Analyzing Rainfall Variability and Trend in Ganga Plain,Uttar Pradesh

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ABSTRACT *Climate change has become a burning issue at present with global consequences. Climate has been a dynamic phenomenon throughout the history and so its component i.e. temperature and rainfall. The principle theme of the paper is to analyse the variability in the nature of rainfall at selected stations of Ganga plain during 1961-2010. The rainfall data, obtained from India Meteorological Department (IMD), has been analysed to examine rainfall anomaly in Ganga plain.In India rainfall is of immense significance for agriculture and regional economy. Various policies also depend on surplus or deficit rainfall year. The present study has shown a highly variable monthly and seasonal rainfall which can adversely affect the country and its people.*

Key words: *Variability, Trend, Rainfall*

INTRODUCTION

It is a well-known fact that climate is a dynamic phenomenon and so are its components. All the climatic parameters and particularly precipitationvaries greatly over space and time. The analysis of changing pattern of rainfall and its trend is one of the crucial segments of climate change studies. Any significant departure of rainfall from its normal pattern or a varying trend can influence fluvial processes as well as can affect socio-economic condition of any place (Kumar et al., 2010). Rainfall is one of the key components of hydrological cycle that brings atmospheric water back to the Earth surface and also equalizes the difference between water surplus and water deficient regions. Water availability in any area is directly or indirectly determined by the amount of water received through precipitation. In India precipitation and particularly rainfall is of immense significance for agriculture and regional economy. Various policies also depend on surplus or deficit rainfall year. Climate change that is being extensively talked about can affect the pattern of rainfall which in turn can create an imbalance between water demand and supply. Therefore, understanding of changing pattern of rainfall is very crucial for any region to appreciate the impact of climatic changes and its consequences. A number of studies have been conducted in order to analyze rainfall variability and its trend covering different parts of the Indian sub-continent (Parthasarathy and Mooley, 1978; Hastenrath et al., 1982; Vines, 1986; Dash et al., 2004; Jain and Kumar, 2012). An increase in temperature with declining rainfall in Ganga Basinhas been confirmed by Kothyari, Singh and Aravamuthan, 1997. A more detailed analysis has been performed by Singh Nityanand and Sontakke (2002) where they have included around 30 rain gauge sites for the period 1829-1999. However, no significant trend in rainfall has beenidentified by Mohan, Divya and Sinha(2010).Rainfall variability in Ganga Basin has also been linked with El Niño and La Niña years (Jha and Ram, 2010).

DATA AND METHODOLOGY

Rainfall data has been obtained from India Meteorological Department (IMD) for the period of 1961 and 2010. Name of the selected stations and data availability is given in the table below-

Table 1.1 Stations selected for the study

S. No.	Station	Data Availability period	Location
1.	Aligarh	1961-2010	27^0 N, 78^0E
2.	Agra	1961-2008	27^0 N, 79^0E
3.	Hardoi	1961-2010	27^0 N, 80^0E
4.	Lucknow	1961-2010	26^0 N, 80^0E
5.	Varanasi	1961-2010	25^0 N, 83^0E

For analysis simple statistical methods have been used.First of all, missing data has been replaced using normal of the respective station. To analyze monthly variability of rainfall Coefficient of variation (%) has been computed. To observe the seasonal variation in rainfall distribution during different seasons (pre-monsoon, monsoon, and post-monsoon) total rainfall for each season has been summed up and represented by bar diagram (Table 1.2).For trend analysis Mann-Kendall test and Sen's Slope has been used.

Table 1.2 Classification of rainy Season

Seasons	Months
Pre-Monsoon	March - May
Monsoon	June - September
Post-Monsoon	October - December

AREA OF STUDY

Ganga plain forms a major physical division of the country and is also a cradle of great human civilizations. A major part of the Ganga plain lies in the state of Uttar Pradesh. The fertile soil helps to produce multiple crops in a year. Ganga along with its tributaries drains the region through its length and width.

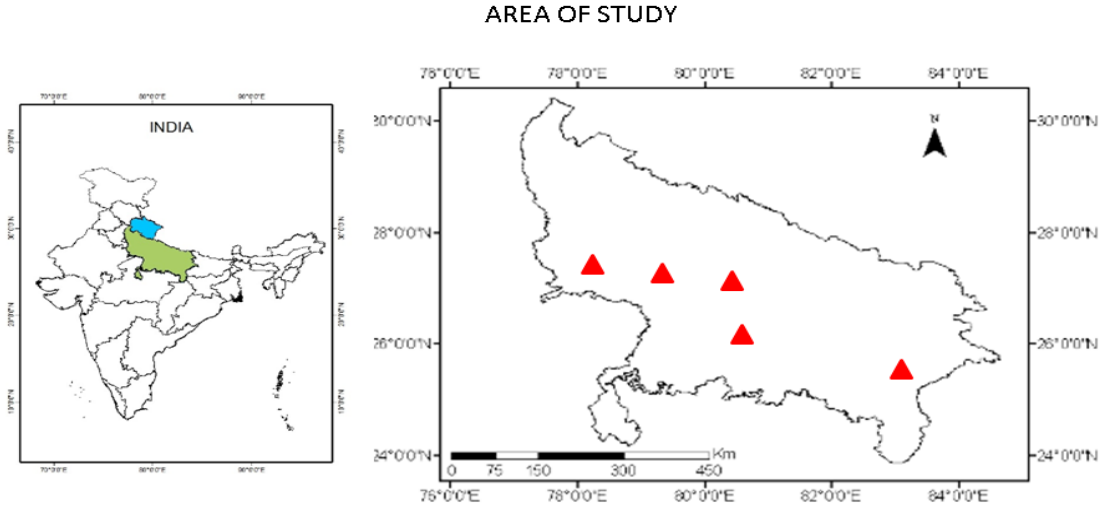

Fig.1.1 Area of Study and location of selected stations

RESULT AND DISCUSSION

MONTHLY VARIABILITY OF RAINFALL

As can be observed (table 1.3) at Aligarh rainfall has been significantly variable between October and December as well as between February and April. A similar pattern of rainfall variability has occurred in the case of Agra. However, variability is comparatively high at this rain gauge site. Low rainfall variability has been received in July and August.However, Hardoihas experienced most variable monthly rainfall as compared to the other stations. Only during monsoon months rainfall variability has appeared to be low in all other months rainfall has varied significantly at Hardoi. Moving towards Lucknow number of months with high rainfall variability has declined. However, at this station also rainfall has been highly variable during October, November and December. Between June and September comparatively less variable rainfall has been received. At Varanasi rainfall has been highly variable during March and April and between October and December.

Table 1.3 Monthly Variability of rainfall (CV in %)

MONTHS	ALIGARH	AGRA	HARDOI	LUCKNOW	VARANASI
JAN	105.8	104.6	117.2	113.5	86.8
FEB	125.8	123.6	131	118.8	117.5
MAR	160.3	145.5	133.2	141.7	154.3
APR	145.3	171.4	144.4	141.9	156.1
MAY	105.4	120.6	128.6	106.9	119.6
JUN	91.7	113.7	81	76.7	83
JUL	56.9	50.4	53.1	52.2	41.2
AUG	44.4	49.3	56.7	55.5	39.7
SEP	87	75.7	61.5	65	58.5
OCT	132.6	138.9	195.5	175.5	130.1
NOV	188.8	218.9	294.4	215.5	240.9
DEC	138.3	210.3	169.8	178.2	188.7

Therefore, it has become obvious from the table thatGanga plain of UttarPradesh has received high monthly variability of rainfall.

SEASONAL VARIABILITY OF RAINFALL

PRE-MONSOON SEASON

At Aligarh total amount of rainfall received during pre-monsoon season has declined to around 150 mm and during none of the years above 150 mm rainfall has occurred (Fig. 1.2a). However, at this station during the later years of study period more variable pattern of rainfall distribution has occurred as compared to the earlier decades. Agra has exhibited

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similar pattern of rainfall distribution during this season (fig. 1.2b). At Agra between 1977 and 1988 more variable distribution of rainfall has been received. At Hardoi rainfall has shown uneven distribution during pre-monsoon season (fig. 1.2c). During most of the years amount of total rainfall has remained between 50 mm and 100 mm and only the year 1971 has experienced more than 200 mm of rainfall. Rainfall during pre-monsoon season has appeared to remain consistence at Lucknow. At this station before the year 2000 total amount of rainfall has never gone above 100 mm. However, from 2000 the amount of rainfall has appeared to increase significantly. In contrast to this at Varanasi towards the end of the study period highly uneven distribution of rainfall has occurred.

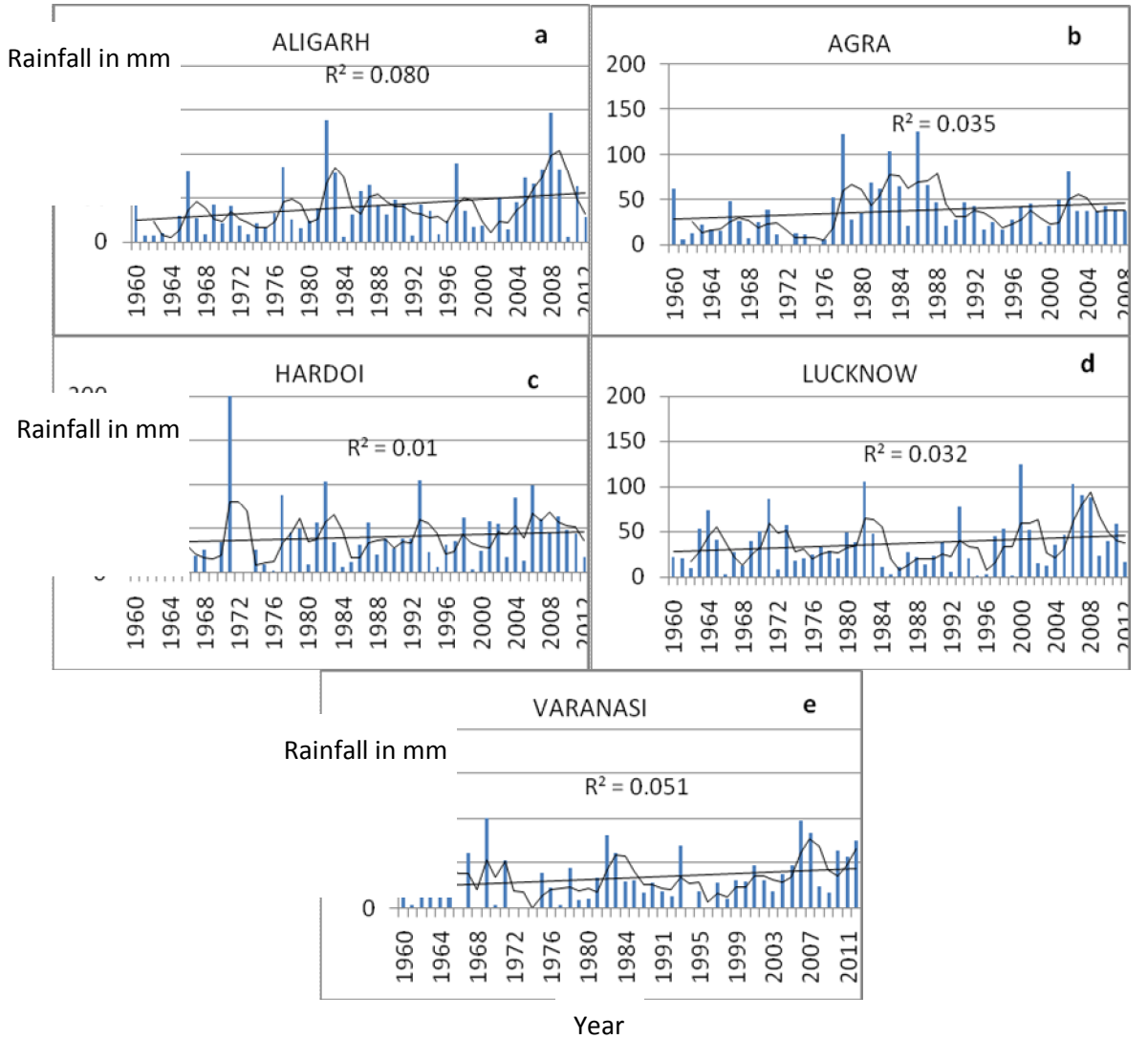

Fig. 1.2 Vvariability of rainfall during pre-monsoon season

MONSOON SEASON

At Aligarh, rainfall amount has appeared to decline towards the end of the study period (fig. 1.3a). However, after the year 2000 amount of rainfall has started to vary. Rainfall has remained to fluctuate throughout the study period at Agra (fig. 1.3b). Only between 1992 and 1998

marginal rise in monsoon rainfall has been observed. Again, after the year 2000 rainfall has become stable at Agra. Similarly, Hardoi has also recorded less variable distribution of rainfall during monsoon season with insignificant fluctuations. At Lucknowamount of rainfall during monsoon season has varied more significantly in the beginning of the study period. This variabilityhas been comparatively more between 1961 and 1985 (fig. 1.3). The amount of rainfall has mostly remained above 1000 mm. After the year 1985 amount of rainfall has decreased significantly. Total amount of monsoon rainfall has recorded to be below 1000 mm during most of the years. Varanasi has experienced low amount of rainfall during monsoon season.

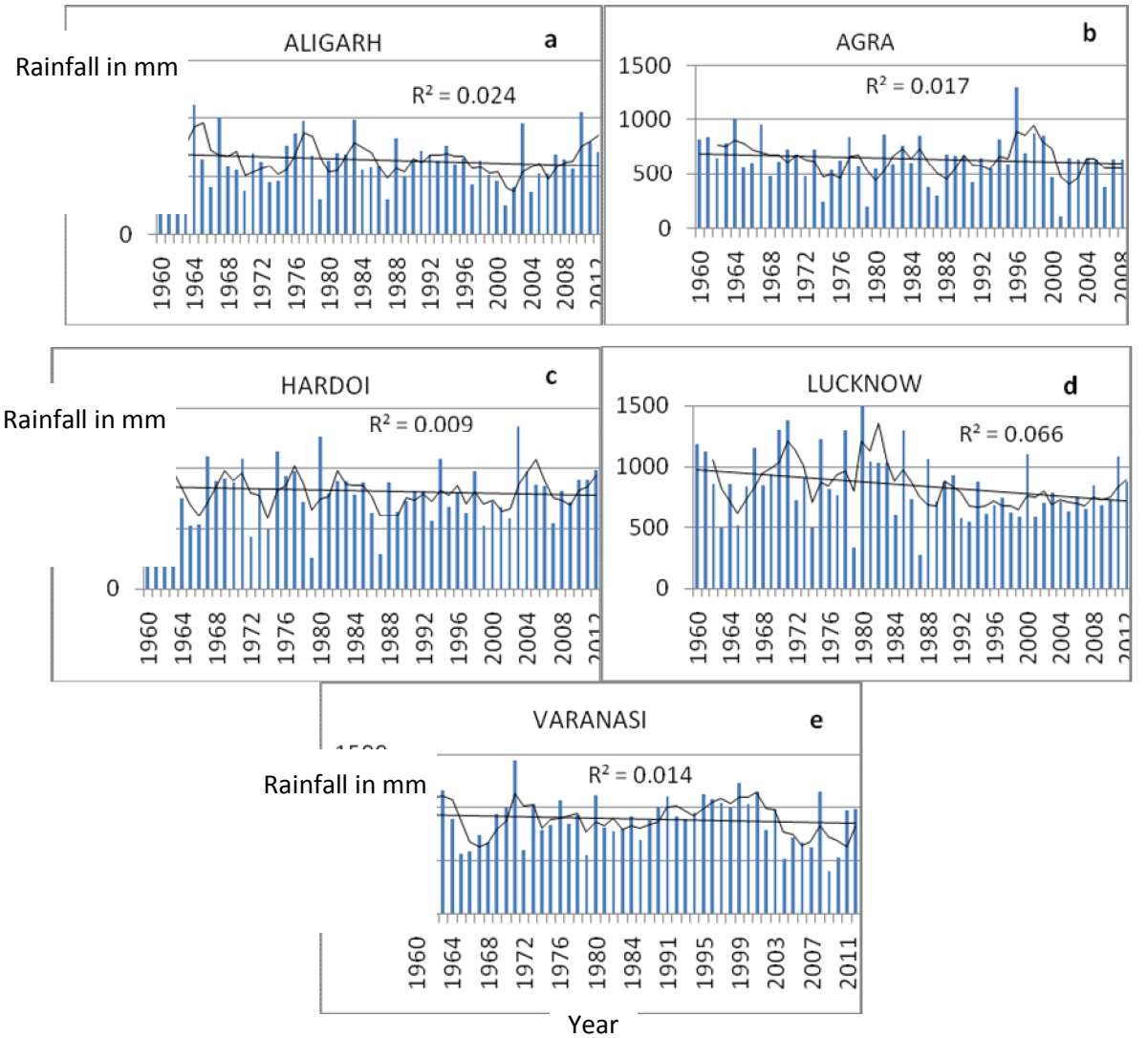

Fig. 1.3 Variability of rainfall during monsoon season

POST MONSOON SEASON

At Aligarh comparatively less variable pattern of rainfall distribution has occurred which has appeared to decline towards the end of the study period. At Agra also rainfall has remained less variable during post-monsoon season (fig1.4b). The amount of rainfall has mostly remained below 100 mm. After the year 1996 a comparatively more variable distribution of rainfall has been observed. A highly variable post-monsoon rainfall can be marked at Hardoi (fig 1.4c). However, towards the end of the study period and mainly between 2003 and 2012 rainfall

variability has appeared to decline. At Lucknow also rainfall has been significantly variable during post-monsoon season (fig 1.4d).Varanasi has received considerably variable rainfall (fig 1.4). More variable pattern of rainfall can be observed between 1961 and 1980. During this time rainfall has exceeded 150 mm in the year 1972 and 1977. Rainfall variability has again increased between 1995 and 2003. However, towards the end of the study period variability of rainfall during post-monsoon season has declined at Varanasi.

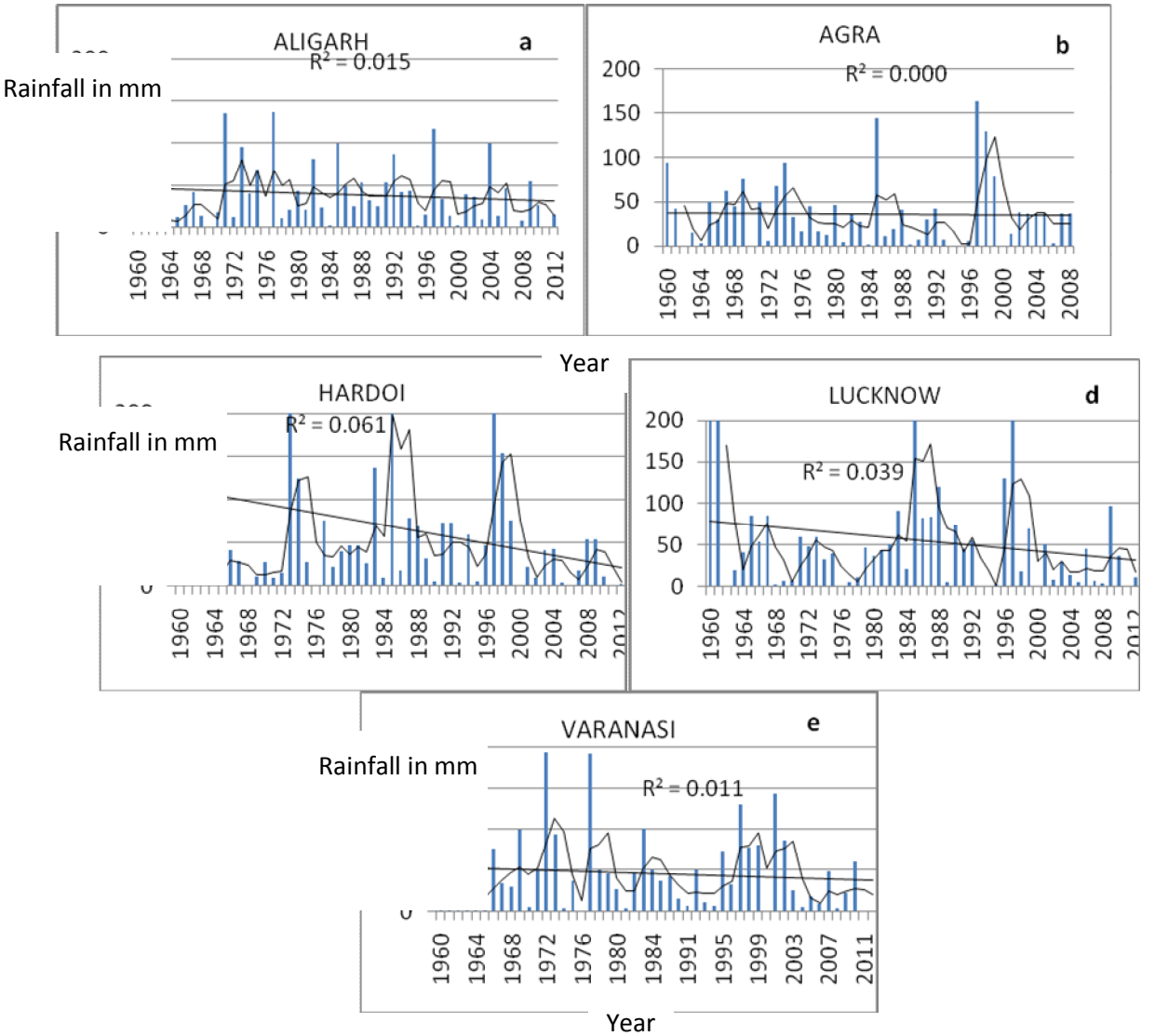

Fig. 1.4 Variability of rainfall during post monsoon season

TREND OF RAINFALL

It has been observed thatrainfall has varied significantly across the region (Table 1.4). However, none of the stations have shown significant change in rainfall pattern during 1961-2010. All the stations have shown a decining trend of rainfall but it is not statistically significant.

Table 1.4 Trendof Rainfall

(M-K trend test and Sen's slope estimate)

STATIONS	MANN-KENDALL TREND	SEN'S SLOPE ESTIMATE		
	Test Z	**Q**	**Qmin95**	**Qmax95**
ALIGARH	-0.69	-1.557	-6.326	2.901
AGRA	-0.40	-1.221	-5.411	3.322
HARDOI	-0.50	-1.180	-6.317	3.881
LUCKNOW	-1.46	-4.815	-10.836	1.629
VARANASI	-0.28	-0.407	-6.203	5.164

CONCLUSION

The study done so far has indicated that rainfall variability and trend has varied significantly in the region. During pre-monsoon and post-monsoon season rainfall has perturbed considerably. During monsoon season, however, rainfall has mostly remained persistent. However, no significant trend of rainfall has appeared in the region during 1961-2010. Rainfall variability during non-monsoon months can also affect the country and its population adversely.

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