To identify the trend of agroclimatic variabilities of eastern U. P.

Prince[1], A. K. Singh[1], S. R. Mishra[1], A. N. Mishra[1] and Rajan Chaudhari[2]

1. Department of Agriculture Meteorology, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya, Uttar Pradesh, India.
2. KVK Khunti, National Institute of Secondary Agriculture Namkum Ranchi.

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ABSTRACT

This study analyzes the annual trends of maximum temperature, minimum temperature, and rainfall across the agroclimatic zones—NEPZ, EPZ, and Vindhyan zone—of Eastern Uttar Pradesh from 2004 to 2023. Linear trend analysis indicated a consistent rise in both maximum and minimum temperatures, while rainfall exhibited a declining trend across all zones. The Mann-Kendall test was employed to determine the statistical significance of these trends at the district level. Results revealed that maximum temperature trends were significantly increasing in Ayodhya, Mirzapur, and Sonbhadra, while minimum temperature trends were significant in Kushinagar and Sonbhadra. Rainfall trends showed significant increases only in Varanasi and Sonbhadra, with other districts showing no statistically significant changes. The findings suggest emerging climatic shifts that may impact agriculture, requiring climate-resilient strategies tailored to district-specific trends.

Introduction:

Understanding the trend of agroclimatic variability in Eastern Uttar Pradesh is crucial for effective planning and adaptation in agriculture, especially in the face of increasing climate uncertainties. This region, forming part of the Indo-Gangetic plains, is characterized by diverse agroecological conditions and a heavy reliance on monsoon-driven rainfall. Recent studies indicate significant spatial and temporal variability in climatic parameters such as rainfall, maximum and minimum temperatures, and extreme weather events that influence cropping patterns, yields, and water availability. The application of statistical tools like Mann-Kendall trend test, Sen's slope estimator, and coefficient of variation has become common for assessing such changes (Khavse *et al.,* 2015; Verma & Chatterjee, 2018; Singh *et al.,* 2021). Several studies have documented rising trends in temperature and erratic rainfall patterns across Eastern U.P., impacting food security and livelihoods (Yadav et al., 2019; Pandey & Singh, 2022; Jaiswal *et al.,* 2023). GIS and remote sensing tools have also enhanced regional agroclimatic zonation for better cropping strategies (Srivastava *et al.,* 2020). Researchers have emphasized the need for climate-resilient agricultural practices in response to observed variability and predicted future scenarios (Sinha et al., 2010; Mall et al., 2011; Sharma & Rai, 2012; Mishra et al., 2013; Kumar & Gautam, 2014). Regional-scale analyses have shown that shifts in climatic trends are more pronounced in Eastern U.P. compared to other parts of the Indo-Gangetic basin (Tiwari et al., 2015; Singh & Tripathi, 2016; Gupta *et al.,* 2017). These trends underline the urgency of integrating climate data into agricultural decision-making and policy (Kumar *et al.,* 2021; Yadav *et al.,* 2022; Verma *et al.,* 2023). Overall, the identification of agroclimatic trends serves as a foundation for adaptive management in agriculture, enabling better preparedness for risks posed by climate change in Eastern Uttar Pradesh.

Materials and Methods:

An experiment was conducted using 20 years climatic data viz., Temperature (max. and min.) and rainfall from 2004 to 2023 of eastern Uttar Pradesh at Acharya Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya, Uttar Pradesh. Eight major districts viz., Ayodhya, Azamgarh, Varanasi, Ghazipur, Sonbhadra, Mirzapur, Kushinagar and Deoria was included in Eastern Uttar Pradesh.

Mean

The average is calculated by dividing the total number of observations by the sum of the supplied observations.

Mean = Sum of the observation/ No. of Numbers

Correlation analysis

The intensity of a link between two variables is referred to as correlation. Whereas a weak or low correlation indicates that the variables are barely connected, a strong or high correlation indicates that two or more variables have a strong association with one another. Using Excel, the correlation coefficients between several climatic factors and rice and wheat yield (2004–2023) were calculated (Kumar & Gautam, 2014; Yadav *et al.,* 2022).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x^2)]\,[n\sum y^2 - (\sum}}$$

Trend analysis

A trend is a notable shift that a random variable exhibits over time. Regression analysis, a parametric test, or Mann-Kendall's test, a non-parametric approach, are typically used to identify the degree of trend in a time series. A linear trend in the time series is assumed by both of these approaches. Both the Mann-Kendall and linear regression tests were used in this specific investigation (Singh *et al.,* 2021; Pandey & Singh, 2022).

Mann-Kendall (MK) Test

Mk test is the rank based nonparametric test and recently used by several researchers to detect trends in temperature data **(Tabari et al., 2011).** It is based on the test statistic S defined as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi)$$

Where, 1, x 2, x 3, x …….. xn represent n data points where *j* represents the data point at the time *j*.

A growing trend is indicated by a very high positive value of S, whereas a falling trend is indicated by a very low negative value. To statistically measure the trend's significance, however, the probability associated with S and the sample size, n, must be calculated. A normal approximation to the Mann-Kennedy test may be applied when the sample size is more than 10. This yields the variance of S as:

$$V(s) = [n(n-1)(2n+5) - \Sigma\, tp\,(tp-1)(2tp+5)]/18, \; p=1,2……p$$

Where *tp* is the number of tiles for pth value and q is the number of tied values. The standardized statistical test is

$Z = S-1/\sqrt{V}\ V(S)$ if $S>0$

$= 0$ if $S = 0$,

$= S + 1 / \sqrt{V}\ (S)$ if $S<0$

The presence of a statistically significant trend is evaluated using Z value

Results and discussion:

Annual trend of maximum temperature, minimum temperature and rainfall at NEPZ of Eastern Uttar Pradesh during 2004 – 2023.

In this study, we conducted a trend analysis of temperature and Rainfall in the NEPZ of Eastern U.P. The results are presented in the accompanying graphs, specifically Graphs 4.2.1, 4.2.2, and 4.2.3, which detail the mean annual temperature and rainfall. A linear trend analysis was performed to assess long-term patterns in Temperature and Rainfall within the NEPZ of Eastern Uttar Pradesh. The analysis indicated a general increase in both the annual maximum and minimum temperature. However, the trend for the rainfall showed a decrease.

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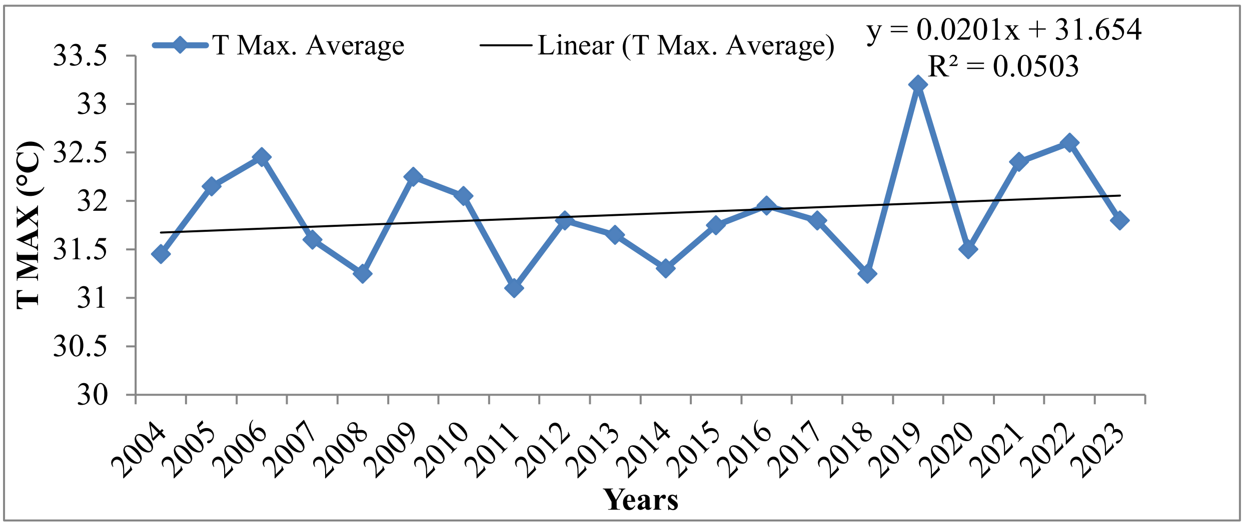
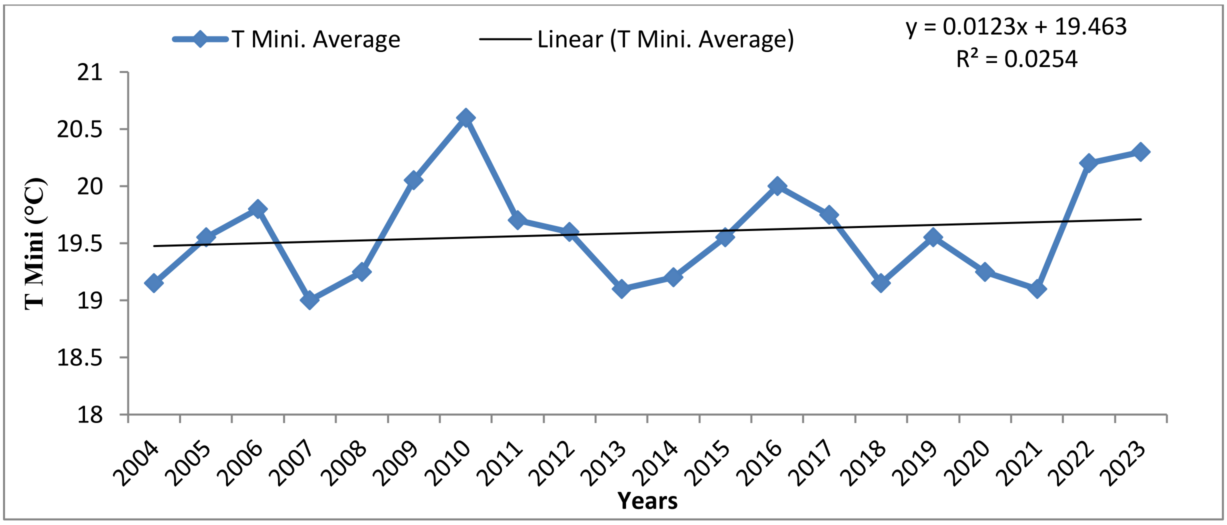
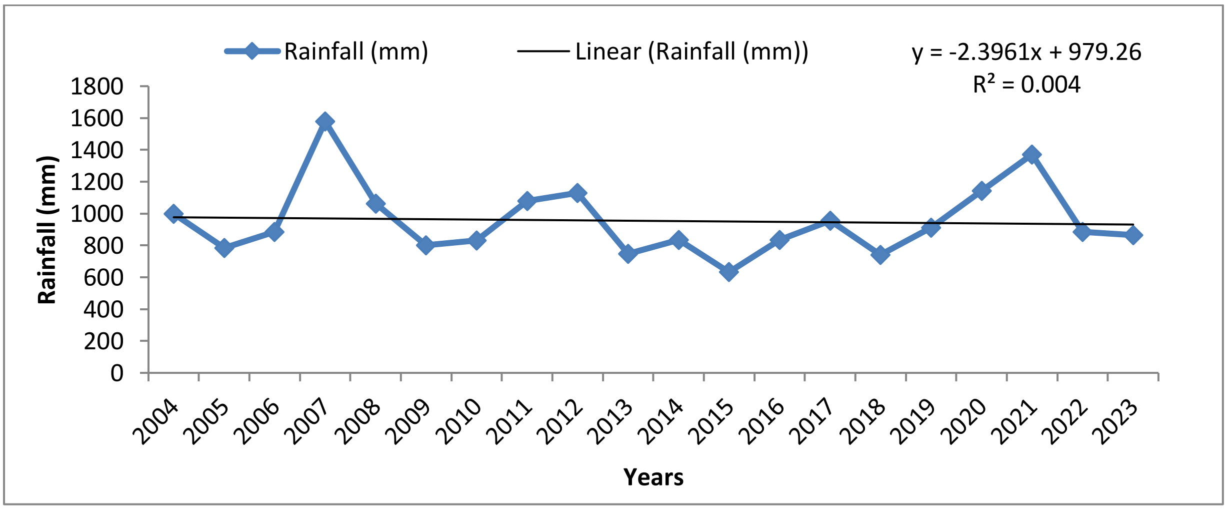


Annual trend of maximum temperature at NEPZ of Eastern Uttar Pradesh



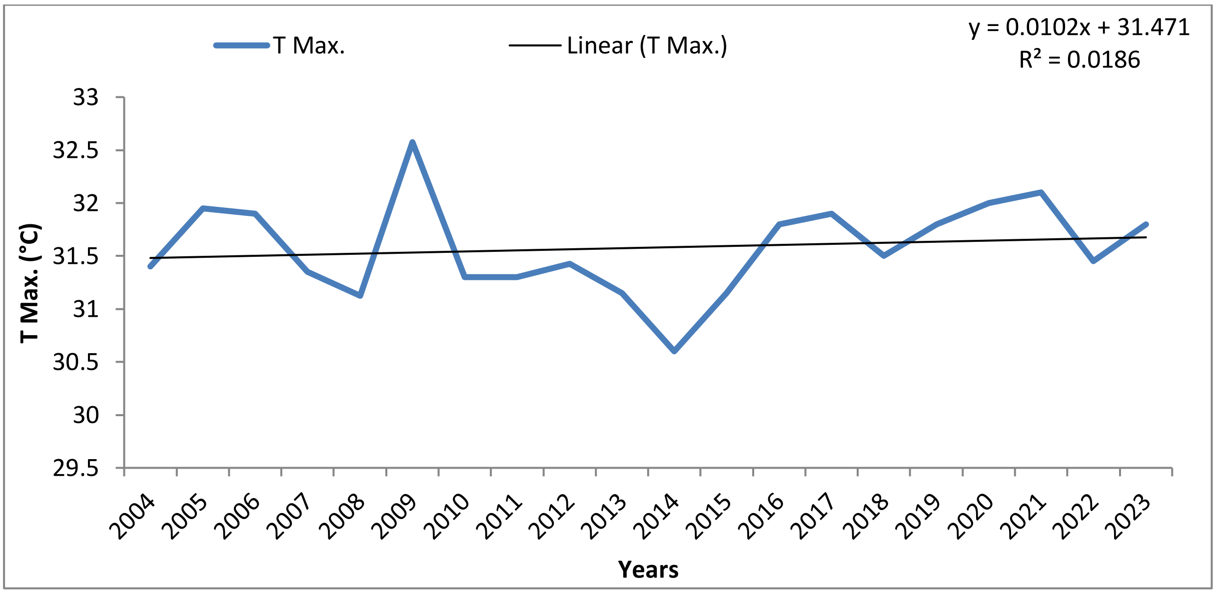
Annual trend of minimum temperature at NEPZ of Eastern Uttar Pradesh



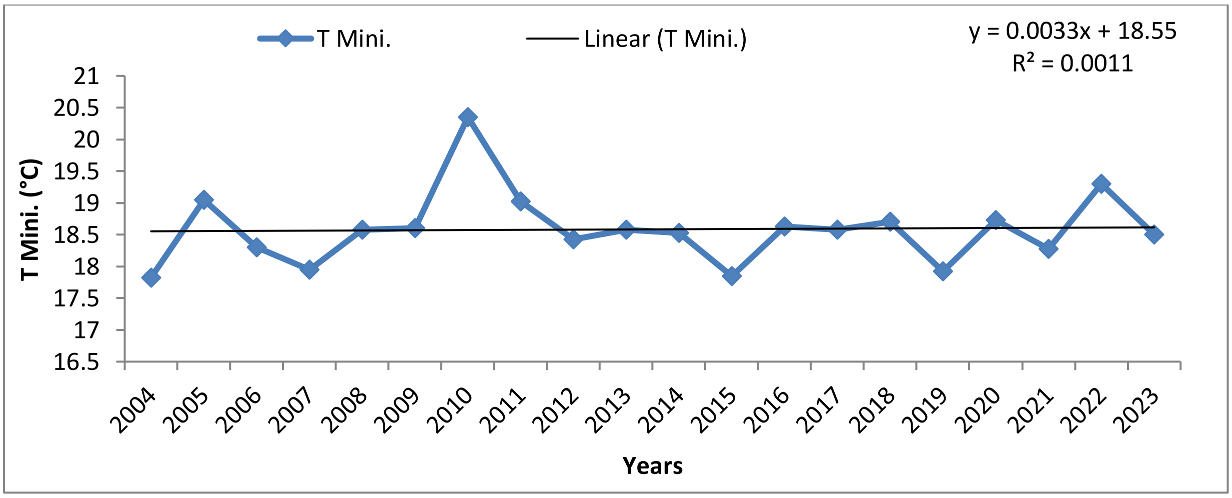
Annual trend of Rainfall at NEPZ of Eastern Uttar Pradesh

Annual trend of maximum temperature, minimum temperature and rainfall at EPZ of Eastern Uttar Pradesh during 2004 – 2023.

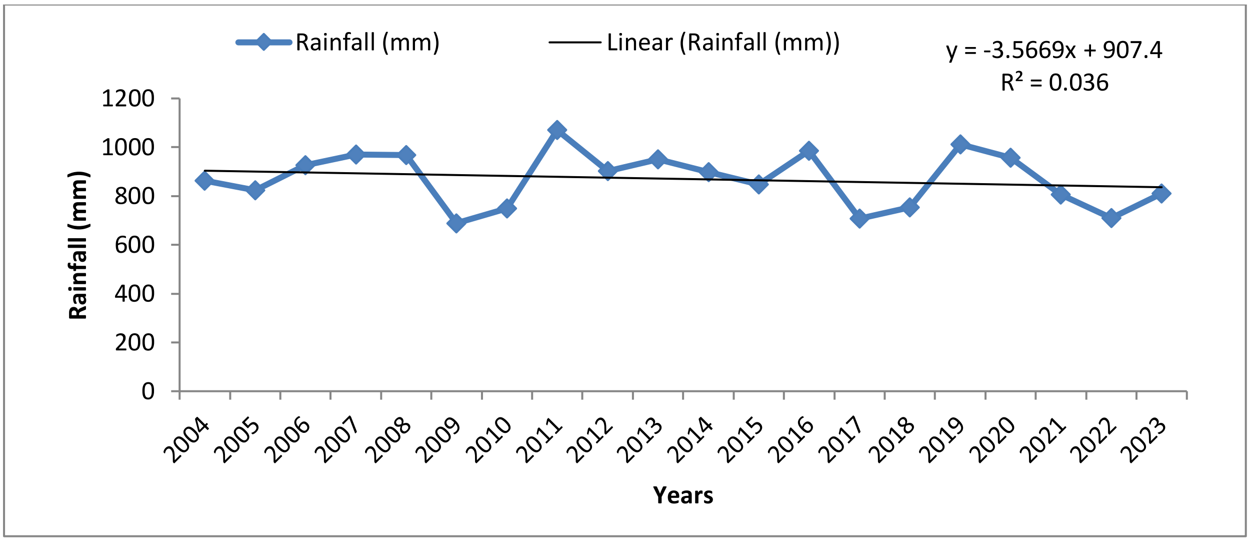
In this study, we conducted a trend analysis of temperature and Rainfall in the EPZ of Eastern U.P. The results are presented in the accompanying graphs, specifically Graphs 4.2.4, 4.2.5, and 4.2.6, which detail the mean annual temperature and rainfall. A linear trend analysis was performed to assess long-term patterns in Temperature and Rainfall within the EPZ of Eastern Uttar Pradesh. The analysis indicated a general increase in both the annual maximum and minimum temperature. However, the trend for the rainfall showed a decrease.



Annual trend of maximum temperature at EPZ of Eastern Uttar Pradesh



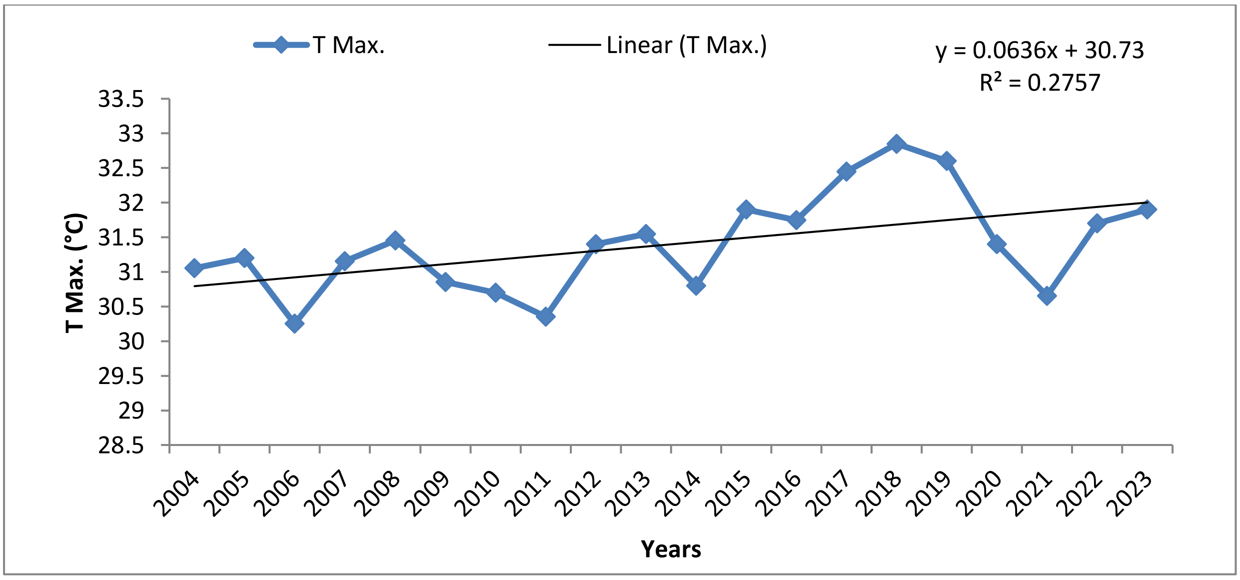
Annual trend of minimum temperature at EPZ of Eastern Uttar Pradesh



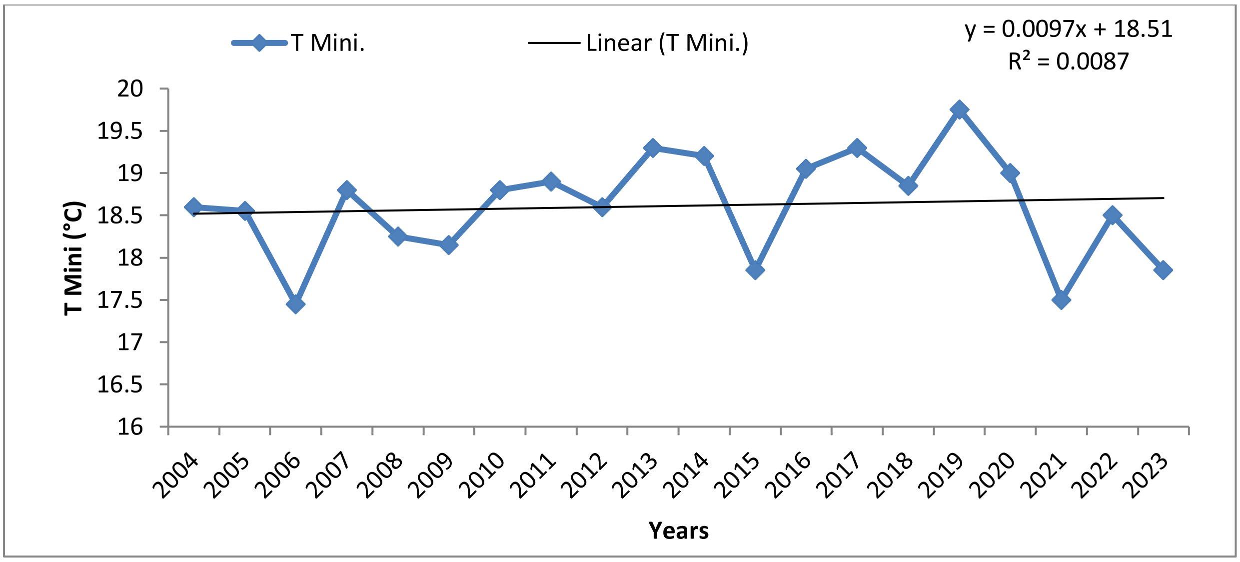
Annual trend of rainfall at EPZ of Eastern Uttar Pradesh

Annual trend of maximum temperature, minimum temperature and rainfall at Vindhyan zone of Eastern Uttar Pradesh during 2004 – 2023.

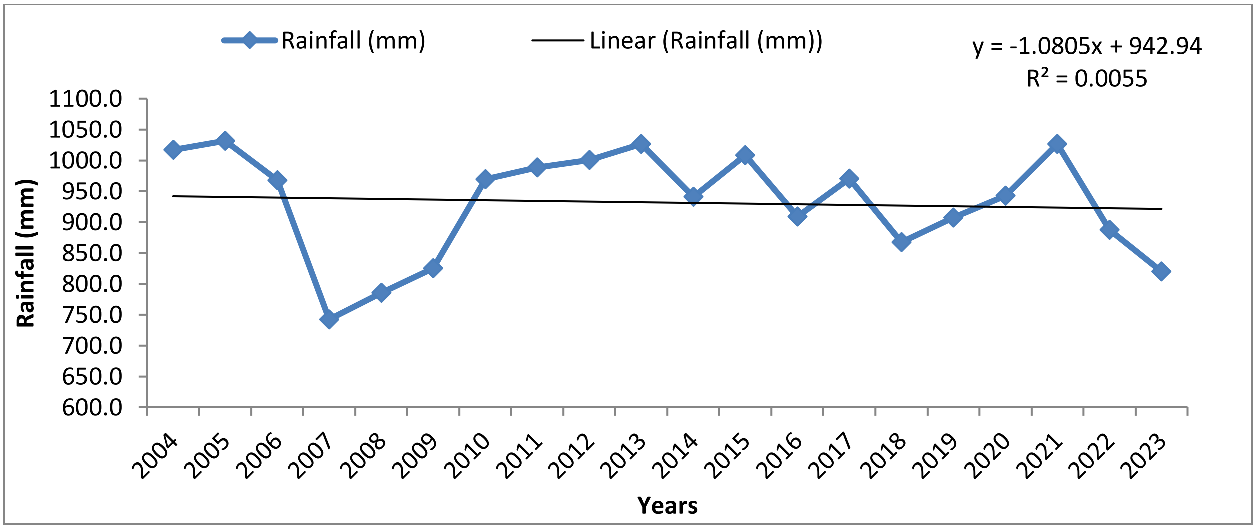
In this study, we conducted a trend analysis of temperature and Rainfall in the Vindhyan zone of Eastern U.P. The results are presented in the accompanying graphs, specifically Graphs 4.2.7, 4.2.8, and 4.2.9, which detail the mean annual temperature and rainfall. A linear trend analysis was performed to assess long-term patterns in Temperature and Rainfall within the Vindhyan zone of Eastern Uttar Pradesh. The analysis indicated a general increase in both the annual maximum and minimum temperature. However, the trend for the rainfall showed a decrease.



Annual trend of maximum temperature at Vindhyan zone of Eastern U. P.



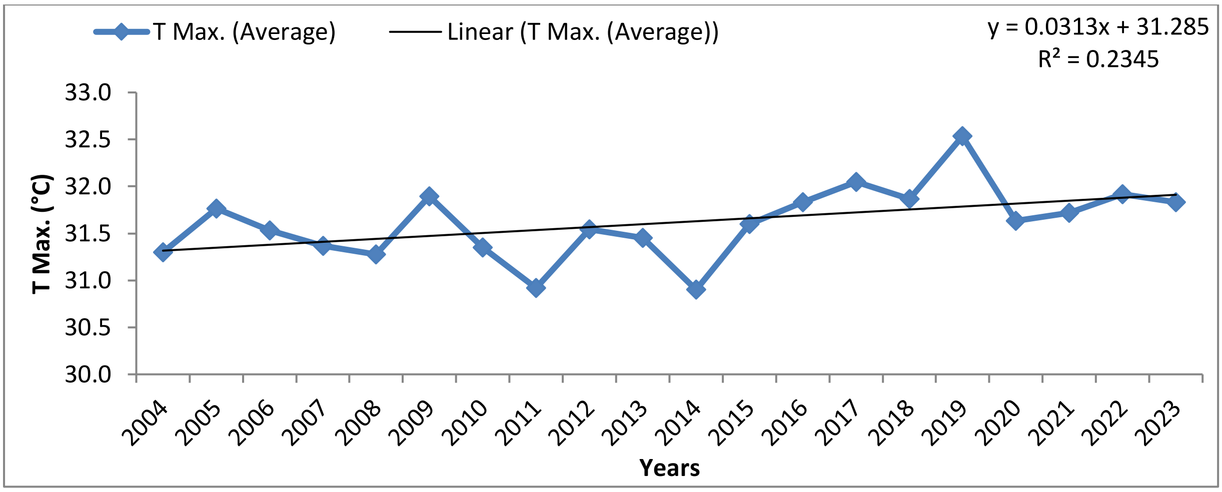
Annual trend of minimum temperature at Vindhyan zone of Eastern U. P.



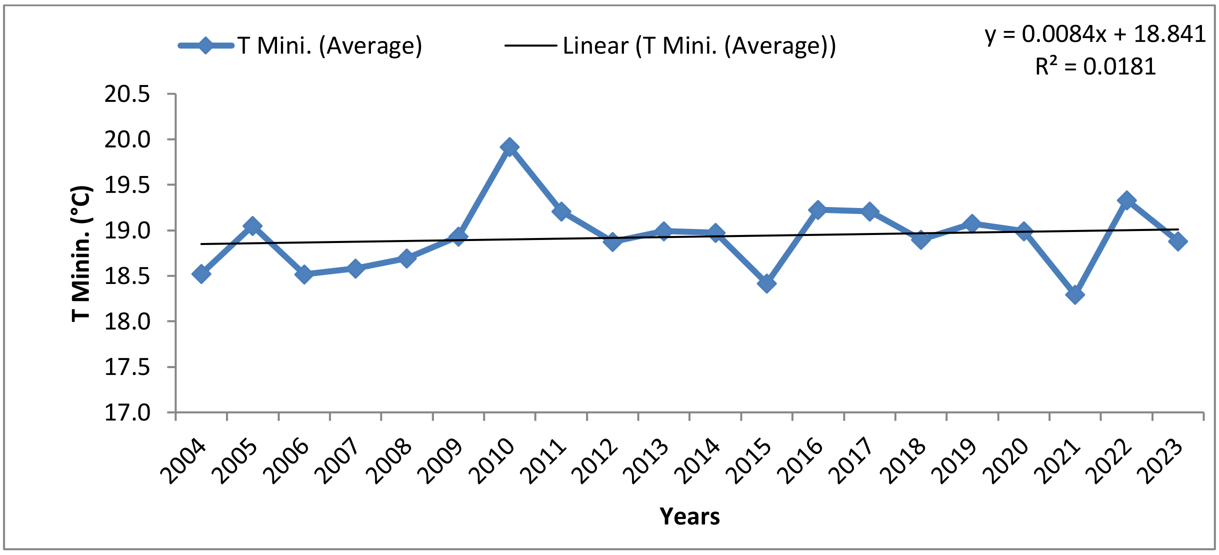
Annual trend of Rainfall at Vindhyan zone of Eastern U. P.

Annual trend of maximum temperature, minimum temperature and rainfall at of Eastern Uttar Pradesh during 2004 – 2023.

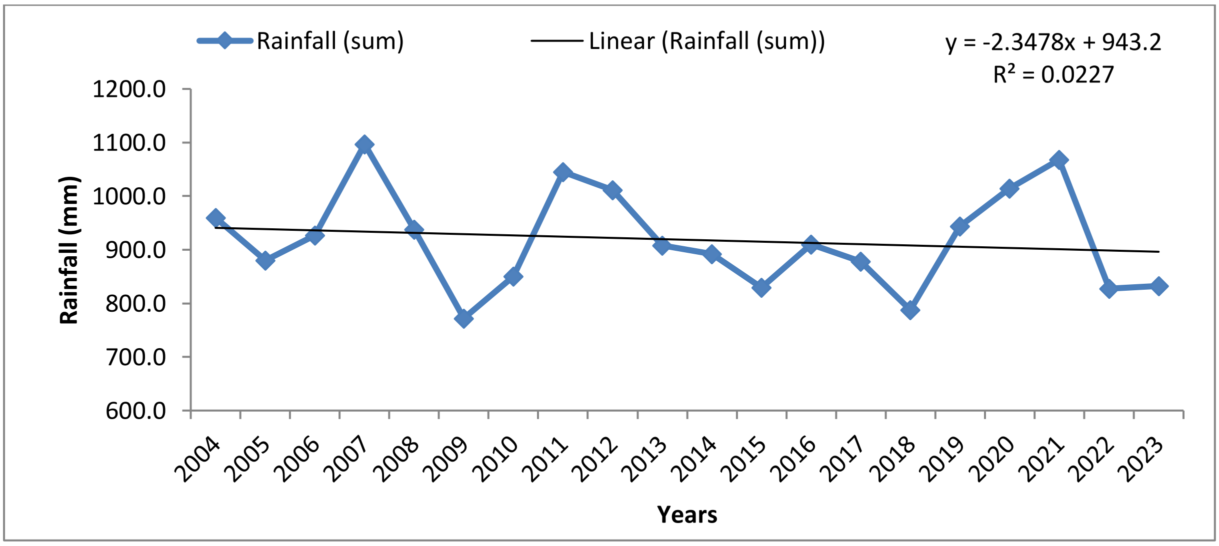
In this study, we conducted a trend analysis of temperature and rainfall in the Eastern Uttar Pradesh. The results are presented in the accompanying graphs, specifically Graphs 4.2.10, 4.2.11, and 4.2.12, which detail the mean annual temperature and rainfall. A linear trend analysis was performed to assess long-term patterns in temperature and rainfall within the Eastern Uttar Pradesh. The analysis indicated a general increasing in both the annual maximum temperature and minimum temperature. However, the trend for the rainfall showed a decreasing. Similar findings were reported by Kumar, V. *et al.* (2010) and Devegowda, S. R. *et al.* (2022).



Annual trend of maximum temperature at Eastern Uttar Pradesh



Annual trend of minimum temperature at Eastern Uttar Pradesh



Annual trend of Rainfall at Eastern Uttar Pradesh.

Result of Man Kendall & liner regression estimate of different district of eastern U.P. during 2004-2023.

The mann-Kendall rank correlation approach is used in this study to analyze the data from 2004 to 2023 in eastern Uttar Pradesh. Although Kendall (1962) determined the frequency function of rank correlation and provided a precise critical value, the approximation test of rank correlation, which is equivalent to the z-test for Pearson's coefficient, is sufficient for all empirical applications.

Tmax. Mann-Kendall

Here, following the test, we discovered that the majority of districts received non-significant results at the 5% and 10% level of significance. These districts include Azamgarh (-1.169), Ghazipur (-0.001), Varanasi (-1.525), Deoria (-0.422), and Kushinagar (-0.195). Other districts, such as Ayodhya (-1.849), Mizrapur (1.720), and Sonbhadra (1.784), demonstrated a significant impact of the Kendall value. We draw the conclusion that Ayodhya, Mirzapur, and Sonbhadra District will benefit from the maximum temperature as a result of this outcome. In contrast, the maximum temperature in Azamgarh, Ghazipur, Varanasi, Deoria, and Kushinagar is unaffected.

District	Parameter							
	Maximum Temperature							
	Mann-Kendall				Linear regression			
		a=0.1	a=0.05	Result		a=0.1	a=0.05	Result
Ayodhya	-1.849	1.645	1.96	S (0.1)	-0.043	1.729	2.093	NS
Azamgarh	-1.169	1.645	1.96	NS	-0.048	1.729	2.093	NS
Ghazipur	0.001	1.645	1.96	NS	-0.004	1.729	2.093	NS
Varanasi	-1.525	1.645	1.96	NS	-0.057	1.729	2.093	NS
Deoria	-0.422	1.645	1.96	NS	-0.013	1.729	2.093	NS
Kushinagar	-0.195	1.645	1.96	NS	-0.014	1.729	2.093	NS
Mirzapur	-1.720	1.645	1.96	S (0.1)	-1.772	1.729	2.093	S (0.1)
Sonbhadra	-1.784	1.645	1.96	S (0.1)	-0.059	1.729	2.093	NS

Tmin. Mann-Kendall

Here, following the test, we discovered that the majority of districts received non-significant results at the 5% and 10% level of significance. These districts include Ayodhya (1.071), Azamgarh (-0.454), Ghazipur (-0.065), Varanasi (-0.584), Deoria (-0.001) and Mirzapur (-0.811). Other districts, such as Kushinagar (1.686) and Sonbhadra (1.685), demonstrated a significant impact of the Kendall value. We draw the conclusion that Kushinagar and Sonbhadra District will benefit from the minimum temperature as a result of this outcome. In contrast, the minimum temperature in Ayodhya, Azamgarh, Ghazipur, Varanasi, Deoria, and Mirzapur is unaffected.

District	Parameter							
	Minimum Temperature							
	Mann-Kendall				Linear regression			
		a=0.1	a=0.05	Result		a=0.1	a=0.05	Result
Ayodhya	1.071	1.645	1.96	NS	0.031	1.729	2.093	NS
Azamgarh	-0.454	1.645	1.96	NS	-0.011	1.729	2.093	NS
Ghazipur	-0.065	1.645	1.96	NS	0.000	1.729	2.093	NS
Varanasi	-0.584	1.645	1.96	NS	-0.019	1.729	2.093	NS
Deoria	0.001	1.645	1.96	NS	0.006	1.729	2.093	NS
Kushinagar	1.686	1.645	1.96	S (0.1)	1.755	1.729	2.093	S (0.1)
Mirzapur	-0.811	1.645	1.96	NS	-0.028	1.729	2.093	NS
Sonbhadra	1.685	1.645	1.96	S (0.1)	-0.028	1.729	2.093	NS

Rainfall Mann Kendall

Here, following the test, we discovered that the majority of districts received non-significant results at the 5% and 10% level of significance. These districts include Ayodhya (-0.162), Azamgarh (1.525), Ghazipur (0.032), Deoria (-0.097), Kushinagar (-0.032) and Mirzapur (1.460). Other districts, such as Varanasi (2.174) and Sonbhadra (2.044), demonstrated a significant impact of the Kendall value. We draw the conclusion that Varanasi and Sonbhadra District will benefit from the rainfall as a result of this outcome. In contrast, the total rainfall in Ayodhya, Azamgarh, Ghazipur, Deoria, Kushinagar and Mirzapur is unaffected.

District	Parameter							
	Rainfall							
	Mann-Kendall				Linear regression			
		a=0.1	a=0.05	Result		a=0.1	a=0.05	Result
Ayodhya	-0.162	1.645	1.96	NS	-0.584	1.729	2.093	NS
Azamgarh	1.525	1.645	1.96	NS	8.620	1.729	2.093	S (0.05)
Gajipur	0.032	1.645	1.96	NS	-1.664	1.729	2.093	NS
Varanasi	2.174	1.645	1.96	S (0.1)	13.214	1.729	2.093	S (0.05)
Deoria	-0.097	1.645	1.96	NS	-0.556	1.729	2.093	NS
Kushinagar	-0.032	1.645	1.96	NS	-0.531	1.729	2.093	NS
Mirzapur	1.460	1.645	1.96	NS	14.924	1.729	2.093	S (0.05)
Sonbhadra	2.044	1.645	1.96	S (0.1)	13.211	1.729	2.093	S (0.05)

Conclusion:

The trend analysis shows a general increase in temperatures and a decline in rainfall in Eastern U.P. Most districts showed no significant changes, but Ayodhya, Mirzapur, and Sonbhadra showed rising maximum temperatures; Kushinagar and Sonbhadra showed rising minimum temperatures; and Varanasi and Sonbhadra showed increasing rainfall trends. These localized changes call for targeted climate-resilient agricultural planning.

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