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Research Article

Rising Temperature and Increasing Climatic Stress in Jammu District: A Trend Analysis (1991–2025)

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Abstract

This study analyses long-term changes in temperature and rainfall in Jammu district from 1991 to 2025. The analysis uses linear regression, the Mann–Kendall (MK) test, and Sen's slope estimator to understand climate trends. The results show a clear and significant increase in temperature over the last 35 years. The annual mean temperature has increased by about 0.043°C per year, which equals nearly 0.43°C per decade. Both the MK test and Sen's slope estimator confirm this warming trend. On the other hand, rainfall shows a slight decreasing pattern, but this change is not statistically significant. Seasonal analysis shows that temperature is rising in both monsoon and winter seasons, while rainfall does not show any clear trend. Extreme-year analysis indicates that recent decades include the warmest and driest years. These changes suggest increasing climatic stress in Jammu district, which may affect agriculture, water availability, and overall regional sustainability.

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KEYWORDS: Mann–Kendall test, Sen's slope estimator, temperature trend, rainfall variability, seasonal analysis, climatic stress

1. INTRODUCTION

Climate change is now a global concern because it affects natural resources, agriculture, and human life. Rising temperature and changing rainfall patterns are creating serious challenges, especially in regions that depend on farming and seasonal rainfall. Climate change is now a global concern because it affects natural resources, agriculture, and human life. Rising temperature and changing rainfall patterns are creating serious challenges, especially in regions that depend on farming and seasonal rainfall. Jammu district lies in a sensitive climatic zone where both monsoon winds and western disturbances influence weather conditions. Because of this, even small changes in temperature and rainfall can strongly affect agriculture, water supply, and livelihoods. Farmers in the region depend heavily on stable weather for crops like rice, wheat, and maize. Although many climate studies focus on large regions or countries, local-level studies are equally important. District-level research helps planners and policymakers understand real problems on the ground. This study therefore focuses on long-term climate trends in Jammu district to assess future risks and support sustainable planning.

2. STUDY AREA

Jammu district is located in the south-western part of the Union Territory of Jammu and Kashmir. It lies between 32°50′–33°30′ north latitude and 74°24′–75°18′ east longitude and covers about 3,097 square kilo metres. Jammu district is located in the south-western part of the Union Territory of Jammu and Kashmir. It lies between 32°50′–33°30′ north latitude and 74°24′–75°18′ east longitude and covers about 3,097 square kilo meteres. The district has a mixed landscape. The northern part is hilly, while the southern part has fertile plains suitable for farming. The climate is sub-tropical, with hot summers, mild winters, and moderate rainfall. Summer temperatures often cross 40°C, while winter temperatures can fall below 10°C.Rainfall mainly comes during the monsoon season (June to September). Some rain is also received in winter due to western disturbances. Agriculture is the main occupation of the people, and most farmers depend on seasonal rainfall and irrigation canals.

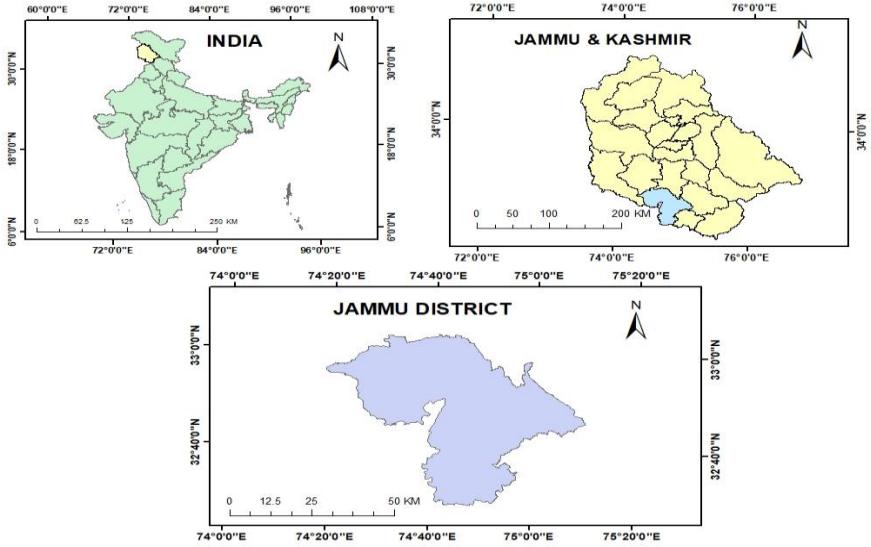


Fig. Study Area Map

Climate of Jammu is subtropical reaching summer high temperature above 40 degrees Celsius and the winter temperature below 15 degrees Celsius, making this area an ideal place to live. It is situated in the south-west of Jammu and form the plains of Jammu region surrounded by Shiwaliks in the northern side. This region experiences western disturbances in the month of late January and February, which causes huge loss to the plantation crops and wheat at the same time. Jammu district is majorly drained by river Tawi which originates from the Kailash Kund glacier in the upper reaches of Himalayas near Bhaderwah. Canals from Chenab River drained whole Jammu district, Ranbir canal from Chenab has proved significant in providing irrigation facilities to farmers especially during rice cultivation.

3. DATA AND METHODOLOGY

The study uses observed temperature and rainfall data from 1991-2025 using linear regression, Mann–Kendall test, and Sen's slope estimator were used to analyse trends. The study uses observed temperature and rainfall data from **1991 to 2025**. This long time period helps in understanding real climate trends instead of short-term fluctuations.

3.1 METHODS USED

To study climate trends, the following methods were applied:

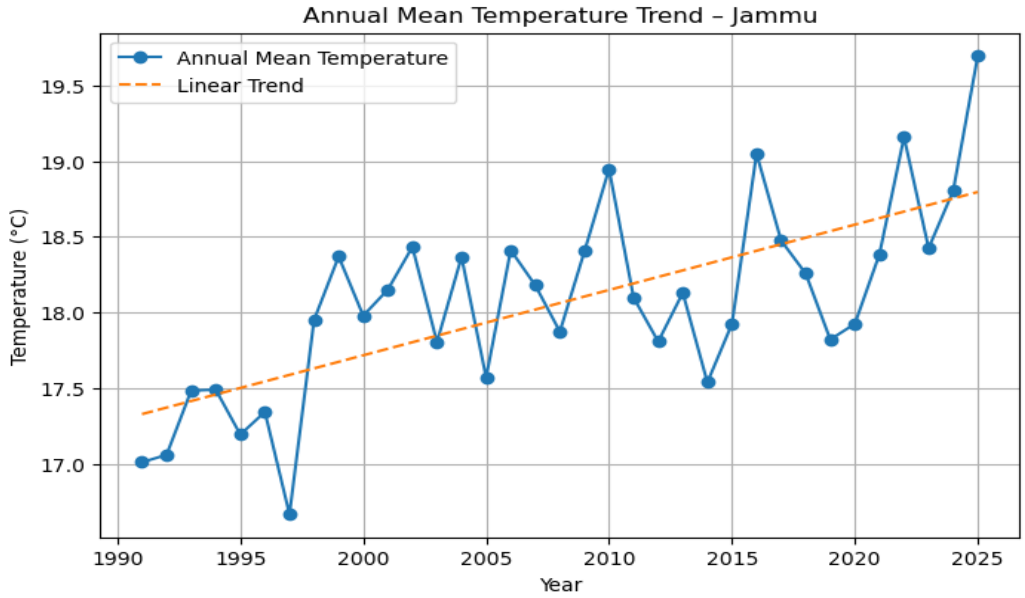
1. **Linear-Regression**
   Used to find whether temperature and rainfall are increasing or decreasing over time.
2. **Mann–Kendall-Test**
   A statistical test used to check whether the trend is significant or not.
3. **Sen's-Slope-Estimator**
   Used to calculate the exact rate of change per year and per decade.
4. **Seasonal-Analysis**
   Separate analysis for monsoon and winter seasons.
5. **Extreme-Year-Analysis**
   Identification of the warmest and driest years to understand climate extremes.

4. RESULTS

4.1 Temperature Trend

The results clearly show that temperature in Jammu district is increasing.

- Annual rise: **0.043°C per year**
- Decadal rise: **0.43°C per decade**



Linear regression analysis of annual mean temperature over Jammu for the period 1991–2025 reveals a clear increasing trend. The fitted linear trend indicates a warming rate of 0.043 °C per year, corresponding to 0.432 °C per decade. This substantial warming highlights an accelerated increase in surface air temperature over the region, consistent with recent observations of enhanced warming in the northwestern Himalayan foothills.

The Mann–Kendall test confirms that this increase is statistically significant. Sen's slope also gives a similar result, proving that warming in Jammu district is real and consistent.

Temperature trend equation:
T = 0.0432 × Year + -68.65
Trend = 0.432 °C per decade

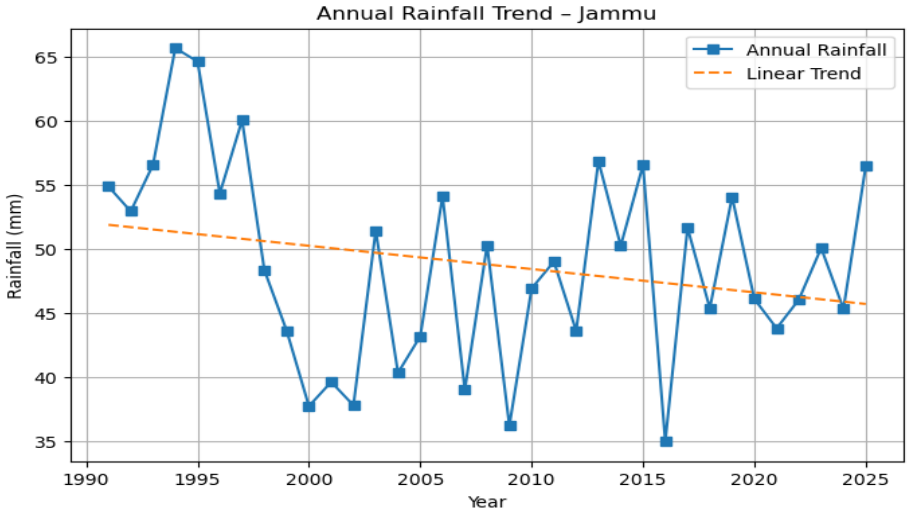
4.2 Rainfall Trend

Rainfall shows a slight decrease:

- About **0.175 mm per year**
- About **1.75 mm per decade**

Rainfall Trend Equation:

- R = -0.182 × Year + 413.5
- Trend = -1.82 mm per decade

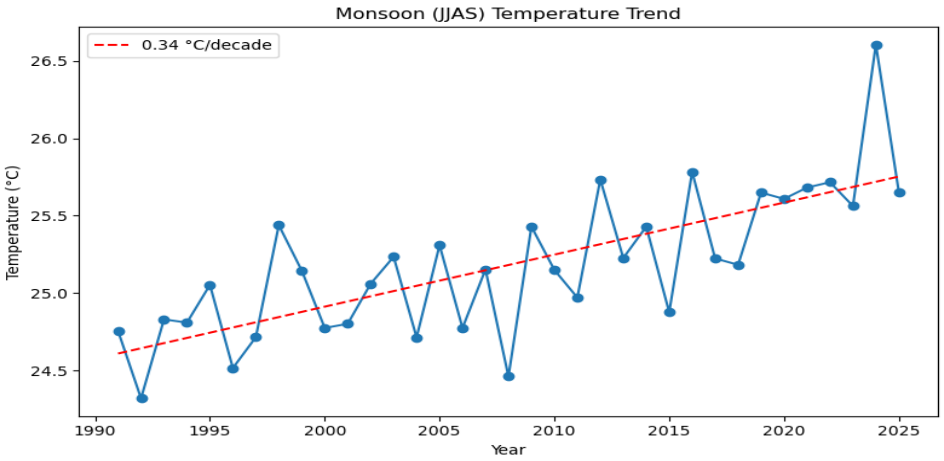


- Linear regression analysis of annual rainfall over Jammu during 1991–2025 indicates a marginal declining trend, with a decrease of approximately **1.82 mm per decade**. Although the magnitude of change is relatively small, the persistent negative tendency, combined with significant warming trends, suggests increasing hydro-climatic stress in the region.
- The simultaneous occurrence of rapid warming (+0.432 °C per decade) and a weak but persistent decline in rainfall (−1.82 mm per decade) points towards increasing climatic aridity in Jammu, potentially amplifying risks related to water scarcity, agricultural stress, and thermal discomfort.

However, this decrease is **not statistically significant**, which means rainfall varies a lot from year to year but does not show a clear long-term decline.

4.3 Seasonal Trends

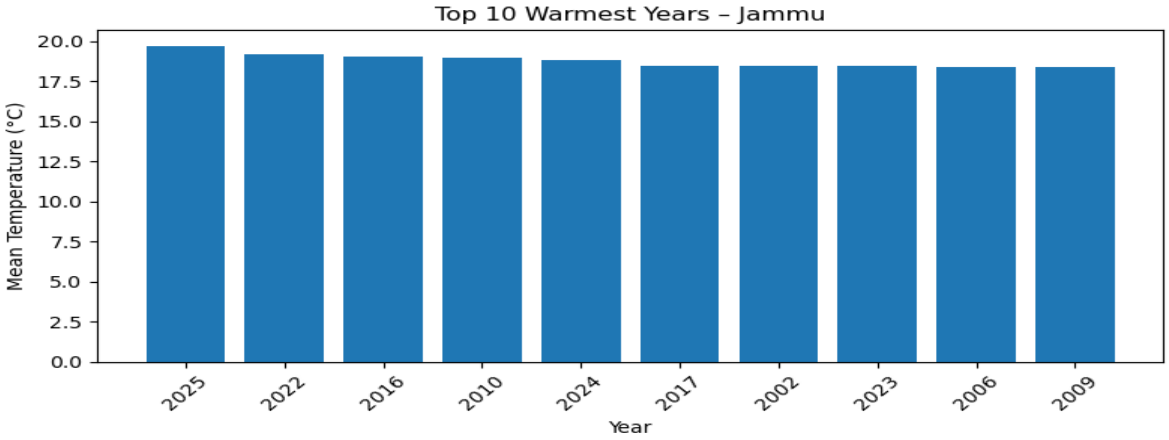
- **Monsoon temperature:** Increasing
- **Winter temperature:** Increasing
- **Monsoon rainfall:** No clear trend
- **Winter rainfall:** No clear trend



This shows that warming is happening in all seasons, but rainfall remains uncertain.

4.4 Extreme Years

- **Warmest years:** 2025, 2022, 2016, 2024
- **Driest years:** 2016, 2009, 2000, 2002



The frequent occurrence of extreme warm years in recent decades shows that climate stress is increasing.

4.5 Mann-Kendall and Sen Slope Estimators

Variable	Period	MK Trend	p-value	Sen's Slope	Interpretation
Mean Temperature	1991–2025	Increasing	4.31×10^{-5}	+0.0426 °C/year	Strong, significant warming
Rainfall	1991–2025	No trend	0.233	−0.175 mm/year	High variability, no significant change

The Mann–Kendall test reveals a statistically significant increasing trend in annual mean temperature over Jammu during 1991–2025 ($p = 4.31 \times 10^{-5}$). Sen's slope estimator indicates a warming rate of 0.0426 °C per year, equivalent to 0.426 °C per decade, demonstrating a pronounced and consistent rise in surface air temperature across the study period The coexistence of rapid and statistically significant warming with a non-significant but weakly declining rainfall tendency indicates increasing climatic stress in Jammu. Even in the absence of a strong rainfall trend, rising temperatures can intensify evapotranspiration, heat stress, and water demand, thereby exacerbating regional climate vulnerability.

5. DISCUSSION

The most important finding of this study is the **strong rise in temperature** in Jammu district. Even though rainfall has not changed much, rising temperature alone can create serious problems.

Higher temperature leads to:

- More evaporation from soil and water bodies
- Increased irrigation demand
- Reduced soil moisture
- Greater stress on crops and livestock

Seasonal warming is also worrying. During monsoon, higher temperature increases water needs of crops. In winter, warming can disturb wheat growth and increase pest problems.

When high temperature combines with dry years, the risk becomes even greater. This situation can reduce crop yields, increase water shortage, and affect rural livelihoods.

6. Implications for Agriculture and Water Resources

6.1 Agriculture

- Crop yields may decline due to heat stress.
- Traditional farming calendars may need change.
- Climate-resilient and heat-tolerant crops should be promoted.

6.2 Water Resources

- Water demand is increasing because of rising temperature.
- Even normal rainfall may not be enough.
- Efficient irrigation systems like drip and sprinkler irrigation are necessary.

6.3 Climate Adaptation

- District-level climate action plans are needed.
- Soil moisture conservation methods should be strengthened.
- Early warning systems for heatwaves and droughts should be improved.

7. CONCLUSION

This study clearly shows that **Jammu district is warming rapidly**. From 1991 to 2025, temperature has increased significantly, while rainfall has remained uncertain. The combination of rising temperature, frequent warm years, and occasional dry years indicates growing climatic stress.

These changes increase risks for agriculture and water resources. To protect future livelihoods, it is important to adopt climate-resilient farming practices, improve water management, and include climate planning in local development policies.

Long-term monitoring and local-level climate studies like this one are essential for building a safer and more sustainable future for Jammu district.

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