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SPATIO-TEMPORAL VARIATION OF RAINFALL DURING POST-MONSOON SEASON OVER BANGLADESH

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ABSTRACT

In the present study daily rainfall data during 1948-2012 of 30 meteorological stations of Bangladesh Meteorological Department (BMD) have been used to understand the rainfall characteristics during post-monsoon season over Bangladesh. Yearly variations of rainfall and rainy days have been studied to see the long term variability. The study period has been divided into six decades starting from 1950 to investigate the decadal and interdecadal spatial and temporal variations. Average rainfall has been found to be 3.53 mm/day with standard deviation of ±1.52 mm/day and coefficient of variation 42.91% during 65 years in the post-monsoon season. Average rainy days have been found to be 10 days with standard deviation of ±3.11 days and coefficient of variation 31.12%. Both rainfall and rainy days have been found to have an annual increasing trend. Rainfall has been found to increase from west to eastward direction and it increased further from the central region to the northeast and southeast direction. Rainfall and rainy days both have been found maximum in the last decade.

Keywords: *Rainfall, Rainy day, post-monsoon, decadal variation*.

1. INTRODUCTION

Precipitation is a natural process and is related to the amount of latent heat transported from the surface to the atmosphere. It is an essential component of scientific investigation of the hydrologic cycle, the global water balance and large scale global atmospheric modeling. But it is one of the most difficult atmospheric parameters to measure because of the large variations in space and time (Kummerow *et al*., 2000).

Indian subcontinent is well known as a southwest monsoon region (Gadgil *et al.,* 2005; Goswami *et al.,* 1994; Hastenrath 1995; Kumar *et al.,* 1995; Pattanaik *et al.,* 2015; Rajeevan 2001; Thapliyal and Kulshreshtha 1992) and Bangladesh is a heavy rainfall area in it. Bangladesh is a narrow flat low land, the maritime continent with the Bay of Bengal is located in the south and the highly elevated Himalayas and Tibetan Plateau are situated in the north which favors development of convection that brings copious rain over the country in the southwest monsoon. The climate of this country is comprised of four meteorological seasons: pre-monsoon (March–May), monsoon (June–September), post-monsoon (October and November) and winter (December–February). The post-monsoon season is a transition period between southwest monsoon and northeast monsoon (winter). Sometimes cyclone forms in the Bay during this season which also causes heavy rainfall over the country.

Singh *et al*. (1999) studied post-monsoon rainfall variability and found large variation of interannual rainfall over India. Kripalani and Kumar (2004) studied rainfall variability over south peninsular India during northeast monsoon and found interannual and decadal variabilities in NEMR reveal alternate epochs of above- and below-normal rainfall. Ahasan *et al.* (2013) studied on the heavy rainfall event and found that the highly localized heavy rain over southeast Bangladesh was the result of an interaction of the large scale monsoon system. Similar works have been done by Alam (2014) for the southern part of Bangladesh. Hossain *et al*. (2014) studied on the variation of rainfall over southwest coastal Bangladesh and found increasing trend of rainfall during post-monsoon season. Similar result obtained by Panthi *et al*. (2015) in the Gandaki River Basin of Nepal.

In this study, an attempt has been made to study the spatial and temporal variation of rainfall and rainy days over Bangladesh during post-monsoon season.

2. DATA AND METHODOLOGY

Daily rainfall data of 30 meteorological stations of Bangladesh Meteorological Department (BMD) from 1948 to 2012 have been used in this study. Data have been collected from the Climate Division of BMD, Agargaon, Dhaka. It is important to note that some of the stations started its operation after 1948 and some data were not available in some stations for a few years. These data have been considered as missing and have not been used in statistical computations.

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The daily rainfall data have been used to obtain monthly and seasonal mean. The station wise rainy days have been identified (if there is any rain) and accumulated for the season. Yearly variations of the rainfall and rainy days along with the trend lines, standard deviation and coefficient of variation have been studied with the standard statistical technique. Five years moving average have been done for both rainfall and rainy days and their variations have also been studied.

To study the decadal variations of the studied parameters the study period have been divided into six decades starting from 1950. 1950-1959 has been designated as Decade1 (D1), 1960-1969 as Decade2 (D2), 1970-1979 as Decade3 (D3), 1980-1989 as Decade4 (D4), 1990-1999 as Decade5 (D5) and 2000-2009 as Decade6 (D6). Here after different decades will be used as D1, D2, D3, D4, D5 and D6. From seasonal average rainfall decadal average has been made for each station for each decade during post-monsoon season (October-November). Spatial distribution of rainfall has been studied for each decade. To understand the climatological variation of rainfall over the country 60 years average (1950-2009) has been made for each station. From this 60 years average rainfall; anomaly (Decade average-60 years station average) have been calculated for each decade during post-monsoon for individual station. Distributions of rainfall anomaly have been studied for each decade over the country during post-monsoon season. Similar works have been done with respect to 60 years country average rainfall. Rainfall anomaly (60 years average for each station - 60 years average for all stations) has been calculated. Distribution of this rainfall anomaly has also been studied during this season. Decadal average has also been made to study the interdecadal variation of rainfall and rainy days over the country.

3. RESULTS AND DISCUSSIONS

Spatial and temporal variations of rainfall and rainy days of thirty meteorological stations over Bangladesh have been studied and are presented in Figs. 1-6. Distribution of sixty years average rainfall and anomaly with respect to country average has been presented in Figs. 1(a & b) respectively. Minimum rainfall is observed in the western part of the country. Rainfall has been found to increase towards northeast and southeast coastal regions of the country. Maximum rainfall has been found 5mm/day over Khepupara. Rainfall anomaly has been found to be negative in the western part of the country and positive in the coastal region of the country. -1mm/day line ran through Jessore, Bogra and Dinajpur while 1 mm/day line passed over Khepupara.

Decadal country average rainfall and rainy days over Bangladesh have been presented in Fig. 1(c). Maximum average rainfall 4.16 mm/day has been found in D6 and minimum rainfall 2.96 mm/day in D2. Average maximum number of rainy days is found 10.66 in D6 and minimum 7.16 in D2. The decadal average rainfall during post-monsoon season is found to have an increasing trend with 0.092 mm/day/decade with coefficient of determination (square of the coefficient of correlation, r^2) 0.158. For the last five decades the increasing trend was 0.267 mm/day/decade with coefficient of determination 0.905 or time variant coefficient of correlation 0.95 with 99% confidence level. The rate of increase of rainy days has been found 0.311days/decade with coefficient of determination 0.184. For the last five decades the increasing trend was 0.865days/decade with coefficient of determination 0.951 or the time variant coefficient of correlation 0.98 with 99.5% confidence level.

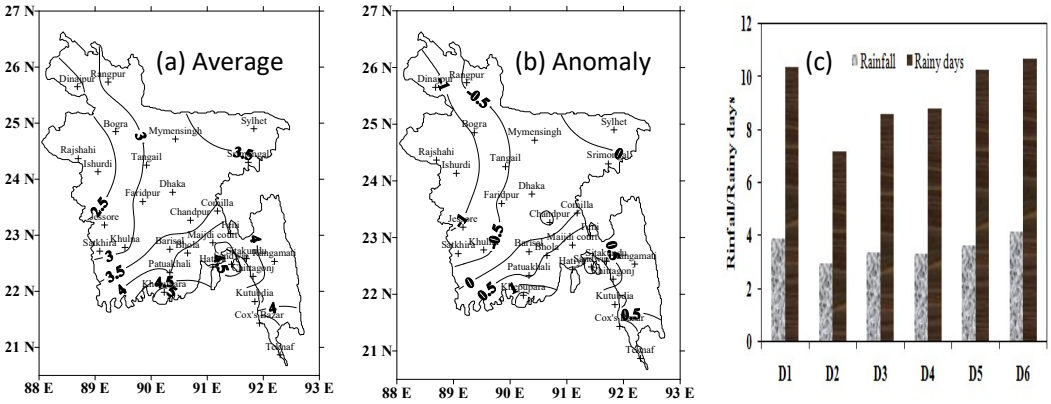

Figure 1: a) Distribution of 60 years average rainfall (mm/day) b) Rainfall anomaly (mm/day) with respect to 60 years country average and c) Decadal average rainfall (mm/day) & rainy days during post-monsoon season over Bangladesh.

Annual variation of rainfall and rainy days along with five years moving average and linear trend lines have been presented in Fig. 2. Both rainfall and rainy days have been found to have an increasing trend with 0.008mm/day/year and 0.056days/year respectively [Fig. 2(a & b)]. Although increasing rate of rainfall is not statistically significant but increasing rate of rainy days is highly significant with 99.5% confidence level.

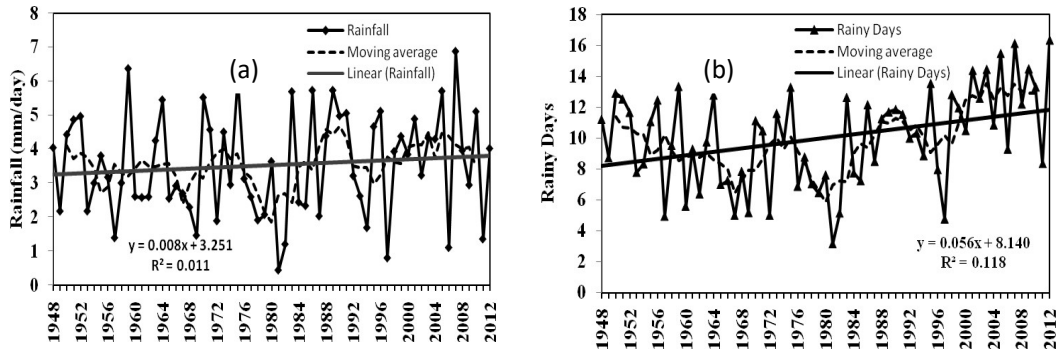

Figure 2: a) Annual variation of rainfall (mm/day) along with five years moving average and the linear trend line and b) Same as (a) but for rainy days.

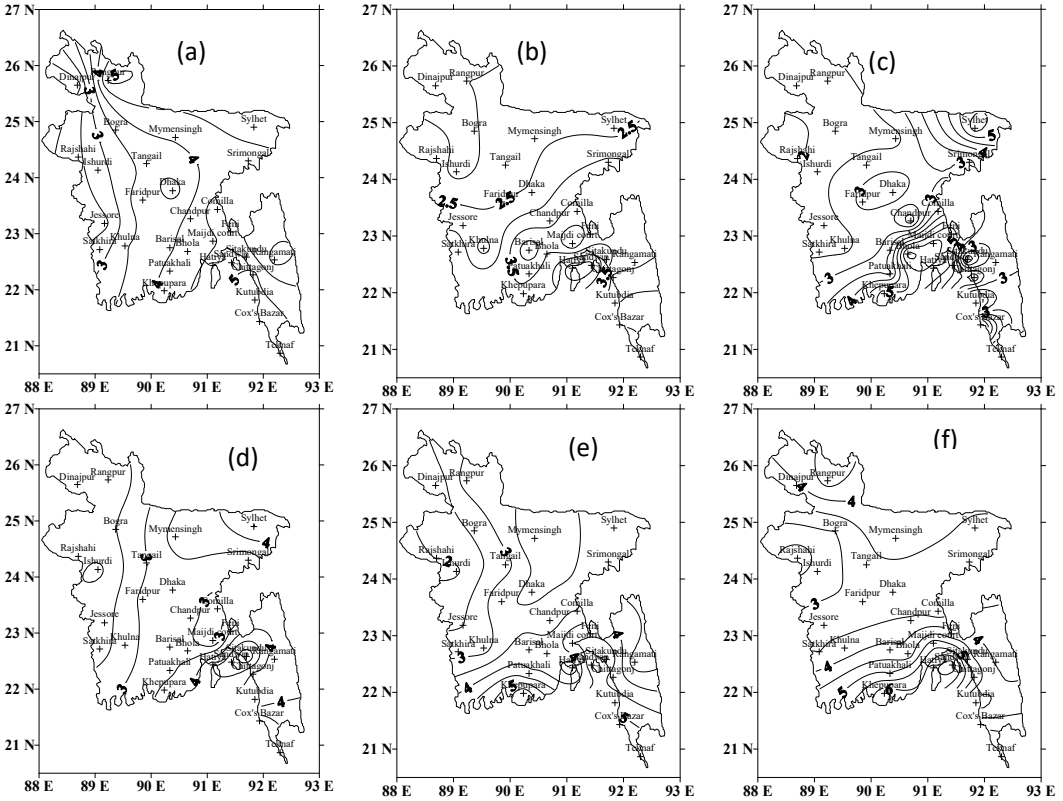

Figure 3: Distribution of average rainfall (mm/day) during post-monsoon season for (a-f) decade D1-D6 respectively.

Decadal distributions of average rainfall during post-monsoon season have been presented in Fig. 3(a-f). The minimum rain has been observed in the post-monsoon season in the west-northwestern region and maximum rain has been observed in the south-southeastern region in all decades. The decadal distribution pattern of rainfall also indicated that the rainfall continuously increased in the south-southeastern region of Bangladesh. In D1 the lines of equal rainfall have been found to run along north south direction in the western part of the country (Fig. 3a). 4mm/day line bulged towards northeast direction and maximum rainfall is found in Rangpur and southeast region of the country. In D2 minimum rainfall has been found to occur in the northwestern part of Bangladesh and increased in the southeast direction (Fig. 3b). In D3 maximum amount of rainfall has been found in the northeast region and the southeast coastal region (Fig. 3c). Similar rainfall distribution pattern has been observed in D4 (Fig. 3d) and D1. In D5 maximum rainfall has been found in the coastal region of the country (Fig. 3e). However in D6 rainfall has been found to increase from north to southward direction (Fig. 3f).

Rainfall anomalies with respect to decadal country average have been presented in Fig. 4(a-f). In D1 western part of the country has been found to be deficit in rain while excess rain is found in the eastern part of the country [Fig. 4(a)]. The zero anomaly line is found to pass over Jessore, Satkhira, Khulna and Srimangal in D2 [Fig. 4(b)]. Rainfall anomaly has been found negative in the northwestern part of the country and positive in the south-southeastern part in D2. Rainfall anomaly is found to be negative in the northwestern part of the country and positive in the northeast part of the country as well as in the southeastern coastal region [Fig. 4(c)]. In many places over the central part of the country there was no rainfall anomaly [Fig. 4(d)] in D4 and positive anomaly had been found in the northeastern and south-eastern parts of the country. In D5 and D6 [Figs. 4(e-f)] positive rainfall anomaly prevailed over the southern coastal region with a maximum of 2mm/day in D6 over Hatiya and Sandwip region.

Rainfall anomalies with respect to sixty years station average have been presented in Figs. 5(a-f). There is no anomaly in the western part of the country in D1 [Fig. 5(a)] while above normal rain has been found in the northeastern part of the country. In D2 rainfall anomaly has been found negative over central and northern part as well as in the southeastern coastal region of the country with a minimum of -2 mm/day over Hatiya [Fig. 5(b)]. In D3 and D4 [Figs. 5(c & d)] over a large area in the western and central part of the country there was no rainfall anomaly. Rainfall has been found to be static (no anomaly) over the country in D5 [Fig. 5(e)] except in the northeast part of the country. Rainfall anomaly has been found to be positive in the northwestern, southwestern and coastal regions of the country in D6 [Fig. 5(f)] with 1.5 mm/day over Rangpur and Dinajpur and 2mm/day above normal over Hatiya and Sandwip.

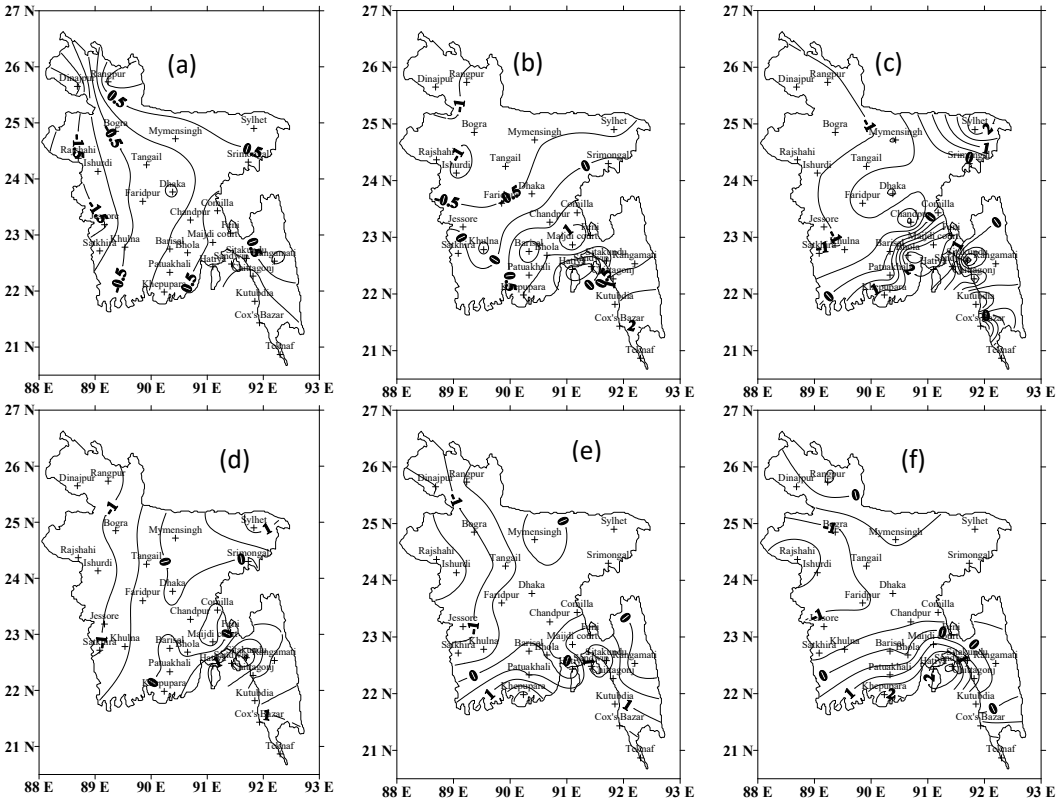

Figure 4: Rainfall anomaly (mm/day) with respect to decadal country average during post-monsoon season for decades (a-f) D1-D6 respectively.

Anomaly of rainy days has been presented in Fig.6. In D1 [Fig. 5(a)] most of the places over central and northern part of the country anomaly is positive with a maximum of 3days over Mymensingh and over a few places in the northwestern part of the country anomaly is found to be negative. Negative anomaly has been found throughout the country in D2 [Fig. 6(b)] with a minimum of -3days over Hatiya-Sandwip region. It is found to be less negative over the country in D3 and D4 [Figs. 6(c & d)]. In D5 it is negative over Mymensingh and positive over rest of the country. In D6 it is mainly positive over the country with maximum anomaly is found over Chandpur.

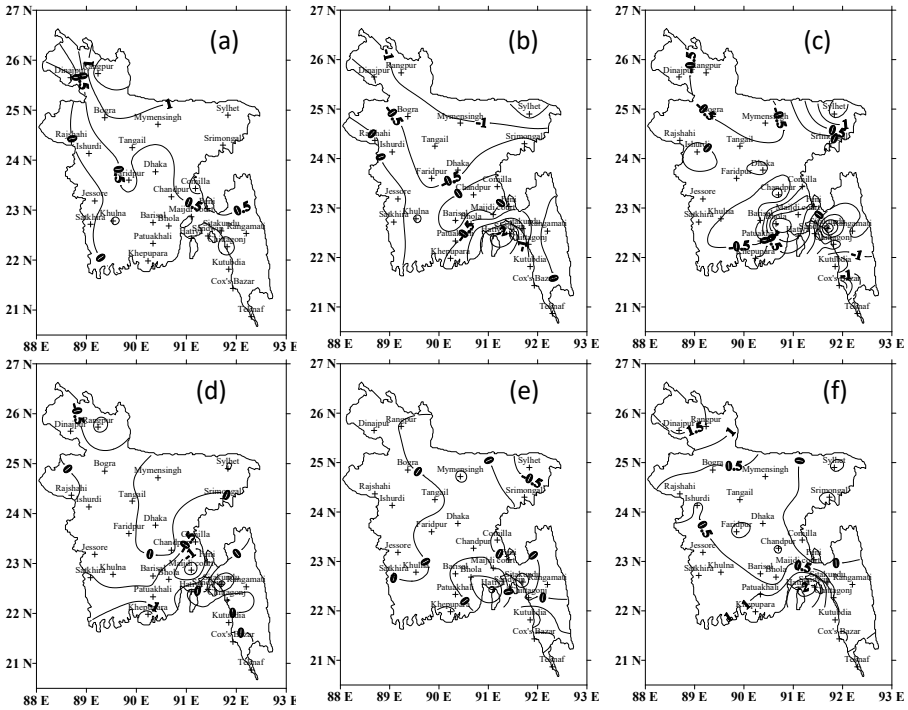

Figure 5: Rainfall anomaly (mm/day) with respect to 60 years station average during post-monsoon season for (a-f) D1-D6 respectively.

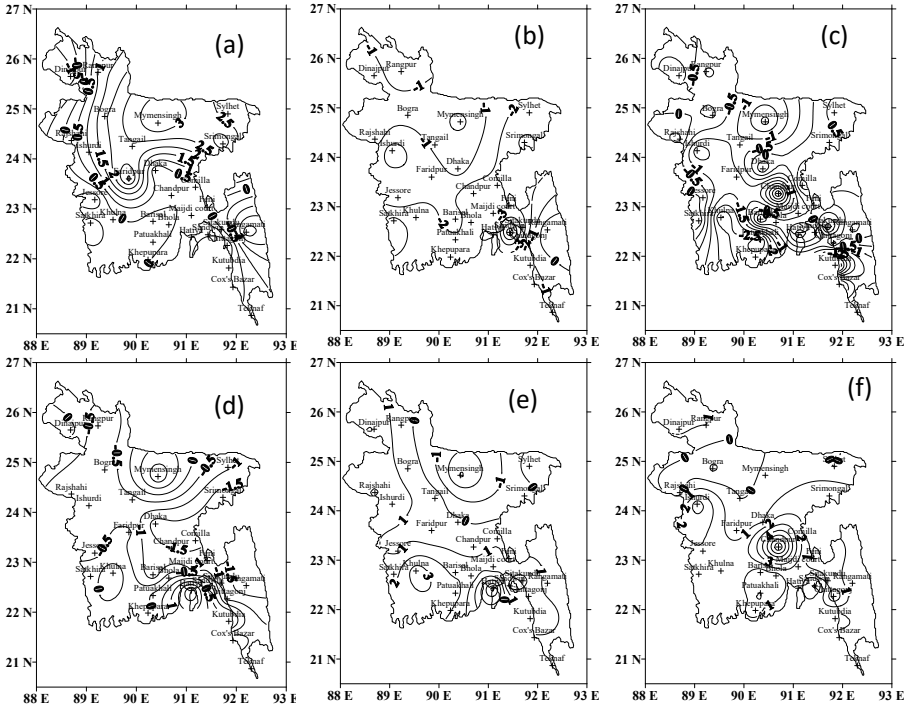

Figure 6: Anomaly of rainy days with respect to sixty years station average for (a-f) D1-D6 respectively during post-monsoon season.

Rainfall and rainy days of 65 years (1948-2012) during post-monsoon season over Bangladesh have been analyzed. Average rainfall has been found 3.53 mm/day with standard deviation ±1.52 mm/day and coefficient of variation 42.91%. Average rainy days have been found 10 days with standard deviation ±3.11 days and coefficient of variation 31.12%.

4. CONCLUSIONS

On the basis of the study presented in this paper, the following conclusions have been drawn:

i. The distribution of rainfall during post-monsoon season over the country has been found similar for decade1 (D1), decade4 (D4) and decade5 (D5). Rainfall has been found to increase from west to east in the western part of the country while it is found to increase towards northeast direction in the northeastern part of the country.

ii. The western part of the country is found to be deficit in rain and the coastal regions have found excess rain in all the decades.

iii. During sixty years decade2 has been found to be deficit in rain and decade6 is found to have excess of rain.

iv. Sixty years average rainfall have been found to increase from west to eastward direction and it increased towards northeast and southeast coastal region through the central part of the country.

v. Minimum amount of rainfall is observed in the western part of the country and the maximum in the coastal belt of Khepupara, Hatiya and Sandwip region.

vi. Minimum amount of rainfall is found in decade2 (2.96 mm/day) and maximum in decade6 (4.16 mm/day) with an average of 3.57 mm/day during 1950 – 2009.

vii. The decadal average rainfall during post-monsoon season is found to have an increasing trend with 0.092 mm/day/decade with coefficient of determination 0.158. In the last 5 decades the increasing trend became 0.267 mm/day/decade with coefficient of determination 0.905 or time variant coefficient of correlation 0.95 with 99% level of confidence.

viii. Both rainfall and rainy days have been found to have a linear increasing trend with 0.008mm/day/year and 0.056days/year respectively. Although increasing rate of rainfall is not statistically significant but increasing rate of rainy days is highly significant with 99.5% confidence level.

ACKNOLEDGEMENT

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