International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2024; SP-9(2): 101-107

https://www.mathsjournal.com
Received: 23-02-2024
Accepted: 27-03-2024

Ankit
Ph.D. Student, Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Mo. Akram
Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Shivam
Mahamaya College of Agricultural Engineering & Technology, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Vikas K Singh
Mahamaya College of Agricultural Engineering & Technology, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Vipin K Roshan
Ph.D. Student, Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Sarvda Nand Tiwari
Ph.D. Student, Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Shashank Verma
Department of Processing and Food Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya

Akanksha Mathur
Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Khwahiz Ali
Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Sakshi Dixit
Department of Soil and Water Conservation Engineering, MCAET, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

PK Mishra
Mahamaya College of Agricultural Engineering & Technology, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Corresponding Author:
Shivam
Mahamaya College of Agricultural Engineering & Technology, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh, India

Analyzing the patterns of extreme rainfall in the eastern Uttar Pradesh

Ankit, Mo. Akram, Shivam, Vikas K Singh, Vipin K Roshan, Sarvda Nand Tiwari, Shashank Verma, Akanksha Mathur, Khwahiz Ali, Sakshi Dixit and PK Mishra

Abstract
This study presents an analysis of rainfall data spanning from 1985 to 2019 in Ambedkar Nagar district, located in the northern state of Uttar Pradesh, India. The dataset includes parameters such as the number of wet days, annual rainfall, and the heavy rainfall days (Number of days with rainfall exceeding 10 mm). Over the 35-year period, significant variations in rainfall patterns are observed, with fluctuations in both the intensity and frequency of precipitation events. The analysis reveals several noteworthy trends, including an overall increase in annual rainfall from 1985 to 2019, with notable peaks in certain years such as 2008 and 2013. Moreover, variations in the number of wet days and R10 events reflect changes in the distribution and intensity of rainfall events over time. These findings contribute to a better understanding of the climatic dynamics in Ambedkar Nagar district and can inform strategies for water resource management, agricultural planning, and disaster preparedness in the region. Further research is warranted to explore the underlying drivers of these observed trends and their implications for local communities and ecosystems.

Keywords: Implications, dynamics, preparedness

Introduction
The earth's water cycle, which includes the constant flow of water between the atmosphere, oceans, land, and living things, depends heavily on rainfall. Determining the quantity and magnitude of rainfall on a seasonal and annual basis requires rainfall analysis (Jain & Kumar 2012, Srilakshmi *et al.* 2022) [4, 11]. A significant part of the water cycle, rainfall analysis entails examining the distribution, frequency, intensity, and variability of precipitation over a given area and time period. According to Thomas *et al.* (2007) [12], rainfall analysis offers important insights into water availability, climate patterns, and possible effects on human activity. Rainfall data serves as a fundamental component in understanding climatic patterns and their impact on various aspects of life, including agriculture, water resources, and ecological systems. In the context of Ambedkar Nagar district, located in the northern state of Uttar Pradesh, India, the analysis of rainfall patterns spanning from 1985 to 2019 provides invaluable insights into the region's hydrological dynamics. This study aims to examine the temporal variations, trends, and anomalies in rainfall within Ambedkar Nagar district over the past three and a half decades. By scrutinizing this extensive dataset, we seek to elucidate the long-term rainfall trends, seasonal fluctuations, and potential implications for local communities, agricultural practices, and environmental sustainability. The analysis of rainfall data from 1985 to 2019 is pivotal in enhancing our understanding of the climatic regime of Ambedkar Nagar district and forms the basis for informed decision-making and adaptation strategies in the face of changing weather patterns.

According to Duhan and Pandey (2013) [2], rainfall trend analysis is the process of using statistical techniques to determine the pattern of changes in a long-term rainfall dataset over a given time frame. Determining whether rainfall patterns are generally increasing or decreasing over time is the goal of trend analysis. A non-parametric technique for finding patterns in data series is the Mann-Kendall test, which may also be used to test for turning points and nonlinear trends using statistic distribution (Mann, 1945; Basistha *et al*. 2009; Oguntunde *et al*. 2011; Shivam *et al*. 2019) [6, 1, 8, 10]. Gupta *et al*. (2021) [3] conducted study on streamflow and rainfall pattern change analysis on a Norhteast river watershed and found significant change in peak flood events and extreme rainfall events.A statistical analysis was conducted on the trends of increase and decrease in the climate data series throughout time. In numerous studies, the Mann-Kendall test has been effectively applied to ascertain statistically significant or insignificant trends in hydrologic climatic variables, such as precipitation, within the framework of climate change. Experiments without any presumptions about the population being studied are called non-parametric tests. It has nothing to do with knowledge of any particular parametric category of probability distributions. Non-parametric methods are also referred to as distribution-free tests because they don't make use of an underlying population. However, whether Sen's slope is utilized to evaluate the magnitude of a trend, such as growing or decreasing magnitude

Study Area Description

Uttar Pradesh is a northern state of India situated between latitudes 23°52'N and 31°28'N and longitudes 77°3'E and 84°39'E. Ambedkar Nagar is a district within Uttar Pradesh, chosen for this study (Fig 1). The study is based on rainfall data from that district.

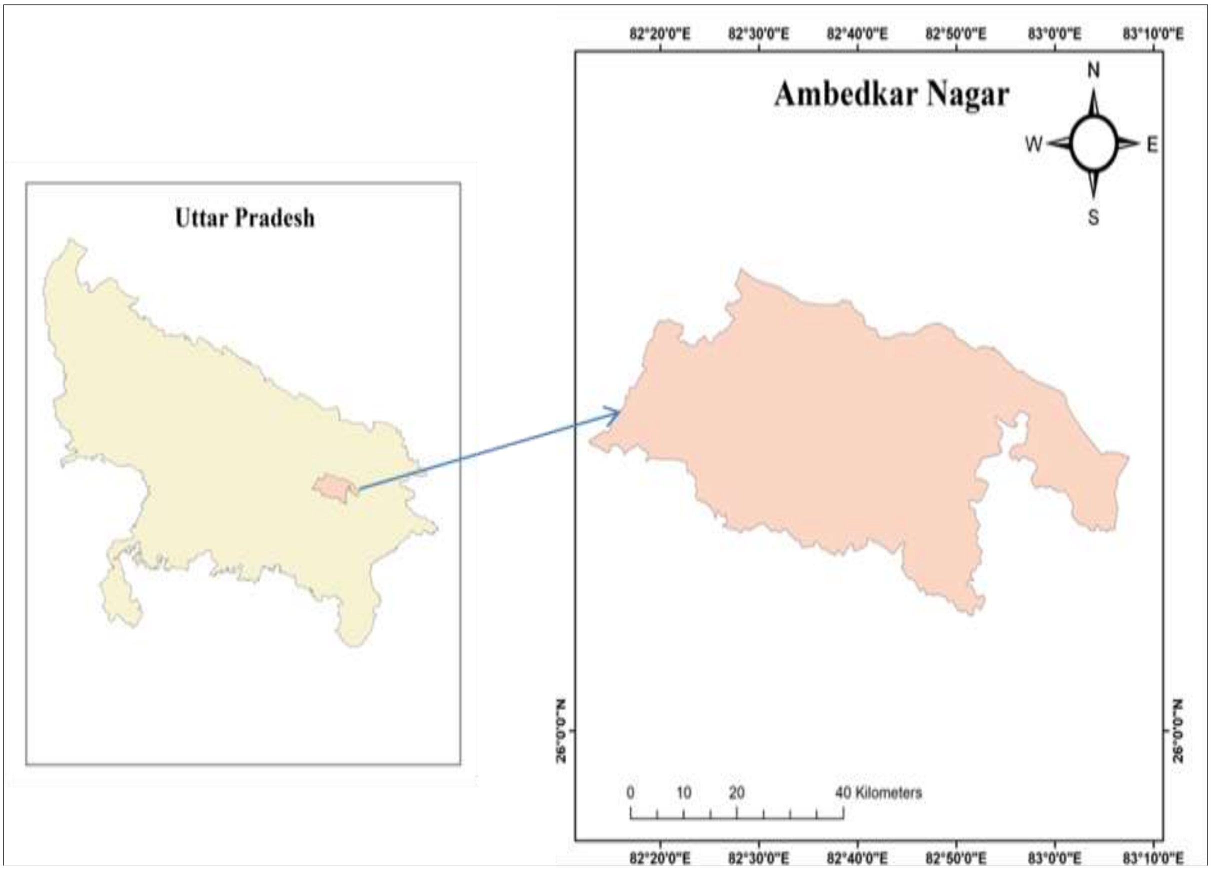

Fig 1: Map of study area Ambedkar Nagar district.

Material and Method

Data

This study is based on historical daily basis rainfall data, which is acquired from NASA Prediction of Worldwide Energy Resources (POWER), for 35 years from 1985 to 2019. Auto-correlation was removed by pre-whitening process during its calculation.

Precipitation Indices

Three precipitation indices were determined: number of rainy days (R1mm), yearly precipitation (PRCPTOT), and consecutive wet days (CWD).

Mann Kendall test

The Mann-Kendall test was proposed by Mann (1945) [6] and Kendall (1975) [5] for the analysis of rainfall climatic time series data. Trend analysis statistically checks the increasing and decreasing trend in rainfall climatic time series data (Mondal *et al*. 2012) [7]. That analysis checked the null hypothesis versus the alternate hypothesis. The formula of Mann-Kendall is listed below-

$$(sign(x_i - x_j)) = \begin{cases} -1 \text{ for } (x_i - x_j) < 0 \\ 0 \text{ for } (x_i - x_j) = 0 \quad \dots 1 \\ 1 \text{ for } (X_i - x_j) > 0 \end{cases}$$

X= data set

i= 1,2,3………n term

j=i+1

For calculating the sum of all signs formula will be used-

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(x_i - X_j) \dots 2$$

S= Sum of all Sign

N= number

The following formula is used to calculate the variance-

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{p-1}^{q} tp(tp-1)(2tp+5)}{18} \qquad 3$$

Var (S) = Variance of sum
n = Total number
tp = Number of terms whose equal value

For calculating Z value will be calculated by following the formula-

$$Z = \begin{cases} \frac{s-1}{\sqrt{var(s)}} \text{ if } S > 0 \\ 0 \text{ if } S = 0 \\ \frac{s+1}{\sqrt{var(S)}} \text{ if } S < 0 \end{cases} \qquad 4$$

Z= Trend Value
Z is an indicator for trend significance. It frequently follows the standard normal distribution. If Z is greater than 0, the series is showing an upward trend, and vice versa. An upward or downward monotonous trend is tested using a significance level (two-tailed test). The 5% level of significance used in this study. The Modified Mann-Kendall (MMK) test is used to determine whether there is a trend in the Rainfall series if it is serially auto- correlated (Rahman *et al.* 2017) [9].

Result and Discussion

Precipitation Indices: Three precipitation indices were determined: number of rainy days (R1mm), yearly precipitation (PRCPTOT), and consecutive wet days (CWD) for all years. And further it classify in to three decades: [1985-1997], [1998-2008], [2009-2019] respectively.

Box plot analysis data from 1985-2019

The box plot analysis of data spanning from 1985 to 2019 provides a comprehensive overview of three key variables: wet days, annual rainfall, and R10. From 1985 to 2019, the number of wet days varied, with notable fluctuations observed across the years. In 2008, the highest count of wet days was recorded at 108, while the lowest count occurred in 1987 and 1992, both with 71 and 77 wet days respectively. The annual rainfall also exhibited considerable variability over this period. The highest rainfall was recorded in 2008 with 1443.33 mm, followed closely by 2019 with 1198.52 mm. Conversely, 1986 witnessed the lowest annual rainfall at 593.09 mm. Regarding R10, which represents the number of days with rainfall exceeding 10 mm, the values ranged from 15 in 2004 to 49 in 2008, indicating significant variability in the occurrence of heavy rainfall events across the years. Overall, the box plot analysis offers valuable insights into the temporal patterns and trends of these meteorological variables over the 35-year period, highlighting the dynamic nature of rainfall patterns and extreme weather events.

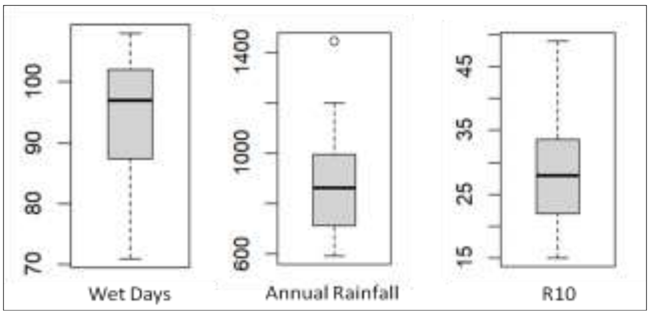

Fig 2: Variation in wet days (days), annual rainfall (mm) and R10 (days) values in first decadal timescale.

Analyzing the data spanning from 1985 to 2019 divided into three decades provides insights into the changing trends and patterns of meteorological variables over time.
In the first decade from 1985 to 1997, there was notable variability in the recorded metrics (Fig 2). Moving to the second decade, spanning from 1998 to 2008, there was a discernible increase in both wet days and annual rainfall. Finally, in the third decade from 2009 to 2019, there was further variability observed in the meteorological variables. Overall, the analysis of the data divided into three decades highlights the dynamic nature of meteorological variables and their changing patterns over time, providing valuable insights into long-term trends and variations in precipitation and extreme weather events.

Box plot analysis data from 1985-97

A box plot analysis of the data from 1985 to 1997 reveals interesting insights into the distribution of wet days, annual rainfall, and R10 values over this period. The number of wet days varied between 71 and 100, with the highest count recorded in 1994 and the lowest in 1987. Annual rainfall exhibited considerable variability, ranging from 593.09 mm in 1986 to 989.76 mm in 1990, with no clear trend apparent. Similarly, R10 values fluctuated, with extremes ranging from 19 to 35 days. These variations could be attributed to various factors, including natural climate variability, atmospheric conditions, and regional weather patterns, which influence the amount and distribution of precipitation. Additionally, localized factors such as topography and land use may also contribute to the observed differences in rainfall patterns across the years. Overall, the box plot analysis provides valuable insights into the temporal variability of meteorological variables during this period, highlighting the dynamic nature of weather patterns and their impact on precipitation and extreme weather events.

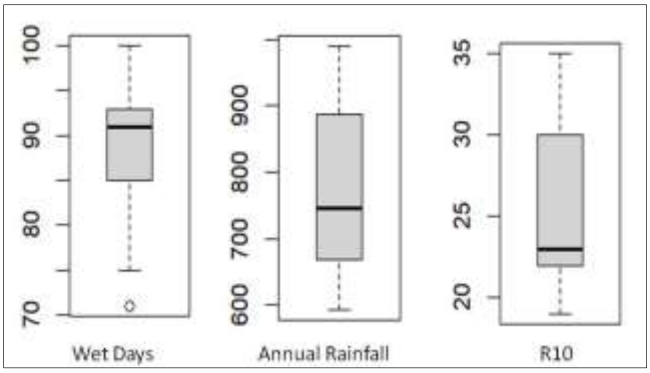

Fig 3: Variation in wet days (days), annual rainfall (mm) and R10 (days) values in second decadal timescale.

Box Plot analysis data from 1997-2008

A box plot analysis of the data from 1998 to 2008 offers valuable insights into the distribution of wet days, annual rainfall, and R10 values during this period (Fig 3). The number of wet days ranged from 86 to 108, with both 2003 and 2008 recording the highest count at 108, while 2002 had the lowest count. Annual rainfall varied considerably, from 637.91 mm in 2002 to 1443.33 mm in 2008, indicating significant fluctuations in precipitation levels over these years. Additionally, R10 values fluctuated, with extremes ranging from 15 days in 2004 to 49 days in 2008, signifying variations in the occurrence of heavy rainfall events. These fluctuations could be attributed to various factors such as climate oscillations, atmospheric conditions, and regional weather patterns, which influence the amount and distribution of rainfall. Furthermore, localized factors like land use changes and urbanization may also contribute to the observed differences in precipitation patterns across the years.

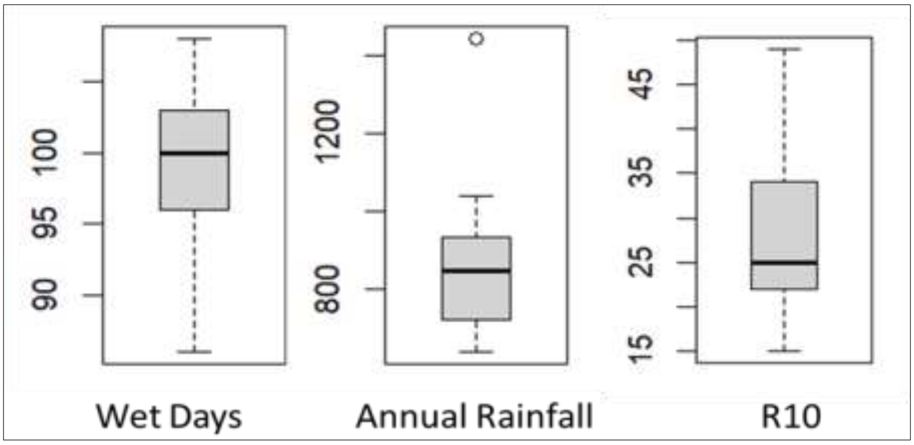

Fig 4: Variation in wet days (days), Annual rainfall (mm) and R10 (days) values in third decadal timescale.

Box plot analysis data from 2009-2019

An examination of the data from 2009 to 2019 using a box plot provides information about the distribution of rainy days, yearly rainfall, and R10 values throughout this time frame. There were 82 to 107 wet days overall; 2012 had the lowest number and 2013 had the greatest. The annual rainfall showed significant variation during these years, varying from 672.85 mm in 2015 to 1198.52 mm in 2019. This suggests variations in the amount of precipitation. Furthermore, R10 values varied, with extremes spanning from 21 days in 2015 to 40 days in 2018, which corresponded to changes in the frequency of intense precipitation episodes. Numerous causes, including atmospheric conditions, regional weather patterns, and climatic cycles, which affect the volume and distribution of rainfall, could be responsible for these fluctuations. Furthermore, the observed variations in precipitation patterns throughout time may also be attributed to specific variables like urbanization and changes in land use. All things considered, the box plot analysis offers insightful information on the temporal variability of meteorological variables throughout this time, emphasizing how dynamic weather patterns are and how they affect precipitation and extreme weather occurrences.

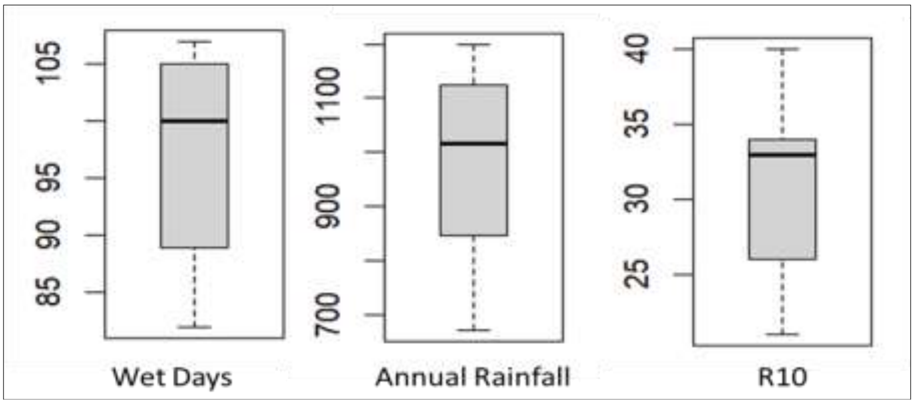

Fig 5: Variation in wet days (days), annual rainfall (mm) and R10 (days) values in third decadal timescale.

Trend Analysis

For the data provided from 1985 to 2019, we will plot the values of wet days, yearly rainfall, and R10 values against the corresponding years to perform a trend analysis using graph representation. This will make any trends or patterns over the previous 35 years easier to see.

The graph shows the variations in the annual total of wet days between 1985 and 2019. There are discernible peaks and troughs over the years, but no discernible upward or decreasing trend. The changing pattern of annual rainfall over time is depicted in this graph. There are noticeable peaks in certain years' annual rainfall, indicating comparatively wetter periods, and decreases in other years.Last but not least, the graph showing the R10 values plotted against the years shows variations in the frequency of severe rainfall events throughout the course of the 35-year period. Higher R10 values for a given year indicate more heavy rainfall events occurring more frequently, whilst lower values indicate fewer incidents. In general, these graphs shed light on the patterns and trends that have occurred throughout time in terms of yearly rainfall, wet days, and R10 values between 1985 and 2019. The figures provide a thorough picture of the variability and volatility found in these meteorological variables over the 35-year period, even though no obvious long-term trends may be evident.

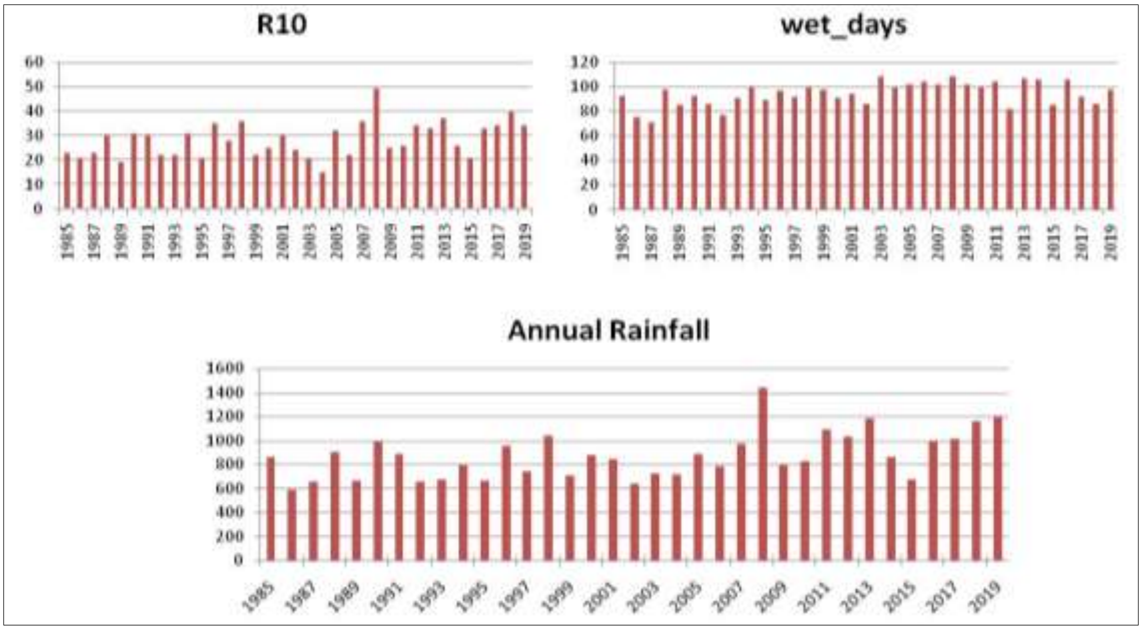

Fig 6: Times series of R10, wet days and annual rainfall for Ambedkarnagar station.

Trend analysis

In trend analysis analyze the pattern of rainfall, R10 and Wet days data from [1985 – 2019]. And further in divides into three decades such as:[1985-1997], [1998-2008], [2009-20019], afterwards analyze the pattern of rainfall, R10 and Wet days data

An examination of the trends and patterns in the variables of wet days, yearly rainfall, and R10 values throughout the period of 1985 to 1997 may be gained by employing a trend analysis utilizing graph representation of the data. The amount of wet days recorded each year varies to some extent, as can be seen by plotting the wet day values against the years. Though there isn't a distinct upward or downward trend, there are discernible highs and lows, as the 1996 rise in the number of rainy days that was followed by a minor decline in 1992 and 1997.

Comparably, a graph of the annual rainfall throughout time reveals a variable pattern, with some years having more rainfall than others. Significant yearly rainfall peaks are found in 1990 and 1996, indicating comparatively wetter years, with notable decreases in 1986 and 1987. A closer look at the R10 values plotted across the years reveals variations in the frequency of heavy rainfall occurrences. While 1989 displays a lower R10 value, indicating fewer occurrences of such events, years like 1996 stand out with higher R10 values, showing an increased frequency of severe rainfall events.

Ultimately, the trend analysis graph shows how dynamic rainfall patterns and extreme weather occurrences are, offering insightful information about the temporal patterns and trends of these meteorological variables over the course of the 13-year period. Although a distinct long-term trend may not be evident, the graph provides a thorough summary of the variability and variations seen in these variables between 1985 and 1997 (Fig 7).

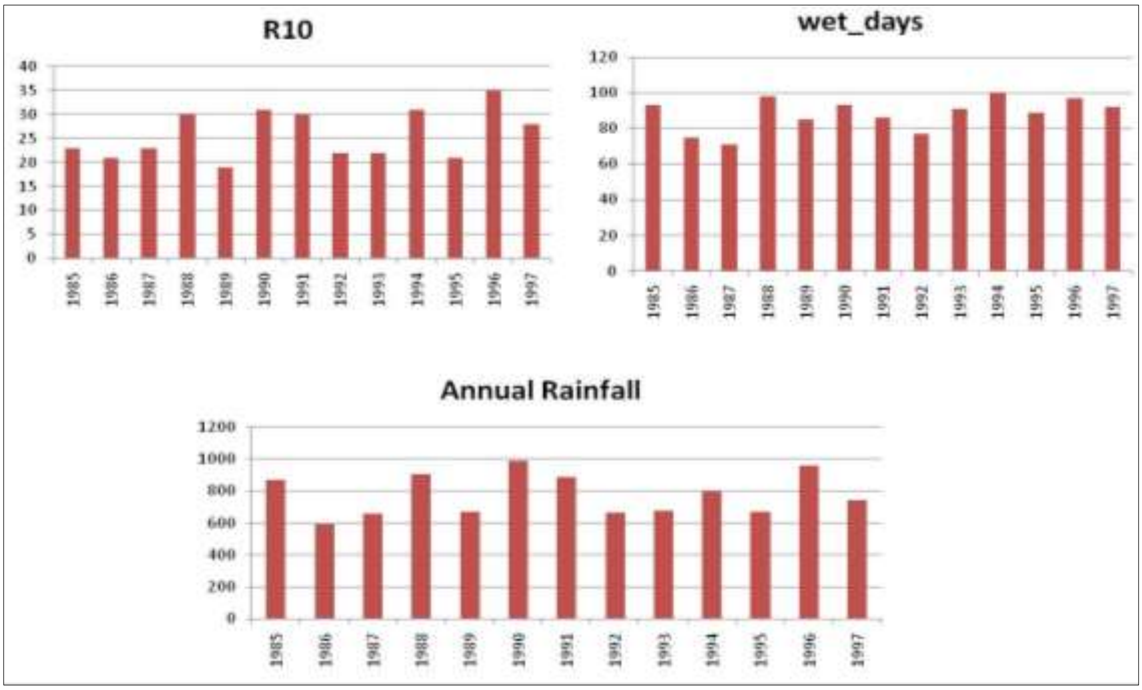

Fig 7: Trend analysis result for 1985-1997

Trend analysis graph from 1998-2008

A trend analysis based on a graph representation of the data from 1998 to 2008 provides important information about the patterns and variations in the variables of yearly rainfall, wet days, and R10 values during this time. There is some variation in the total number of wet days reported annually when the values of wet days are plotted against the years. There are discernible peaks and troughs, such as the spikes in wet days recorded in 2003, 2007, and 2008, even though there isn't a definite upward or decreasing trend.

A similar fluctuating pattern may be seen when the annual rainfall is shown over the years, with some years having larger totals than others. The annual rainfall shows notable increases in 2008, suggesting an exceptionally wet year, and declines in 2002 and 2004. The changes in the frequency of severe rainfall events can also be seen by looking at the R10 values plotted across the years. Years with higher R10 values, such as 2008, stand out as having more frequent heavy rainfall events, whereas 2004 had a lower R10 value, indicating less of these events.The trend analysis graph, which emphasizes the dynamic nature of rainfall patterns and extreme weather occurrences, offers insightful information on the temporal patterns and trends of various meteorological variables over the course of an 11-year period. The graph provides a thorough summary of the variability and variations seen in these variables from 1998 to 2008, even if no obvious long-term trend is evident.

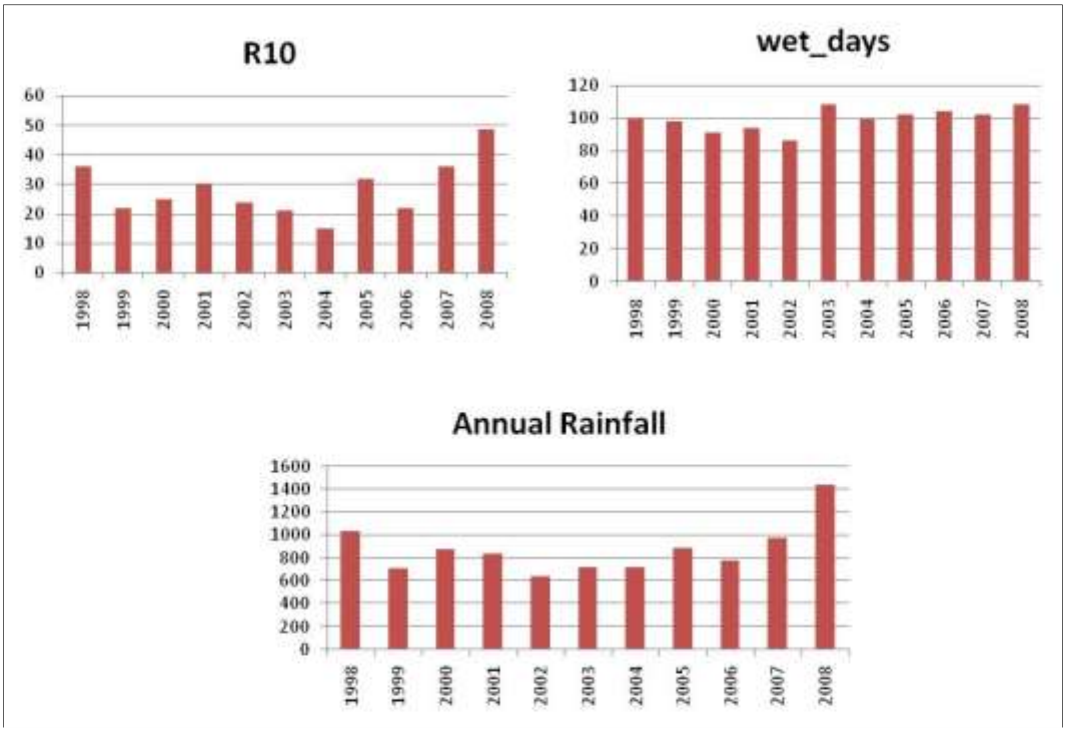

Fig 8: Trend analysis result for 1998-2008

Trend analysis graph from 2009-2019

A trend analysis graph representation of the data from 2009 to 2019 provides a visual depiction of the fluctuations and patterns observed in the variables of wet days, annual rainfall, and R10 values over this period. Plotting the values of wet days against the years reveals some variability in the number of wet days recorded each year (Fig 8). While there isn't a clear upward or downward trend, there are noticeable peaks and troughs, such as the spike in wet days observed in 2013 followed by a slight decrease in 2014.

Similarly, graphing the annual rainfall over the years shows a varying pattern, with some years experiencing higher rainfall totals than others. Notable peaks in annual rainfall are observed in 2011, 2013, and 2018, while dips are seen in 2015 and 2012.Examining the R10 values plotted against the years also illustrates fluctuations in the occurrence of heavy rainfall events. Years like 2013 and 2018 stand out with higher R10 values, indicating an increased frequency of heavy rainfall events, while 2015 shows a lower R10 value, suggesting fewer occurrences of such events.

Overall, the trend analysis graph provides valuable insights into the temporal patterns and trends of these meteorological variables over the 11-year period, highlighting the dynamic nature of rainfall patterns and extreme weather events. While no clear long-term trend may be apparent, the graph offers a comprehensive overview of the variability and fluctuations observed in these variables from 2009 to 2019 (Fig 9).

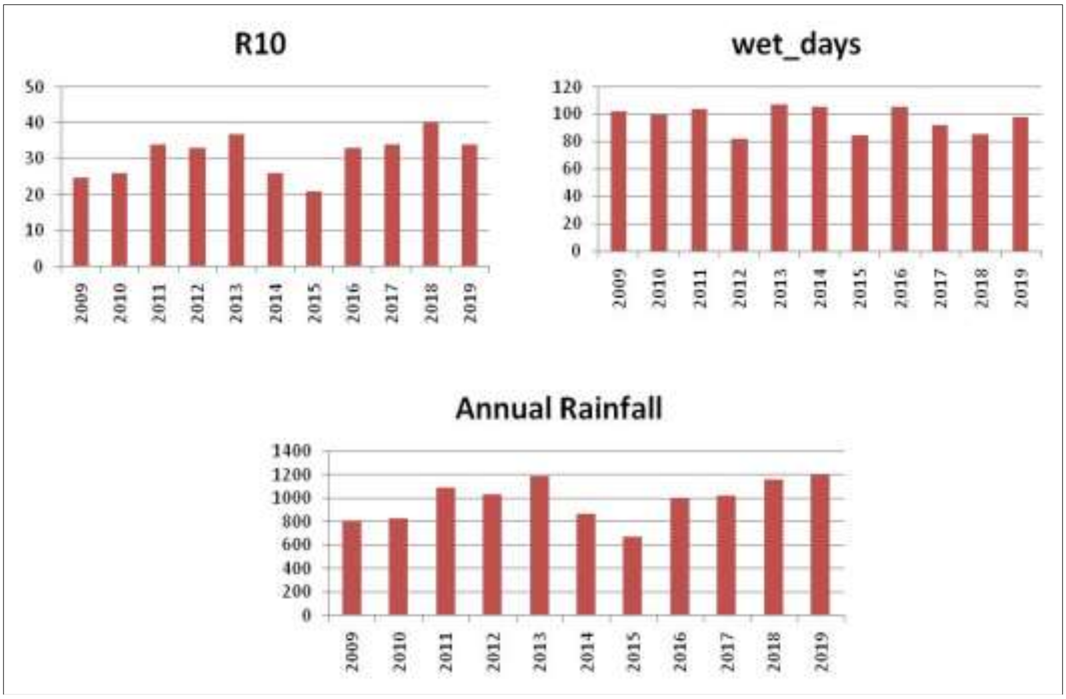

Fig 9: Trend analysis result for 2009-2019

Conclusion

The analysis of rainfall data from Ambedkar Nagar district spanning from 1985 to 2019 reveals several important trends and patterns. Over the 35-year period, there is evidence of variability in annual rainfall, with fluctuations observed from year to year. However, an overall increasing trend in annual rainfall is apparent, suggesting a gradual rise in precipitation levels in the region over the study period. Additionally, variations in the number of wet days and the occurrence of intense rainfall events (R10) provide insights into changes in rainfall distribution and intensity over time. While some years exhibit higher than average rainfall and increased frequency of wet days, others experience lower rainfall totals and reduced occurrences of intense precipitation events. The observed trends in rainfall data have significant implications for various sectors, including agriculture, water resource management, and disaster preparedness, in Ambedkar Nagar district. Understanding these trends is crucial for developing effective strategies to mitigate the impacts of climate change, enhance resilience to extreme weather events, and ensure sustainable development in the region.

References

1. Basistha A, Arya DS, Goel NK. Analysis of historical changes in rainfall in the Indian Himalayas. International Journal of Climatology. 2009;29:555–572.
2. Duhan D, Pandey A. Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India. Atmospheric Research. 2013;122:136-149.
3. Gupta S, Goyal MK, Sarma AK. Assessment of hydroclimatological changes in eastern Himalayan River catchment of Northeast India. Journal of Hydrologic Engineering. 2021;26(10):05021027.
4. Jain SK, Kumar V. Trend analysis of rainfall and temperature data for India. Current Science; c2012. p. 37-49.
5. Kendall MG. Rank Correlation Methods. 4th edition. London, U.K.: Charles Griffin; c1975.
6. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13:245-259.
7. Mondal A, Kundu S, Mukhopadhyay A. Rainfall trend analysis by Mann-Kendall test: A case study of north-eastern part of Cuttack district, Orissa. International Journal of Geology, Earth and Environmental Sciences. 2012;2(1):70-78.
8. Oguntunde PG, Abiodun BJ, Olukunle OJ, Olufayoa AA. Trends and variability in pan evaporation and other climatic variables at Ibadan, Nigeria, 1973–2008. Meteorological Applications; c2011. doi: 10.1002/met.281.
9. Rahman MA, Yunsheng L, Sultana N. Analysis and prediction of rainfall trends over Bangladesh using Mann–Kendall, Spearman's rho tests and ARIMA model. Meteorology and Atmospheric Physics. 2017;129(4):409-424.
10. Shivam Gupta, Ankit Gupta, Sushil K, Himanshu, Ronald Singh. Analysis of the Extreme Rainfall Events Over Upper Catchment of Sabarmati River Basin in Western India Using. Advances in Water Resources Engineering and Management: Select Proceedings of TRACE 2018. 2019;39:103.
11. Srilakshmi M, Jhajharia D, Gupta S, Yurembam GS, Patle GT. Analysis of spatio-temporal variations and change point detection in pan coefficients in the northeastern region of India. Theoretical and Applied Climatology. 2022, 1-15.
12. Thomas DS, Twyman C, Osbahr H, Hewitson B. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. Climatic Change. 2007;83(3):301-322.