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Trend Analysis of Rainfall In Uttar Pradesh

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Abstract : In the changing scenario of climate, the present study is carried out to identify the recent trends of rainfall variability in different sectors of Uttar Pradesh. Analysis of rainfall (1901-2017) was made for two regions of U.P. (Eastern, Western 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 eastern U.P. was faster as compared to western U.P. 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. has been shifted to 19th June, from the normal date of 15th 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 Western U.P. ranged was 13 days. Rainy day and rainfall intensity both reduced in all sectors of U.P.

INTRODUCTION

The changing pattern of rainfall is a topic within this field that deserves urgent and systematic attention, since it affects both the availability of freshwater and food production (Dore, 2005). It governs the overall cropping pattern, productivity and sustainability of agriculture enterprise. The standard of living and wellbeing of humans is largely dependent on rainfall intensity and frequency. Less than 2 percent of the earth's water is ground water, though it provides 30 percent of our fresh water.

The average annual rainfall in India is 119 cm, but it varies greatly. A change detection study using monthly rainfall data for 306 stations distributed across India was made by Rupa Kumar et al. (1992). They showed that areas of the northeast peninsula, northeast India and northwest peninsula experienced a decreasing trend in summer monsoon rainfall.

The Secondary data has been taken from Open Government Data Platform and is analysed for the Trend and the Seasonal variations.

The major bearer of rain in most parts of U.P. is the Bay of Bengal branch of the Indian Monsoon. The South-West Monsoon brings most of the rain here while the western disturbances and North-East Monsoon contribute small quantities towards the overall precipitation. Annual rainfall in the state ranges from 40–80 inches (1,000–2,000 mm) in the east to 24–40 inches (600–1,000 mm) in the west. About 90 percent of the rainfall occurs during the southwest monsoon, lasting from about June to September.

The rainfall received in any area is an important factor in determining the amount of water available to meet various demands, such as agriculture, horticulture, livestock, industries and domestic water supply etc. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the risk of increasing occurrences of droughts and floods.

The southwest (SW) monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation.

Changes in climate over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall economy of the country.

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 scenarios for crop planning and management (Jain & Kumar 2012).

1.1 Background and Importance of Rainfall Analysis

Rainfall is one of the most critical climatic factors influencing the agricultural productivity, water resources, and overall economic stability of a region. In India, where a significant portion of the population relies on agriculture as their primary livelihood, rainfall plays a crucial role in shaping both local and national economies. Uttar Pradesh (UP), being one of the most agriculturally productive states in India, is highly dependent on the seasonal monsoon rains to sustain its vast agricultural activities. The state's varied geography, ranging from the plains of the Gangetic Valley to the semi-arid regions of Bundelkhand, results in complex rainfall patterns that exhibit substantial spatial and temporal variability.

Rainfall in UP is primarily governed by the southwest monsoon, which brings the majority of annual precipitation from June to September, while additional moisture is supplied by western disturbances during the winter months. However, in recent decades, there has been growing concern regarding the changing patterns of rainfall, with numerous studies indicating shifts in its intensity, frequency, and distribution. This has significant implications for agriculture, water resources management, and overall socio-economic development.

Trend analysis of rainfall over a long period is essential for understanding these changes and their impacts. By examining rainfall data spanning several decades, researchers and policymakers can assess whether the region is experiencing increasing or decreasing trends in precipitation, identify potential causes of such trends, and predict the future course of climatic conditions. This is particularly important for a state like Uttar Pradesh, where agriculture constitutes a significant portion of the state's GDP, and where variations in rainfall can lead to devastating consequences such as droughts, floods, crop failure, and water scarcity.

1.2 Problem Statement

The problem of changing rainfall patterns is increasingly being recognized as a critical challenge for the state of Uttar Pradesh. Despite the crucial role of rainfall in the region's agriculture, water resources, and urban planning, comprehensive studies on the long-term trends in rainfall have been limited. While some studies have focused on specific aspects of rainfall variability, such as extreme weather events or seasonal distribution, there is a need for a holistic, long-term analysis of rainfall patterns over an extended period. Specifically, this research aims to analyse the trends in rainfall in Uttar Pradesh over the period 1901–2017, to provide insights into any significant shifts in precipitation trends and their implications for the state.

Given the state's reliance on monsoon rains, it is important to determine whether rainfall in Uttar Pradesh has been decreasing or increasing over time, and how these trends may impact the future agricultural landscape and water resource management strategies. The study of such trends is particularly relevant in the context of global climate change, which has been shown to impact precipitation patterns around the world.

1.3 Significance of the Study

Understanding rainfall trends in Uttar Pradesh is vital for several reasons. The state is home to over 200 million people, and a significant portion of its population depends on rain-fed agriculture. Variability in rainfall can lead to either water shortages or excess water, both of which can have severe consequences for crop yields, food security, and the livelihoods of farmers. Furthermore, given the state's large and diverse geographical area, rainfall patterns exhibit significant spatial variability, which complicates the implementation of uniform water and land management strategies.

Recent evidence suggests that the frequency and intensity of extreme weather events, including droughts and floods, are increasing in many parts of India, including Uttar Pradesh. These extreme events, in combination with long-term trends in rainfall reduction, pose a major risk to food security, water availability, and socio-economic development. Therefore, this study is significant because it aims to provide a comprehensive, long-term perspective on rainfall variability in UP, contributing to informed policy-making that can help mitigate these risks.

Moreover, the study's findings could contribute to the broader field of climate science, particularly in understanding regional responses to global climate change. By identifying the local impacts of changing rainfall patterns, this research could aid in the development of region-specific adaptation strategies that can be applied to other states with similar climatic conditions.

Objectives :

- To identify any significant upward or downward trends in the annual and seasonal rainfall data of Uttar Pradesh from 1901 to 2017.
- To analyse how rainfall trends vary across different seasons (monsoon, post-monsoon, and winter) and regions within the state.
- To see any increase or decrease in average length of rainy season.

Literature Review

Rainfall trend analysis refers to the process of examining long-term rainfall data to identify any significant patterns, variations, or changes in precipitation over a specific period. In regions like Uttar Pradesh (UP), which are highly dependent on agricultural productivity, understanding rainfall patterns is crucial for managing water resources, mitigating the impacts of climate change, and ensuring sustainable development.

This literature review synthesizes the existing studies and research related to rainfall trends in Uttar Pradesh between 1901 and 2017. The analysis covers changes in precipitation patterns, the impact of these trends on agriculture, and methodologies used for such studies. It also includes regional variations within UP, as well as broader implications for climate science and policy.

Uttar Pradesh, located in northern India, experiences a tropical monsoon climate. Its rainfall patterns are predominantly influenced by the southwest monsoon, which lasts from June to September, contributing approximately 85% of the total annual rainfall. Other precipitation sources include western disturbances during the winter months, which provide additional moisture to the region.

Historically, rainfall in Uttar Pradesh has been highly variable, with significant inter-annual and intra-seasonal fluctuations. The region has experienced both severe droughts and excessive rainfall leading to floods, making it a focal point for the study of climatic variability. Since the beginning of the 20th century, UP has undergone significant socio-economic changes, influencing the agricultural and hydrological systems that are directly impacted by rainfall trends.

A variety of statistical and computational techniques have been employed in analysing rainfall trends in Uttar Pradesh. Some of the commonly used methods include:

Linear and Non-Linear Regression Models: These methods assess long-term trends and identify whether rainfall has been increasing or decreasing over time. Studies by *Sharma et al. (2010)* and *Kumar et al. (2015)* have employed regression analysis to examine rainfall trends across different time scales.

Mann-Kendall Test: This non-parametric test is frequently used to detect trends in climatological time series data, including rainfall. It is ideal for cases where data does not follow a normal distribution. Studies like *Sivakumar (2013)* and *Rao et al. (2017)* have used this test to assess whether there is a statistically significant trend in the rainfall series for UP.

The rainfall in India is widely variable with respect to time and different regions. The study of precipitation trends is critically important for a country like ours whose food security and economy are almost completely dependent on the felicitous availability of water. The trend analysis of rainfall pattern in Uttar Pradesh is studied through time series analysis of rainfall for a long period of 50 years. The statistical analysis of the data relating with rainfall pattern during the period from 1968-2017 has been done by procuring the data from Open Government Data Platforms. The present paper is targeted towards analysing the trend of rainfall for the state of Uttar Pradesh (U.P.).

Comparison of this trend with other states (namely Rajasthan, Odisha, Kerala, Madhya Pradesh and Arunachal Pradesh) has been done and average annual rainfall has been indexed for inter and intra state comparison. (Meghna Athwani et al. (2020))

In the changing scenario of climate, the present study was carried out to identify the recent trends of rainfall variability in different sectors of Uttar Pradesh. 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. (Krishna Deo at al. (2016))

Sen's Slope Estimator: This is often used in conjunction with the Mann-Kendall test to quantify the magnitude of the trend. It estimates the slope of the trend by calculating the median of the slopes between all pairs of data points. Researchers such as *Khandekar et al. (2011)* used this method to estimate changes in rainfall over several decades.

Time Series Analysis: Techniques like moving averages and Fourier transformations have been used to decompose the time series data into seasonal, trend, and residual components. This method is particularly useful for distinguishing between natural variability and significant long-term changes in rainfall patterns

Geographical Information Systems (GIS) and Remote Sensing: With the advent of satellite technology and GIS tools, studies like those by *Kumar and Singh (2016)* have utilized spatial analysis to assess rainfall distribution and variability across UP. These studies highlight the regional disparities in rainfall and their correlation with land use and topography.

Several studies conducted on rainfall trends in Uttar Pradesh reveal differing conclusions based on the period of study, the statistical methods used, and the regional focus. However, a few broad observations can be drawn:

Increasing or Decreasing Rainfall Trends: Most studies suggest a trend of decreasing rainfall in Uttar Pradesh over the

20th and early 21st centuries, particularly in the western and central parts of the state. Research by *Sivakumar (2013)* found that regions like Agra and Mathura experienced a significant reduction in the annual rainfall between 1951 and 2000. This finding is supported by *Kumar et al. (2015)*, who reported a decreasing trend in annual rainfall in the state's agricultural zones, which has implications for crop yields.

However, some studies indicate regional variations. *Singh et al. (2014)* found that certain eastern districts of UP, such as Gorakhpur and Varanasi, exhibited an increasing rainfall trend, which may be due to shifts in monsoon patterns or the influence of local topography. Thus, while the general trend suggests decreasing rainfall, localized variations complicate the overall picture.

Monsoon Rainfall Patterns: The monsoon is the primary source of rainfall in Uttar Pradesh.

Several studies have documented changes in the timing and intensity of the monsoon, with consequences for crop sowing and harvesting. *Pandey et al. (2018)* observed a delay in the onset of the monsoon season over the last few decades, which can result in a shorter growing season for crops such as rice and maize, which are highly sensitive to rainfall timing.

Extreme Weather Events: Studies like those by *Choudhury et al. (2016)* have documented an increase in the frequency and intensity of extreme rainfall events in Uttar Pradesh, which contribute to both droughts and floods. This trend, coupled with changes in the annual rainfall distribution, is consistent with global climate change patterns. The increase in extreme events has a significant impact on agriculture, particularly in rain-fed areas, leading to greater vulnerability to both floods and droughts.

Spatial Variability: Research has shown significant spatial variability in rainfall patterns across Uttar Pradesh. For example, the southern parts of the state, such as Bundelkhand, face more frequent drought conditions, while the northern and eastern regions tend to receive higher rainfall. *Jain and Kumar (2017)* used GIS and remote sensing techniques to map rainfall variability and found a strong spatial correlation with factors such as altitude, proximity to water bodies, and urbanization.

The trends identified in the rainfall patterns of Uttar Pradesh have profound implications for agriculture, water resources, and overall regional development.

Agricultural Productivity: The primary sectors affected by rainfall variability in UP are agriculture and horticulture. Rainfall decreases, particularly during the monsoon, can lead to water scarcity, reduced crop productivity, and food insecurity.

Conversely, excessive rainfall can cause flooding, soil erosion, and crop damage. Understanding rainfall trends helps in planning irrigation, choosing crop varieties, and improving water conservation strategies.

Water Resources Management: The decreasing trend in average annual rainfall, as suggested by studies like *Pandey et al. (2016)*, calls for better management of existing water resources. Integrated water management strategies, including rainwater harvesting, watershed management, and the construction of small-scale reservoirs, are necessary to ensure water availability during dry periods.

Climate Change Adaptation: Given the potential for increasing variability in rainfall patterns due to climate change, researchers like *Rao et al. (2017)* stress the need for adaptive strategies in both agricultural and urban planning. These include diversifying cropping systems, developing drought-resistant crops, and investing in early-warning systems for extreme weather events.

The analysis of rainfall trends in Uttar Pradesh from 1901 to 2017 reveals a complex interplay of declining rainfall in some areas, increasing rainfall in others, and a rising incidence of extreme weather events. While regional disparities complicate a unified conclusion, it is clear that rainfall patterns in UP have undergone significant changes, with profound implications for agriculture, water management, and climate adaptation strategies.

Future research in this area should focus on high-resolution spatial data, explore the causes of regional discrepancies in trends, and further investigate the links between rainfall trends and socioeconomic impacts. A better understanding of these patterns will assist policymakers and stakeholders in developing resilient systems that can withstand the growing challenges posed by changing climatic conditions.

STUDY AREA

Uttar Pradesh occupies a unique position in the map of India as it is the leading state in terms of area, population and location. In the national context, it enjoys a strategic location lying at the intersection of Himalayan Region in the north and Peninsular Region in the south, encompassing the extremely fertile plains of river Ganges and Yamuna. It lies between 23°52' N to 30°28' N latitudes and 77°03' to 84°39' E longitudes and covers an area of 2,40,928 sq. km., which accounts for 7.3% area of the country’s total. It has a geo-political significance sharing the international boundary with Nepal. The study area is bounded by Madhya Pradesh in the south, by Uttarakhand in the north-west, Haryana, Rajasthan, and Delhi in the west, Bihar in the east and Nepal in the north. The eastern and western boundary of Uttar Pradesh is demarcated roughly by River Gandak and Yamuna respectively. The state includes 75 districts. It ranks first in terms of total population i.e. 24 Cr (2011), 912:1000 (F:M) gender ratio, while in terms of population density it ranks fourth with 829 persons/sq. Kilometer.

Uttar Pradesh

DATA AND RESEARCH METHODOLOGY

The present study is based on Secondary Data. The data - Sub Divisional Monthly Rainfall from 1901 to 2017 in Uttar Pradesh is taken from Open Government Data (OGD) Platform and the contributors of this data are Ministry of Earth Sciences and India Meteorological Department (IMD).

The intrastate analysis of rainfall has been done for the two zones of U.P., viz; Eastern Zone and Western Zone. The respective zones have been compared in regard to trend analysis of rainfall in the proposed work. The data was analysed and graph was plotted between annual rainfall and time.

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Data

Year	Annual Rainfall In mm (East U.P.)
1901	873.2
1902	905.2
1903	1216.4
1904	1071.2
1905	891.6
1906	997.7
1907	666.3
1908	744.7
1909	1106.9
1910	1116.4
1911	1113.9
1912	879.6
1913	861.4
1914	988.8
1915	1409.8
1916	1201.9
1917	1216.5
1918	650.7
1919	1023.4
1920	860.2
1921	1114.7
1922	1364
1923	1076.2
1924	1119.9
1925	1114.1
1926	989.5
1927	1031.2
1928	804.8
1929	1014.8
1930	1069.5

Year	Annual Rainfall In mm (East U.P.)
1931	1047.1
1932	738.5
1933	977.5
1934	1068.4
1935	919.8
1936	1545.5
1937	1035.3
1938	1374.2
1939	945
1940	866.8
1941	798.2
1942	1028.6
1943	1101.1
1944	1061.5
1945	980.4
1946	1038.9
1947	1006.3
1948	1323.1
1949	1131
1950	951.4
1951	752.5
1952	935.9
1953	1266.9
1954	969.7
1955	1424.3
1956	1254.1
1957	955.7
1958	1016.9
1959	869.2
1960	1170

Year	Annual Rainfall In mm (East U.P.)
1961	1214.3
1962	1072
1963	996.3
1964	1036.6
1965	685.5
1966	707.8
1967	1029.4
1968	840
1969	1024.6
1970	1132.3
1971	1311.1
1972	666.9
1973	955.7
1974	882.2
1975	1225.5
1976	923.5
1977	914.1
1978	1116.3
1979	696.5
1980	1488.5
1981	1110.1
1982	1110.6
1983	1204.8
1984	1076.7
1985	955.7
1986	1016.9
1987	869.2
1988	1170
1989	1214.3
1990	1072

Year	Annual Rainfall In mm (East U.P.)
1991	996.3
1992	1036.6
1993	685.5
1994	707.8
1995	1029.4
1996	840
1997	1024.6
1998	1132.3
1999	1311.1
2000	666.9
2001	955.7
2002	882.2
2003	1225.5
2004	923.5
2005	914.1
2006	1116.3
2007	696.5
2008	1488.5
2009	1110.1
2010	1110.6
2011	1204.8
2012	1076.7
2013	1041.4
2014	701.2
2015	603.3
2016	871.7
2017	695
Total	114176.2
%	54.22183

Table 1: U.P. East – Total Annual

Year	Annual Rainfall In mm (West U.P.)
1901	775.9
1902	736.6
1903	808.4
1904	945.2
1905	433.5
1906	978.7
1907	589.5
1908	866.3
1909	903
1910	875.9
1911	751.6
1912	804.5
1913	495.3
1914	887.5
1915	802.5
1916	1114.2
1917	1120.2
1918	371.9
1919	969.1
1920	622.8
1921	992.3
1922	1000.8
1923	902.3
1924	1064.1
1925	943.8
1926	917
1927	934.2
1928	644.6
1929	650.1
1930	788.1
1931	930.8
1932	706
1933	1035.3
1934	897.7
1935	784.6
1936	1218.4
1937	676.7
1938	730.4
1939	721.1
1940	783.9
1941	516.4
1942	1088.2
1943	850.4
1944	770.3
1945	966
1946	896.6
1947	809.2

Year	Annual Rainfall In mm (West U.P.)
1948	1028.1
1949	906.7
1950	834
1951	728.9
1952	875.3
1953	761.8
1954	879.3
1955	1060.9
1956	1064.4
1957	1005.2
1958	1165.3
1959	768.3
1960	1129.8
1961	1198.3
1962	798.2
1963	929.7
1964	1002
1965	673.5
1966	756
1967	1157.2
1968	693.3
1969	878.1
1970	863.8
1971	1003.1
1972	585.1
1973	805.9
1974	668.9
1975	989.5
1976	653.2
1977	994.3
1978	1244.2
1979	558
1980	984.7
1981	739.6
1982	969.1
1983	1191.7
1984	781.3
1985	957.2
1986	715.2
1987	466.8
1988	1035.6
1989	657.3
1990	958
1991	748.7
1992	820.6
1993	771.9
1994	806.8

Year	Annual Rainfall In mm (West U.P.)
1995	1028.1
1996	906.7
1997	834
1998	728.9
1999	875.3
2000	761.8
2001	879.3
2002	1060.9
2003	1064.4
2004	1005.2
2005	1165.3
2006	768.3
2007	1129.8
2008	1198.3
2009	798.2
2010	929.7
2011	1002
2012	673.5
2013	756
2014	1157.2
2015	693.3
2016	878.1
2017	585.2
Total	96396.2
%	45.77817

Table 2: U.P. West – Total Annual

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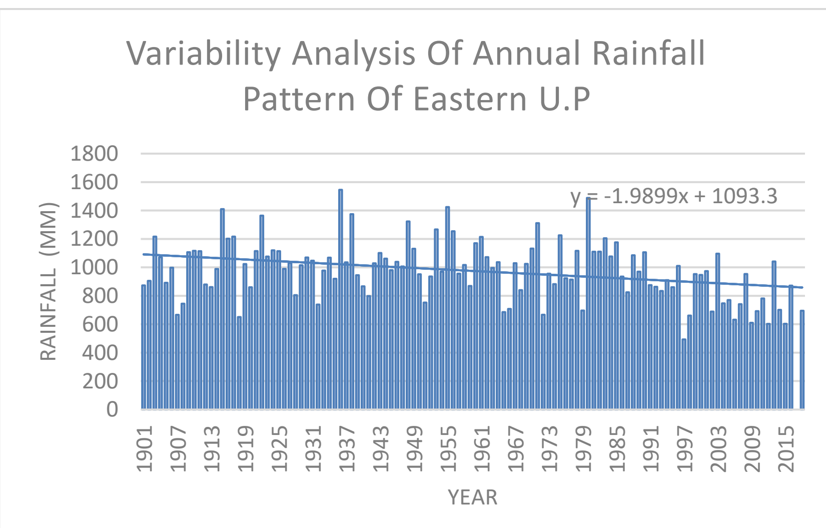
RESULT AND DISCUSION

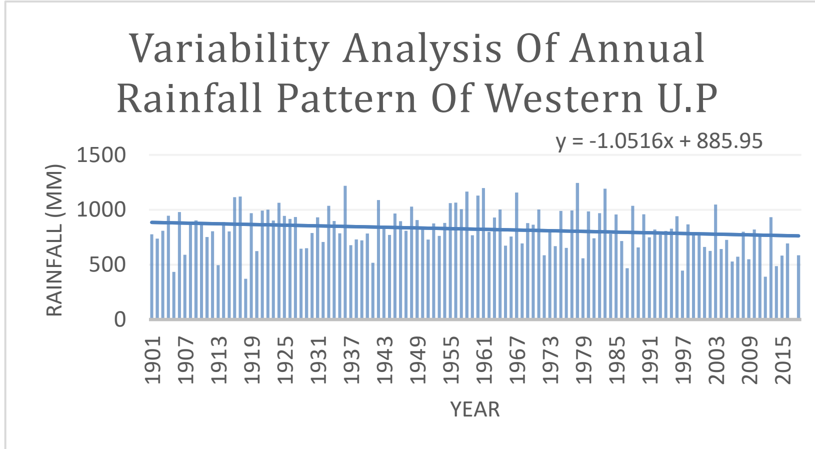
Average annual rainfall in Eastern U.P. was maximum (975.86 mm) than Western U.P. (823.89 mm) (Table 1) based on time series data (1901-2017) of U.P.

The variability and trend of annual rainfall for these sectors has been depicted in Fig. 2 and it was observed that annual rainfall in all sectors of U.P. decreased in recent years. The rate of decrease of rainfall in eastern U.P. was more than western U.P. The rate of decrease was in order of Eastern U.P.> Western U.P.

Subdivision	Average Annual Rainfall
East UP	975.8649573
West UP	823.8991453

Table 3: Average Annual





- In the equation y= mx+c, the slope (m) of the **Trendline** represents the **Rate of change in rainfall.** If m is negative it indicates a decrease in rainfall.
- The rate of decrease of rainfall in Eastern U.P. is -1.9899 and Western U.P. is -1.0516.
- The rate of decrease of rainfall (eastern U.P.>western U.P.) in Eastern U.P. was higher than Western U.P.

Seasonal rainfall : Mansoon (June, July, August, September); Post Mansoon (October, November); Winter (December, January, February) and Summer (March, April, May).

The highest rainfall percentage of the total rainfall in U.P. was obtained during during south-west monsoon season in eastern U.P. was 47.73% followed western U.P. (39%) (Fig.2). The rainfall percentage 2.6% was obtained in eastern U.P. during post monsoon season followed by western U.P. (1.79%). The rainfall of (2.34%) was received during winter season in western U.P followed by eastern U.P. (2.06%) .

The lowest rainfall during summer season was obtained in order of eastern U.P. (1.81%) followed by western U.P. (1.66).

Subdivision	Mansoon %	Post Mansoon %	Winter %	Summer %
East UP	47.7323714	2.608461508	2.064658	1.816049967
West UP	39.9714777	1.793064998	2.344277	1.669259599

Table 4: Percentage Of Seasonal

Onset /withdrawal dates of monsoon and length of rainy season :

Onset/withdrawal dates of monsoon and length of rainy season in different sectors of U.P. has been shown in table 2. The average onset date of south-west monsoon in eastern U.P. was shifted to 19 June from normal onset date followed by western U.P. (21 June). Normal onset date in eastern U.P. is 15th June and that in western U.P. 17th June. The onset date in U.P. delayed 4 days from the normal. The yearly variation of onset and withdrawal dates and length of rainy season in different sectors of U.P. has been shown in table 3. It has been observed that in different years,
the range of onset date of south-west monsoon in eastern U.P. was in between 8th to 26th June, whereas in western U.P., it lies between 9th to 27th June. i.e., one days ahead from eastern U.P. This shows that monsoon covers entire U.P. within one day from east to west.

Withdrawal date of south-west monsoon in different sectors of U.P. was 21st September except eastern U.P. where, average date of withdrawal was realized as 25th September against the normal date 30th September. The withdrawal of south-west monsoon shifted 5-9 days early toward rainy season. (Krishna Deo at al. 2016)

Length of rainy season was therefore, drastically reduced from normal 108 days to 99 days in eastern U.P. i.e., 9 days, whereas it reduced from normal 106 days to 93 days in western U.P. i.e., 13 days. This ultimately forced to reconsider the crop planning and selection of rice crop varieties of short duration as to minimize the risk losses.

Sectors	Onset date of SWM (June)	Withdrawal date of SWM (September)	Length of rainy season of SWM (days)	Departure from normal
Eastern U.P.	19 (15)	25 (30)	99 (108)	-9
Central U.P.	19 (16)	21 (30)	95 (107)	-12
Western U.P.	21 (17)	21 (30)	93 (106)	-13
Bundelkhand region of U.P.	20 (17)	21 (30)	94 (106)	-12

Table 5: Onset and withdrawal dates and length of rainy season during south-west monsoon period (*Figures in parentheses show the normal dates/days as per IMD, Govt. of India.)

CONCLUSION

It is concluded that the quantum of total annual rainfall decreased in all sectors of U.P. with eastern U.P. at faster rate as compared to western U.P. Results of decrease of seasonal rainfall in different sectors were also in same order and magnitude as that of total rainfall. It may also be concluded from this study that the total rainfall is related to the shift of onset of monsoon towards rainy season. The amount of rainfall decreased by 9.5%, if the onset of monsoon shifts from 15th June to 25th June. Crop planning is required accordingly.
Length of rainy season is also reduced from normal 108 days to 99 days in U.P. Therefore, crop planning for short duration and low water requiring variety of rice in U.P. or sectors of U.P., needs to be developed

The monsoon in the future seems to be arriving later than the present observed condition.

FUTURE WORK

In this study only graphical approach has been used to analyse the rainfall trend.

Different models can be used further to analyse the rainfall data like Numerical models (General Circulation Models or GCMs), representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations.

Statistical downscaling model can be used for establishing a statistical relationship between the data. Using this downscaling model the possible future scenarios of temperature and precipitation variations are generated using large-scale predictor variables obtained from the Global Climate Model (GCM) outputs.

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