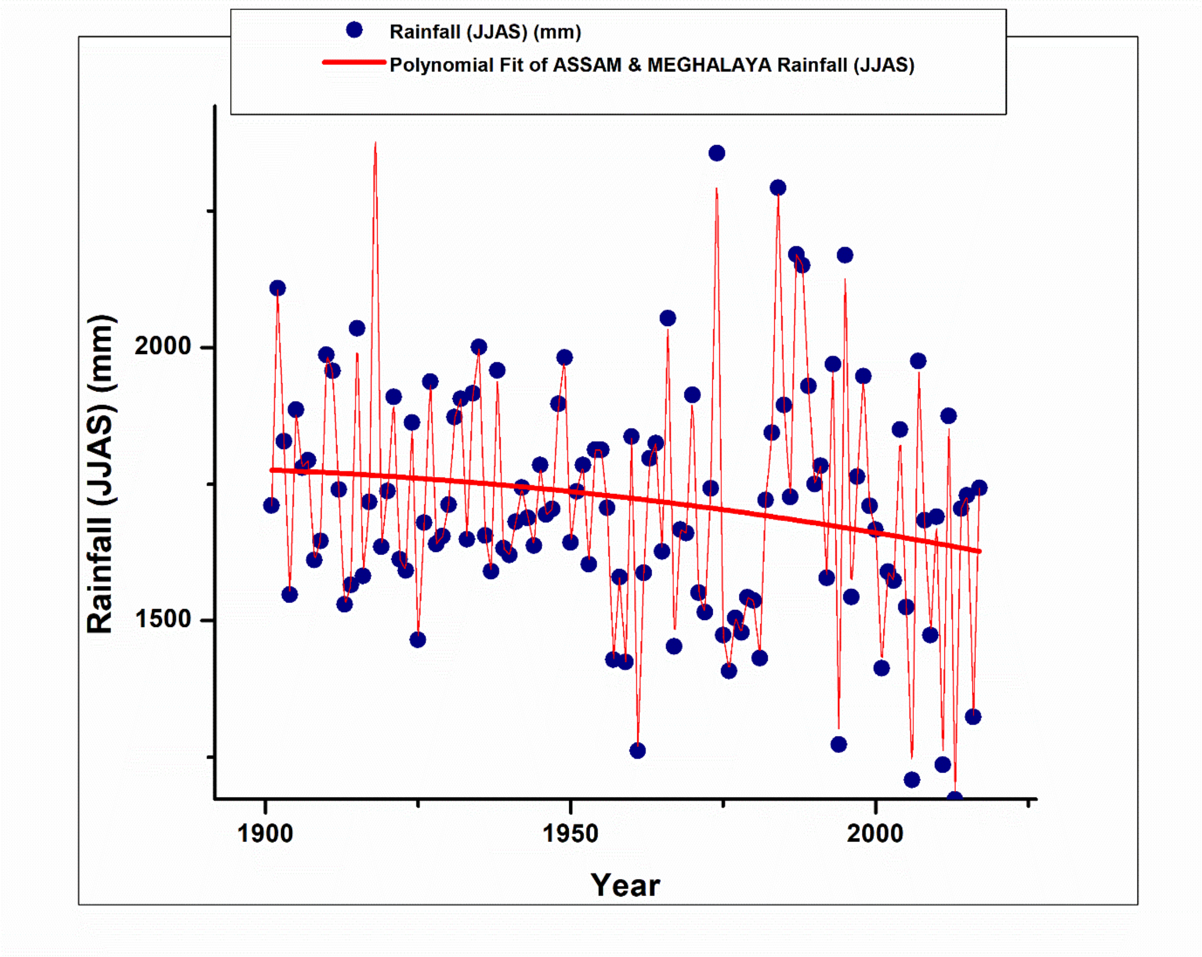

Figure 1: JJAS rainfall in mm for Assam & Meghalaya from 1901-2017

Table 2: Descriptive Statistics of NMMT from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	1652.42333	162.34117	49572.7	0.09824	1394.9	1598.7	2145.5
Period 2	30	1786.65333	236.71944	53599.6	0.13249	1119	1810.9	2271.1
Period 3	30	1578.94667	453.22196	47368.4	0.28704	898.7	1415.05	3050.2
Period 4	30	1394.86667	208.26415	37661.4	0.14931	995.2	1367.9	1829.8

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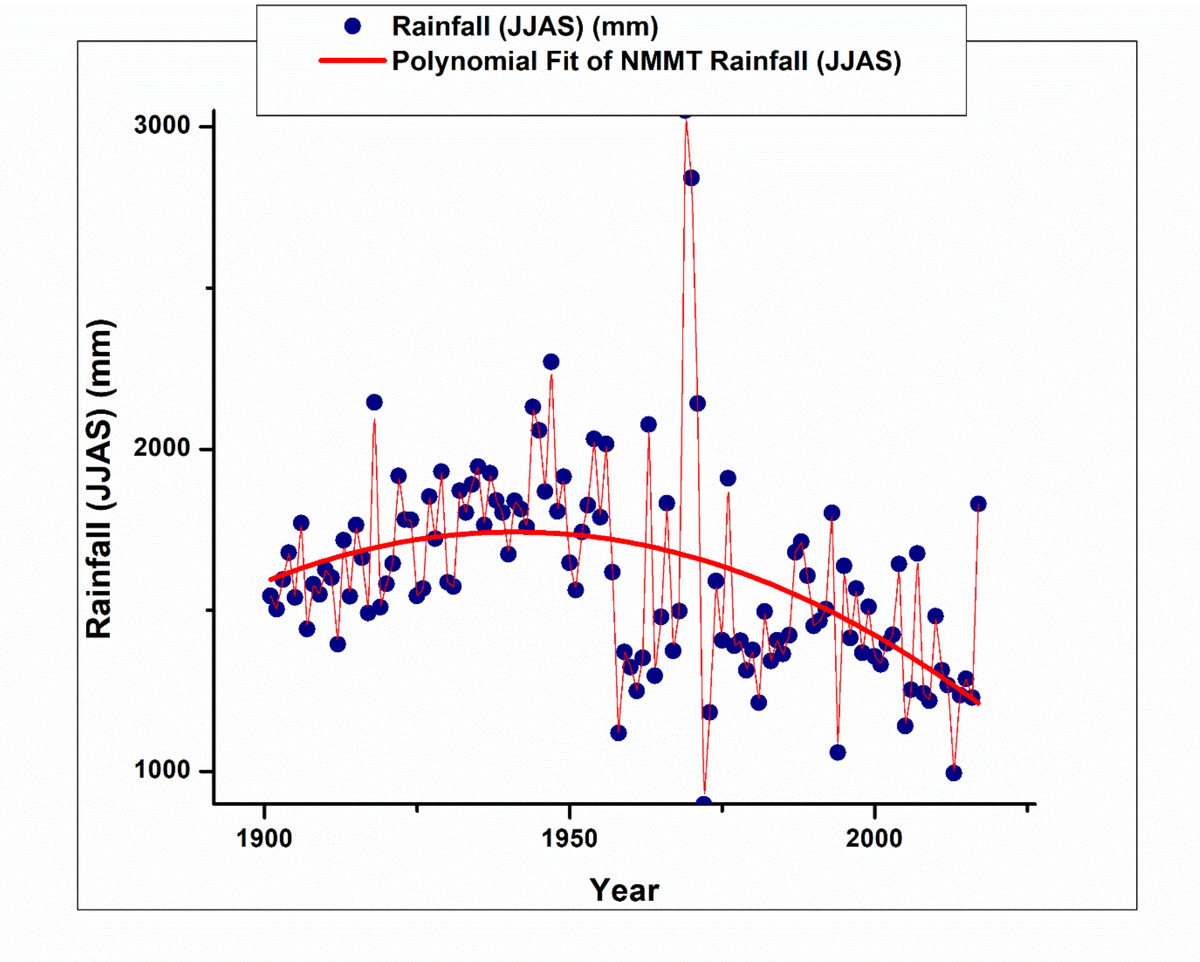

Figure 2: JJAS rainfall in mm for NMMT from 1901-2017

Table 3: Descriptive Statistics of SHWB & Sikkim from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	2166.32667	320.71873	64989.8	0.14805	1503.7	2173.25	2756.6
Period 2	30	2140.05	232.26804	64201.5	0.10853	1734.2	2092.1	2596.9
Period 3	30	2165.51333	279.81689	64965.4	0.12922	1711.1	2144.2	2726
Period 4	30	2016.02593	331.01083	54432.7	0.16419	1443.6	1980.1	2846.8

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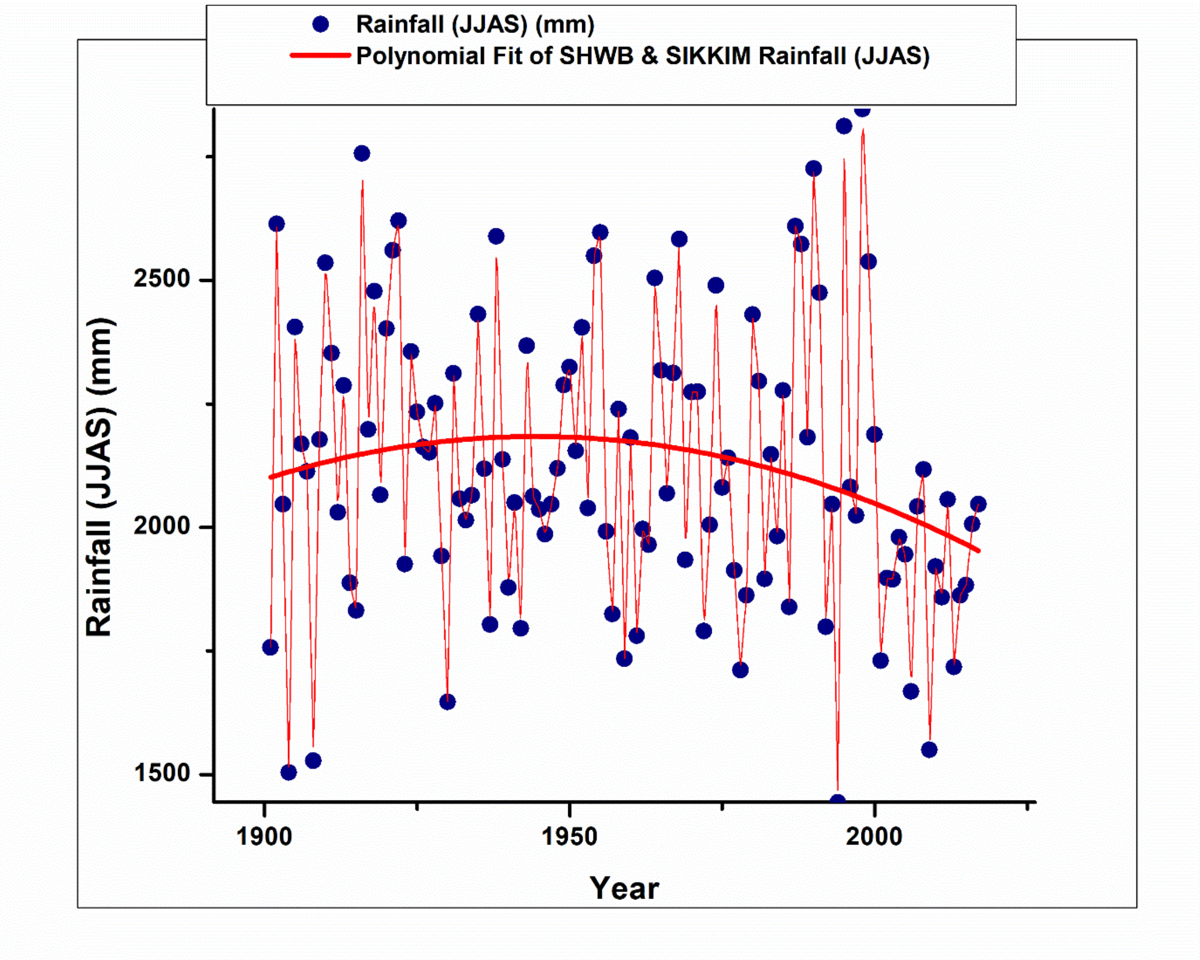

Figure 3: JJAS rainfall in mm for SHWB & Sikkim from 1901-2017

Table 4: Descriptive Statistics of Gangetic West Bengal from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	1088.72	153.0395	32661.6	0.14057	847	1070.15	1467.7
Period 2	30	1081.86333	173.50835	32455.9	0.16038	804.3	1036.45	1398.9
Period 3	30	1167.68667	200.78115	35030.6	0.17195	830.4	1136.9	1568.4
Period 4	30	1191.63704	192.18705	32174.2	0.16128	770.7	1192.3	1624.2

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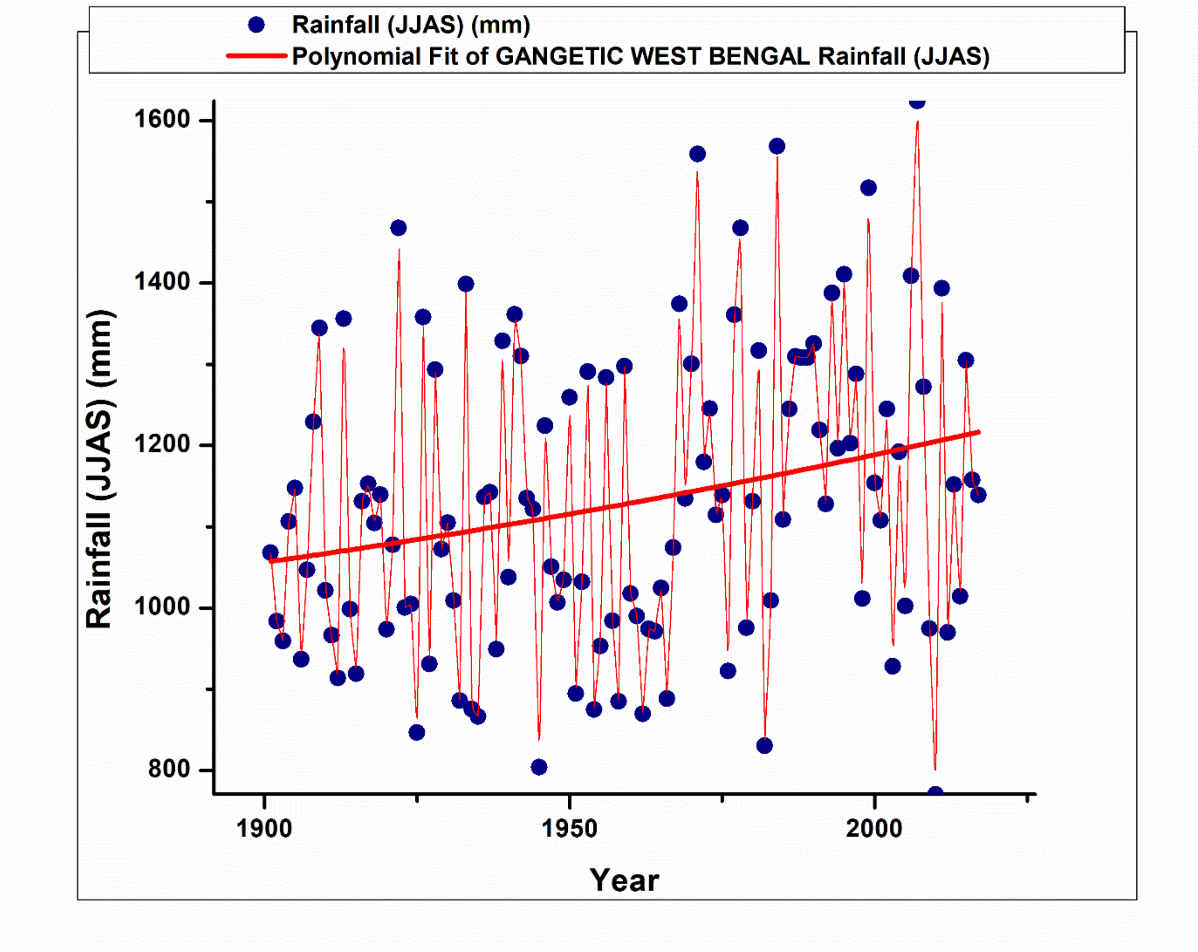

Figure 4: JJAS rainfall in mm for Gangetic West Bengal from 1901-2017

Table 5: Descriptive Statistics of Jharkhand from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	1126.98	137.75901	33809.4	0.12224	819.3	1119.5	1325.9
Period 2	30	1126.16	143.05744	33784.8	0.12703	880.7	1129.7	1412.3
Period 3	30	1047.44667	176.61591	31423.4	0.16862	724.3	1008.05	1539
Period 4	30	1029.49259	191.47207	27796.3	0.18599	578.4	1031.5	1366.3

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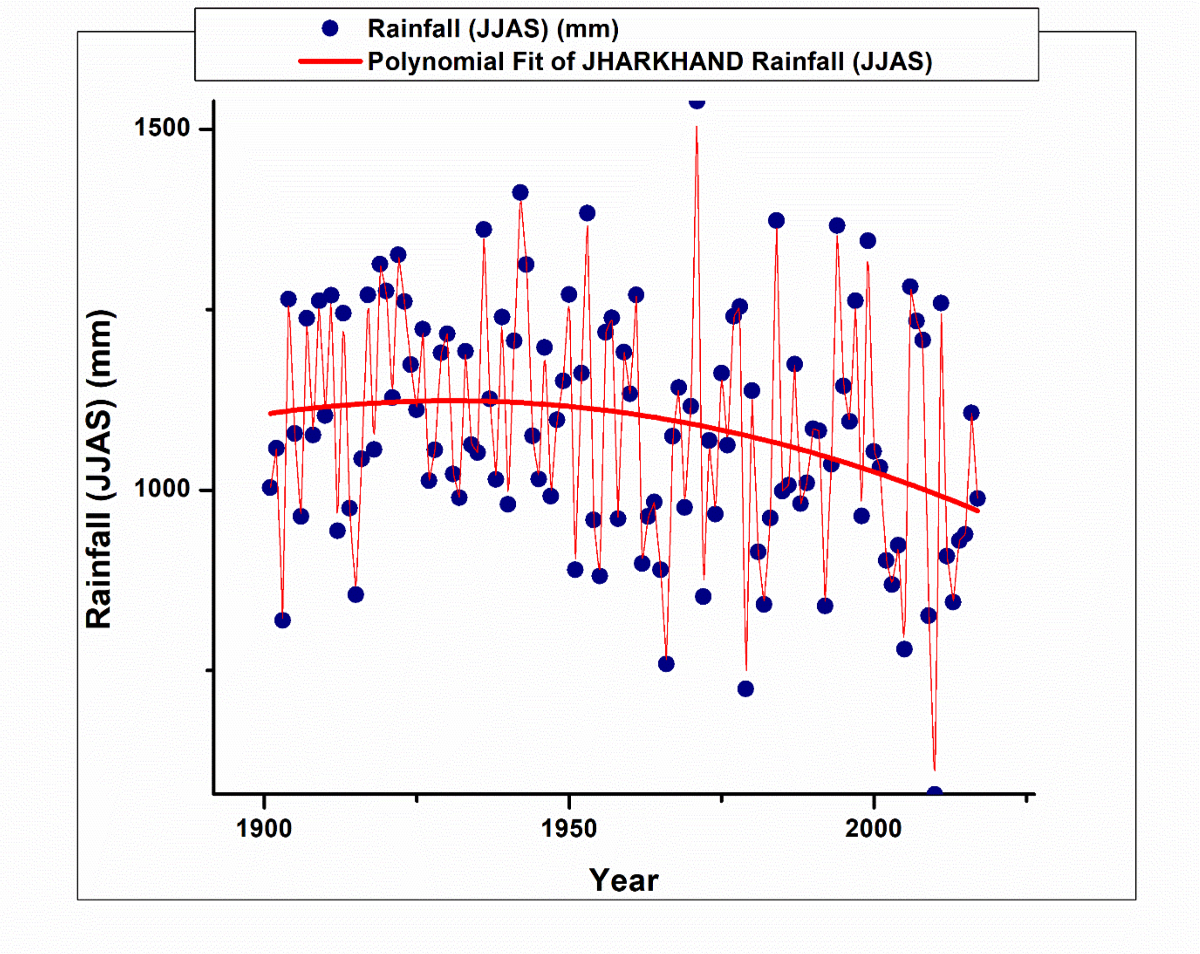

Figure 5: JJAS rainfall in mm for Jharkhand from 1901-2017

Table 6: Descriptive Statistic of Bihar from 1901-2017

Period	N total	Mean	Standard Deviation	Sum	Coefficient of Variation	Minimum	Median	Maximum
Period 1	30	1059.62	182.6378	31788.6	0.17236	613.6	1058.8	1377.9
Period 2	30	1045.07667	145.87265	31352.3	0.13958	756.8	1068.7	1361.9
Period 3	30	1003.98	179.40296	30119.4	0.17869	584.7	1008.8	1515.1
Period 4	30	943.91852	176.86222	25485.8	0.18737	536.2	950.5	1369.4

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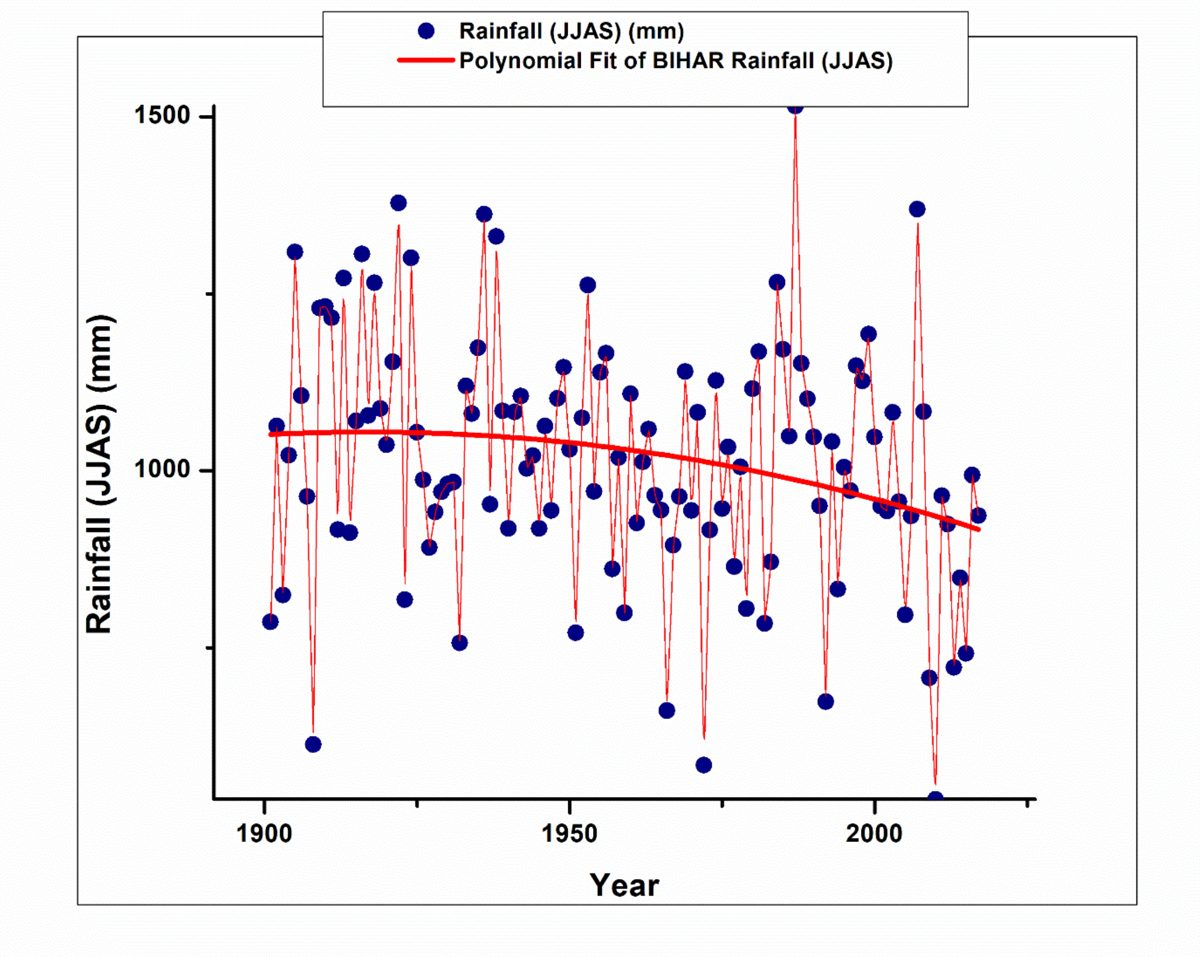

Figure 6: JJAS rainfall in mm for Bihar from 1901-2017

4. Conclusion

In this study the JJAS rainfall trend studied for six meteorological subdivisions of East and North-East India over 117 years (1901-2017). The regions are Assam & Meghalaya, NMMT, Sub Himalayan West Bengal (SHWB) & Sikkim; Gangetic West Bengal; Jharkhand & Bihar respectively. Among these six regions rainfall trend decreases except Gangetic West Bengal. It is not a matter about either increasing or decreasing. It is all about variations and unpredictability. Even a small variation affect agriculture a lot especially the SMR is highly important for Kharip crops. As observed here the Coefficient of Variation (CV) increasing during period 3 and period 4. Only the low CV observed during period 2 for Assam & Meghalaya; period 1 for NMMT; very high CV observed in case of Gangetic West Bengal and Jharkhand. The highest CV was observed for Bihar which is a major concern. So, water management needs to be increased systematically for socio-economic well-being.

Acknowledgments

Thankful to Dr. Palash Sinha, Scientist, School of Earth, Ocean and Climate Sciences, IIT, Bhubaneswar. Also thankful to JIS College of

Engineering, Kalyani, and National Institute of Technology Durgapur for their support.

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