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Rainfall variability analysis of eastern plain zone of Uttar Pradesh

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Abstract
The rainfall data of last 30 years (1991-2020) of Eastern plain zone of Uttar Pradesh (Faizabad, Varanasi and Ballia) were collected from Acharya Narendra dev university of agriculture and technology Kumarganj Ayodhya (Faizabad), Banaras Hindu university (Varanasi) and Krishi vigyan Kendra (Ballia). The collected data was analysed to observe the past trend and variability of annual rainfall and the comparative relationship of rainfall distribution in the above districts. The trend of rainfall reflects a decrease in annual and seasonal rainfall during the past 30 years. Results revealed that annual rainfall in the Eastern Plain Zone of the district (Ayodhya, Varanasi, & Ballia) has declined over the normal 1001.7 mm, 1009 mm, and 1022.0 mm respectively in recent years. In relation to the current grain need scenario for the world population, a decreasing trend in rainfall resulted in decreased agricultural production.

Keywords: Annual rainfall variability, trend, eastern plain zone

Introduction
Rainfall is the synonym form of precipitation, is the principal element of hydrological cycle on earth surface. The annual and seasonal rainfall received and the variability directly influence success or frailer of crops. Through its beneficial or adverse effect on growth and yield. Therefore, the study of the variability of annual and seasonal is essential in sectional of suitable crops and to take appropriate mitigating measures based on rainfall characteristics. Scientific study on the quantum and distribution of rainfall if made mould enable the forming community to adjust or modify the cropping programs. Change in rainfall due to global warming or after 1990's (after industrialization) in the country, may influence the hydrological cycle and rainfall pattern. This compelled to review the demand of water hydrological design and agricultural practices. Therefore, long term trend analysis of rainfall and other weather parameters on different spatial scales will help in framing the future scenario for crop planning and management (Jain & Kumar, 2012) [1]. Analysis of rainfall (1971-2011) was made for four sectors *viz*. Eastern, Western, Central and Bundelkhand region of U.P. It was found that in general, annual rainfall decreased in all sectors of U.P. but the rate of decrease of rainfall in western U.P. was faster as compared to other sectors of U.P. and was in the order of Western U.P.> Eastern U.P.> Central U.P.>Bundelkhand region. Variability of seasonal rainfall in different sectors of U.P. was also in the same order and magnitude as that of total rainfall. Average onset dates of south west monsoon in Eastern U.P. and central U.P. have shifted to 19th/and 20th June respectively, from the normal date of 15th June. Total rainfall in relation to onset of monsoon, decreased by 6%, if monsoon reaches on 19th June in Eastern U.P. (normal date of onset is 15th June) and 9.5%, if monsoon reaches on 25th June. Consequent upon length of rainy season was also decreased from normal 108 days to 99 days in Eastern U.P. whereas reduction in length of rainy season in other sectors of U.P. ranged between 12-13 days. Rainy day and rainfall intensity both reduced in all sectors of U.P. In Eastern U.P. rainfall intensity reduced from 25 mm/day (1971-1990) to 17.2 mm/day (1992-2011), i.e., 32% reduction, hence crop planning may be made accordingly in respective sectors. (Deo *et al.* 2016**)** Keeping above facts in view the present investigation was under taken.

Materials and Method
The rainfall data of last 30 years (1991-2020) of Eastern plain zone of Uttar Pradesh (Faizabad, Varanasi and Ballia) were collected from Acharya Narendra dev university of agriculture and technology Kumarganj Ayodhya (Faizabad), Banaras Hindu university (Varanasi) and Krishi vigyan Kendra (Ballia).

The annual and seasonal rainfall data for period between 1991 - 2020 for 30 years, of Eastern plain zone of Uttar Pradesh (Faizabad, Varanasi and Ballia) were studied for their variability and dependability. Faizabad situated at 26.773°N Latitude 82.146°E Longitude altitude 104 meter at mean sea level. (MSL). Varanasi situated at 25.3176° N Latitude, 82.9739° E longitude elevation of 80.71 meters (264.8 ft) at mean sea level and Ballia situated at 25.8307° N Latitude, 84.1857° E longitude elevation of 57 meters (187 feet) at mean sea level (MSL). The rainfall is measured on daily basis; hence, its weekly, seasonal and annual totals are considered for analysis. Amongst the seasonal, total it is again sub-classified as monsoon season (June to September) are crop growing season (sowing to harvest) rainfall. The mean weekly, seasonal and annual rainfall is worked out to study the rainfall climatology of that area. The formula is given below:

$$R = \frac{1}{n} \sum_{i=1}^{n} Ri$$

Where
R_i, Rainfall of year (i)
n, i= 1,2,3…… n no. of years.
R, Mean total rainfall (mm

Results and Discussion
Annual Rainfall Variability
Data related to annual (January to December) rainfall variability (mm) of Ayodhya, Varanasi and Ballia district have been depicted in fig.1 fig2 and fig3 respectively. It can be observed from the data analysed over last 30 years (1991-2020) that annual rainfall of Eastern Plain Zone of district Ayodhya, Varanasi and Ballia has declined over the normal 1001.7 mm 1009 mm, and 1022.0 mm respectively in recent years to come. The highest rainfall recorded in the year 1997 (1285.7 mm) while lowest in 2015 (542.9 mm) at Faizabad, the highest rainfall recorded in the year 2007 (1628.7 mm) while lowest in 2015 (644.9 mm) at Ballia and the highest rainfall recorded in the year 2008 (1442.9 mm) while lowest in 2009 (428.7 mm) at Varanasi. The decreasing trend was found in annual rainfall variability (mm) over the normal rainfall which is directly influenced the production of rice and maize (about 80% of maize is cultivated during monsoon season). Untimely distribution of rainfall also occurs due to climatic variability. (Deo *et al*. 2018)

Decadal rainfall variability
The rainfall data analysed over last 30 years and divided into 3 three decades to know which decades starts the decreasing trend of rainfall. It is represented in Fig.4, Fig 5 and Fig 6, which are First (1991-2000), second (2001-2010) and third 2011-2020 decades respectively. It is quite observable from the data analysed over 30 years (1991-2020) that annual rainfall (mm) of Ayodhya declined over normal rainfall 1001.7 mm in recent years to come while trend of rainfall in first decade was found slightly increase over the normal rainfall. In first decade, the year 1991,1997 and 1999 highest rainfall recorded which is higher over the normal rainfall. The highest rainfall 1285.7mm occurred in 1997 in the first decade (1991-2000). In second decade (2001-2010) highest rainfall 1270 mm recorded in the year 2008 which is higher over normal rainfall followed by year 2003 and 2009. After the year 2003 rainfall has decreased from normal rainfall for 4 consecutive years. First year (2011) of the third decade (2011-2020) highest 1239.9 mm recorded which is higher over normal rainfall represented in Fig 6 So, trend of annual rainfall in third decade found decreasing over normal at Ayodhya.
Varanasi declined over normal rainfall 1009.0 mm in recent years to come while trend of rainfall in first decade was found extremely increased over the normal rainfall. In first decade continuously for two years (1997 and 1998) highest rainfall recorded which is higher over the normal rainfall. The highest rainfall 1313.1 mm occurred in 1997 followed by 1998 (1313.4 mm) while lowest rainfall was recorded 826.2 mm in the 1992. In second decade (2001-2010) highest rainfall **(**1442 mm**)** recorded in the year 2008 which is higher over normal rainfall followed by year 2003 and 2001. In contrast, the lowest rainfall was recorded in 2009. From the year 2004 rainfall was decreased from normal rainfall for consecutive years except in the year 2008. Last year (2020) of the third decade (2011-2020) highest 1171.7 mm recorded which is higher over normal rainfall while lowest recorded 477.0 in 2018. It was found that in the third decade only 4 years (2011-16 and 2020) of annual rainfall was more than normal, so trend of annual rainfall was decreased in third decade which is shown in Fig.9
Annual rainfall (mm) of Ballia declined over normal rainfall 1022.0 mm in recent years to come while trend of rainfall in first decade was found slightly decreased over the normal rainfall. In first decade, highest rainfall 1197.6mm recorded in 2000 followed by 1998 (1313.4 mm) which is higher over the normal rainfall while lowest rainfall was recorded 787.4 mm in the 1992. In second decade (2001-2010) highest rainfall (1628.9 mm) recorded in the year 2007 which is higher over normal rainfall followed by the first year of the second decade 2001 and in contrast, the lowest rainfall 832.3 mm was recorded in 2010. From the year 2004 rainfall was decreased from normal rainfall for consecutive years except in the year 2007. Last year (2020) of the third decade (2011-2020) highest 1593.2 mm recorded which is higher over normal rainfall while lowest recorded 644.4 in 2015. It was found that in the third decade only 4 years (2011, 2012, 201 and 2020) of annual rainfall was more than normal, so trend of annual rainfall was decreased in third decade which is shown in Fig.12 Annual rainfall variability of district Mirzapur of U.P. gradually declined over the normal rainfall (993.0 mm) over last 20 years (2000-2009). After the year of 2002 rainfall decreasing trend found over normal rainfall similar result reported by Kumar, *et al.*, (2020) [2].

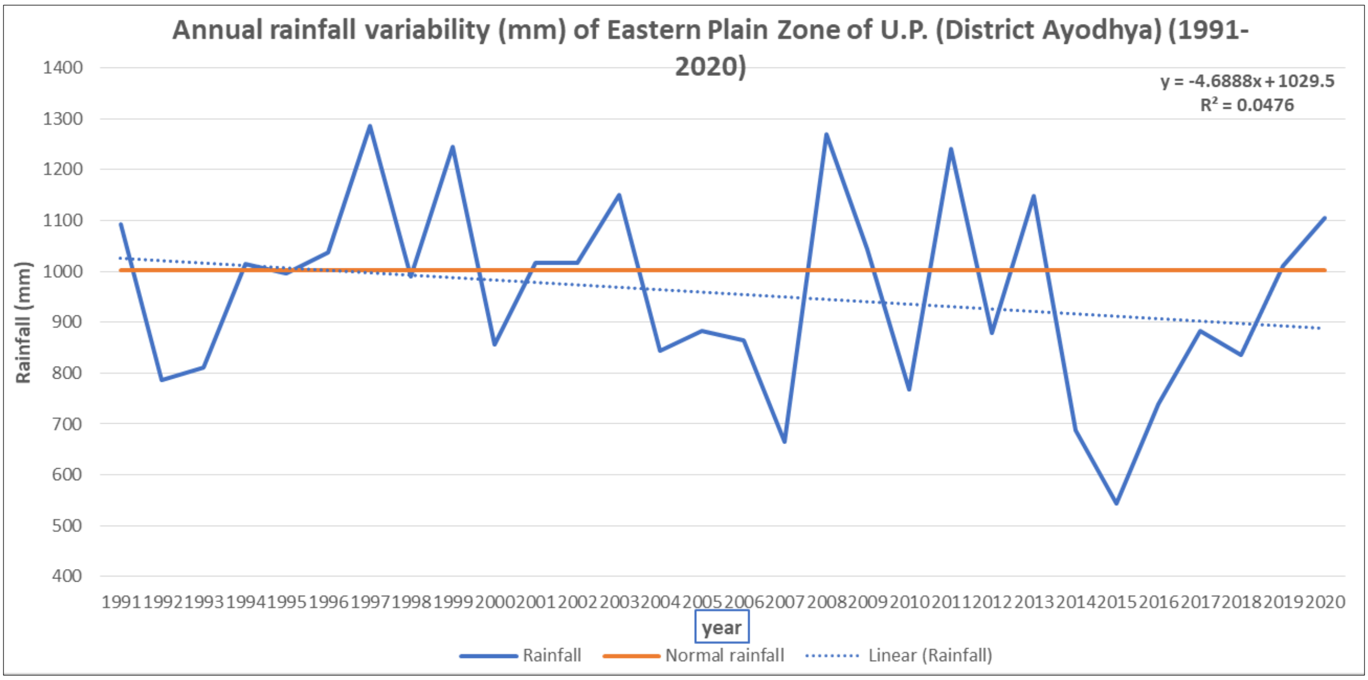

Fig 1: Annual rainfall (mm) variability of Eastern Plain Zone of U.P. during 30 Years (District Ayodhya) (1991- 2020)

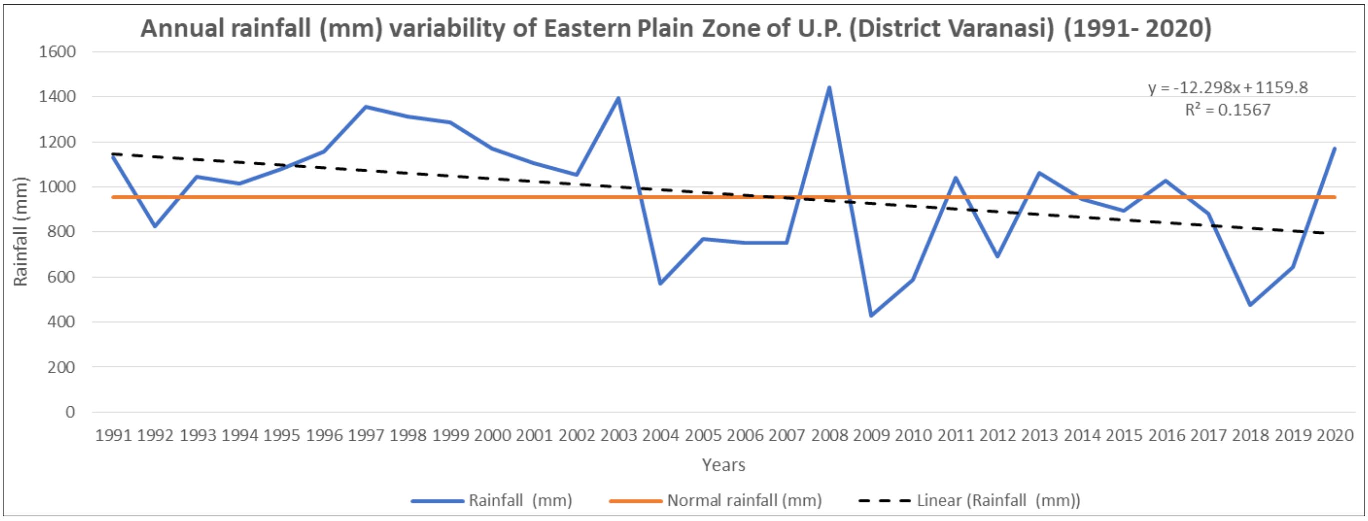

Fig 2: Annual rainfall (mm) variability of Eastern Plain Zone of U.P. during 30 Years (District Varanasi) (1991-2020)

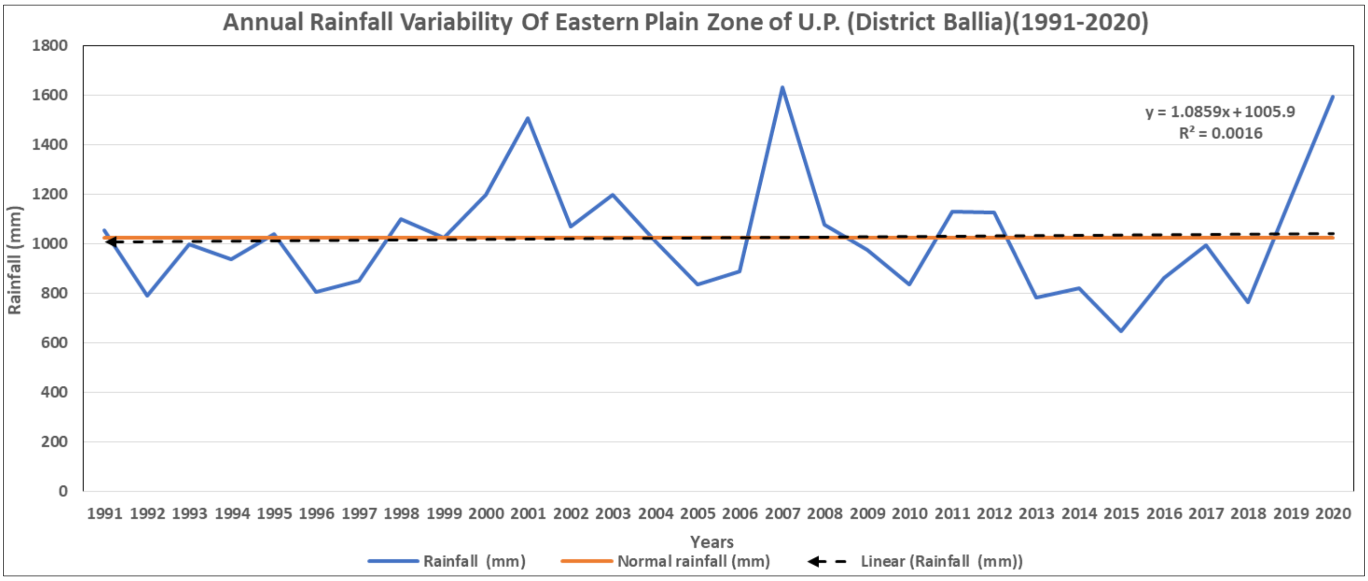

Fig 3: Annual rainfall (mm) variability of Eastern Plain Zone of U.P. during 30 Years (District Ballia) (1991- 2020)

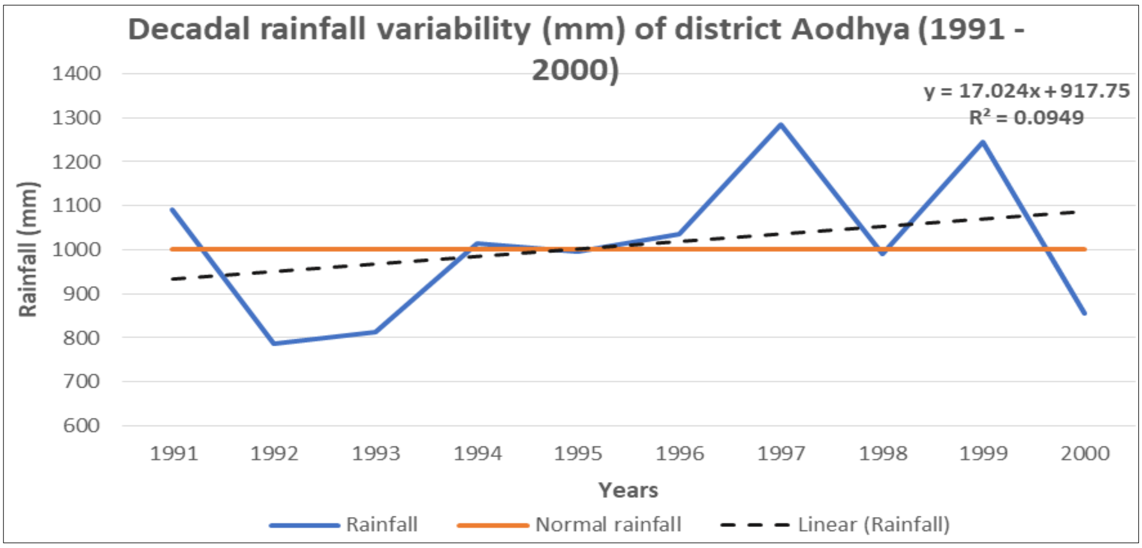

Fig 4: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ayodhya) (1991-2000)

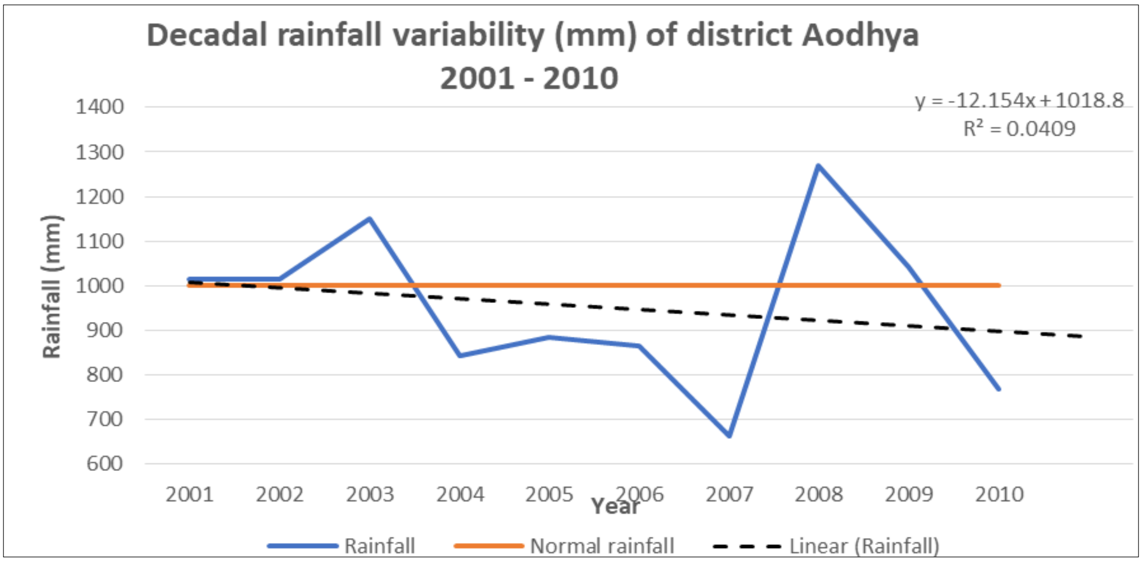

Fig 5: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ayodhya) (2001-2010)

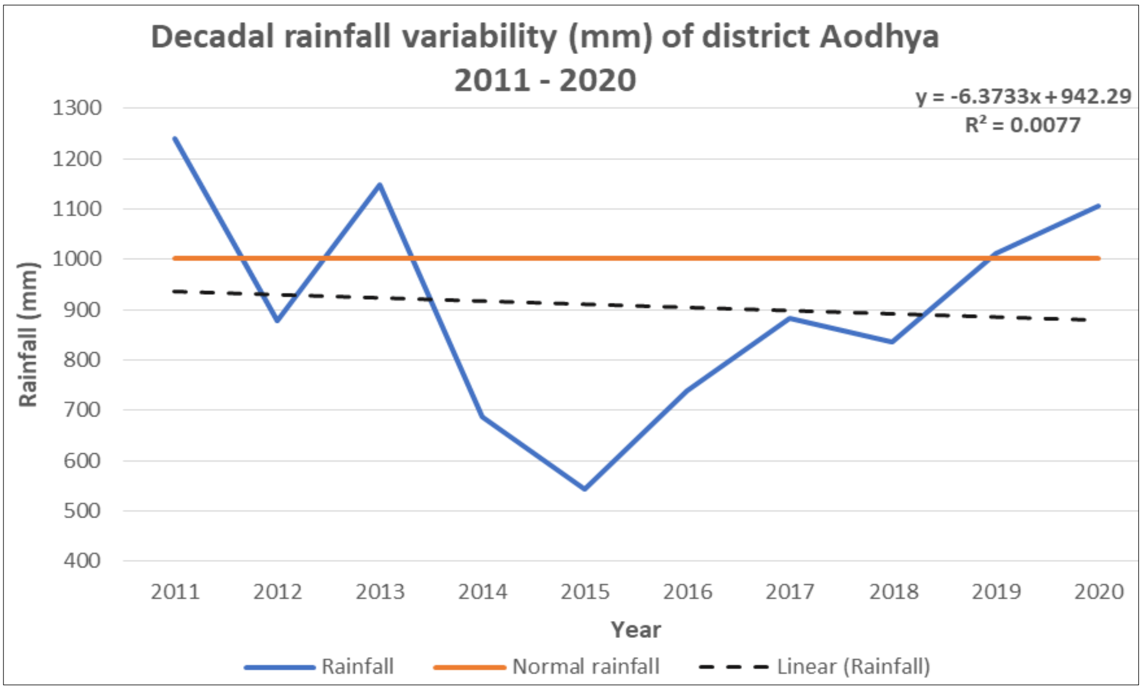

Fig 6: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ayodhya) (2011-2020)

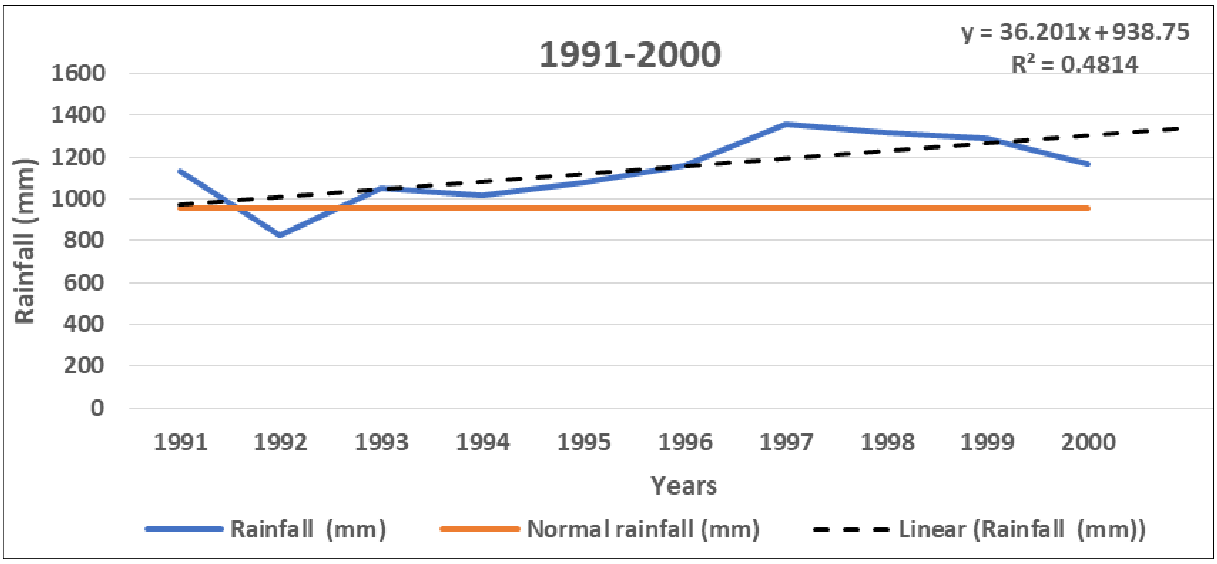

Fig 7: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Varanasi) (1991-2000)

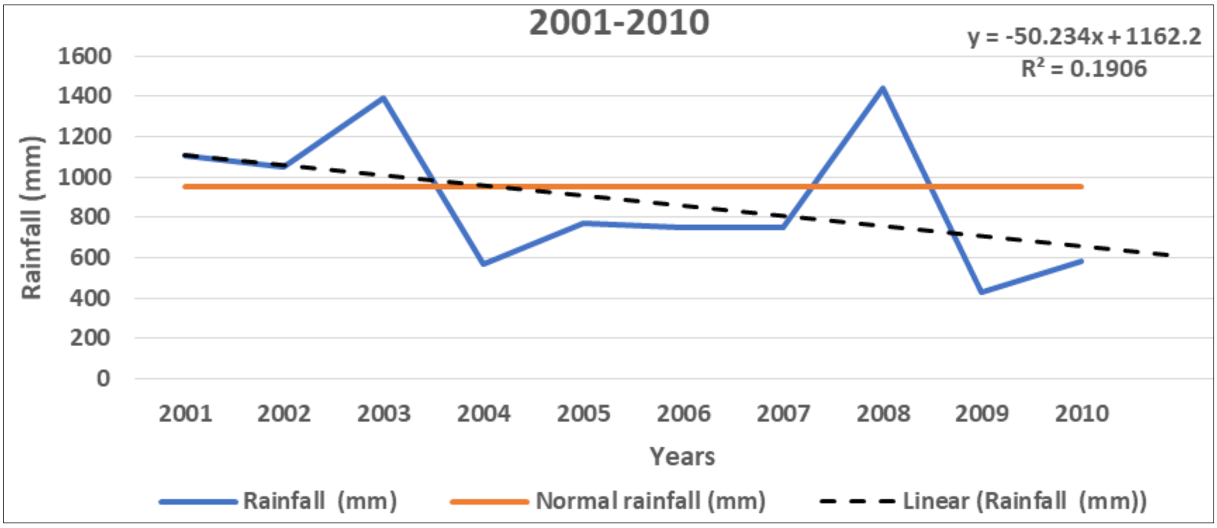

Fig 8: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Varanasi) (2001-2010)

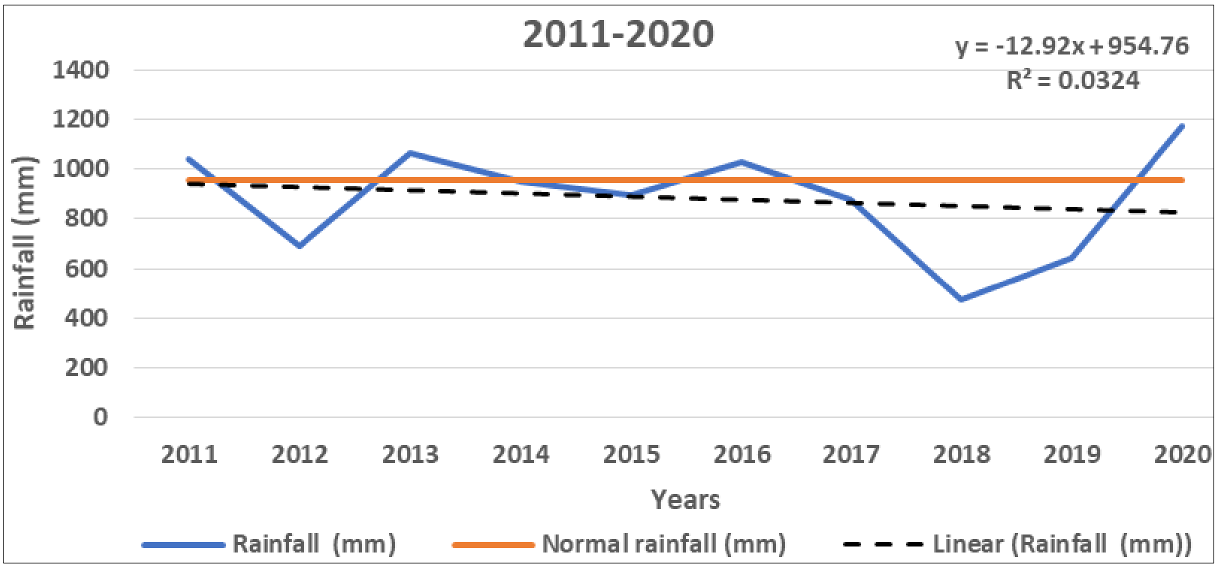

Fig 9: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Varanasi) (2011-2020)

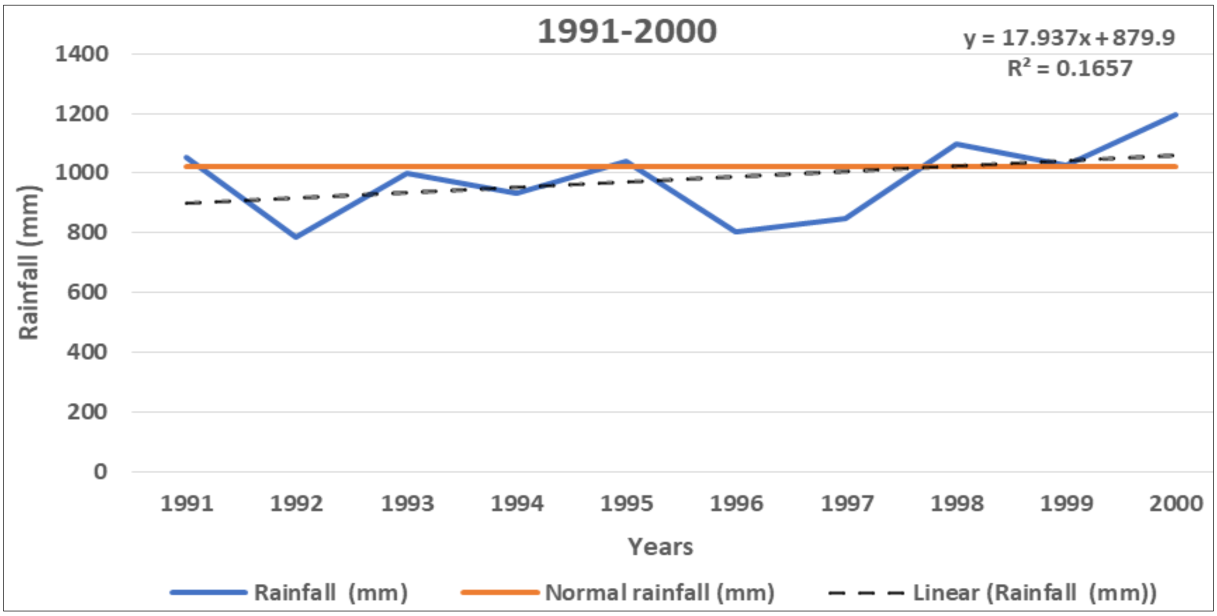

Fig 10: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ballia) (1991-2000)

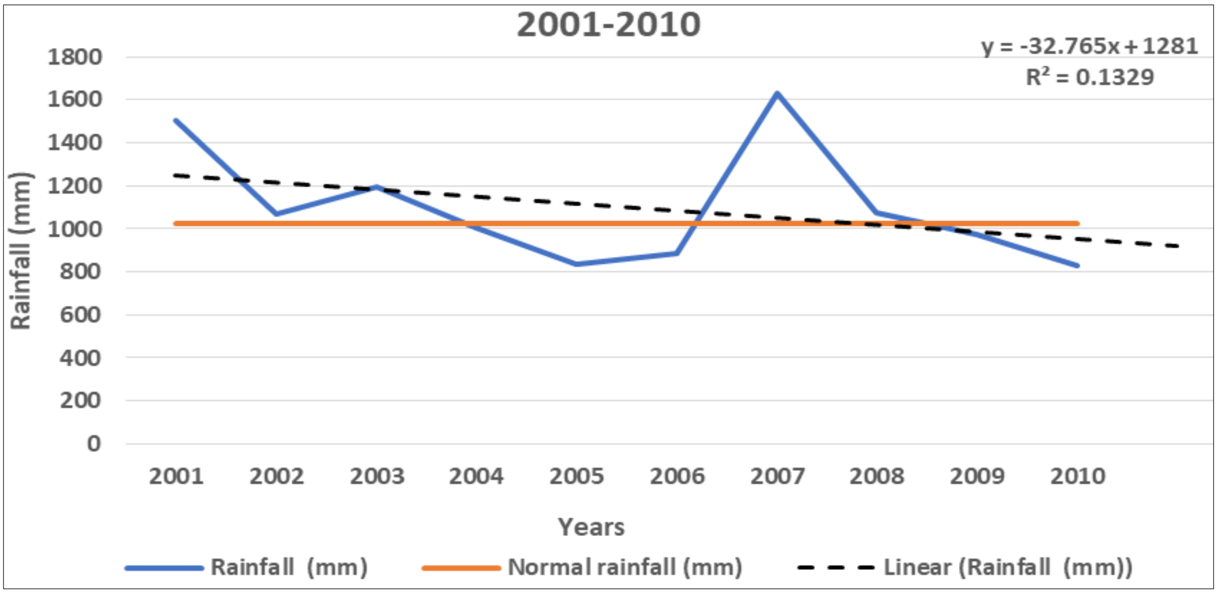

Fig 11: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ballia) (2001-2010)

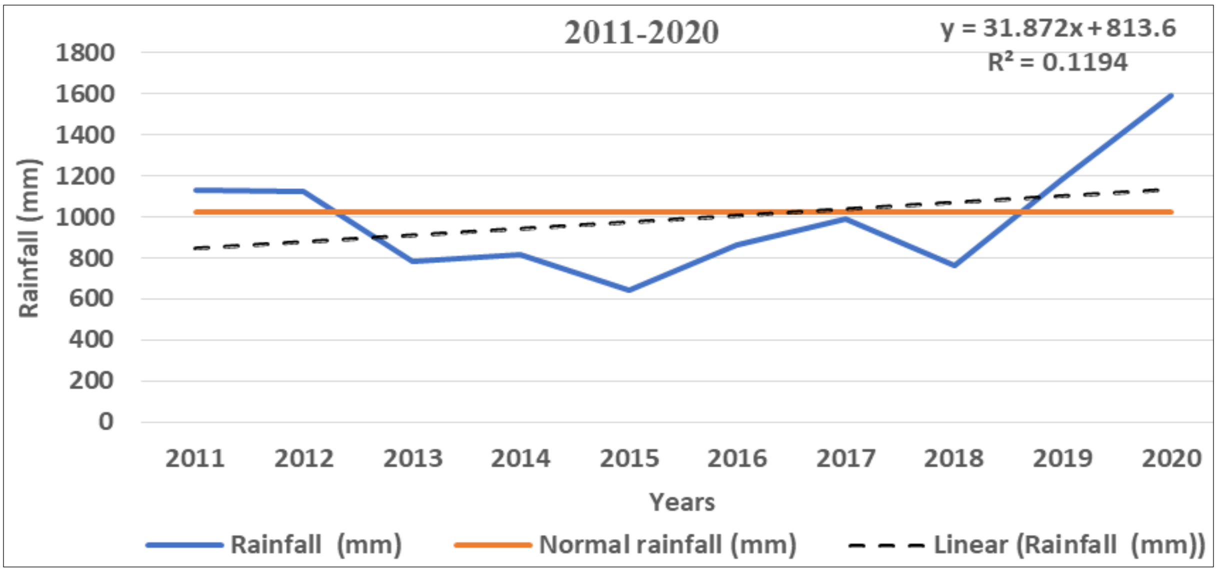

Fig 12: Decadal rainfall (mm) variability of Eastern Plain Zone of U.P. (District Ballia) (2011-2020)

Conclusions
On the basis of results, it may be concluded that annual rainfall variability of Eastern plain zone of Uttar Pradesh (Ayodhya, Varanasi and Ballia) gradually declined over the normal 1001.7 mm, 1009 mm, and 1022.0 mm respectively in recent years. The highest rainfall recorded 1285.7 mm at Ayodhya in the year 1997, 1442.9 mm at Varanasi in 2008 and 1628.9 mm at Ballia in 2007 while lowest rainfall recorded 542.9mm in 2015, 428.7mm in 2009 and 644.4 mm in 2015 respectively. Thus, it is found that the minimum rainfall recorded in the Eastern Plain Zone of U.P. (both districts Ayodhya and Ballia) was in the year 2015. The production of rice and wheat is directly impacted by the annual rainfall trend (mm). Rice (Oryza sativa L.) needs a lot of water while it is growing. Climate variability also contributes to an erratic and dispersed distribution of rainfall. The key environmental factor influencing plant growth, development, and adaptation, as well as phonology, is temperature. Because high temperatures in October prevent early seeding of the main crop and late sowing of wheat in the Paddy-wheat sequence, the little upward trend in the average maximum temperature has an impact on wheat production as well. Major production obstacles include moisture stress during the last phases of growth, undulating terrain and places near rivers, which increases the risk of flooding, and a lack of adequate irrigation capacity since there is insufficient electricity to create an alternate plan.

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