E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(8): 593-599
Received: 13-06-2025
Accepted: 15-07-2025

Kuldeep Singh
Ph. D. Scholar (Agro-meteorology and Environmental Sciences), Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Shradhha Rawat
Assistant Professor, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Kuldeep Singh
Ph. D. Scholar (Agro-meteorology and Environmental Sciences), Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

The influence of climate variability on temperature and precipitation patterns in Punjab

Kuldeep Singh and Shradhha Rawat

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8i.3606

Abstract
This study investigates the regional variations in temperature and precipitation across Punjab, India, and explores their implications for agriculture, environmental conditions, and socio-economic development. The analysis highlights significant disparities in both maximum and minimum temperatures (Tmax and Tmin) across the state's districts. Northern regions, such as Gurdaspur and Pathankot, experience cooler temperatures, while southern districts, including Malerkotla, report notably higher Tmax values. Precipitation patterns show considerable variability, with the northern districts, like Pathankot, receiving higher rainfall, while southern areas such as Bathinda and Fazilka face lower rainfall levels, contributing to more semi-arid conditions. These findings emphasize the importance of developing region-specific agricultural strategies, particularly in the drier southern regions where efficient water management practices and irrigation systems are essential. While temperature patterns across Punjab remain relatively stable, the unpredictability of precipitation presents challenges, such as the risks of both drought and flooding. Therefore, tailored climate adaptation strategies are crucial for ensuring sustainable agricultural practices and fostering long-term socio-economic resilience across the state.

Keywords: Regional climate variation, temperature, precipitation, climate adaptation, drought, flood risks

1. Introduction
Punjab, a state in northern India, exhibits a climate that is both complex and shaped by its varied geography. The region, while predominantly temperate, also experiences elements of both semi-arid and subtropical climates, which differ substantially across its districts. This diversity arises from the juxtaposition of the arid Thar Desert to the southwest and the fertile plains of the Indo-Gangetic region. Such geographical variation has a profound impact on the state's agricultural practices, water resources, and the livelihoods of its communities.

The climate of Punjab is significantly influenced by the southwest monsoon, which occurs between June and September. During this period, the state receives the bulk of its annual rainfall. However, the distribution and intensity of rainfall are not uniform, resulting in significant regional disparities. For instance, districts located in the central and southern parts of the state, such as Bathinda and Mansa, tend to experience relatively lower rainfall and face challenges related to water scarcity. In contrast, the northern and northeastern regions, such as Amritsar and Pathankot, benefit from higher and more consistent rainfall. These differences in precipitation are pivotal in determining the viability of various agricultural practices, with some areas more conducive to crop cultivation than others.

Temperature variations further complicate the climate of Punjab. Summers can be intensely hot, with temperatures often exceeding 40°C, particularly in districts like Faridkot and Ferozepur. Conversely, winter temperatures in certain regions of the state can drop as low as 2°C, especially in the plains and areas bordering the foothills of the Himalayas. These extreme temperature fluctuations present challenges for agriculture, as crops require specific climatic conditions to thrive. In addition, the changing temperature patterns influence water consumption, energy demand, and the general comfort of the population, making the state's climate a key factor in daily life.

In recent years, Punjab has increasingly felt the effects of climate change. Rising temperatures, irregular rainfall patterns, and the frequency of extreme weather events—such as droughts,

floods, and unseasonal rains—pose growing risks to agricultural productivity and, by extension, the state's economy. These changing conditions threaten the stability of traditional farming methods and complicate water resource management. As such, it is crucial to better understand the state's climate variability and to develop strategies that address these emerging challenges, ensuring that Punjab can adapt and build resilience in the face of climate change.

2. Methodology

2.1 Study area: Punjab, located in the northern region of India, spans latitudes 29°30'N to 32°32'N and longitudes 73°55'E to 76°50'E, covering an area of about 50,000 square kilometers. The state's landscape is predominantly composed of the fertile alluvial plains of the Indo-Gangetic region, but it also includes a variety of geographic features that create distinct regional differences. To the west, the plains of the Ravi and Sutlej rivers define the terrain, while the northeast is influenced by the foothills of the Shivalik range. The southern regions merge into the arid zones of Rajasthan, and the eastern parts of Punjab are shaped by its river systems, which enrich the landscape and contribute to the state's agricultural productivity.

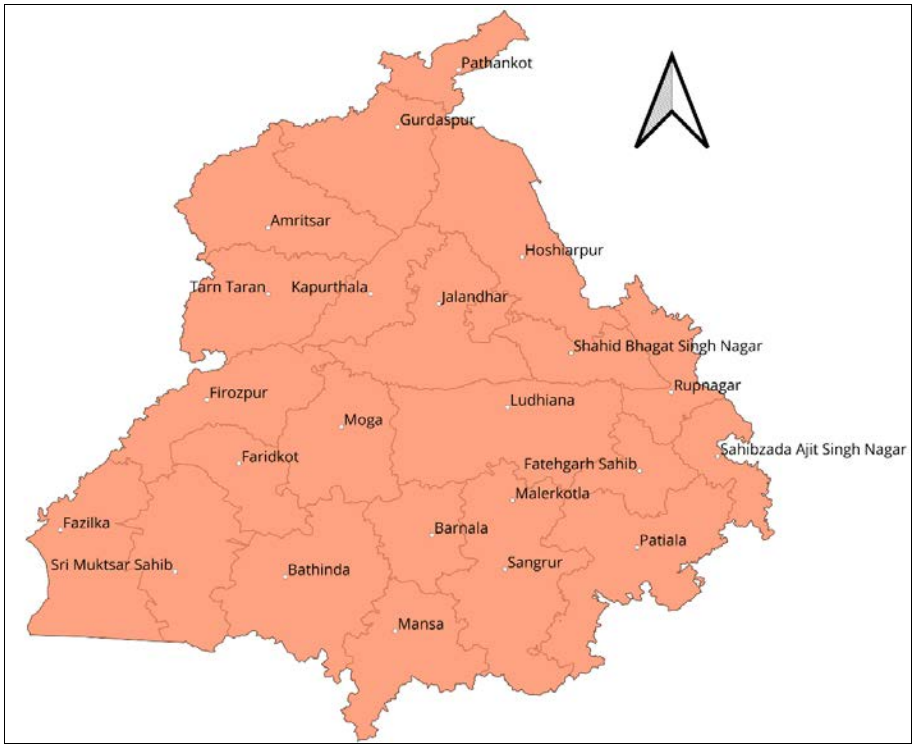

Fig 1: Study Area

2.2 Data Collection

For this research, we used IMD Gridded data of temperature and rainfall from 1980 to 2023 for 23 districts of Punjab. To understand how the climate has behaved over time. We observed at two key temperature measures the maximum (Tmax) and minimum (Tmin) temperatures recorded each day, as well as the total annual precipitation (rainfall) in millimeters.

2.3 Statistical Analysis

To better understand the data, we calculated a few key statistical measures:

- **Mean:** This gives us the average temperature and rainfall for each district.
- **Standard Deviation (SD):** This tells us how much the data fluctuates around the average. High SD means a lot of variation, while low SD means more stability.
- **Coefficient of Variation (CV):** By dividing the SD by the mean, we get a relative measure of variability. It's especially useful when comparing districts with different types of data like temperature vs. precipitation. These measures helped us see where the climate is stable and where it fluctuates dramatically.

3. Results and Discussion

3.1 Temperature Patterns

The average maximum temperatures (Tmax) across Punjab in Fig. 2 reveals significant regional variations, influenced by the state's geography and climatic zones. The northern districts, such as Amritsar, with a Tmax of 30.68 °C, exhibit moderate warmth, typical of the cooler regions of the state. These areas experience relatively milder summer temperatures compared to their southern counterparts. Barnala (30.74 °C), situated in the central part of Punjab, shows slightly higher temperatures, indicating a shift towards the warmer conditions that are more prevalent in the southern districts.

The southern regions of Punjab experience much higher temperatures, with districts such as Bathinda, Faridkot, Fazilka, Firozpur, and Sri Muktsar Sahib reporting Tmax values of 30.99 °C. These areas experience some of the highest temperatures in the state, especially during peak summer months, due to their location in the southern part of Punjab, which is more exposed to heat. The district Malerkotla stands out with the highest Tmax value of 31.43 °C, making it the hottest district in the state. This can be attributed to its positioning in the southern belt, where the climate is markedly hotter than in northern regions.

In contrast, the northern districts of Gurdaspur and Pathankot experience relatively cooler temperatures, with Tmax values of 26.26°C. These areas benefit from a milder climate, which is a characteristic of the northern region of Punjab. The cooler temperatures in these districts are likely due to their proximity to

the foothills of the Himalayas, which provide some climatic relief from the intense heat experienced in other parts of the state. Similarly, Shahid Bhagat Singh Nagar (26.9 °C) falls into the cooler category, though it experiences slightly warmer temperatures than Gurdaspur and Pathankot.

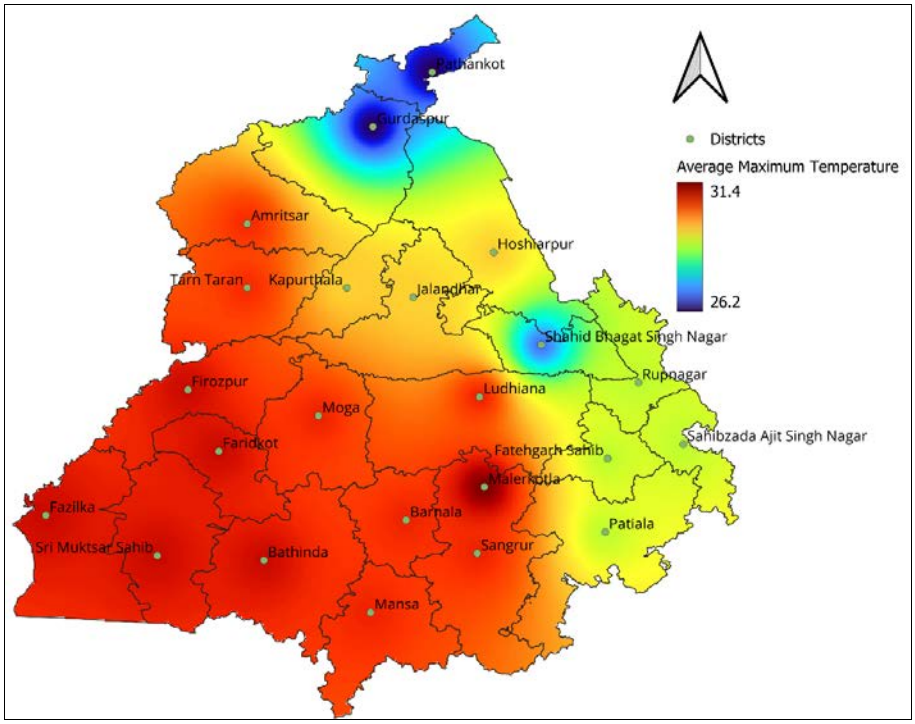

Fig 2: Average Maximum Temperature of Punjab

Central districts such as Hoshiarpur, Jalandhar, and Kapurthala experience more moderate temperatures, with Tmax values 29.64 °C. These districts, situated in the transitional zone between the cooler north and the hotter south, exhibit more balanced temperature conditions, providing relatively comfortable climates during the summer. Ludhiana (30.74 °C), Mansa (30.74 °C), and Moga (30.74 °C) also experience moderate temperatures, typical of central Punjab. While these areas are warmer than the northern regions, they do not experience the extreme heat of the southern districts. Patiala (28.86 °C), Rupnagar (28.86 °C), and Sahibzada Ajit Singh Nagar (28.86 °C) exhibit cooler temperatures compared to the southern districts but are still warmer than the northern regions. These districts, which are centrally located, benefit from a more temperate climate, though they do experience warmer temperatures than the cooler northern parts of Punjab.

Overall, Malerkotla emerges as the hottest district, with the highest Tmax of 31.43 °C, while Gurdaspur and Pathankot represent the cooler extremes, with a Tmax of 26.26 °C. The central and northern parts of Punjab, including districts such as Amritsar, Ludhiana, Jalandhar, and Kapurthala, experience moderate temperatures, while the southern districts such as Fazilka, Firozpur, and Bathinda endure the highest Tmax values, contributing to the extreme heat conditions during summer. This temperature variation plays a crucial role in shaping the agricultural, environmental, and socio-economic patterns across Punjab.

Minimum Temperature: The Tmin (minimum temperature) of Punjab demonstrates notable regional variations in nighttime temperatures across its districts in Fig.3. The coolest districts, Gurdaspur and Pathankot, record the lowest Tmin values of 13.14 °C, indicating that these areas experience the coldest nights in the state. In contrast, Malerkotla stands out with the highest Tmin of 17.35 °C, making it the warmest district in terms of minimum temperatures and reflecting relatively mild nighttime conditions. A significant portion of the state, including districts like Bathinda, Faridkot, Fazilka, Firozpur, and Sri Muktsar Sahib, records Tmin values of 16.92 °C, which points to a generally warm climate at night. Other districts, such as Mansa, Moga, and Ludhiana, follow closely with Tmin values of 16.74 °C, suggesting similarly warm temperatures during the nighttime.

Districts such as Fatehgarh Sahib, Patiala, Rupnagar, and Sahibzada Ajit Singh Nagar report slightly cooler Tmin values of 16.02 °C, positioning them among the more moderate areas of the state. Similarly, Hoshiarpur, Jalandhar, and Kapurthala exhibit Tmin values of 16.25 °C, indicating a moderate climate, though slightly warmer than the previously mentioned districts.

The data further reveals geographic patterns in Tmin values, with northern regions generally experiencing cooler temperatures, while the southern districts are warmer. For example, Shahid Bhagat Singh Nagar records a Tmin of 14.17 °C, reflecting slightly cooler conditions than most other districts. Additionally, Amritsar and Tarn Taran both exhibit Tmin values of 16.52 °C, which situates them within the moderate range of temperatures, comparable to many central Punjab districts. The Tmin data for Punjab highlights a range of temperatures across the state, from the cooler northern districts to the warmer southern regions. While the majority of districts experience moderate to warm temperatures, regional differences suggest distinct climatic conditions that vary by geography, contributing to the overall diversity of Punjab's climate.

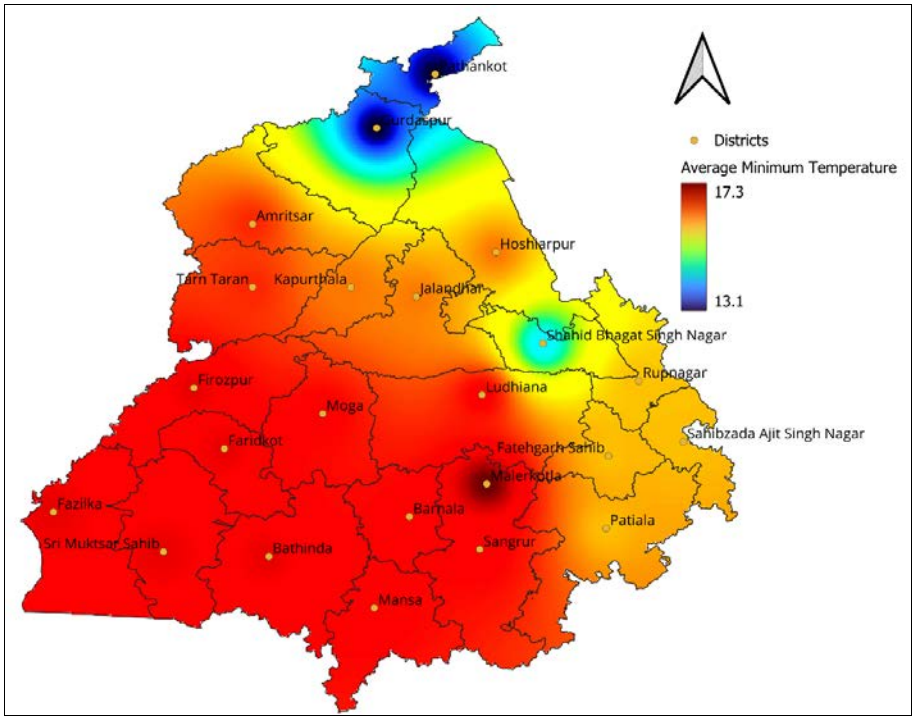

Fig 3: Average Minimum Temperature of Punjab

3.2 Precipitation Patterns

The Average precipitation of Punjab reveals considerable regional variation in Fig.4, which has important implications for agriculture across the state. Pathankot emerges as the wettest district, receiving 1350.33 mm of precipitation. This high level of rainfall supports a fertile agricultural environment, where a wide variety of crops can thrive without significant dependency on irrigation. Sahibzada Ajit Singh Nagar and Hoshiarpur, with 1192.75 mm and 1105.54 mm of precipitation respectively, also experience high rainfall, creating similarly favorable conditions for crop production. These districts benefit from consistent rainfall, which plays a key role in sustaining the agricultural activities that are central to the region's economy.

In contrast, some districts, such as Bathinda (332.97 mm) and Fazilka (325.75 mm), experience significantly lower precipitation. These areas are characterized by semi-arid conditions, where water availability is a major concern for agricultural productivity. The scarcity of rainfall in these regions means that irrigation systems are essential for crop growth, and agriculture is more vulnerable to water shortages. Malerkotla and Sri Muktsar Sahib, with precipitation levels of 392.71 mm and 402.65 mm respectively, also receive relatively low rainfall, contributing to their drier climate and further emphasizing the need for effective water management.

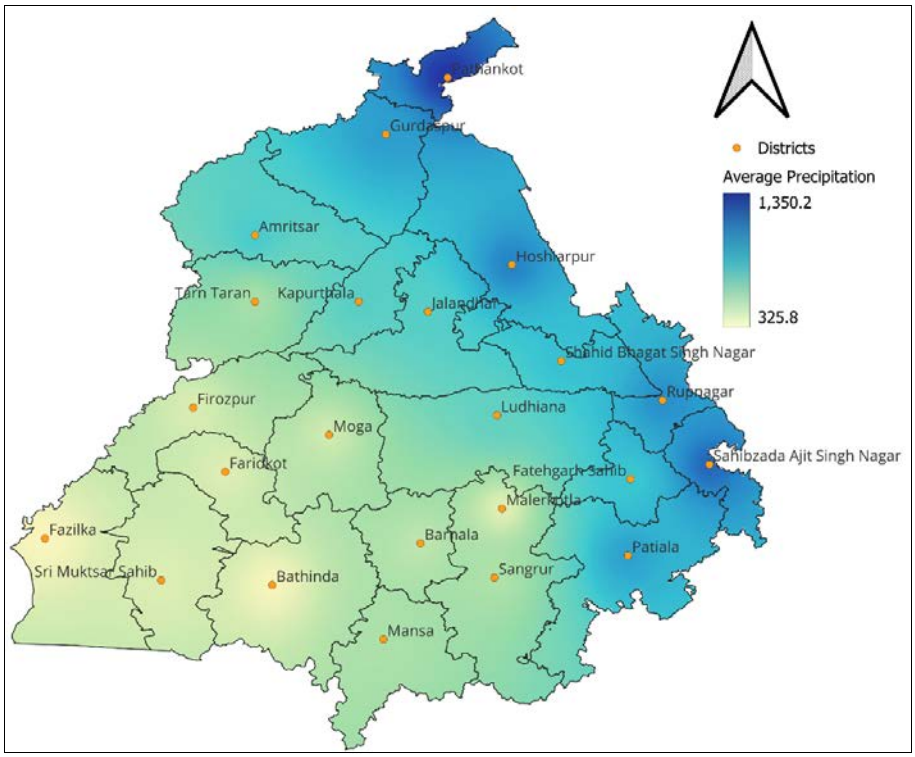

Fig 4: Average precipitation of Punjab

On the other hand, districts like Amritsar (789.55 mm), Ludhiana (725.72 mm), Mansa (521.45 mm), and Tarn Taran (533.73 mm) receive moderate levels of precipitation, which allows for stable agricultural conditions. While these districts are not as wet as the northern regions, their rainfall is sufficient to support a variety of crops, though irrigation might still be necessary during drier periods. The variation in precipitation across Punjab illustrates a clear divide between the wetter regions, which benefit from more reliable rainfall, and the drier southern and western districts, which face challenges related to water scarcity. This variation underscores the importance of tailored agricultural strategies, with more water-efficient techniques and irrigation systems being crucial in the drier areas, while the wetter regions can focus on optimizing crop yields through sustainable farming practices.

3.4 Long term variability of temperature and precipitation of Punjab

The climate Statistics for Punjab's districts reveal significant variability in both temperature and precipitation patterns in table 1, with distinct trends observed across the region. Maximum temperatures (Tmax) range from 26.3 °C in Pathankot and Gurdaspur to 31.4 °C in Mansa, with the majority of districts exhibiting average Tmax values between 28.9 °C and 31. 0°C. The data shows minimal variability in Tmax, as indicated by the low standard deviation (SD) of approximately 0.5 °C to 0.6 °C, suggesting that maximum temperatures remain relatively stable throughout the year. Furthermore, the coefficient of variation (CV) for Tmax is low, ranging from 1.9% to 2.4%, indicating consistent and moderate fluctuations in Tmax across the state.

In contrast, minimum temperatures (Tmin) across the districts generally range between 13°C and 16.9°C, with district such as Mansa showing slightly higher Tmin values around 17.4°C. Similar to Tmax, the variation in Tmin remains low, with a standard deviation of around 0.5°C. However, the CV for Tmin is somewhat higher, ranging from 2.0% to 3.5%, suggesting that minimum temperatures exhibit slightly more variability throughout the year, especially during colder months.

Precipitation patterns, however, demonstrate considerable variability. Rainfall ranges from 325.8 mm in Fazilka to 1350.3 mm in Pathankot, with most districts experiencing an average annual precipitation between 400 mm and 1000 mm. This marked variability indicates unpredictable rainfall patterns across Punjab. The SD for precipitation is high, ranging from 127.7 mm in Shri Mukhtar Sahib to 528 mm in Pathankot, reflecting substantial year-to-year fluctuations. The CV for precipitation is also elevated, varying from 24.8% to 55.3%, further highlighting the significant variation in rainfall. This suggests that some districts are more prone to drought due to low and inconsistent rainfall, while others face heightened flood risks during periods of excessive rainfall. temperature patterns in Punjab show relative stability, precipitation exhibits considerable unpredictability, resulting in a climate characterized by both drought and flood risks.

Table 1: Variability of temperature and precipitation of Punjab (1980-2023)

Districts	Tmax Mean	SD	CV	Tmin Mean	SD	CV	Precipitation Mean	SD	CV
Amritsar	30.7	0.6	2.0	16.5	0.5	2.7	789.5	227.2	28.8
Barnala	30.7	0.6	2.0	16.7	0.5	2.8	481.5	190.8	39.6
Bhatinda	31.0	0.6	1.9	16.9	0.5	2.8	333.0	144.4	43.4
Faridkot	31.0	0.6	1.9	16.9	0.5	2.8	402.2	141.0	35.1
Fatehgarh sahib	28.9	0.6	2.0	16.0	0.5	3.0	824.9	286.5	34.7
Fazilka	31.0	0.6	1.9	16.9	0.5	2.8	325.8	161.0	49.4
Firozpur	31.0	0.6	1.9	16.9	0.5	2.8	416.8	221.4	53.1
Gurdaspur	26.3	0.6	2.4	13.1	0.5	3.5	994.4	286.8	28.8
Hoshiarpur	29.6	0.6	2.0	16.3	0.5	2.9	1105.5	276.4	25.0
Jalander	29.6	0.6	2.0	16.3	0.5	2.9	758.2	247.7	32.7
Kapurthala	29.6	0.6	2.0	16.3	0.5	2.9	752.9	278.3	37.0
Ludhiana	30.7	0.6	2.0	16.7	0.5	2.8	725.7	250.6	34.5
Mansa	31.4	0.6	2.0	17.4	0.5	2.8	392.7	288.3	55.3
Melar Kotla	30.7	0.6	2.0	16.7	0.5	2.8	521.4	159.3	40.6
Moga	30.7	0.6	2.0	16.7	0.5	2.8	439.8	187.8	42.7
Pathankot	26.3	0.6	2.4	13.1	0.5	3.5	1350.3	528.1	39.1
Patiala	28.9	0.6	2.0	16.0	0.5	3.0	986.3	244.2	24.8
Rupnagar	28.9	0.6	2.0	16.0	0.5	3.0	1054.4	273.0	25.9
Sahibzada Ajit singh Nagar	28.9	0.6	2.0	16.0	0.5	3.0	1192.7	303.1	25.4
Sangrur	30.7	0.6	2.0	16.7	0.5	2.8	512.6	187.3	36.5
SBS Nagar	26.9	0.6	2.2	14.2	0.5	3.2	851.2	303.1	35.6
Shri mukhtar sahib	31.0	0.6	1.9	16.9	0.5	2.8	402.7	127.7	31.7
Tara Taran	30.7	0.6	2.0	16.5	0.5	2.7	533.7	224.3	42.0

4. Conclusion

The climate patterns across Punjab exhibit considerable regional variation, which significantly influences the state's agricultural, environmental, and socio-economic dynamics. The temperature data reveals distinct trends, with the northern districts, such as Gurdaspur and Pathankot, experiencing cooler conditions due to their proximity to the Himalayan foothills. These areas tend to have milder maximum and minimum temperatures compared to the southern districts, which are more exposed to heat, particularly in regions like Malerkotla. Malerkotla records the highest Tmax value of 31.43°C, making it the hottest district in the state.

Precipitation patterns across the state are similarly diverse. Northern districts like Pathankot receive the highest rainfall, fostering fertile agricultural conditions and reducing dependency on irrigation. In contrast, the southern districts, including Bathinda and Fazilka, face significantly lower rainfall, with amounts falling below 400 mm annually. These areas experience semi-arid conditions, where irrigation plays a vital role in sustaining agricultural productivity. Such discrepancies in rainfall necessitate tailored agricultural strategies, especially in the drier regions, where water-efficient practices are crucial to

mitigating the effects of water scarcity.

The overall climate analysis highlights that while temperature variations across Punjab are relatively stable, precipitation is much more unpredictable, resulting in an increased risk of both droughts and floods in different regions. This climatic variability underscores the importance of developing region-specific strategies to address the challenges posed by these environmental conditions. Such strategies are not only vital for agricultural sustainability but also for long-term socio-economic development in the region.

5. Acknowledgement

The authors would like to extend their gratefulness to the Agronomy Department, at the Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh for providing the resources that were required to conduct the study.

6. References

1. Azhar G, Saha S, Ganguly P, Mavalankar D, Murtugudde R, Godfrey S, *et al*. Heat wave vulnerability mapping for India. Int J Environ Res Public Health. 2017;14:1–17.
2. Chauhan AS, Singh S, Singh RK, Maurya RKS, Danodia A. Spatio-temporal analysis of rainfall in relation to monsoon teleconnections and agriculture at regional scale in Haryana, India. Reg Environ Change. 2023;30(55):116781–116803.
3. Kumar A, Jain SK, Singh V, Singh P, Singh M, *et al*. Rainfall trend, variability and changes over the state of Punjab, India. Weather Clim Extremes. 2021;31:100313.
4. Kumar P, Kumari P. A study on climate change scenario in Haryana: Trends, impacts, and adaptation strategies. Int J Multidiscip Res. 2024;6(4):1–7.
5. Kumar V, Niwas R, Kh ML. Influence of climatic variability on rainfall of western region of Haryana. Int J Res Agron. 2024;7(7):585–588.
6. Rahul, Mishra RP, Negi BS. A study on climate change scenario in Haryana. Int J Agric Ext Soc Dev. 2024;7(9):299–309.
7. Rohini P, Rajeevan M, Srivastava AK. On the variability and increasing trends of heat waves over India. Sci Rep. 2016;6:26153.
8. Sharma CS, Panda SN, Pradhan RP, Singh A, Kawamura A. Precipitation and temperature changes in eastern India by multiple trend detection methods. Atmos Res. 2016;180:211–225.
9. Singh A, Kumar R, Sharma P. Assessment of climate variability impacts on agriculture in Haryana. Res Sq [Preprint]. 2023. Available from: https://doi.org/10.21203/rs.3.rs-3125893/v1