punjab geographer

A JOURNAL OF THE ASSOCIATION OF PUNJAB GEOGRAPHERS, INDIA

VOLUME 2

OCTOBER 2006

PUNJAB GEOGRAPHER Volume 1 Number 2 October 2006

CLIMATE VARIABILITY IN INDO-GANGETIC PLAIN OF INDIA: IDENTIFYING TRENDS

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Abstract

Over 80 per cent of the annual rainfall occurs during the summer monsoon season in the Indo-Gangetic Plain Region of India. Variability is an intrinsic feature of Indian climate. Rainfall is regarded as essence of climate and, therefore, its variability is often considered as synonym of climate variability. The country's food security is extremely vulnerable to rainfall anomalies. Food production varies from year to year in response to rainfall performance. Climate change as noticed through trends of rainfall variability in this region is of fundamental concern. In the present paper, therefore, an attempt has been made to identify the trends on different spatio-temporal scales in the IGPR. The decreasing trends are implicitly displayed at different scales impelling to adopt strategies for refashioning the cropping system by the policy-makers and farming communities for sustainable agricultural development and ensuring secured food security. The finding of this study may be further strengthened if the weekly rainfall variability is investigated in more detail. Because, deficient as well as uneven distribution of rainfall even for a shorter period say fortnight or week during the cropping season may be disastrous to both crop output and yield.

Introduction

Indo-Gangetic Plain Region (IGPR) cuts across Pakistan, Nepal, India and Bangladesh and includes the adjacent fluvial plains of the Indus and Ganges river systems, the largest in the world. Indo-Gangetic Plain is developed from the deposition of a huge amount of silt brought down by the rivers emerging from the mighty Himalayas, namely, the Indus, Ganga, Yamuna, Ghaghra, Gandak and Koshi. It is considered one of the largest plains in the world formed by the river systems (Singh, N. et al. 2002). It is well known for its remarkably flat topography, deep fertile soil, adequate potable surface and ground water, and benign climate, all conducive for human living and rich agricultural activities. Running like a strip along the foot of the Himalayan mountain ranges and bounded by Pakistan in the west, Bangladesh in the east and the Indian Peninsula in the south. The region is about 1700 km long (east-west) and 200 to 300 km wide (north-south) and occupies a geographical area of about 4.99,828 km^2. Average annual rainfall varies spatially between 300 mm and 1600 mm and increases roughly linearly eastward at the rate of 0.6 mm/km. Types of weather events highly depend upon the season: winter (January-February), summer (March-May), summer monsoon (June-September) and post-monsoon (October-December). Most of the annual rainfall (above 80 per cent) occurs during the summer monsoon season. However, there is a considerable spatio-temporal variation within the region in terms of distribution in quantity of rainfall, and onset and end of monsoon rain. The IGPR of India constitutes nearly 21 per cent of country's geographical area and accounts for 26 per cent of the net cropped area, and 31 per cent of the gross cropped area. It also contributes more than 51 per cent (2003-04) of the food grain production of the country. As a whole, the population of the IGPR is the densest in the world and is also proliferating at an alarming rate. Climate and its variability govern the very pulse of life in this region. Our food system and food security are extremely vulnerable to rainfall anomalies. Agricultural production varies from year to year in response to the variations of rainfall. Thus, from the points of view of impacts, rainfall is undoubtedly the most important climatic variable. In the ancient and medieval periods there was no way for scientific study on the vagaries of the rainy season. However, the need for investigation of the rains was actually felt and has been amply summed up by Varahamihira (505-587 A.D.) a 6th century scholar (Prasad, 1980) who in his encyclopedic work ***'BRHAT SAMHITA'*** observed:

"Food is the elixir for all life,
That food depends on rains,
There it is worthwhile to investigate,
The rains with considerable effort."

Variability is an intrinsic feature of Indian climate. Understanding the nature of climate variability and climate change is not only one of the challenging areas of scientific endeavor, but also of great practical importance in a country whose fortunes are tied to the vagaries of monsoons. Such understanding is essential to identify the strategies for sustainable development in the face of climate variability. Such a kind of study will also contribute to the realistic assessment of policy options for adopting mitigatory measures whenever the impact of climate variability on socio-economic condition of the people is expected to be considerable.

Rainfall is regarded as the essence of climate and, therefore, aberration in rainfall pattern is often considered as synonym of climate variability. Evidences suggest that in the past, many socio-economic changes in the country were associated with rainfall fluctuations. The main problem to be addressed is the identification of the trends of variability of rainfall for appropriate farming strategies for attaining specific objectives in a variable climate. A distinguishing attribute of agricultural production in the region, despite good irrigation potential remains to be the large variations in crop yield from year to year. From the available historical records of the last 2500 years on droughts, floods, and famines one can get some fair ideas of climatic variation over the IGPR. Though, entire IGPR is situated in the sub-tropical belt, it experiences moderate rainfall and benign climatic conditions due to the occurrence of summer monsoon circulation, typical geographical location and orographic effect of the lofty Himalayan mountain ranges. However, rainfall is not a very simple phenomenon. It is the product of the interactions of a large number of complex atmospheric processes. A big contrast exists in the climatic conditions from the western to eastern end of the region. However, change in patterns of the main climatic parameter is quite systematic in the east-west direction. Mean annual rainfall varies from 1222.4 mm in Bihar Plains to 876.2 mm in West U.P. Plains, of which 84.44 to 88.1 per cent respectively is received during the four monsoon months from June to September . In the present paper therefore, a modest attempt has been made to investigate in-depth the characteristics of the variability of rainfall on different spatio-temporal scales and identify the trend.

India: Location of Meteorological Subdivisions

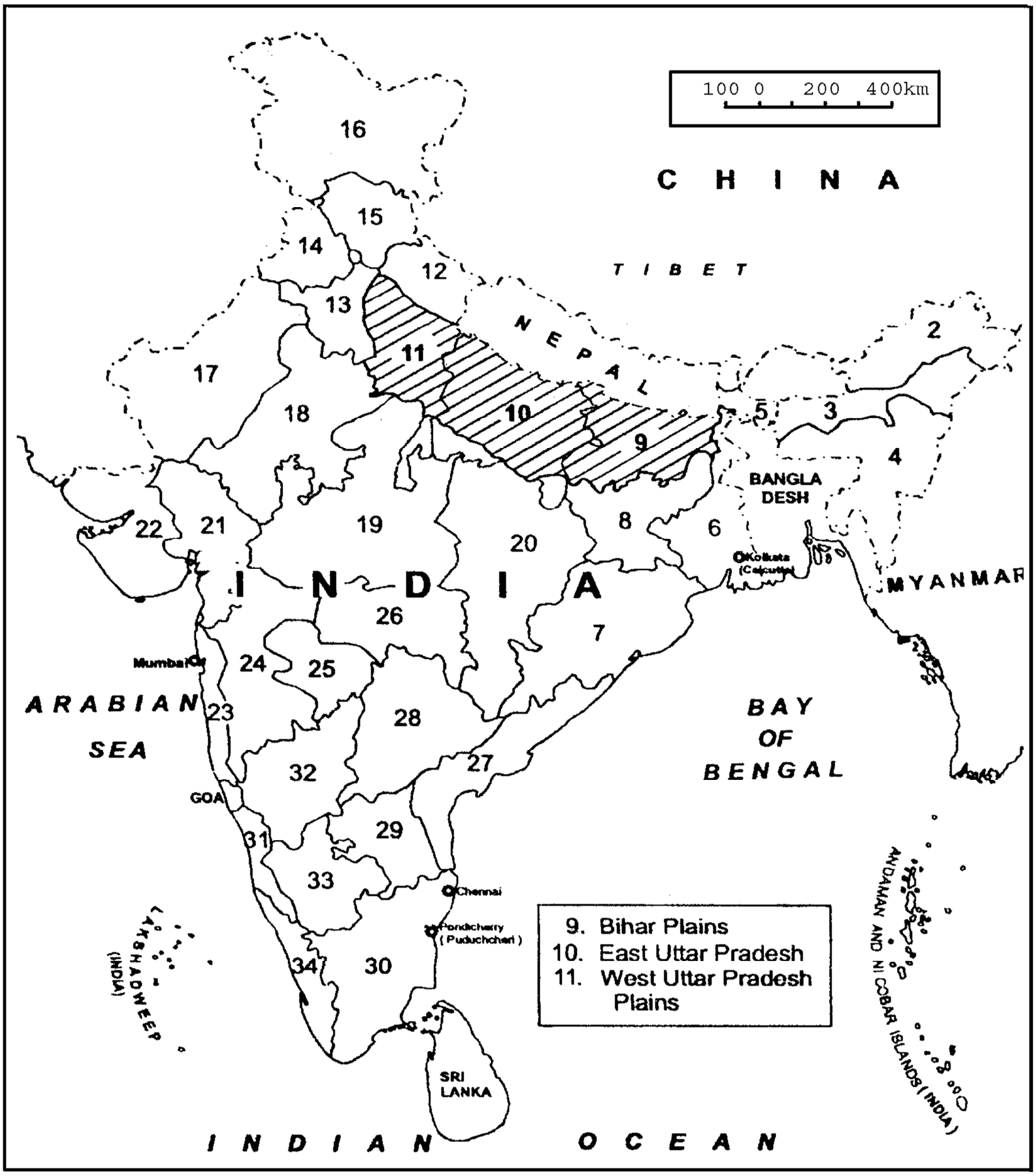

Fig 1

Source: Parthasarathy, B., et al. (1995)

Study Area

The study area covers only three meteorological sub-divisions, namely, Bihar Plains, East Uttar Pradesh and West Uttar Pradesh Plains (Fig. 1) constituting 337,526 km^2 (53 per cent) area of the total geographical area (499,828 km^2) of Indo-Gangetic Plain falling in India. It is a homogeneous region comprising six meteorological subdivisions, namely, Gangetic West Bengal, Haryana, Punjab, Bihar Plains, East UP, and West UP Plains. The geographical location of the region approximately extends between Latitudes 21^0 to 32^0 north and 74^0 to 82^0 east longitudes. Physiographically, this region is divided into eight units: Punjab Plain, Ganga–Yamuna Doab, Rohilkhand Plains, Awadh Plains, North Bihar Plains, South Bihar Plains, North Bengal Plains and Bengal Basin. The IGPR of India incorporates five states and two union territories (UTs) of the country, namely, states of Punjab, Haryana, Uttar Pradesh, Bihar (excluding Chhota Nagpur Plateau) and West Bengal, and Union Territories of Delhi and Chandigarh. The combined population of these states and union territories stands at 389.63 Million (2001) i.e. nearly 38 per cent of the country's population of 1028.7 million. The density of population is very high, varying between 447 persons per km^2 in Harayana and 9294 in the Union Territory of Delhi, with an average density of 779 km^2 in the IGPR as a whole.

Data Base and Methodology

The monthly, seasonal and annual rainfall data are collected from two main sources: (i) Monthly and Seasonal Rainfall Series for All-India Homogeneous Regions and Meteorological Subdivisions: 1871-1994 by Parthasarathy B. et al. 1995. (ii) For the recent period (1995-2001) data have been collected from the official India Meteorological Department (IMD) journal MAUSAM and directly supplied by the IMD office, Pune. The earliest year for which reliable data are available is 1871. In this study a long rainfall data series from 1871 to 2001 (130 years) have been used. The Hydrology Unit of the IMD Pune compiles the monthly rainfall data based on all reported observatory stations (about 350) for all 35 meteorological subdivisions of India at the end of the year and these are published in the subsequent issue of MAUSAM. From these sources division-wise monthly rainfall data for the study area are obtained. Parthasarathy et al. (1995) have used area weighted mean monthly rainfall (January through December) for each of the 29 meteorological subdivisions prepared by assigning the district area as the weight for each representative rain-gauge stations for the period 1871-1994. A very simple method is followed to classify the performance of monsoonal as well as annual rains based on the departure of rainfall from their mean in comparison to the standard deviation (SD). The years with the deficiency of rainfall on different spatial scales are also determined. The deficiency of rainfall is expressed as (i) 25 per cent or above; (ii) 50 per cent or above; and (iii) 75 per cent or above. Numbers of years of different categories are also identified. Since agricultural activities are adapted to the prevailing climatic pattern of the region including the mean as well as variability of rainfall, an attempt is also made to assess the coefficient of variation (COV) over different meteorological subdivisions in the region. The COV varies between 19.4 (monsoon season) and 17.7 (annual) in Bihar Plains and 23.4 (monsoon season) and 20.8 (annual) in the West U.P. Plains. Based on the results of calculations and analysis of monsoonal, monthly, seasonal and annual rainfall data, trends of variability are identified and presented through construction of various graphs and tables.

Objectives

The present paper is structured to elucidate with the following main objectives:

1. To provide information of the main climatic parameter – rainfall variability which is most likely to affect the sustainability of the natural and agricultural ecosystems.
2. To examine fluctuations of rainfall on meteorological sub–division basis for predicting changes in the variability trends,
3. To point out specific spatio – temporal variations in the patterns of monsoon rainfall,
4. To examine the rainfall pattern on the basis of instrumental data and identify and project future trends for the next 100 years up to 2100 AD.
5. To provide some useful information for practical purpose and agricultural policy reorientation,

Variability Scenario

Seasonality and large spatial-temporal variability characterize rainfall occurrences in India. Large variation in any climatic parameter from its long-term mean is referred to as anomaly. These climate anomalies are part of climate variability and change. The rainfall pattern comprises a succession of wet and dry spells in the monsoonal regions in general (Rao et al., 2000) for example, in Bihar Plains (20 dry and 19 wet), East Uttar Pradesh (18 dry and 20 wet) and West U.P. Plains (17 dry and 20 wet spells) have occurred during 1871 to 1994 (Parthasarathy B. et al. 1995). Apart from absolute deficiency of rainfall its un-seasonability also proves destructive to crops and produce famine or scarcity conditions even in the area of fairly high rainfall. If a dry-spell occurs at a critical stage of crop growth the yield decreases markedly in India. The choice and combination of crops in each of the agro–meteorological regions of the country are nicely adjusted to the quantity and intra-seasonal distribution of rainfall. According to Singh (1978) local sayings nicely sum up this situation. The English translation is given hereunder:

"The half of adra passes dry,
No rain in hathia brings relief,
If rainless magh and magha fly,
The husbandman is flunged into grief."

(**Note:** *Adra / Aridhra nakshatra* is from 22 June to 5 July, *Hathia (hasta)* – 27 September to 9 October, and *Magh/Magha (Makha)* 17-30 August).

"Adra barse punarbas jai,
Deen ann kou na khai."

(If there is rain in *Adra* but not in *Punarbas / Punarvasu* (6-19 July) the poor will not get grains to eat).

Monsoon over IGPR shows considerable month to month and year to year variation. There are months when rainfall is much above the normal followed by months of much below normal rainfall. Also, there are years of much above normal rainfall and *vice-versa.* Thus, there is a certain mode of monsoon variability, which is common on inter- annual scales. It is a well known fact that drought years and wet years are the most salient features of rainfall variability. In the present study, however, only drought or deficient years have been considered to investigate this aspect of rainfall variability. For the purpose, coefficient of variations (COV) and standard deviation (SD) of annual, monsoon and monthly rainfall are calculated. Table: 1 clearly shows the extent of variability and frequency of occurrence of deficient rainfall year with 25 per cent or above departure from the normal of both monsoon and annual rainfall. Table 2 shows the mean monthly, monsoonal and annual rainfall with their SD and COV which apparently indicate the pattern of the variability of rainfall in the region. We notice in table 1 that there have been

Table 1

Statistics of Rainfall Variability on Meteorological Subdivisions Basis (1871-2001)

1.	Meteorological Subdivision	Bihar Plains	East Uttar Pradesh	West Uttar Pradesh Plains
2.	Mean Annual Rainfall (mm)	1222.4	1029.0	876.2
3.	Mean Monsoon Rainfall (mm)	1032.2	905.7	763.1
4.	Standard Deviation (SD)	Annual – 216.3 JJAS – 200.1	Annual – 216.1 JJAS – 203.5	Annual – 182.2 JJAS – 178.9
5.	Co-efficient of Variation (COV)	Annual – 17.7 JJAS – 1 9.4	Annual – 21.0 JJAS – 22.5	Annual – 20.8 JJAS – 23.4
6.	No. of Years Examined	130	130	130
7.	No. of Deficient Years (Between 25 to 50% of Normal)	Annual – 13 JJAS – 15	Annual – 16 JJAS – 17	Annual – 18 JJAS – 17
8.	No. of Deficient Years (Between 50 to 75% of Normal)	Annual – 0 JJAS – 0	Annual – 0 JJAS – 01	Annual – 02 JJAS – 04
9.	No. of Deficient Years (Below 75% of Normal)	Annual – 0 JJAS – 0	Annual – 0 JJAS – 0	Annual – 0 JJAS – 01
10.	Years with Negative Departure from Normal	**Annual** Below 25% (1873, 84, 96, 1903, 08, 23, 32, 51, 66, 67, 72, 82, 1992) =13 Below 50% = (0) Below 75% = (0) **Seasonal** Below 25% (1877, 84, 91, 96, 1903, 08, 23, 27, 32, 51, 59, 66, 72, 82, 1992) = 15 Below 50% = (0) Below 75% = (0)	**Annual** Below 25% (1877, 80, 83, 96, 1907, 08, 18, 28, 41, 51, 65, 66, 72, 79, 87, 1951) = 16 Below 50% = (1877) = 01 Below 75% = (0) **Seasonal** Below 25% (1877, 80, 83, 96, 1907, 08, 13, 18, 28, 41, 51, 59, 65, 66, 72, 79, 87) = 17 Below 50% = (0) Below 75% = (0)	**Annual** Below 25% (1877, 83, 96, 99, 1905, 07, 13, 18, 20, 28, 29, 41, 44, 65, 72, 79, 87, 92) = 18 Below 50% = (1905, 1918) = 02 Below 75% = (0) **Seasonal** Below 25% (1877, 83, 96, 1905, 07, 11, 13, 18, 28, 29, 37, 41, 51, 65, 79, 86, 1987) = 17 Below 50% (1877, 1905, 18, 1979) = 04 Below 75% = (1877) = 01

Source: Compiled by the author based on rainfall data for the period 1871-2001 collected from various sources.

Table 2

Indo-Gangetic Plain: Month and Season-wise Rainfall Variability (1871-2001)

Month	Meteorological Subdivisions											
	West Uttar Pradesh Plains				East Uttar Pradesh				Bihar Plains			
	SD	Mean	COV	% of the JJAS	SD	Mean	COV	% of the JJAS	SD	Mean	COV	% of the JJAS
June	61.06	86.5	70.96	11.33	67.34	116.0	58.1	12.80	84.3	177.7	47.5	17.21
July	88.46	265.49	33.32	34.79	105.6	302.7	34.9	33.43	102.2	326.1	31.5	31.6
August	98.5	261.9	37.6	34.32	87.4	294.0	29.7	32.46	91.4	303.6	30.1	29.41
September	91.4	149.6	61.1	19.60	86.4	192.4	44.92	21.24	91.8	224.8	40.1	21.78
October	46.3	28.0	165.6	3.19*	59.9	46.2	129.6	4.49*	62.6	67.0	94.4	5.48*
JJAS	178.9	763.1	23.4	87.09	203.5	905.7	22.5	88.01	200.1	1032.2	19.4	84.44
JJASO	188.9	79.13	33.9	90.3	216.6	951.2	22.6	92.44	209.1	1099.2	19.02	89.92
Annual	182.2	876.2	20.8	100.0	216.1	1029	21.0	100.0	216.3	1222.4	17.7	100.0

Source: Compiled by the author based on rainfall data for the period 1871-2001 collected from various sources.

* Per cent to Annual

13 to 17 years on meteorological subdivision basis where rainfall deficiency exceeds 25 per cent of the annual mean whereas 13 to 18 years of the seasonal mean. In an earlier study on the basis of the analysis of about 10 decades (1891–1998) of annual and summer season rainfall data of Bihar Plateau meteorological sub- division, Singh (2000) found that there was no any clear increasing of decreasing trend of rainfall over the region. However, there appear to be some signals on decadal scale variability leading to persistence of above or below normal rainfall for several years in a run. For example, 1901-10 and 1960-80 in case of both annual and seasonal rainfall at Daltonganj, and 1901-1915 and 1980-1990 at Dumka station have been below normal. On meteorological sub-division scale the nature of rainfall variability also remains by and large the same in Bihar Plateau (Jharkhand) as a whole. This study does not suggest any long- term trend. The investigation of rainfall variability on micro-level e.g. Patna meteorological observatory in Bihar Plains based on 70 years rainfall data reveals that over this period 15 annual, 19 monsoonal and 34 *Hathia* droughts have occurred (Singh, 1978). On all India scale, studies made by several authors in India e.g., Mooley and Parthasarathy (1984), Sarker and Thapliyal (1988), and Kulshrestha and Thapliyal (1991) have shown that there is no statistically significant trends in the all India rainfall. Studies made by Rupa Kumar et al. (1992) have shown that areas of northeast peninsula, northeast India and northwest peninsula show widespread decreasing trend in the summer monsoon rainfall. The inter-annual variability, however, is the most dominant feature of the overall variability.

Some of the model based studies for example, Lal et al. (1994) have found that there is no evidence for a significant change in the mean variability. Less precipitation could occur over the southern peninsular India in the next 100 years. Sikka and Pant (1991), after an analysis of a number of atmospheric general circulation models (AGCMs) indicated that the monsoon rainfall over India would slightly decrease by 2050 AD and the extreme events like wet and dry spells would become more variable. On all India scale, monsoon rainfall is trendless and mainly random in pattern.

Result and Discussion

The meteorological subdivision-wise analysis of monsoon as well as annual rainfall shows more or less decreasing trends (See appendix: Fig. 1 to 24) in all the subdivisions under the study area. Analysis of monthly rainfall data of monsoon season also suggests the similar trends. However, the degree of trends slightly differs between the months as well as between the divisions. Sharp decreasing trends are observed in case of June in Bihar and West U.P. Plains (Fig. 1, 17). In contrast, the magnitude of decrease in rainfall trend over East Uttar Pradesh is marginal in comparison to West U.P. Plains and Bihar Plains. On monthly basis, in Bihar Plains, the trend has an increasing tendency in the month of July (Fig. 2) whereas it is decreasing in West U.P. Plains (Fig. 18). However, it appears to be trendless in East UP. The trend in August rainfall in Bihar Plains and East UP tends to be significantly decreasing (Fig. 3,11). While slightly increasing trend is evident in August rainfall in the West U.P. Plains. Significant increasing trends in both the meteorological subdivisions of Bihar Plains and West UP Plains in case of October rainfall have been noticed (Fig. 5, 21), but like July, October rainfall is also found to be trend-less in East UP (Fig. 13). It may be mentioned here that rainfall in October though little in quantity yet is very crucial for *Kharif* as well as *Rabi* crops in the region. The summer monsoon rainfall trend in all three meteorological subdivisions exhibited a noticeable decreasing tendency. However, in the Bihar Plains and West U.P. Plains the trends are more pronounced (Fig. 7, 23). In Bihar Plains the quantity of rainfall may decline from about 200mm in 1871 to 100mm by the end of 21st Century, which may turn to be a dangerous signal of climate variability to compel the scientific and farming communities to reschedule the farming systems in the region in the light of these changes. This trend also indicates that the month of June may be out of place as far rainy season is concerned. Another significant trend appears to be an increasing tendency in October rainfall. If these trends continue for another 100 to 200 years the month of June would obviously get excluded from the monsoon season and the month of October would be included in it indicating impending shift of monsoon season rainfall while October is currently a post-monsoon month. Thus, it has been observed that there is a contracting tendency in the duration of monsoon season in this part of the region. However, there are some variations on the spatial scales in the magnitude in rainfall fluctuations. West U.P. Plains and Bihar Plains apparently show a shift in monsoonal rainfall activities towards October. Having noticed some marked trendy patterns in the monsoon rainfall in these divisions of the IGPR it is felt pertinent to go much deeper in examining the fluctuations of the monsoon rainfall by the researchers not only in the IGPR but also other meteorological subdivisions of the country with full exercise of caution in using data series and methodologies for sophisticated analysis and critical inferences for the reorientation of the cropping pattern in the light of significant fluctuations in monsoon rainfall which is the most significant climatic parameter for agriculture.

Concluding Remarks

The results of the study are quite amazing. It is implicitly indicated that variability of rainfall on various spatio-temporal scales is significantly evident. However, this finding does not collaborate with some of the earlier studies. It is noteworthy that broadly there are clear trends of decreasing rainfall on seasonal, monthly and annual bases during the last 130 year period. But on each scale the trend is not identical in intensity. Monthly rainfall is more variable, for example, June rainfall has shown clearly decreasing trend. The decreasing rainfall tendency in June is a clear signal of shifting of monsoon season. Therefore, it demands to examine carefully and thoroughly the issue of rainfall variability to refashioning the existing cropping systems in the light of the changing rainfall trends in the Gangetic Plain. Finally, it is suggested that efforts should be made to re-examine the trends of climate variabilities and its impact keeping in view the relevant data and techniques on various spatio-temporal scales.

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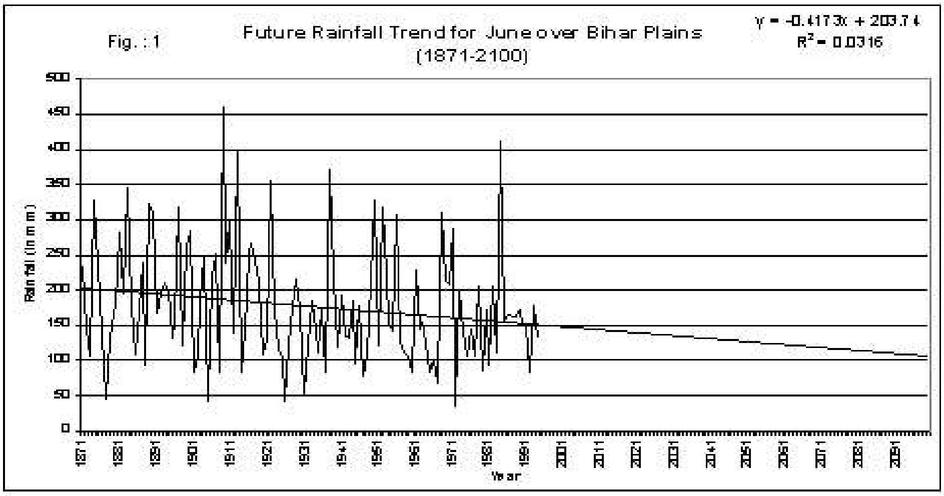
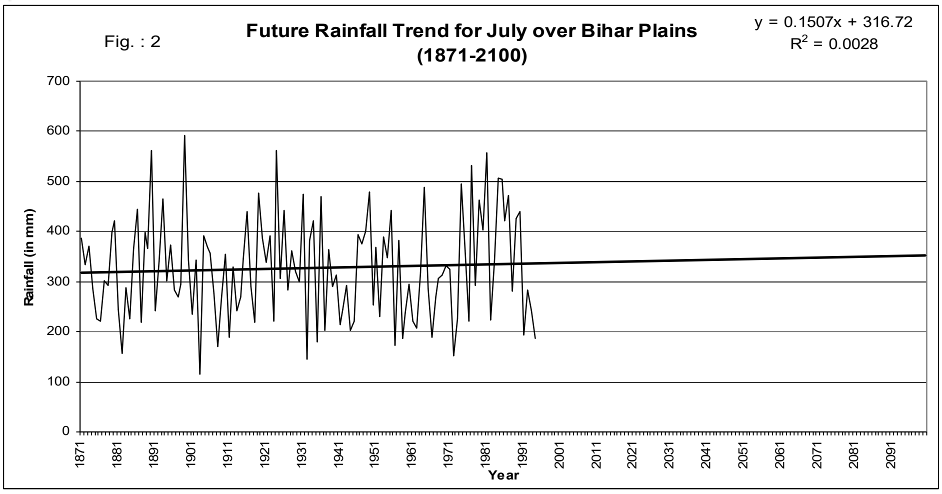
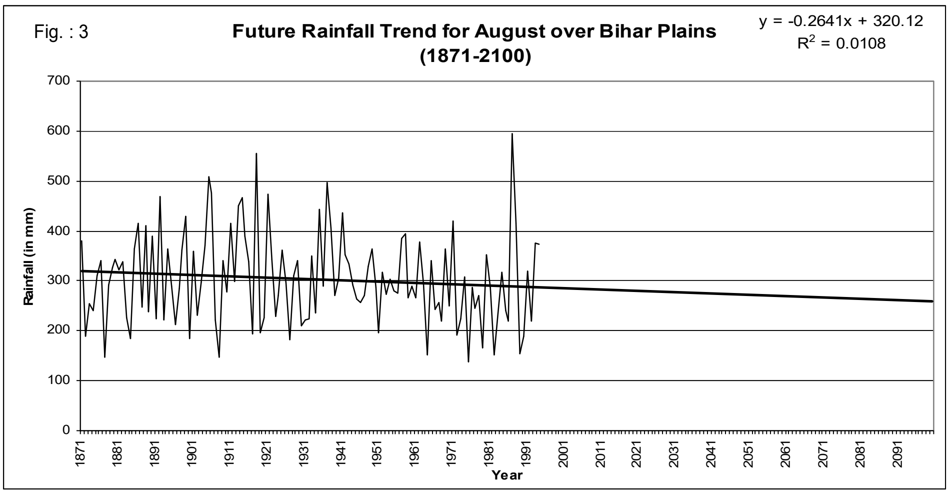
Appendix:
Rainfall trends on spatio-temporal scales-1871-2001 and projected up to 2100







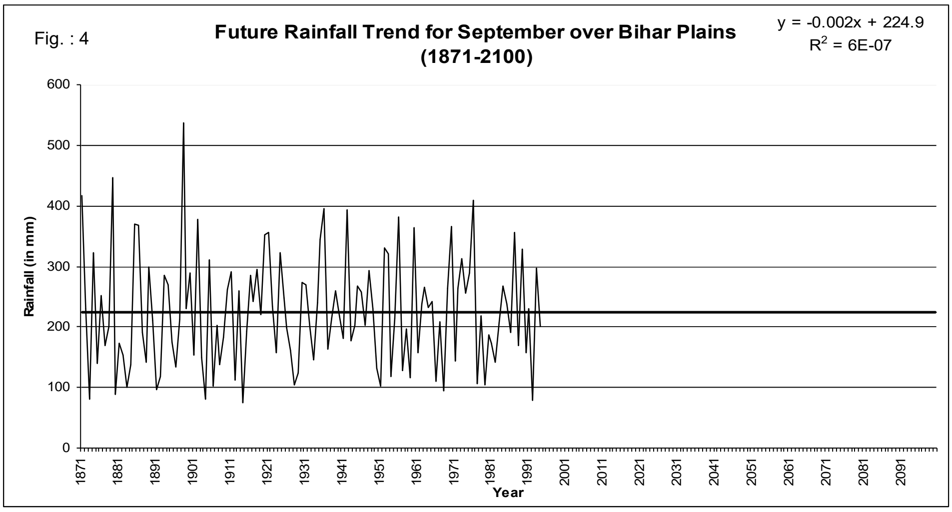


Fig. : 4
Future Rainfall Trend for September over Bihar Plains
(1871-2100)
y = -0.002x + 224.9
R^2 = 6E-07
Rainfall (in mm)
Year

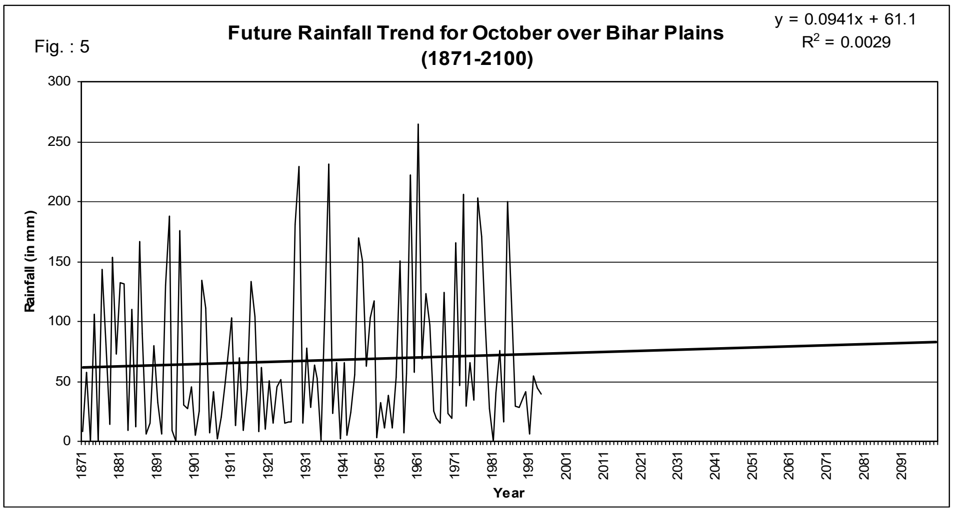


Fig. : 5
Future Rainfall Trend for October over Bihar Plains
(1871-2100)
y = 0.0941x + 61.1
R^2 = 0.0029
Rainfall (in mm)
Year

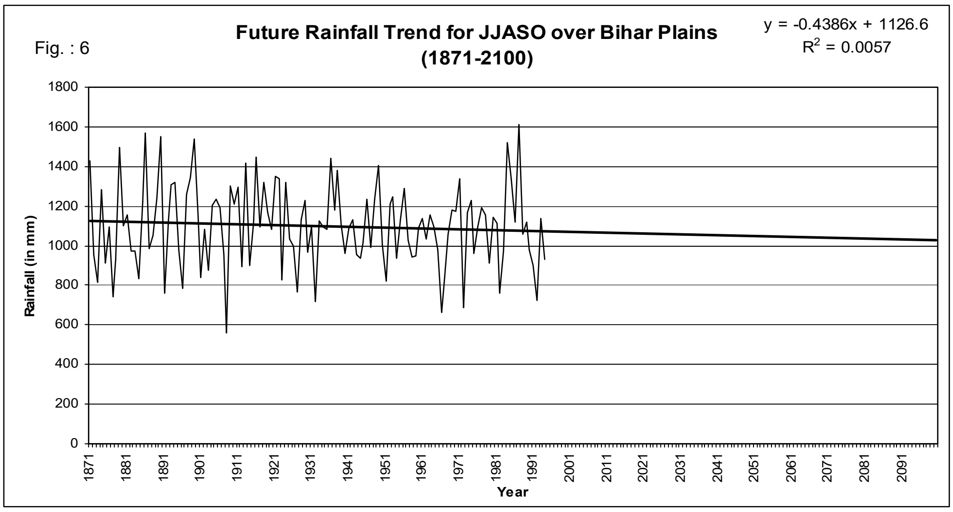


Fig. : 6
Future Rainfall Trend for JJASO over Bihar Plains
(1871-2100)
y = -0.4386x + 1126.6
R^2 = 0.0057
Rainfall (in mm)
Year

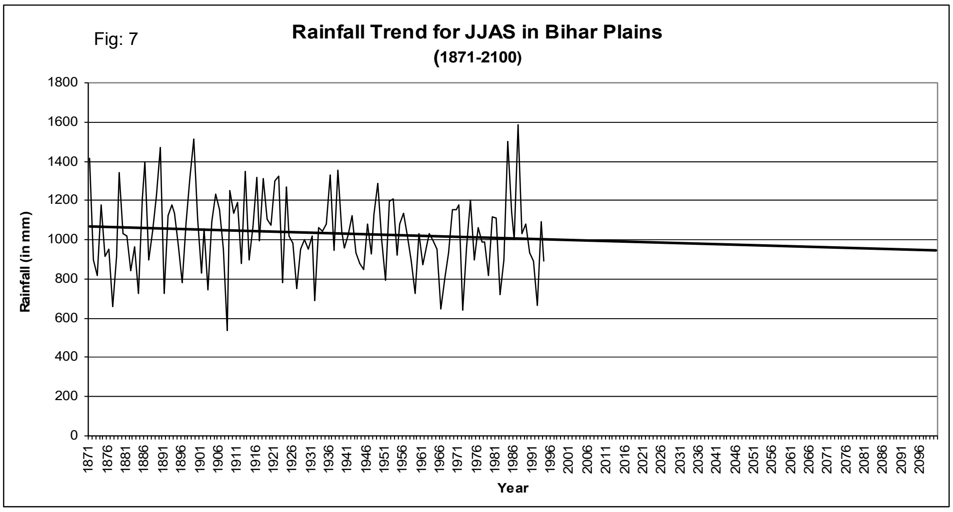


Fig: 7
Rainfall Trend for JJAS in Bihar Plains
(1871-2100)
Rainfall (in mm)
Year

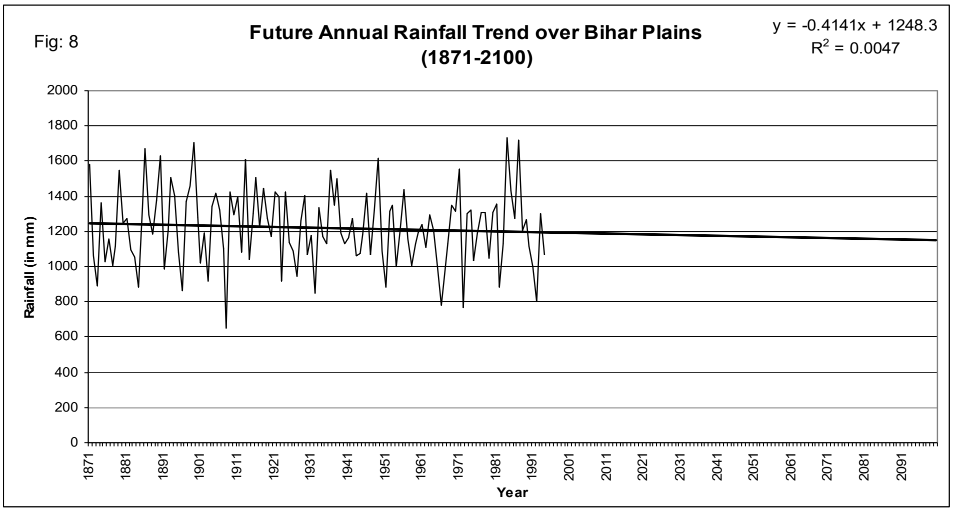


Fig: 8
Future Annual Rainfall Trend over Bihar Plains
(1871-2100)
y = -0.4141x + 1248.3
R2 = 0.0047
Rainfall (in mm)
Year

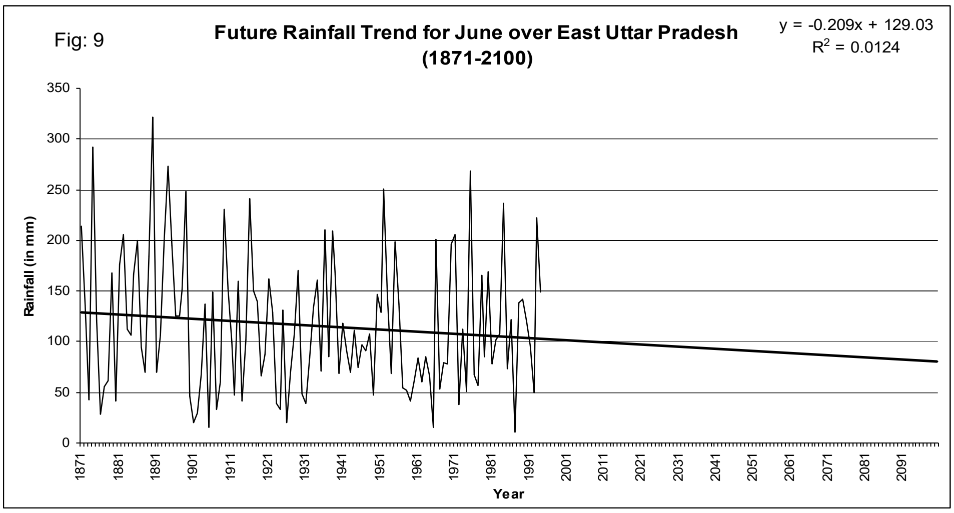
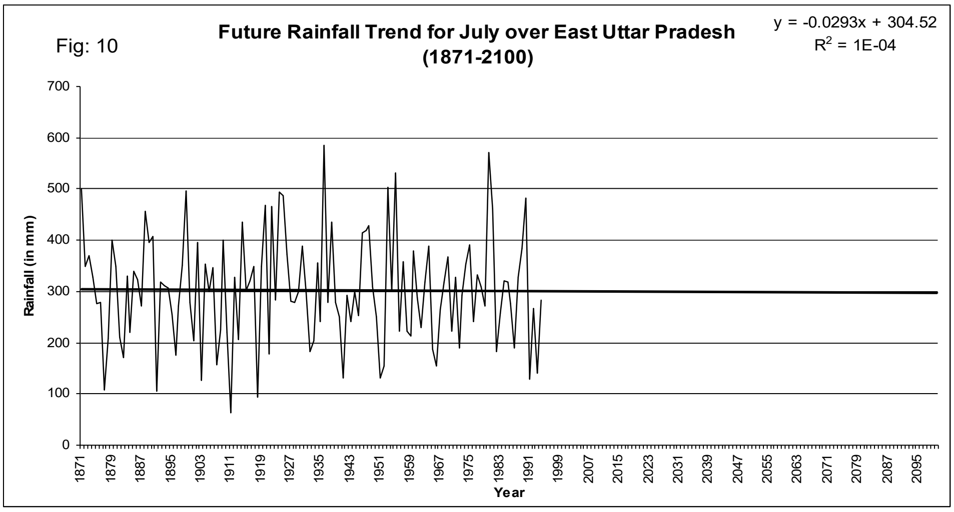


Fig: 9
Future Rainfall Trend for June over East Uttar Pradesh
(1871-2100)
y = -0.209x + 129.03
R2 = 0.0124
Rainfall (in mm)
Year

Fig: 10


Future Rainfall Trend for July over East Uttar Pradesh
(1871-2100)
y = -0.0293x + 304.52
R2 = 1E-04
Rainfall (in mm)
Year

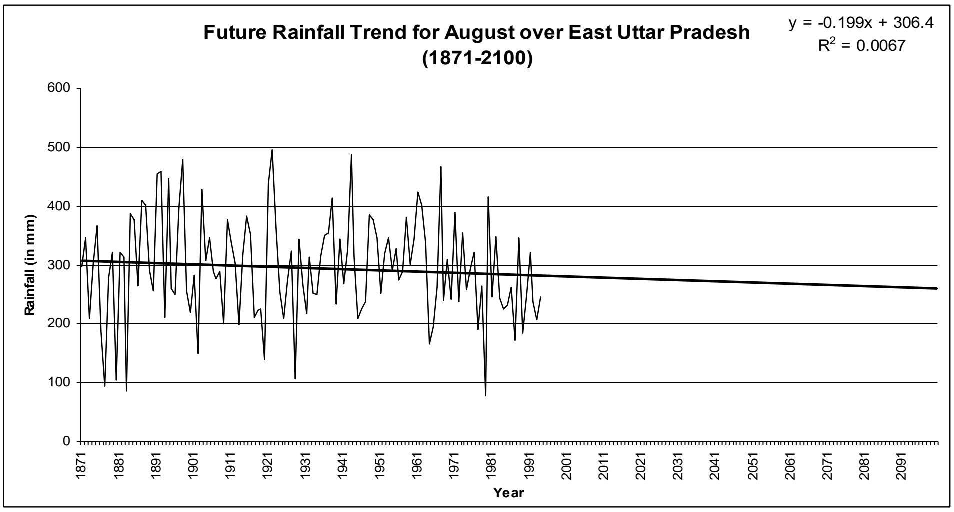
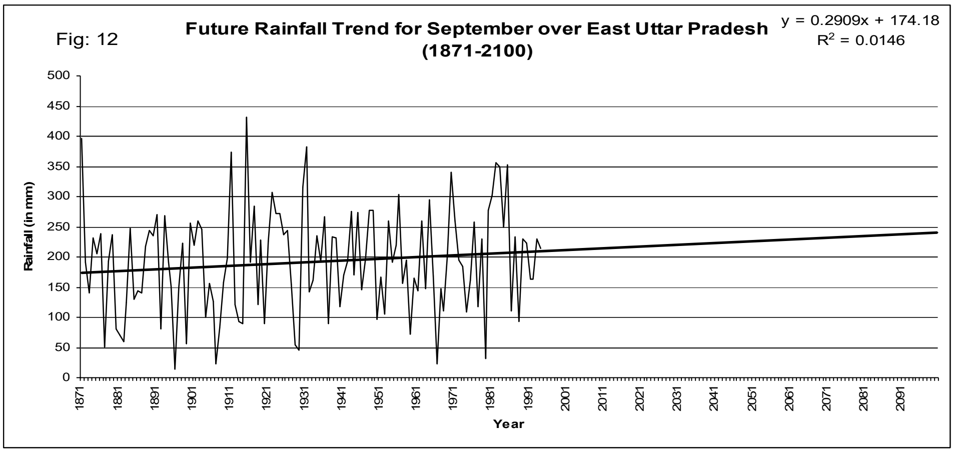

Future Rainfall Trend for August over East Uttar Pradesh
(1871-2100)
y = -0.199x + 306.4
R2 = 0.0067
Rainfall (in mm)
Year

Fig: 12


Future Rainfall Trend for September over East Uttar Pradesh
(1871-2100)
y = 0.2909x + 174.18
R2 = 0.0146
Rainfall (in mm)
Year

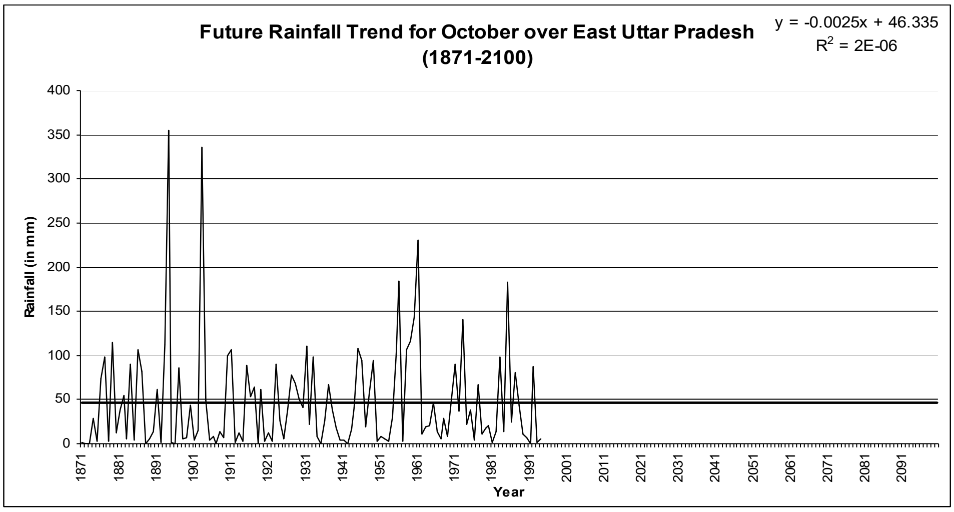

Future Rainfall Trend for October over East Uttar Pradesh
(1871-2100)
y = -0.0025x + 46.335
R2 = 2E-06
Rainfall (in mm)
Year

Fig: 14

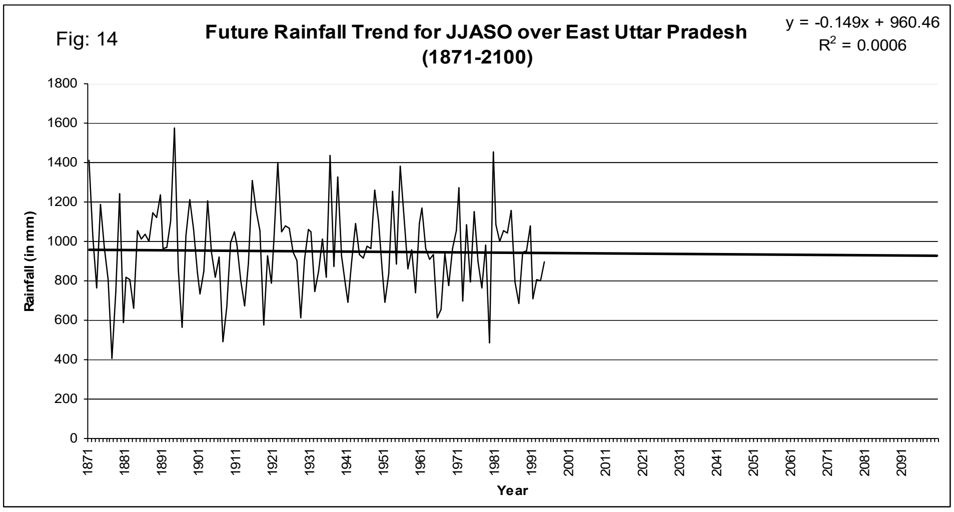
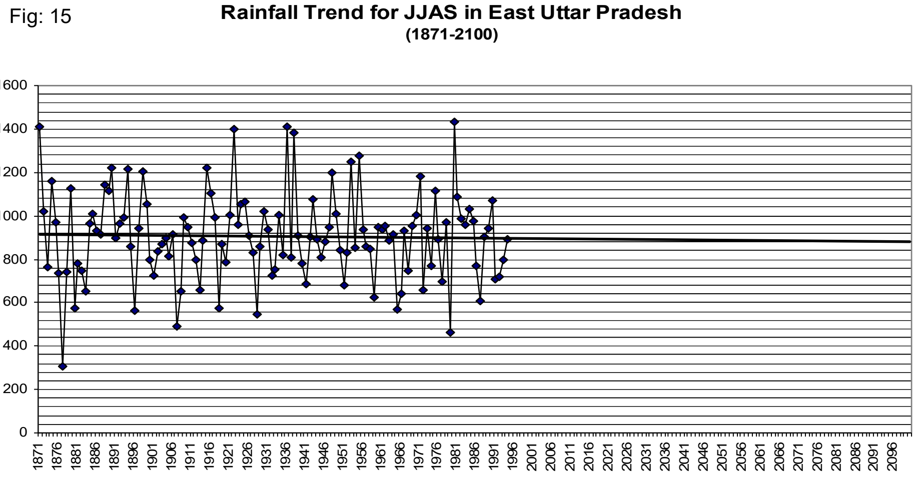

Future Rainfall Trend for JJASO over East Uttar Pradesh
(1871-2100)
y = -0.149x + 960.46
R2 = 0.0006
Rainfall (in mm)
Year

Fig: 15


Rainfall Trend for JJAS in East Uttar Pradesh
(1871-2100)

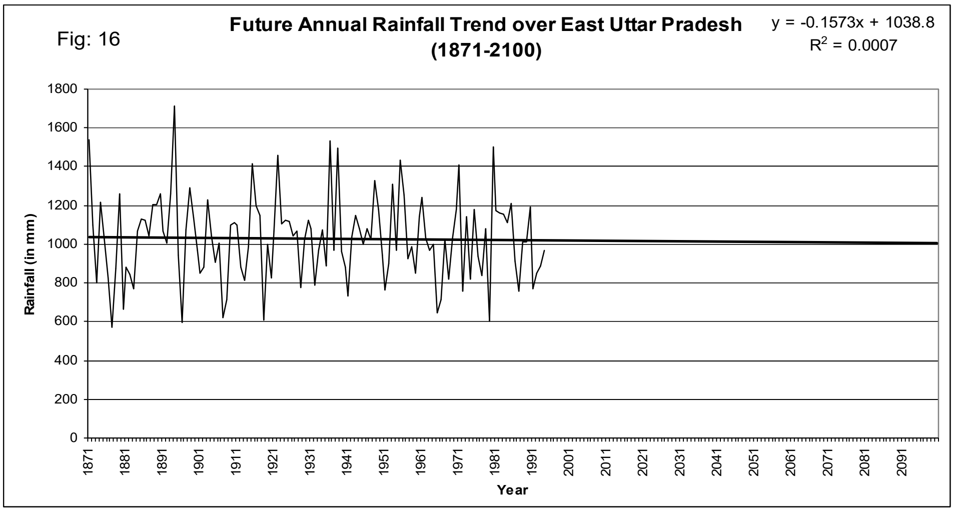


Fig: 16
Future Annual Rainfall Trend over East Uttar Pradesh
(1871-2100)
y = -0.1573x + 1038.8
R2 = 0.0007
Rainfall (in mm)
1800
1600
1400
1200
1000
800
600
400
200
0
1871 1881 1891 1901 1911 1921 1931 1941 1951 1961 1971 1981 1991 2001 2011 2021 2031 2041 2051 2061 2071 2081 2091
Year

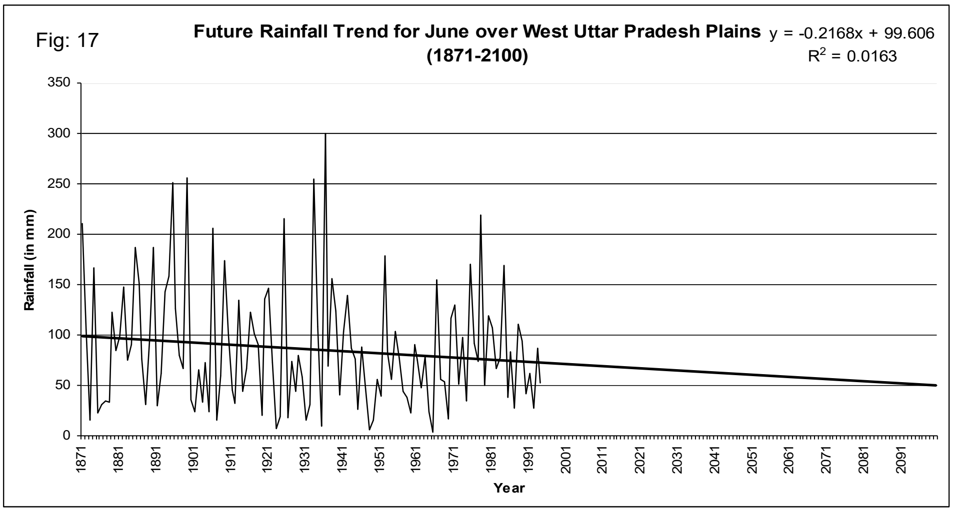


Fig: 17
Future Rainfall Trend for June over West Uttar Pradesh Plains
(1871-2100)
y = -0.2168x + 99.606
R2 = 0.0163
Rainfall (in mm)
350
300
250
200
150
100
50
0
1871 1881 1891 1901 1911 1921 1931 1941 1951 1961 1971 1981 1991 2001 2011 2021 2031 2041 2051 2061 2071 2081 2091
Year

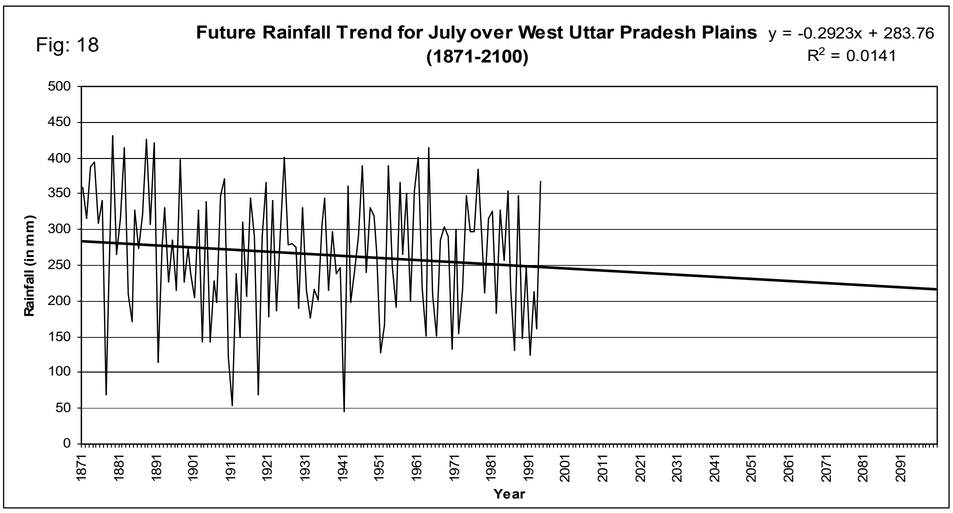


Fig: 18
Future Rainfall Trend for July over West Uttar Pradesh Plains
(1871-2100)
y = -0.2923x + 283.76
R2 = 0.0141
Rainfall (in mm)
500
450
400
350
300
250
200
150
100
50
0
1871 1881 1891 1901 1911 1921 1931 1941 1951 1961 1971 1981 1991 2001 2011 2021 2031 2041 2051 2061 2071 2081 2091
Year

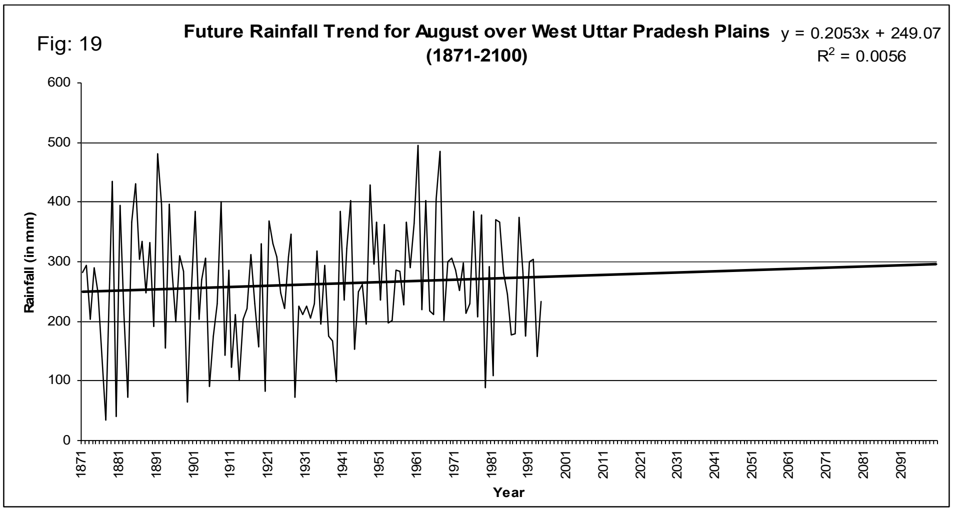


Fig: 19
Future Rainfall Trend for August over West Uttar Pradesh Plains
(1871-2100)
y = 0.2053x + 249.07
R^2 = 0.0056
Rainfall (in mm)
Year

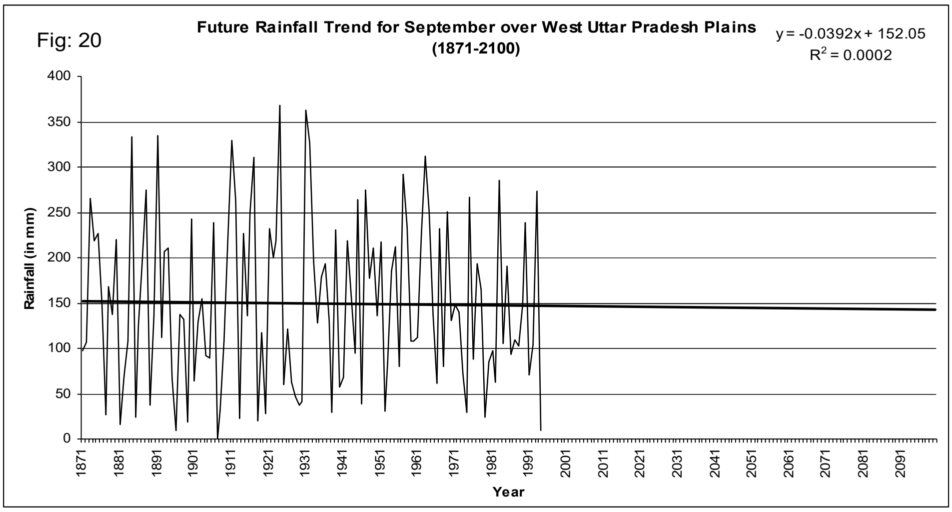


Fig: 20
Future Rainfall Trend for September over West Uttar Pradesh Plains
(1871-2100)
y = -0.0392x + 152.05
R^2 = 0.0002
Rainfall (in mm)
Year

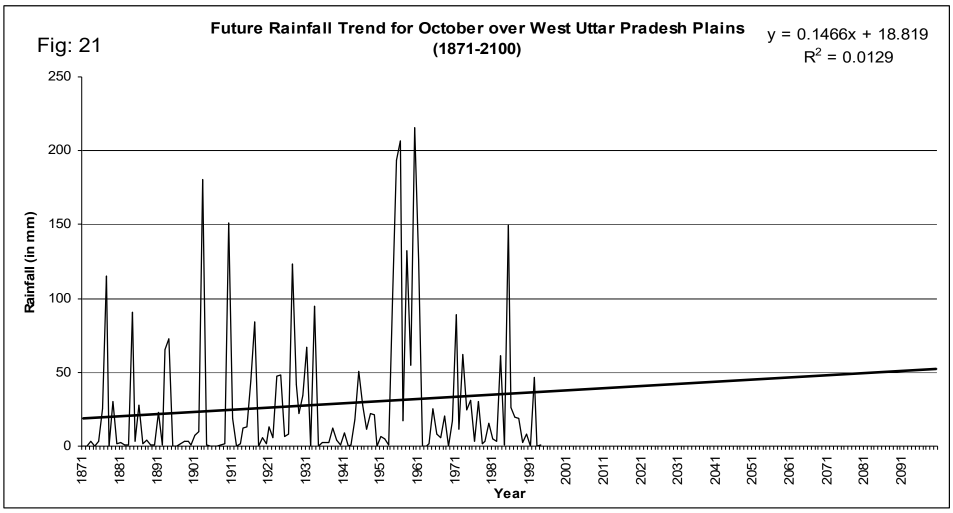


Fig: 21
Future Rainfall Trend for October over West Uttar Pradesh Plains
(1871-2100)
y = 0.1466x + 18.819
R^2 = 0.0129
Rainfall (in mm)
Year

Fig: 22

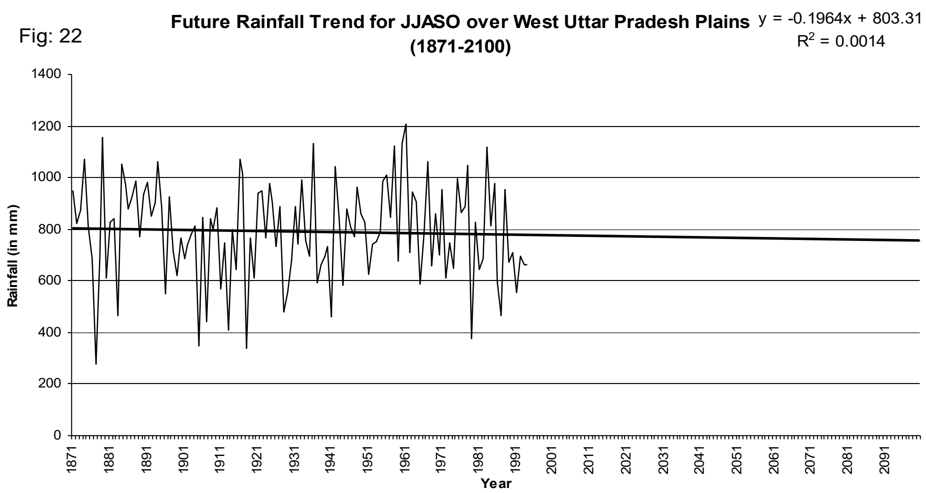


Fig: 23

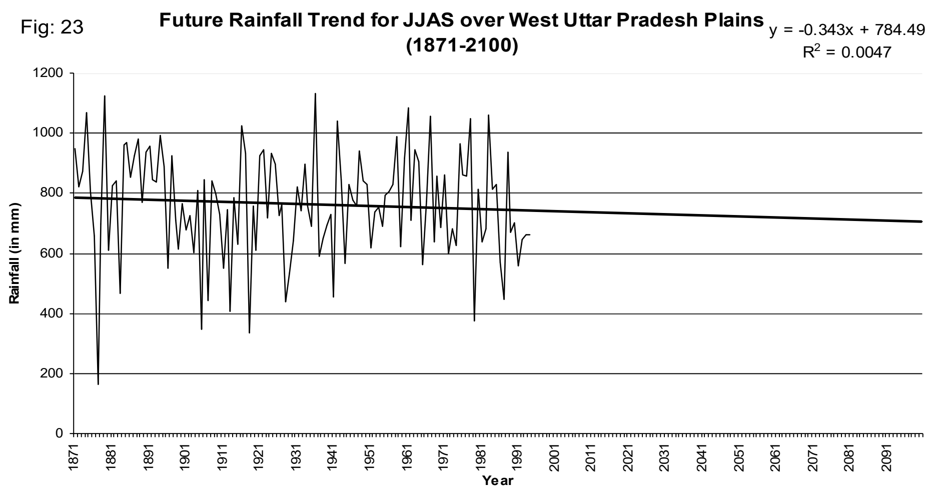


Fig: 24