THE CURIOSITY CUP 2025

A Global SAS® Student Competition

"Melting Winters, Shifting Seasons: Tracking 50 Years of Climate Change in the UK"

"DATA NINJAS"

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ABSTRACT

The UK's climate has undergone significant transformations over the past five decades, with rising temperatures, changing seasonal patterns, and increasingly unpredictable rainfall trends. This study analyzes historical weather data from 1974 to 2024 to identify key climate trends and uses SARIMA time-series forecasting to predict changes up to 2050. The results indicate a continued rise in maximum and minimum temperatures, leading to warmer summers, milder winters, and fewer frost days. Sunshine hours are expected to increase, reinforcing longer growing seasons, while rainfall remains variable, with a high likelihood of extreme wet events persisting. These shifts are reshaping agriculture, ecosystems, and weather stability in the UK. By linking past climate trends with future projections, this study provides valuable insights into the trajectory of the UK's climate, highlighting the long-term changes that will shape its environment, economy, and way of life in the coming decades.

INTRODUCTION

Imagine a UK where winters are barely cold, spring arrives too soon, and summers stretch longer than ever. Snowfall is becoming rare, frost days are vanishing, and rainstorms are growing more intense. These changes aren't predictions, they're already happening. Over the past 50 years, UK temperatures have steadily risen, seasons have shifted, and extreme weather events have increased. But what does this mean for the future? Using decades of historical climate data, this study uncovers key trends shaping agriculture, ecosystems, and daily life. By forecasting conditions until 2050, we aim to provide a clearer understanding of how these shifts may evolve. For the UK, a warming climate brings both challenges and unexpected opportunities, from increased flood risks to the potential of becoming a rival to France in wine production (Seasonal shift: Climate change causing a shift in seasons). Climate change isn't just a global issue; it's reshaping Britain's landscape, economy, and way of life right now.

PROBLEM STATEMENT

The UK's climate is changing faster than expected, with winters growing shorter and rainfall patterns becoming more erratic. These shifts don't just affect temperatures, they reshape entire seasons, disrupt ecosystems, and challenge industries like agriculture and infrastructure. While warming trends and extreme weather events are widely discussed, how much has the UK's climate changed, and what does the future hold? Understanding these long-term trends is critical for planning, adaptation, and preparing for a future where British weather may look very different from the past.

METHODOLOGY

The methodology involves analyzing UK climate data (1974–2024) to identify long-term trends and forecast future conditions. Data preprocessing and feature engineering were applied for trend analysis. For forecasting, SARIMA modeling was used, chosen for its ability to capture seasonality and long-term trends. In depth Exploratory Data Analysis, modeling, and forecasting were carried out using SAS Viya for Learners, SAS Visual Analytics, Excel, Python (for data wrangling and statistical modeling)

DATA PREPARATION

Ensuring high-quality data is essential for accurate climate analysis, as is the precision of the steps taken to clean, refine, and enhance the dataset for meaningful insights.

DATA OVERVIEW

The UK Historic Station Dataset, sourced from the Met Office, originally covered 37 weather stations (1853–2024). However, due to station closures and missing values, the dataset was refined to 32 stations covering 1974–2024 to ensure data consistency and reliability. The dataset provides monthly climate records, including - Maximum and minimum temperature (°C), Total rainfall (mm), Sunshine duration (hours), Air frost days (count per monthWe chose station data over the grid dataset because the latter only offers monthly 30-year averages (1991–2020) and lacks recent data or extreme weather events. In contrast, station data provides yearly and monthly climate records, enabling us to analyze long-term trends (1974–2024), track shifting seasonal patterns, and assess the increasing frequency of extreme rainfall events, key to understanding the UK's evolving climate. Key climate indicators such as frost days and sunshine duration which are essential for analyzing seasonal changes are only available in station data.

DATA CLEANING AND PRE-PROCESSING

Reliable climate trend analysis depends on data integrity, consistency, and completeness. However, the dataset initially contained missing values, non-standardized recordings, and station closures, which could bias assessments. To ensure accuracy, extensive data cleaning and preprocessing were conducted. Originally, 37 stations were included, but five, such as Chivenor and Cwmystwyth, were removed due to prolonged missing data (≥10 years) or station closures that caused gaps between 1974 and 2025. Data before 1974 was excluded due to inconsistencies, ensuring a reliable dataset of 32 stations (Eischeid, Bruce Baker, Karl, & Diaz, 1995). Short-term missing values were filled using station-specific averages, preserving local climate trends (Barrios, Trincado, & Garreaud, 2018). Sunshine duration was historically measured using Campbell-Stokes recorders but switched to Kipp & Zonen sensors in the 2000s. Since these instruments measure sunshine differently, the Met Office applies corrections to standardize newer data. In our dataset, 83% of records come from Campbell-Stokes and 17% from Kipp & Zonen sensors. While we retain raw values, minor variations in long-term trends may exist. With a clean and standardized data set, we can now apply feature engineering techniques to extract meaningful insights, transforming raw climate data into structured variables for trend analysis.

FEATURE ENGINEERING

To better understand how the UK's climate is changing, we created new features from raw weather data. A growing season length feature was added to measure how long the frost-free period lasts, helping track seasonal shifts. We calculated last spring frost and first autumn frost to see if winters are shortening. Extreme rainfall frequency was tracked by selecting the top 10% wettest events each year to see if heavy rain is becoming more common, which helps assess flood risks. Date column was created to structure the data for time-series analysis, while a season column categorized data into winter, spring, summer, and autumn. Average temperature was introduced to track overall climate trends, and latitude & longitude were added to allow regional climate comparisons (Norris & Clair, n.d.).

CLIMATE TRENDS & ANALYSIS

Long-term climate trends highlight the gradual transformation of UK seasons.

UK WINTERS ARE MELTING AWAY

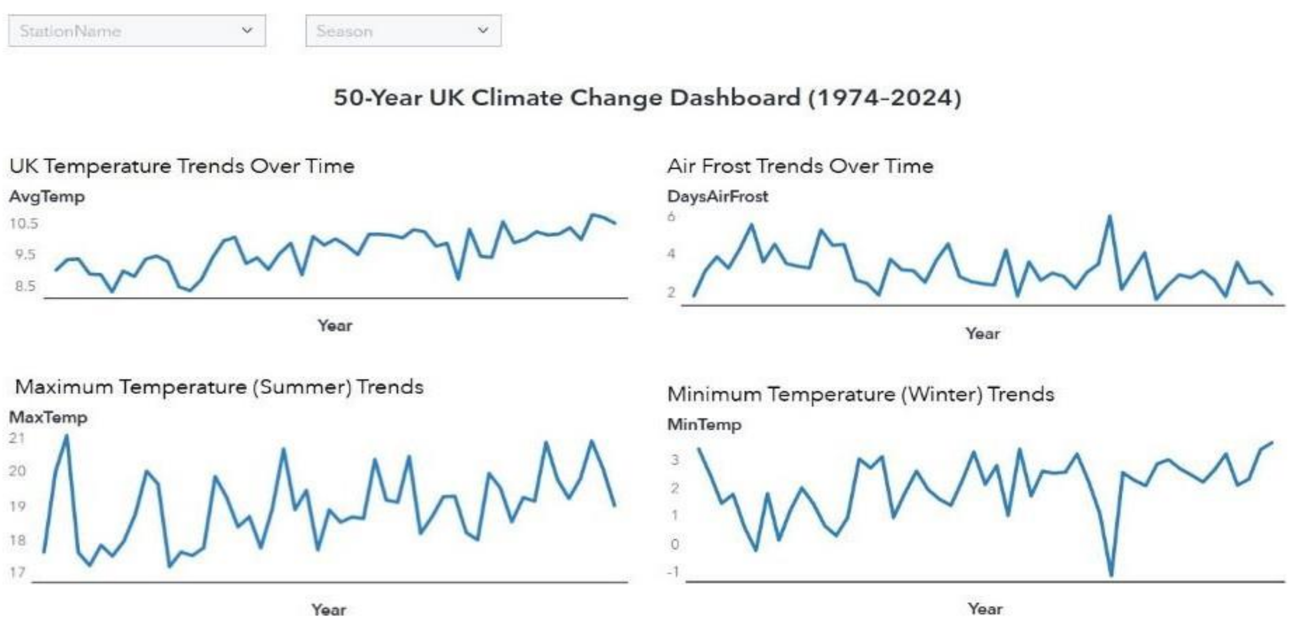


Figure 1: Trends in UK Climate (1974–2024): Evidence of Milder and Shorter Winters

This UK winter has warmed significantly over the past 50 years. The average winter UK winters have warmed significantly over the past 50 years. The average winter temperature has risen from ~8.99°C in the 1970s to ~10.50°C in the 2020s, an increase of ~1.51°C. Statistical analysis confirms a steady warming trend of ~0.031°C per year. Minimum temperatures have also increased, reducing extreme cold events. Additionally, frost days per year have declined from ~3.65 in the 1970s to ~2.48 in the 2020s, suggesting shorter winters.

These findings align with broader climate research, which estimates UK winters have warmed by ~1°C over the past century (Tandon, 2024). While occasional extreme cold events, such as the Big Freeze of 2010, still occur, the overall trend remains clear. UK winters are steadily becoming milder and shorter, with long-term changes shaping the country's climate.

WINTERS ARE ON BORROWED TIME AS SPRING ARRIVES EARLIER

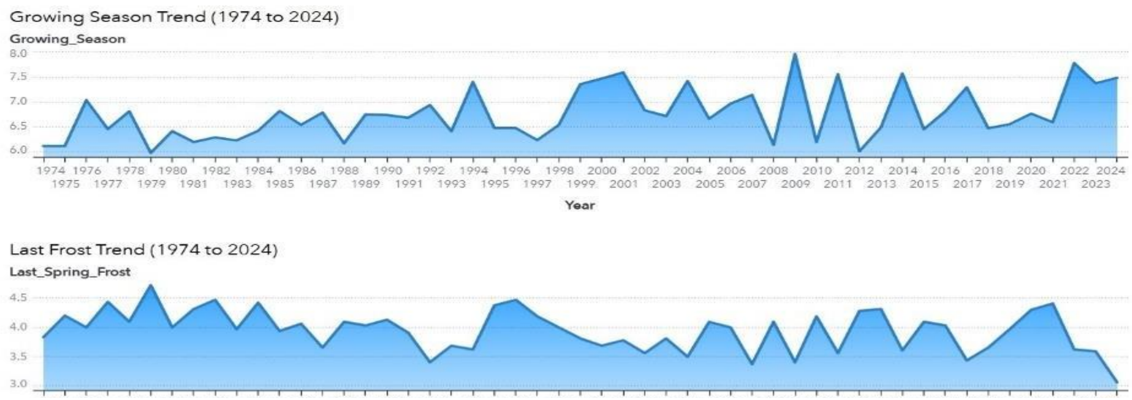
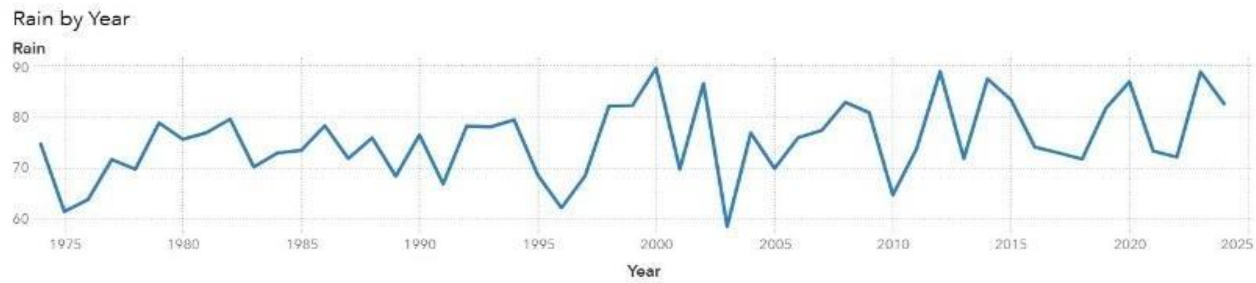


Figure 2: Trends in Growing Season Length and Last Spring Frost (1974–2024)

Spring in the UK is not shifting later; it is arriving earlier. Analysis of last recorded spring frost dates (1974–2024) shows a consistent trend of earlier frost endings, shifting approximately 11 days earlier over 50 years (-0.0073 months per year). The earliest last frost occurred in 2024, while the lastest was in 1979. This shift has contributed to a growing season that has lengthened by ~22 days, confirming earlier spring onsets and extended summers.

These changes align with observed shifts in seasonal markers, such as earlier tree blooming and butterfly emergence, reported in recent studies (Signs of spring have sprung earlier than usual in recent years - but it's not all good news, 2024). At the same time, the first autumn frost is occurring later, reinforcing that winters are shortening rather than spring being delayed. Ecological research further supports this, showing that plants and wildlife are adjusting their seasonal behaviours in response to these earlier conditions (Beale, 2022).

WHEN IT RAINS IT POURS AND IT IS POURING LIKE NEVER BEFORE



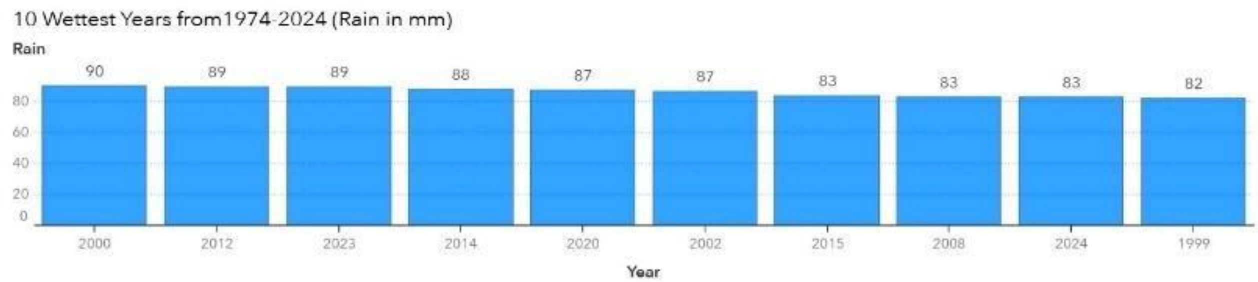


Figure 3: Increasing Rainfall Trends and the UK's Wettest Years (1974–2024)

Analysis of UK rainfall data from 1974 to 2024 confirms a statistically significant increase in extreme rainfall events. The wettest years mostly occurred after 2000, with 2000, 2012, 2023, 2014, and 2020 among the highest. Average annual rainfall has risen from ~70.12 mm in the 1970s to ~80.80 mm in the 2020s, a +10.68 mm increase. A t- test ($p = 0.039$) confirms that this trend is statistically significant, meaning the increase is real and not random. Rainfall has also become more unpredictable, with the 2000s showing the highest variability (9.05 mm standard deviation).

Our findings align with Met Office reports, which show UK rainfall increased by 9% since 1961-1990 (Office, UK and global extreme events – heavy rainfall and floods, n.d.), and extreme wet days have risen by 20% in recent decades (Temperature extremes and records most affected by UK's changing climate, n.d.). This confirms that climate change is driving heavier, more erratic rainfall, increasing flood risks and the need for climate adaptation in the UK.

FORECASTING & CLIMATE IMPACT

FORECASTING

The SARIMA model was used to forecast UK climate variables—maximum temperature, minimum temperature, sunshine hours, days of air frost, and rainfall—until 2050. SARIMA was chosen over Simple Exponential Smoothing (SES) because it accounts for both long-term trends and seasonality, making it more suitable for climate data.
The forecast indicates a steady rise in temperatures, with summer highs reaching 18-20°C and winter lows increasing to 5-7°C by 2050. This suggests warmer summers and milder winters, continuing the historical warming trend. Sunshine hours are expected to increase, reinforcing longer summers, while frost days will continue to decline, reducing the frequency of extreme cold events. Rainfall forecasts remain uncertain, showing continued fluctuations rather than a consistent increase or decrease. However, given past variability, extreme rainfall events could persist, leading to potential flooding risks. These projections align with observed trends, reinforcing expectations of warmer, longer summers and milder winters with ongoing climate variability. The results provide a data-driven outlook on future weather conditions, helping inform climate planning and adaptation strategies in the UK.

THE HEAT IS ON AND SO ARE OUR CLIMATE RECOMMENDATIONS

The analysis confirms a warming trend in UK temperatures, with summer highs projected to reach 18-20°C and winter lows rising to 5-7°C by 2050. This aligns with historical patterns, suggesting a continued shift toward warmer summers, shorter winters, and fewer frost days. These changes may reduce cold-related disruptions but could also present challenges for agriculture, biodiversity, and energy demand as temperature extremes become more frequent. A longer growing season and earlier springs may benefit certain crops but could also disrupt natural ecosystems, altering plant blooming cycles and wildlife migration patterns. Such shifts might influence food production and ecological stability in ways that require further study. While rainfall trends remain highly variable, past data suggests that extreme wet years could persist, potentially affecting flood risks and water resource management. As climate patterns continue to evolve, further research on how these trends impact urban infrastructure, natural ecosystems, and seasonal resource planning may help in anticipating future challenges. Understanding these shifts will be crucial for ensuring long-term environmental and economic resilience in the UK.

CONCLUSION

The analysis of UK climate trends from 1974 to 2024, combined with SARIMA-based forecasting until 2050, confirms a clear warming pattern. Both maximum and minimum temperatures are projected to rise, leading to hotter summers and milder winters. The decline in frost days and the shift toward earlier springs indicate shorter winters and longer growing seasons. While rainfall trends remain variable, the historical increase in extreme wet events suggests that flood risks and weather unpredictability may persist. The increase in sunshine hours further reinforces the expectation of longer, warmer summers.
Although these forecasts provide valuable insights, additional data on crop yields, natural disasters, energy consumption, and biodiversity changes would improve predictions and help assess wider environmental and economic impacts. The consistency between past trends and forecasts highlights the long-term shift in the UK's climate, emphasizing the need for informed strategies to manage and adapt to these changes in the coming decades.

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APPENDIX

1. THE INTERACTIVE DASHBOARD

This interactive drill-down dashboard allows users to explore UK-wide or station-specific weather trends across different years and months. It provides insights into temperature, sunshine, rainfall, and frost days, enabling flexible analysis of seasonal and regional variations. While not part of EDA or Forecasting, this tool serves as an appendix resource for deeper exploration of historical climate patterns.

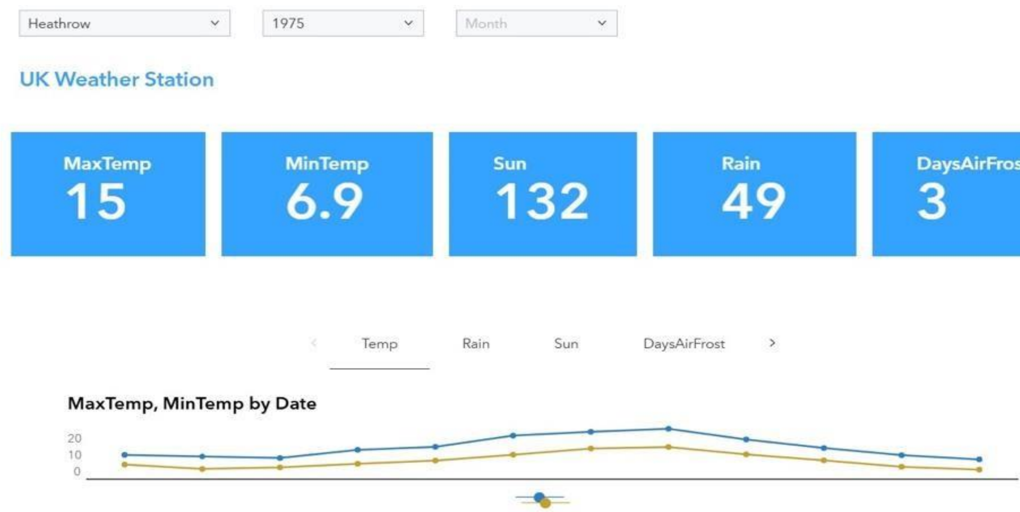

Figure 4:Interactive Climate Dashboard: Explore UK Weather by Station & Year

2. REGIONAL CLIMATE VARIATIONS ACROSS THE UK

This map illustrates regional climate variations across the UK, with bubble sizes representing rainfall intensity and colors indicating temperature trends.

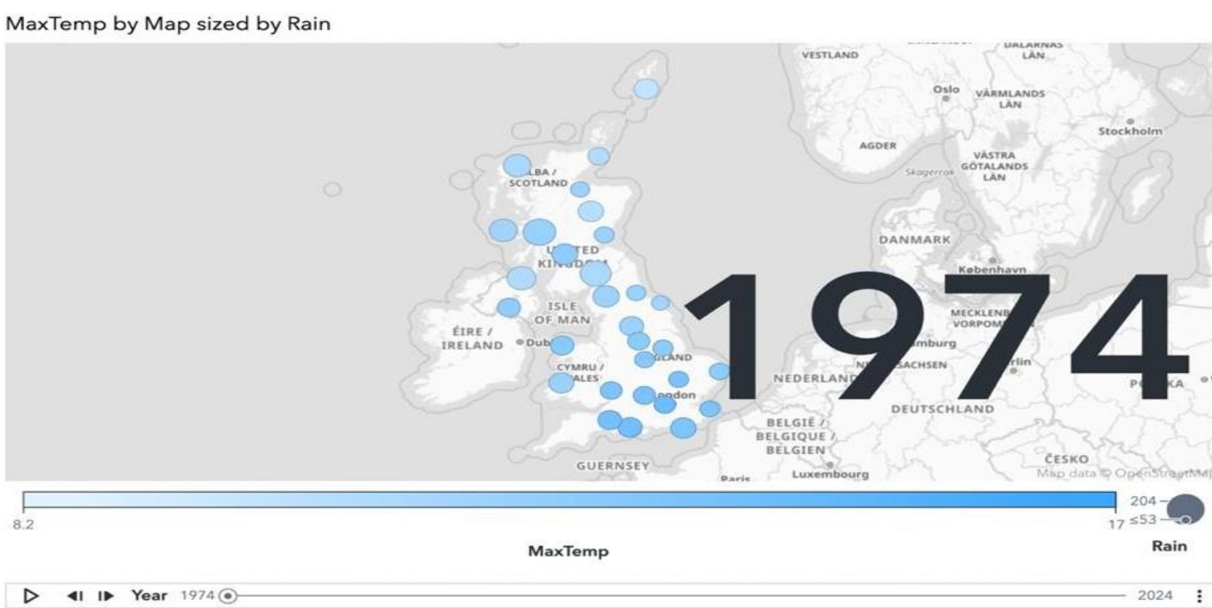

Figure 5: From Past to Present - UK Climate Data Across Regions.

3. ASSUMPTIONS, LIMITATIONS AND RECOMMENDATIONS

Assumption	Limitation	Recommendation
Past Trends Can Predict Future Climate	Climate can change unexpectedly due to extreme events.	Use models that consider unexpected climate shifts.
Climate Change Happens Gradually	Some changes can be sudden, not slow, and steady.	Test models that detect sudden shifts in climate.
SARIMA is the Best Forecasting Method	SARIMA assumes seasonality is fixed, but real patterns change.	Compare with other models (e.g., ARIMA, LSTM) for better accuracy.
Rainfall Trends Are Clear	Rainfall is highly unpredictable, making patterns hard to track.	Use detailed rainfall models to study extreme wet events.
UK-Wide Trends Apply Everywhere	Some areas warm faster than others.	Study regional climate trends separately.
Short-Term Climate Extremes Were Not Modeled	Floods, storms, and droughts are not covered in long-term forecasting.	Future research should focus on extreme events.
Sunshine Recording Has Been Consistent	Measuring methods changed over time, which could affect long-term trends.	Make sure sunshine data is adjusted correctly across different years.

4. STATISTICAL CLIMATE INSIGHTS

Statistical Measure	Purpose	How It Answers Our Research Questions?	Key Findings
Regression Slope (°C per year)	Measures the rate of temperature change over time.	Confirms long-term warming trends in maximum, minimum, and average winter temperatures.	UK winters warmed by ~0.031°C per year, with average temperatures rising from ~8.99°C (1970s) to ~10.50°C (2020s).
R^2 (Coefficient of Determination)	Assesses how well time explains climate change trends.	Shows the strength of temperature and frost day trends over time.	Winter temperature trend R^2 = 0.541 (moderate-strong correlation). Frost trends had weaker R^2 (~0.129), indicating variability in seasonal shifts.
p-value (Significance Test)	Confirms if detected trends are statistically significant ($p < 0.05$).	Determines if rainfall increases are real or just random fluctuations.	p = 0.039 for rainfall trends, confirming that extreme rainfall events have increased significantly over the decades.
Standard Deviation (mm, °C, days)	Measures variability in rainfall, temperature, and frost patterns.	Identifies whether extreme rainfall is becoming more erratic over time.	Rainfall showed the highest fluctuations in the 2000s (SD = 9.05 mm), reinforcing evidence of increasing extreme wet years.
Extreme Rainfall Frequency (% of Top 10% Wettest Years in Each Decade)	Measures whether heavy rain events are becoming more frequent.	Identifies if the wettest years are clustering more in recent decades.	Most of the top 10% wettest years occurred after 2000, confirming a rise in extreme rainfall.