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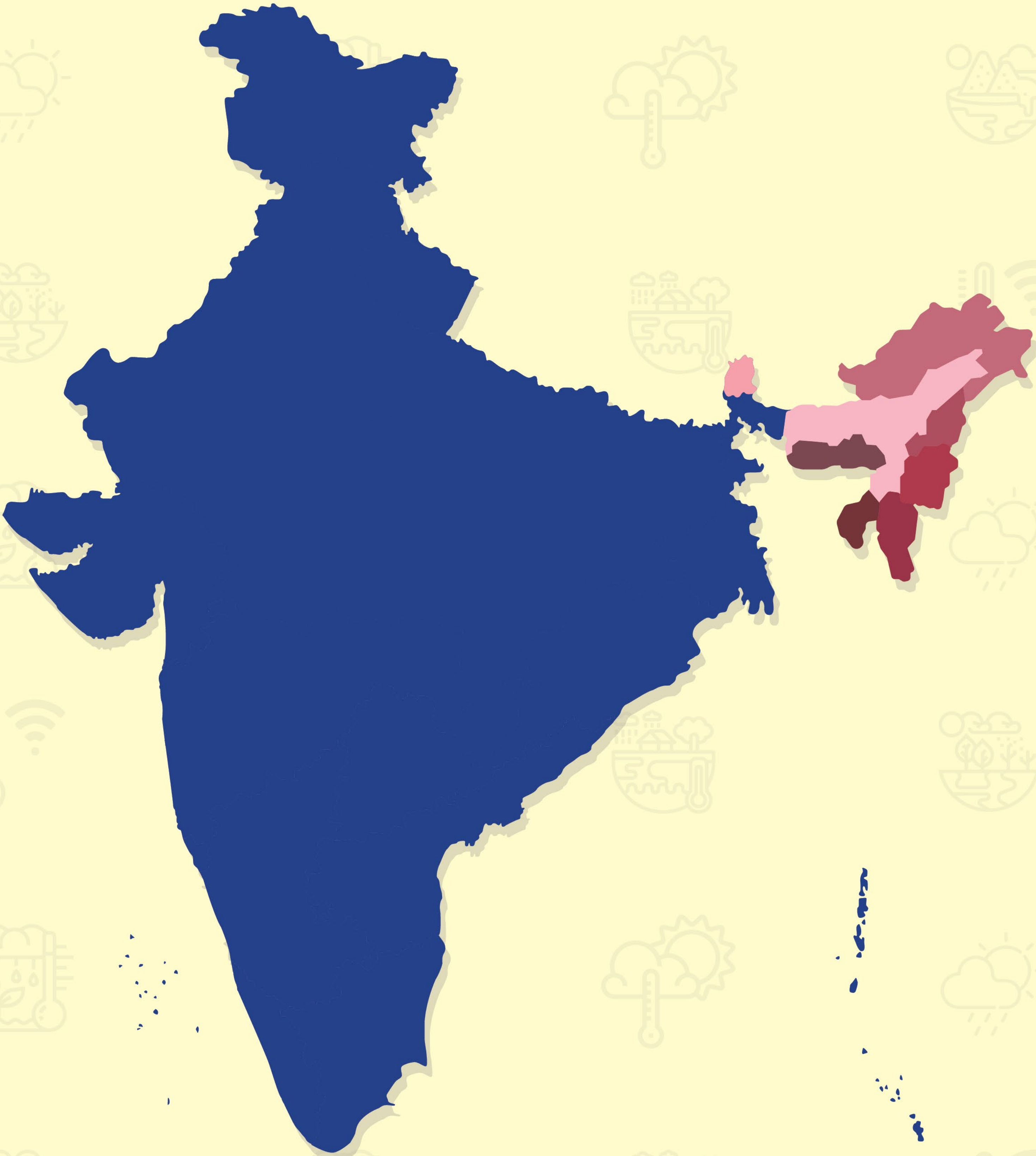
DISTRICT-LEVEL CHANGES IN CLIMATE:

HISTORICAL CLIMATE AND CLIMATE CHANGE PROJECTIONS FOR THE NORTH-EASTERN STATES OF INDIA



District-Level Changes in Climate: Historical Climate and Climate Change Projections for the North-Eastern States of India

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CSTEP

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Executive Summary

Background and motivation: The impacts of climate variability, climate change, and extreme events are visible globally and in India. The Global Climate Risk Index 2021 ranks India seventh, considering the extent to which India has been affected by the impacts of weather-related loss events (storms, floods, heatwaves, etc.). The index signals that the repercussions of escalating climate change are exacerbating and can no longer be ignored. The Government of India and state governments are committed to reducing the vulnerability of communities and ecosystems to climate change and building resilience to climate change risks. A good understanding of the historical climate trends and climate change projections at a district scale is essential in this endeavour as much of the decision-making, planning, and implementation happens at the district level.

Objective: This study analyses the historical climate and projects the temperature and rainfall of the eight north-east Indian states: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura.

Methodology: Historical climate analysis and climate change projections have been made at a district level for the eight north-east states of India. Historical climate analysis for the recent 30-year period (1990–2019) and climate change projections for the 2030s (2021–2050) have been made using the India Meteorological Department (IMD) data and CORDEX model outputs. Climate change projections for summer maximum and winter minimum temperatures, kharif season rainfall projections and rainfall variability (coefficient of variation), the occurrence of heavy rainfall events (51–100 mm/day and >100 mm/day), and rainfall deficient years (<20% of long period average rainfall) have been analysed under two representative concentration pathways (RCP): RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. The findings from this study on future climate in the 2030s are presented as change compared to the historical period for all the districts of north-east India.

Findings: Historically, temperature and rainfall have increased, and rainfall variability is high across all the north-eastern states. Climate change projections indicate an overall warming of both summer and winter minimum temperatures, an increase in the number of rainy days (>2.5 mm rainfall/day), and an increase in the number of heavy rainfall events across almost all the districts of the north-eastern states. Rainfall variability shows mixed trends, and rainfall deficient years are projected to decline.

Temperature

The summer maximum and the winter minimum temperature are projected to increase in all the districts of north-east India. The summer maximum temperature is projected to increase largely by 1^{0}C to 1.5^{0}C under the RCP 4.5 scenario and 1^{0}C to 2^{0}C under the RCP 8.5 scenario. The winter minimum temperature is projected to increase largely by 1^{0}C to 1.5^{0}C under the RCP 4.5 scenario and 1^{0}C to 2^{0}C under the RCP 8.5 scenario in a majority of the districts of north-east India.

Rainy days

The number of rainy days is projected to increase in the 2030s in almost all the districts of north-east India compared to the historical period. The increase is by 1 to 24 days under the RCP 4.5 scenario, with the maximum increase projected in Sikkim and a minimum increase in Assam. The increase is by 1 to 22 days under the RCP 8.5 scenario, with the maximum increase projected in Sikkim.

Monsoon rainfall

Rainfall during kharif (June to September) and rabi (October to December) seasons are projected to increase in the 2030s in almost all the districts of north-east India compared to the historical period. The projected increase in the kharif season rainfall is by 3%–10% under the RCP 4.5 scenario and 6%–19% under the RCP 8.5 scenario. The maximum increase in the kharif season rainfall is projected in the districts of Manipur. The rabi season rainfall is projected to increase by 4%–19% under the RCP 4.5 scenario and 3%–49% under the RCP 8.5 scenario.

Rainfall variability

The variability (coefficient of variation) of both kharif and rabi season rainfall shows largely a decline in the 2030s across the districts of north-east India compared to the historical period. Mixed trends in rainfall variability during the kharif season are projected in the districts of Assam, Manipur, and Nagaland under the RCP 4.5 scenario and only in Manipur under the RCP 8.5 scenario.

Heavy rainfall events

An increase in high-intensity (51–100 mm/day) and very high-intensity (>100 mm/day) rainfall events is projected in the 2030s across all the districts of north-east India compared to the historical period. The increase in high-intensity rainfall events per annum is by one to four events under the RCP 4.5 scenario and one to five events under the RCP 8.5 scenario. The increase in very high-intensity rainfall events is largely by one to two events under the RCP 4.5 scenario and one to three events under the RCP 8.5 scenario.

Rainfall deficient years

A decline in rainfall deficient years is projected in the 2030s across almost all the districts of north-east India compared to the historical period. The decline in rainfall deficient years is by 1 to 4 years out of 30 years under the RCP 4.5 scenario and 1 to 5 years under the RCP 8.5 scenario in the various districts of north-east India.

Discussion: It is evident from the study that in the future, climate in the districts of north-east India will be different from the historical climate. This has implications for water availability and management, agriculture, forest and biodiversity, health, and infrastructure. It also underpins the need for integrated strategies to combat multiple hazards, floods due to heavy rainfall or dry spells and droughts at other times.

Recommendations: The district-level climate change assessment for the north-eastern states provides an understanding of the historical climate and climate projections for the 2030s. States need to integrate this information into the State Action Plans on Climate Change, which are currently under revision. Additionally, states need to formulate plans and strategies based on climate risk assessments, which account for climate hazards, vulnerability, and exposure. Instituting studies to map climate risks will contribute to climate preparedness and help the states buffer the loss and damage likely to be incurred from extreme climate events.

Contents

1. Introduction

Climate change results in higher temperatures, intense rainfalls, and an increase in the frequency of extreme weather events—floods, droughts, and heatwaves (IPCC, 2014). It has already impacted communities, livelihoods, and infrastructure and is projected to worsen in the coming years and decades.

The Intergovernmental Panel on Climate Change (IPCC; 2021) defines *climate* in a narrow sense as 'the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years.' *Climate variability* is defined by the IPCC as 'deviations of climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events.'

So far, the bulk of the efforts, as well as investments, have focused on mitigation to address climate risks. This is because mitigation is believed to have global benefits, while adaptation is seen to address local problems that need to be tackled by individual countries. India is already facing and is likely to face severe climate-related hazards, and given our vulnerabilities, the impacts may be dire. Adaptation has not received the same degree of attention as mitigation in India. Currently, India's adaptation initiatives are typically embedded in development programmes across a range of sectors. Adaptation needs to be addressed in a bottom-up manner, progressing from the local level to the national level. Adaptation strategies need to be implemented at the local, regional, and national levels because climate hazards and impacts vary in nature and severity across regions. Consequently, the capacity to manage and deal with incidents differs across populations, regions, and economic sectors. The lack of a comprehensive strategy and ground-level efforts is a serious drawback in the fight against climate change in India. Data on climate variability and change at different temporal and spatial scales would definitely aid in formulating implementable mitigation and adaptation measures.

Climate models are valuable tools as they provide the required information on changes in climate over different temporal and spatial scales.

1.1 Why model climate outputs?

Scientists use climate models to understand complex interactions between various components of the Earth system. These models are an extension of weather forecasting models, and they simulate the climate of our planet on decadal to centennial timescales. Specifically, they can project changes in average conditions over the coming decades for a region and help determine whether the predicted changes are climate variations or the result of imposed changes such as changes in land-use pattern and increase in greenhouse gases, aerosols, and land-use change. Climate models provide crucial information for the adaptation and mitigation of climate change. Simulations and predictions of climate models help us understand the consequences of not reducing emissions. They help us foresee what is at stake, what might be lost, and the cost of inaction when viewed from different regional and sectoral perspectives.

Climate models also inform climate adaptation strategies. Detailed, location-specific climate information can protect infrastructure by ensuring that it is robust enough to withstand climate change impacts in location, construction, and management.

1.2 The need for district-level climate model outputs

Climate data gathering at the district level is essential for risk planning, developing coping strategies, and adaptation. To frame climate change policies, data on the impacts of climate change across different spatial and temporal scales and sectors are needed. For assessing the impacts of climate change on a sector, for instance, on crops such as rice, wheat, maize, millet, and pulses, there is a need to consider the variations in climate and the multiplicity of conditions under which they are grown. This is because different approaches are adopted for growing a particular crop in different regions based on climate and traditional practices.

Similarly, assessing the impact of climate on health requires data on temperature and rainfall extremes, and fisheries requires data on rainfall, sea level, salinity, and so forth. The demand for climate information at different scales is multifold. Further, the State Action Plans on Climate Change are being revised. These require climate information to be presented and plans prepared, taking into consideration the projected changes in climate. In this context, data on district-level changes in temperature and precipitation find utility. They can be the basis for State Action Plans on Climate Change (SAPCC) and assessing climate risks and impacts on different sectors, regions, and communities. This directly feeds into the information needed for developing adaptation strategies.

This report is intended for the use of state- and district-level government officials, policymakers, and non-specialists. It, therefore, avoids extensive scientific and technical details and statistical analysis. The report presents critical information on changes in temperature and rainfall with the aim of sensitising and building awareness on climate change. The focus is on the short-term period (2021–2050) at a district level to aid decision-making in the short term, thus providing a valuable resource to the state- and district-level planners and development administrators.

2. Methodology

The study analyses historical climate information and projects climate for a future period using climate models. The data sources, models, climate scenarios, and methods are presented in this segment.

2.1 Historical climate analysis

Two key climate variables, temperature and rainfall, have been analysed. Gridded daily datasets for grids of 0.25° x 0.25° (~25 km X 25 km) for rainfall (Pai et al., 2014) and 1.0°x 1.0° (~100 km X 100 km) daily temperature datasets (Srivastava et al., 2009) for temperature from the Indian Meteorological Department (IMD) have been used. The present-day or historical data span 30 years, from 1990 to 2019.

Temperature has been analysed for the summer season (March to May) and the winter season (December to February). The occurrence of heatwaves has also been analysed for this 30-year period.

Heatwaves: Heatwaves—based on the departure from the normal temperature—have been computed following the IMD's criteria[1]. The IMD declares a heatwave when the departure from the normal temperature is 4.5°C to 6.4°C. A severe heatwave is declared when the departure from the normal temperature is >6.4°C.

Rainfall has been analysed for the kharif season (June to September) and the rabi season (December to February). During these two seasons, the variability of rainfall has also been analysed by computing the coefficient of variation (CV). Additionally, the number of rainy days, heavy rainfall events, and rainfall deficient years have been analysed.

Rainy day: A *rainy day*, according to the IMD, is defined as any day receiving >2.5 mm rainfall.

Heavy rainfall events: Based on the amount of rainfall received per day (in mm) during the kharif season, heavy rainfall events have been analysed considering three categories:

- Low-intensity rainfall: Less than 50 mm/day
- High-intensity rainfall: 51–100 mm/day
- Very high-intensity rainfall: More than 100 mm/day

Rainfall deficient years: Considering the total quantum of rainfall received during the kharif season, rainfall deficient years have been analysed. Following the criterion defined by IMD[2], years that receive <20% of rainfall, compared to the long period average of rainfall during the kharif season, are categorised as rainfall deficient years.

[1]https://internal.imd.gov.in/section/nhac/dynamic/FAQ_heat_wave.pdf
[2]https://mausam.imd.gov.in/imd_latest/monsoonfaq.pdf

2.2 Climate change projections

Climate science is continuously advancing as groups involved in modelling worldwide are constantly updating and incorporating better spatial resolution, new physical processes, and biogeochemical cycles. The Coupled Model Intercomparison Projects (CMIP) is a forum where different modelling groups coordinate. The fifth assessment report (AR5) of the IPCC featured the fifth generation of CMIP—the CMIP5. In India, the high-resolution regional climate modelling work of CMIP5 is coordinated by the Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology, Pune.

CCCR provides high resolution downscaled projections for different climate scenarios under the Coordinated Regional Climate Downscaling Experiment (CORDEX) South Asia programme. The CORDEX regional models are driven by data from the atmosphere-ocean coupled general circulation model runs conducted under the CMIP5 (Taylor et al., 2012) for the representative concentration pathway (RCP) scenarios.

In this study, CORDEX model outputs were used for projecting temperature and rainfall at the district level. An ensemble mean from 15 bias-corrected CORDEX South Asia simulations was used for making climate change projections. The IPCC recommends the use of ensemble means for achieving more reliable and quantitative information on future climate compared to a single model run.

- Model resolution: 0.5° x 0.5° grid resolution (~50 km x 50 km)
- Time period: Short term (2021–2050), referred to as the 2030s
- Climate scenarios: Moderate emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5)

All data in this analysis were first re-gridded to a common 0.25° x 0.25° (~25 km x 25 km) resolution, which is the resolution of historical rainfall data from the IMD. Changes in temperature and rainfall during the projected period were computed as the difference between the model-simulated ensemble average of the projected 30-year period (2021–2050) and the 30-year historical period (1990–2019).

District-level averages of climatic variables were prepared using outputs from the re-gridded data. The mean value for a district was obtained by considering the mean of multiple grid points that might cover a district. Only grid points that fall fully within a district or those with at least 60% of the area falling within a district were considered for computing the mean. If a district fell within only one grid cell, then that single grid cell value was used for analysis. All the analyses were performed using these district means, using gridded (latitude–longitude) information of the districts.

Temperature projections: Summer maximum (March to May) temperature, potentially causing heat stress, and winter minimum (December to February) temperature, critical for human comfort and winter crops, were analysed. The changes during the projected period (2021–2050) under the two climate scenarios, relative to the historical period (1990–2019), were analysed.

Heatwaves: As the incidence of heatwaves is typically limited to a few districts, the analysis of heatwaves was done for a few selected districts, using the historical record of heatwaves in a state. The criterion defined by the IMD, described in Section 2.1, was adopted, and the change during the projected period, relative to the historical period, was computed.

Rainfall projections: The number of rainy days, the magnitude of rainfall during the kharif and rabi seasons, heavy rainfall events, and rainfall deficient years were analysed, and changes, compared to the historical period (1990–2019), are presented. Rainfall variability was also computed for the projected period, and changes relative to the historical period are presented.

The projected climate (2021–2030) was compared with the historical climate (1990–2019) to estimate the magnitude of climate change. This is aligned with the World Meteorological Organization's approach—the use of 30-year averages for representing the climatology of the present-day (1990–2019) and short term (2021–2050)[3]. This is unlike the United Nations Framework Convention on Climate Change (UNFCCC) and IPCC reports, where a comparison of the projected climate is with pre-industrial periods.

2.3 Limitations of the study

In this report, we have provided climate change projections for RCP 4.5 (moderate emissions) and RCP 8.5 (high emissions) scenarios to provide a range of possibilities. The results presented in this report are likely to have some uncertainty because of the coarse resolution of the projected climate change data, which is derived from CORDEX data at 0.5° x 0.5° resolution. This resolution is inadequate for decision-making at a farm, village, or sub-watershed level but adequate for decision-making at the district level. Further, since we have not downscaled this data to a finer resolution, the sub-grid variability within the 0.5° x 0.5° resolution grid is not captured in the analysis, which is likely to introduce some uncertainty. However, the direction of changes in temperature, rainfall, and extreme events are largely in agreement with the literature at the global, South Asia, and national levels.

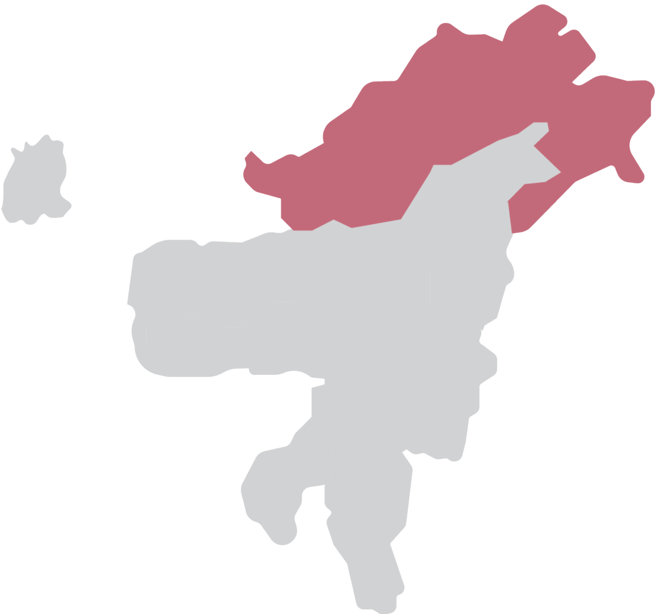
2.4 The organisation of the report

This report is for the north-eastern states of India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. The state chapters are organised as follows:

- Historical trends in temperature and rainfall
- Climate change projections at the district level, in the form of spatial maps and graphs
- Summary of projected changes in temperature and rainfall
- Key highlights at the district level of temperature, rainfall, and extreme events as tables in the Appendix

[3]https://public.wmo.int/en/media/news/new-two-tier-approach-%E2%80%9Cclimate-normals%E2%80%9D

3. Arunachal Pradesh



Arunachal Pradesh is situated in the eastern-most part of India, which is why it is also known as the land of the rising sun. Arunachal Pradesh shares its domestic borders with Assam and Nagaland to the south and its international borders with Myanmar to the east, Bhutan to the west, and China to the north and north-east. It is the largest state among the north-eastern states, with a geographical area of 83,743 sq. km and a population of 1.38 million as per the 2011 Census. Of the total population, close to 77.06% live in rural areas. Arunachal Pradesh is rich in natural resources and has 25 districts.

The state is vulnerable to all major natural hazards (drought, flood, cyclone, earthquake, landslides, fires, etc.). It receives a very high average annual rainfall of 2500–3000 mm. Floods and landslides in the state occur largely due to the prevailing hydrometeorological, geomorphologic, and topographical features and diminishing forest cover, resulting in erosion of fertile agriculture/horticulture fields.

These characteristics make Arunachal Pradesh climate-sensitive, underpinning the need for climate information. Climate data could serve as a basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

3.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

3.1.1 Trends in temperature

Arunachal Pradesh has recorded a moderate warming of 0.16°C to 0.27°C in the summer maximum temperature and 0.15°C to 0.33°C in the winter minimum temperature during the historical period. Figure 3-1 presents the mean summer maximum and winter minimum temperatures in Arunachal Pradesh during the historical period.

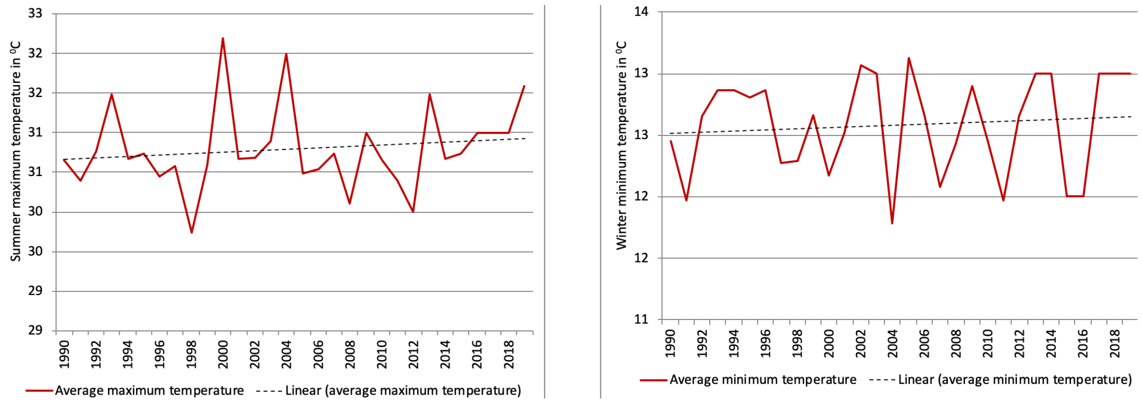


Figure 3-1: Mean summer maximum and winter minimum temperatures in Arunachal Pradesh during the historical period (1990–2019)

3.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual and kharif season rainfall, the main monsoon season, was recorded across all the districts of Arunachal Pradesh during the historical period. The increase in the annual rainfall was in the range of 5%–10% in a majority of the districts, and the increase in the kharif season rainfall was 10%–15% in all the districts during this period. Figure 3-2 presents the mean annual rainfall in Arunachal Pradesh during the historical period.

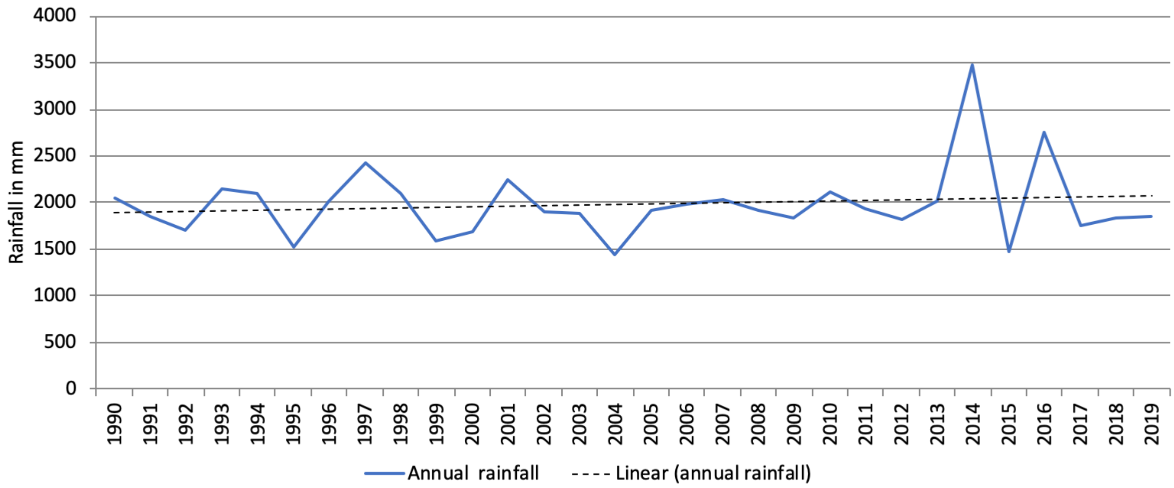


Figure 3-2: Mean annual rainfall in Arunachal Pradesh during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 13% in Lohit to 70% in Tawang (Figure 3-3). The rabi season rainfall variability was in the range of 36% in Lohit to 75% in West Siang, indicating a complete failure of rainfall during the historical period (Figure 3-3).

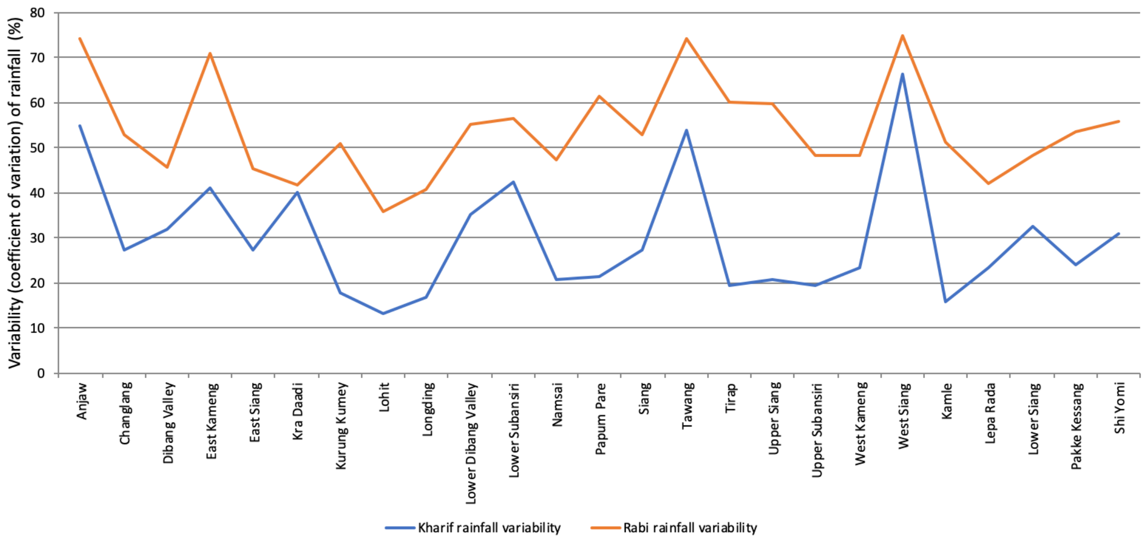


Figure 3-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

3.2 Climate change projections

Temperature and rainfall have been projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

3.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Arunachal Pradesh are presented in Figure 3-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by 1°C to 2°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

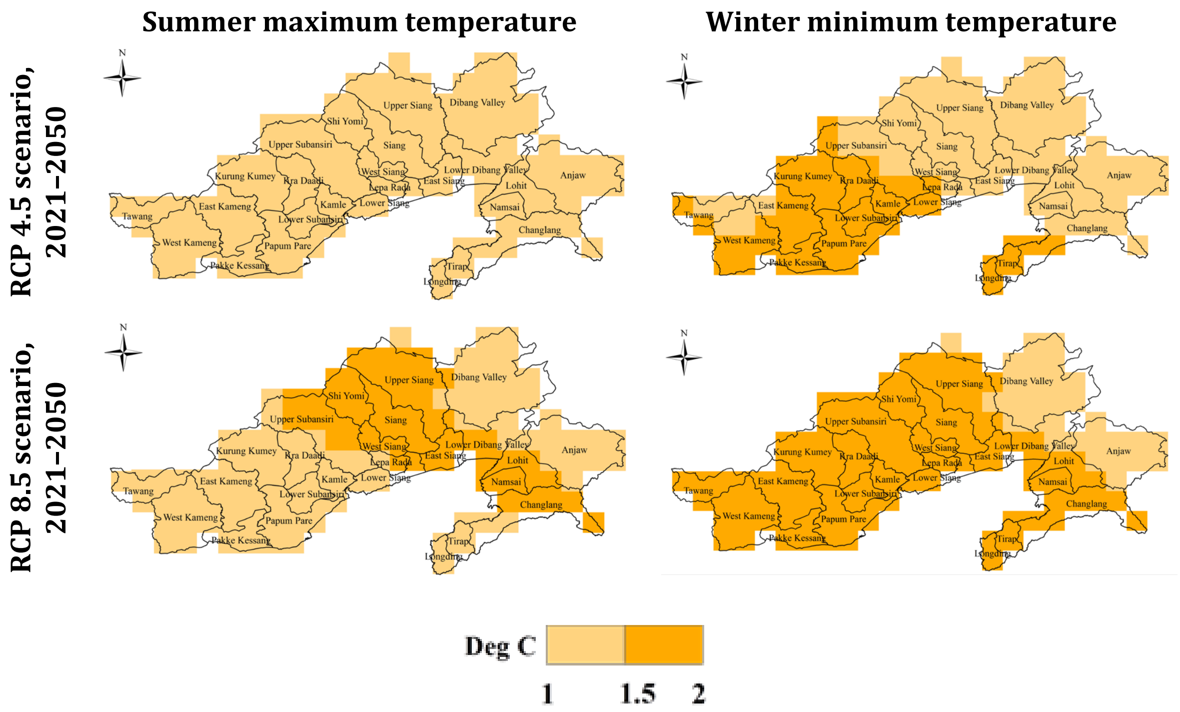


Figure 3-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

3.2.2 Rainfall projections

3.2.2.1 *Number of rainy days*

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 3-5). The number of rainy days during the historical period and the projected 2030s under RCP 4.5 and 8.5 scenarios is presented in Appendix 3-3. The total number of rainy days that ranged from 1495 to 2670 days over the 30-year historical period increases to 1568 to 2747 days under the RCP 4.5 scenario and 1677 to 2789 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 1 to 8 days annually in all the districts. The increase is by 8 days in Kurung Kumey; 4 days in Upper Siang and Anjaw; 3 days in Dibang Valley, Namsai, Pakke Kessang, Papum Pare, Tawang, Upper Subansiri, Shi Yomi, and West Kameng; 2 days in Changlang, East Kameng, East Siang, Lohit, Kamle, Longding, and West Siang; and one day in Kra Daadi, Lower Dibang Valley, Lower Subansiri, Lower Siang, Siang, Lepa Rada, and Tirap.

RCP 8.5 scenario: Projected to increase in the range of 2 to 9 days annually in all the districts. The increase is by 9 days in Kurung Kumey; 8 days in East Siang; 6 days in Anjaw, Siang, Shi Yomi, and Changlang; 5 days in Papum Pare, East Kameng, and Namsai; 4 days in Tawang, Lohit, Kamle, Upper Siang, Dibang Valley, Upper Subansiri, Pakke Kessang, and West Kameng; 2 to 3 days in Lower Dibang Valley, Lower Subansiri, Lower Siang, Tirap, West Siang, Longdin, Kra Daadi, and Lepa Rada.

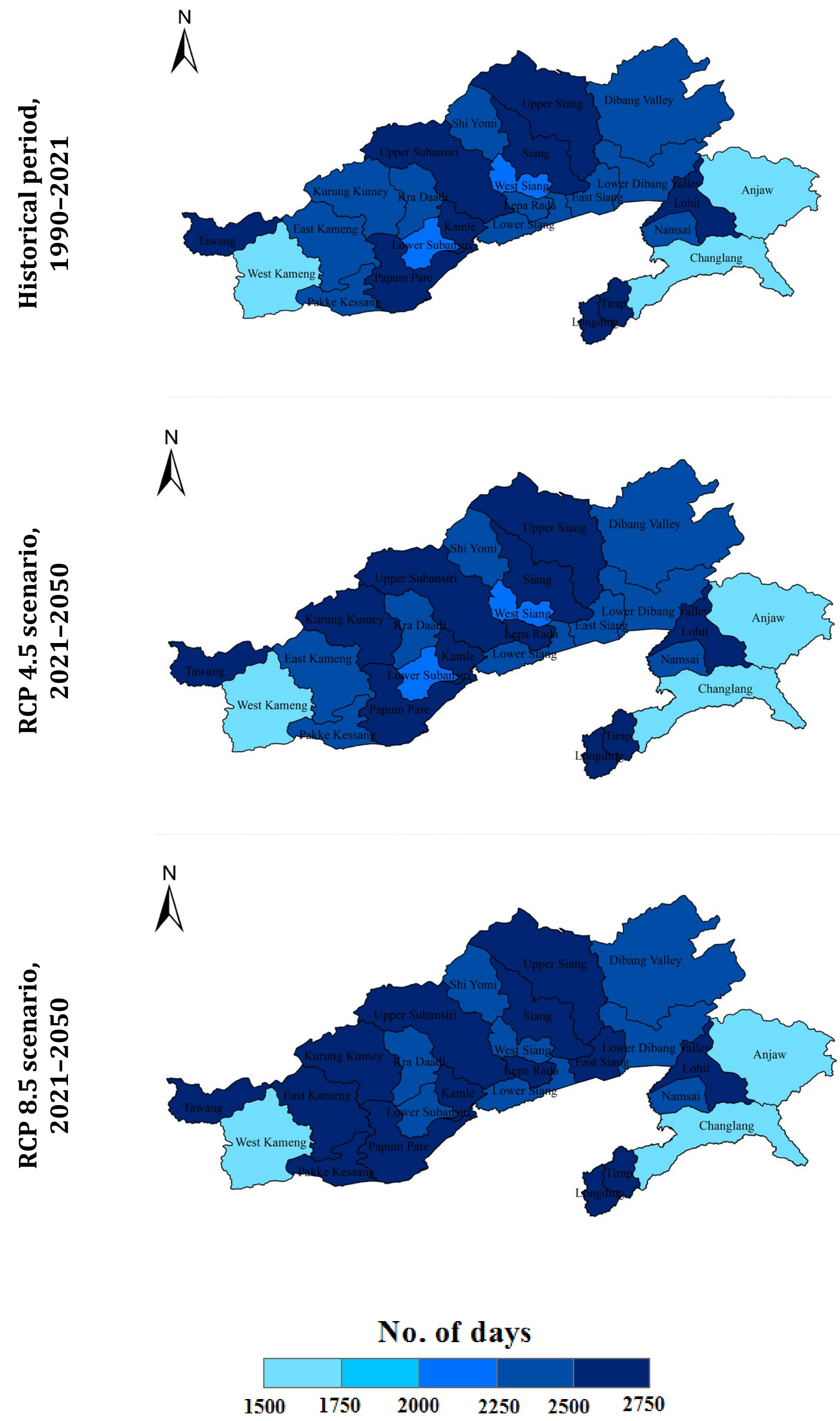


Figure 3-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

3.2.2.2 *Mean rainfall and rainfall variability during the kharif season*

Arunachal Pradesh receives rainfall from south-west and north-east monsoons. The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 3-6 presents district-wise changes in the kharif season rainfall, and Figure 3-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 7% in Kamle to 28% in West Siang	Declines in all the districts, by 1% in Kamle and Lohit to 31% in Tawang
RCP 8.5	Increases in all the districts, from 12% in Dibang Valley and Kamle to 30% in West Siang	Declines in 23 of 25 districts, by 1% in Lower Siang and Lepa Rada to 28% in Tawang; no change in Kamle and Pakke Kessang

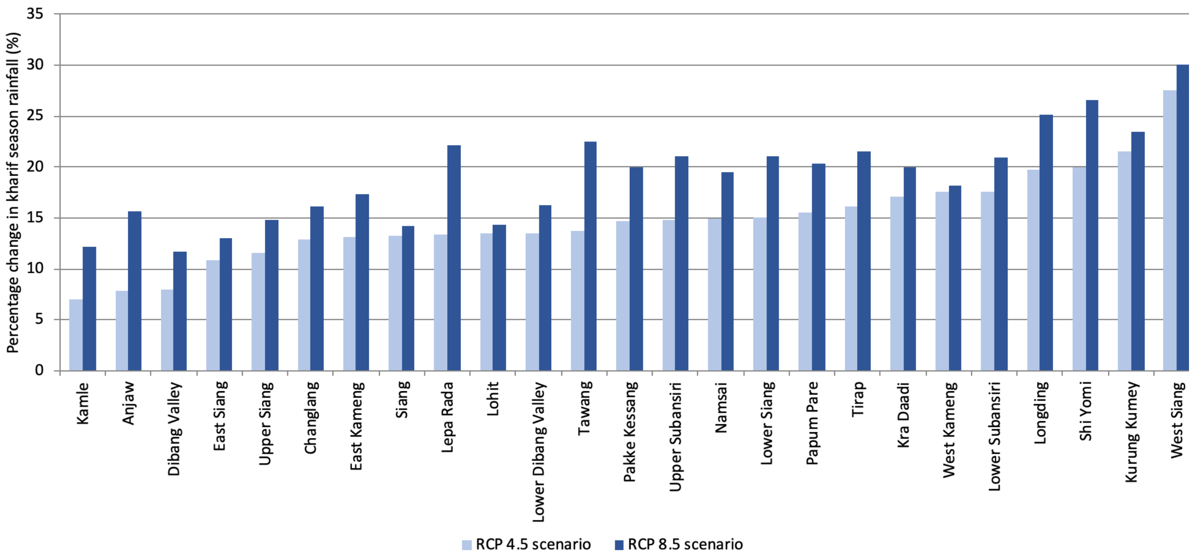


Figure 3-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

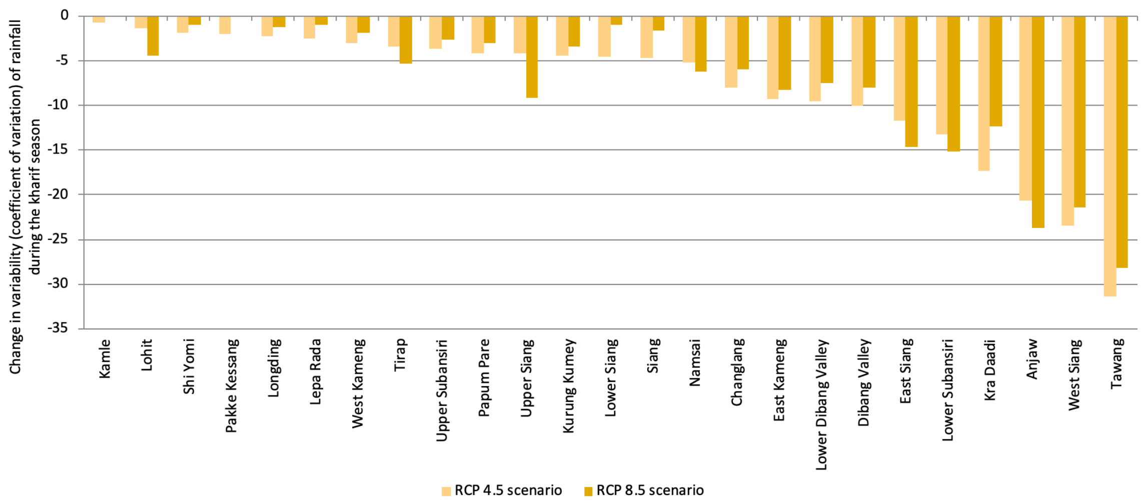


Figure 3-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

3.2.2.3 *Mean rainfall and rainfall variability during the rabi season*

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 3-8 presents district-wise changes in the rabi season rainfall, and Figure 3-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 4% in Changlang to 39% in Lower Subansiri	Declines in all the districts, by 1% in Lepa Rada to 41% in West Siang
RCP 8.5	Increases in all the districts, from 13% in Changlang to 49% in Upper Subansiri	Declines in all the districts, by 2% in Kra Daadi and Pakke Kessang to 42% in West Siang

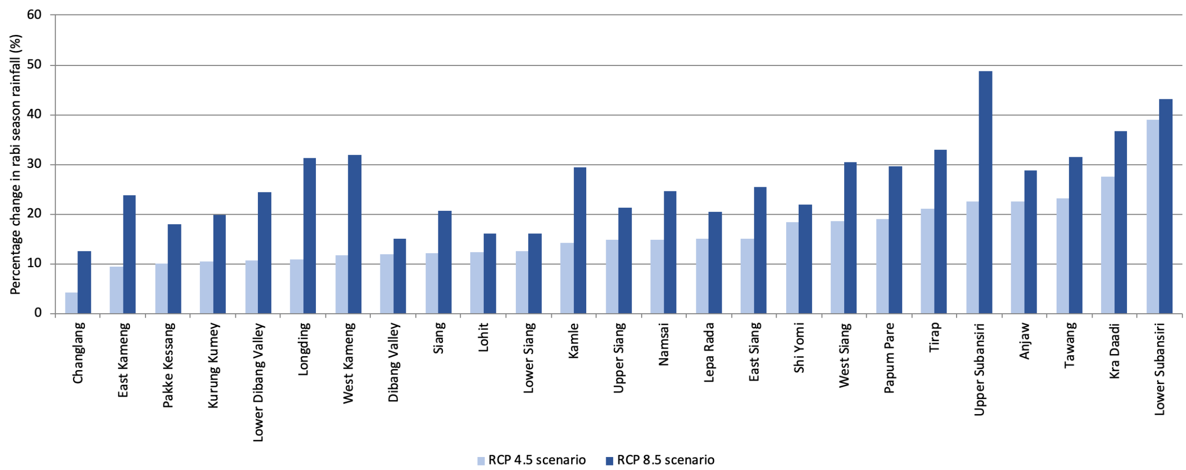


Figure 3-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

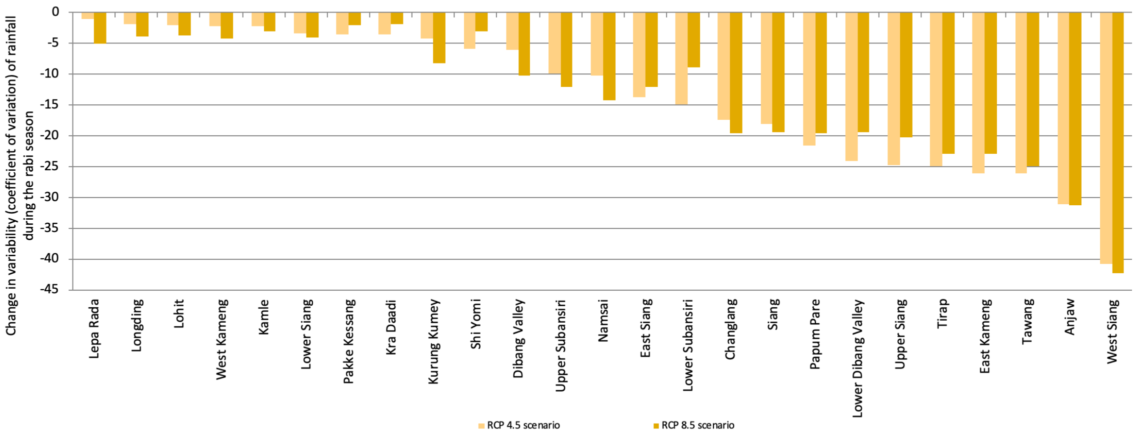


Figure 3-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

3.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical and projected 2030s under the two climate scenarios, and the change was computed for all the districts of Arunachal Pradesh.

High-intensity rainfall events (Figure 3-10)

The total number of high-intensity rainfall events increases from 68 to 305 days during the historical period (1990–2019) to 75 to 324 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 98 to 378 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to two events in all the districts except Anjaw and Lohit. The increase is by two events in East Kameng, Lower Subansiri, and Namsai and one event in 20 districts including Changlang, Dibang Valley, East Siang, Kra Daadi, Kurung Kumey, Longding, Lower Dibang Valley, Papum Pare, Siang, and Tawang.

RCP 8.5 scenario: The projected increase per annum is by one to three events in all the districts. The increase is by three events in East Kameng, Pakke Kessang, Lower Siang, and Namsai; two events in 16 districts including Changlang, Dibang Valley, East Siang, Kra Daadi, Kurung Kumey, Longding, Lower Dibang Valley, Lower Subansiri, Siang, Tawang; and one event in Anjaw, Lohit, Tirap, Papum Pare, and West Kameng.

Very high-intensity rainfall events (Figure 3-11)

The total number of very high-intensity rainfall events increases from 8 to 99 days during the historical period (1990–2019) to 36 to 124 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 55 to 166 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to two events in all the districts. The increase is by two events in Siang, Tawang, Upper Subansiri, Pakke Kessang, West Kameng, and West Siang and one event in the remaining districts.

RCP 8.5 scenario: The projected increase per annum is by one to three events in all the districts. The increase is by three events in Shi Yomi, Pakke Kessang, and Upper Subansiri; two events in 17 districts including Anjaw, Changlang, East Kameng, East Siang, Kurung Kumey, Longding, Lower Subansiri, Namsai, Papum Pare, Siang, and Tawang; and one event in Dibang Valley, Kra Daadi, Lohit, Lower Dibang Valley, and Tirap.

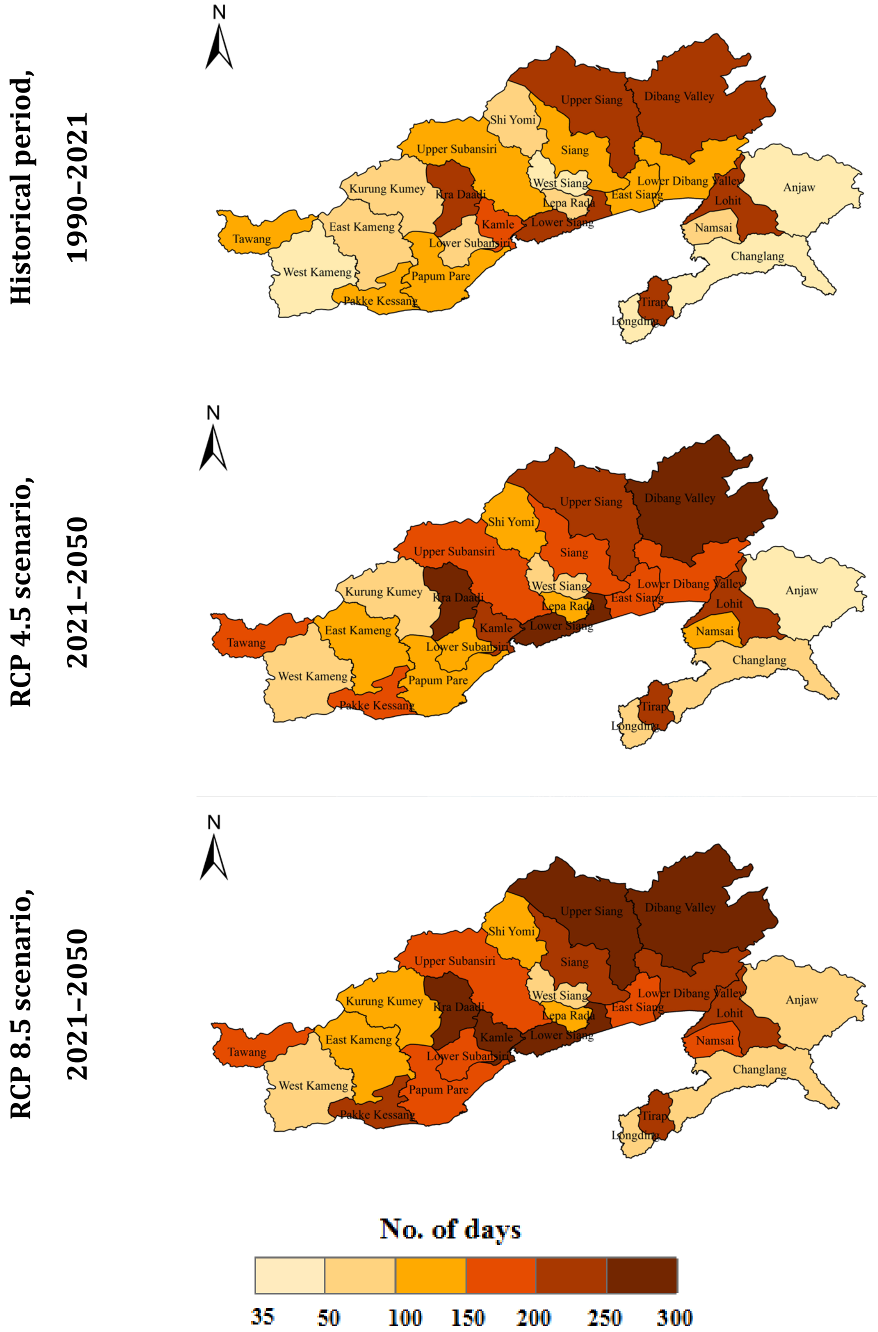


Figure 3-10: The total number of high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

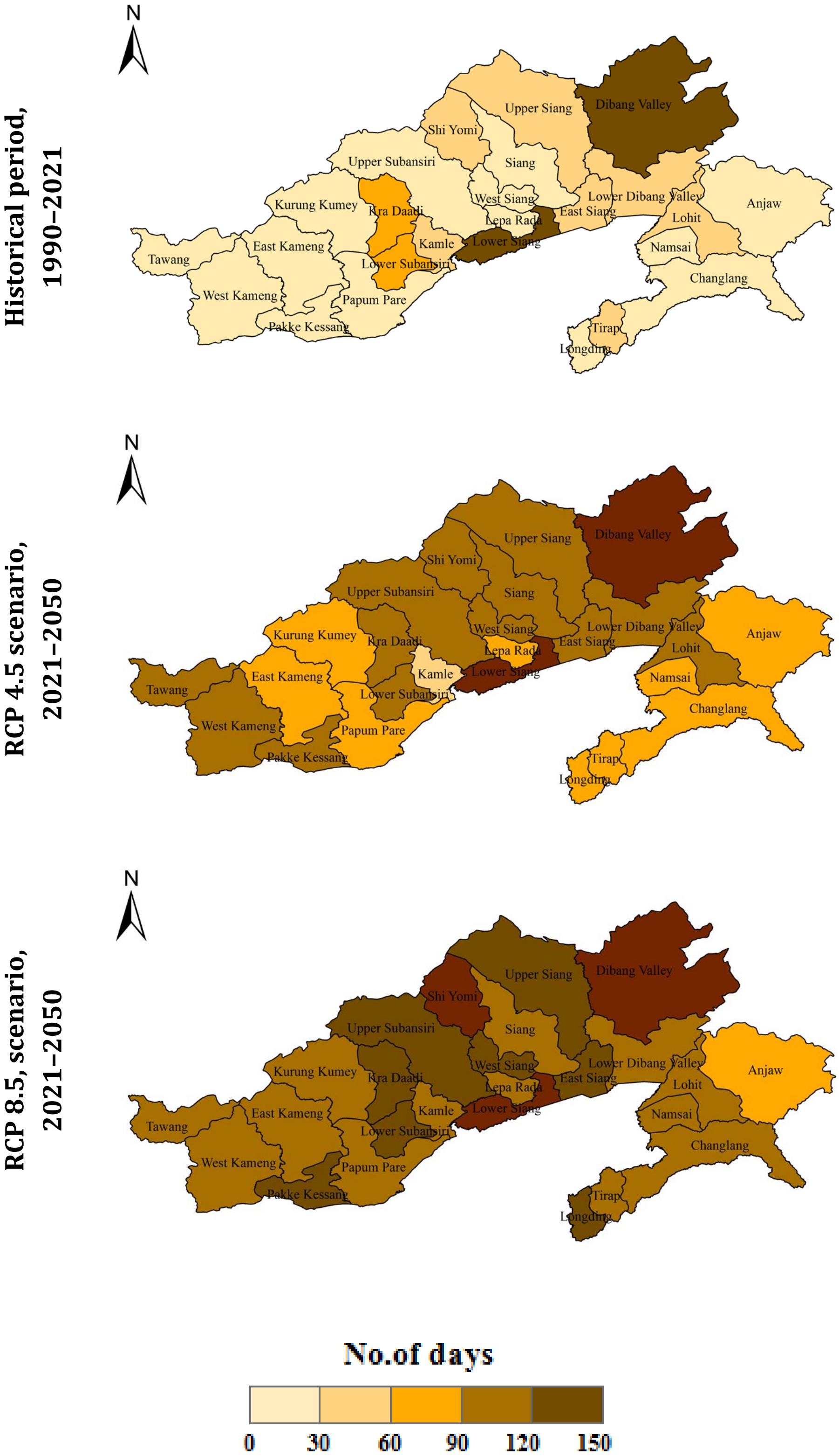


Figure 3-11: The total number of very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

Rainfall deficient years (Figure 3-12)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected to decline in all the districts of Arunachal Pradesh under both climate scenarios. The number of rainfall deficient years declines from 6 to 15 years during the historical 30-year period to 5 to 12 years under the RCP 4.5 scenario and 4 to 11 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 1 to 3 years (over a 30-year period) with a 3-year decline in Dibang Valley and East Kameng and a 1-year decline in 14 districts including East Siang, Kra Daadi, Lohit, Longding, Lower Dibang Valley, Namsai, Tirap, Lepa Rada, Upper Siang, and Upper Subansiri. No changes are projected for Anjaw, Changlang, Kamle, Kurung Kumey, Lower Subansiri, Papum Pare, Tawang, West Kameng, and West Siang.

RCP 8.5 scenario: The projected decline is by 1 to 4 years (over a 30-year period) with a 4-year decline in Dibang Valley and East Kameng; a 2-year decline in Kra Daadi, Lepa Rada, Lohit, Longding, Namsai, Lower Siang, Siang, Tirap, Pakke Kessang, and Upper Subansiri; and 1-year decline in Anjaw, Changlang, East Siang, Kurung Kumey, Lower Subansiri, Shi Yomi, Lower Dibang Valley, Papum Pare, Tawang, and Upper Siang. No changes are projected for Kamle, West Kameng, and West Siang.

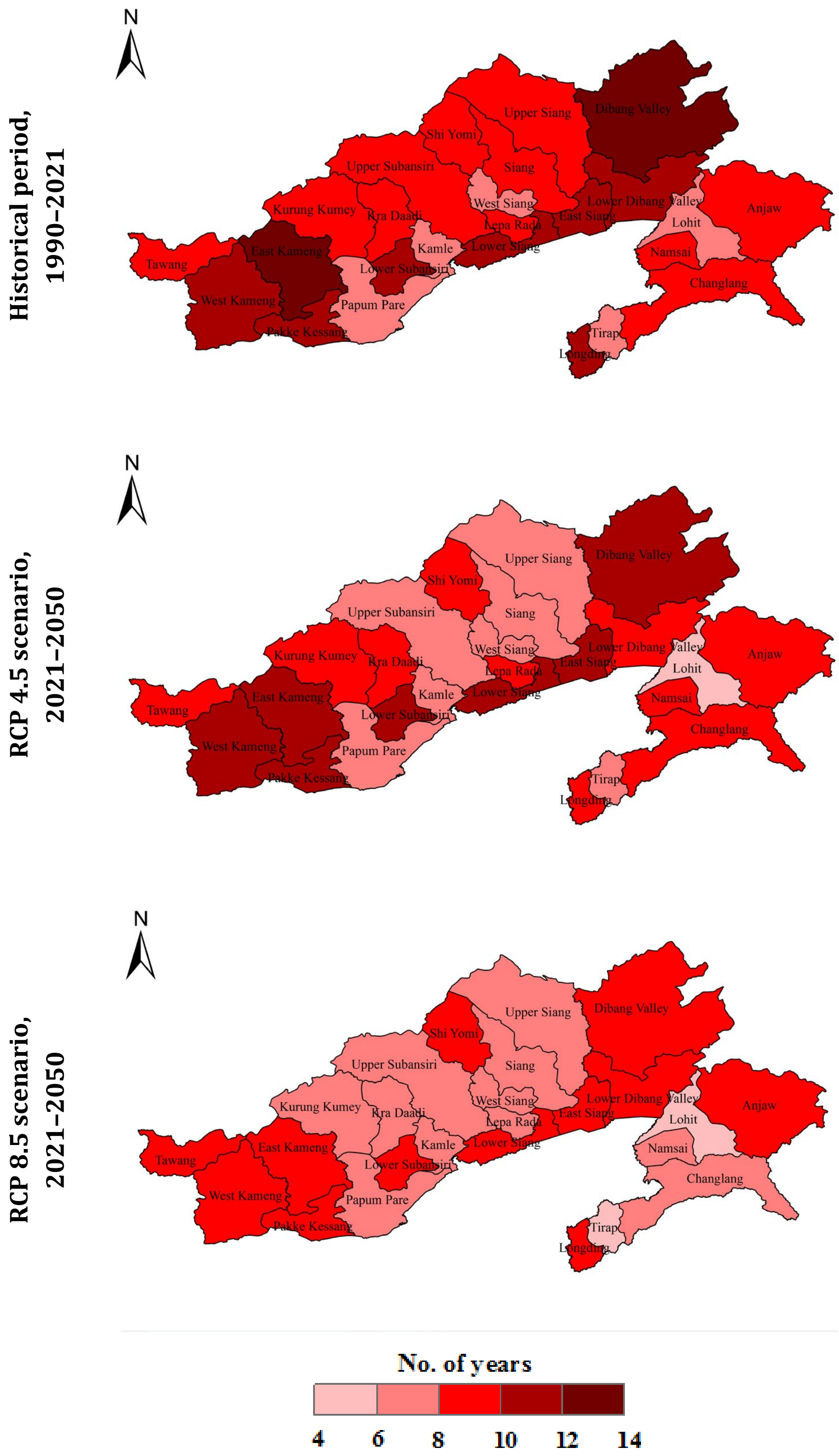


Figure 3-12: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

3.4 The summary of projected changes in the climate for Arunachal Pradesh

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 3-1).

- The summer maximum and winter minimum temperatures are projected to warm by 1°C to 1.5°C uniformly across all the districts under the RCP 4.5 scenario and 1°C to 2 °C under the RCP 8.5 scenario.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 3-2).

- There will be a notable increase in rainfall particularly in the northern districts under RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the kharif season is projected under both climate scenarios in all the districts. Lohit and Longding have the least variability, and Tawang and West Siang have the highest variability.

Rainfall variability during the rabi season is projected to decline in all districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the rabi season is projected under both climate scenarios in all the districts. Lohit and Longding have the least variability, and Tawang and West Siang have the highest variability.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 3-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 8 days under the RCP 4.5 scenario and 2 to 9 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 3-4).

- A larger increase is expected particularly in the northern districts of Arunachal Pradesh.

Rainfall deficient years are projected to decline in 16 of the 25 districts under the RCP 4.5 scenario and in 22 of the 25 districts under the RCP 8.5 scenario compared to the historical period (1990–2019; Appendix 3-4). No change is projected in the remaining districts during this period.

Appendix

Appendix 3-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Anjaw	1.2	1.5	1.2	1.7
Changlang	1.1	1.8	1.3	1.8
Dibang Valley	1.3	1.5	1.4	1.5
East Kameng	1.1	1.3	1.4	1.7
East Siang	1.2	1.6	1.6	1.8
Kamle	1.3	1.5	1.6	1.7
Kra Daadi	1.4	1.5	1.4	1.7
Kurung Kumey	1.1	1.6	1.4	1.9
Lepa Rada	1.1	1.7	1.4	1.8
Lohit	1.2	1.7	1.4	1.8
Longding	1.3	1.6	1.4	1.7
Lower Dibang Valley	1.3	1.8	1.4	1.6
Lower Siang	1.4	1.8	1.5	1.9
Lower Subansiri	1.3	1.4	1.7	1.9
Namsai	1.2	1.6	1.3	1.8
Pakke Kessang	1.4	1.6	1.4	1.9
Papum Pare	1.3	1.5	1.6	1.7
Shi Yomi	1.5	1.8	1.4	1.7
Siang	1.4	1.7	1.6	1.8
Tawang	1.2	1.5	1.1	1.4
Tirap	1.1	1.6	1.4	1.8
Upper Siang	1.2	1.7	1.4	1.6
Upper Subansiri	1.4	1.5	1.6	1.8
West Kameng	1.2	1.4	1.4	1.9
West Siang	1.3	1.4	1.5	1.8

Appendix 3-2: Changes in rainfall under climate scenarios

Districts	Changes (%) in rainfall during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Anjaw	13	14	8	16	23	29
Changlang	9	16	13	16	4	13
Dibang Valley	5	11	8	12	12	15
East Kameng	16	17	13	17	9	24
East Siang	14	20	11	13	15	25
Kamle	8	15	7	12	14	29
Kra Daadi	17	19	17	20	27	37
Kurung Kumey	123	129	22	24	11	20
Lepa Rada	11	19	13	22	15	21
Lohit	11	12	13	14	12	16
Longding	20	24	20	25	11	31
Lower Dibang Valley	14	15	14	16	11	24
Lower Siang	7	28	15	21	13	16
Lower Subansiri	16	18	18	21	39	43
Namsai	12	17	15	20	15	25
Pakke Kessang	9	23	15	20	10	18
Papum Pare	15	18	16	20	19	30
Shi Yomi	13	24	20	27	18	22
Siang	13	16	13	14	12	21
Tawang	12	18	14	23	23	31
Tirap	20	23	16	22	21	33
Upper Siang	13	15	12	15	15	21
Upper Subansiri	15	21	15	21	23	49
West Kameng	13	18	18	18	12	32
West Siang	13	19	28	30	19	30

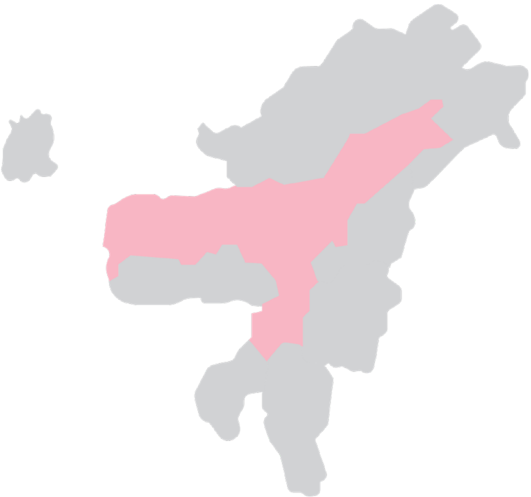
Appendix 3-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Anjaw	1536	1657	1701
Changlang	1495	1568	1678
Dibang Valley	2336	2422	2456
East Kameng	2361	2433	2501
East Siang	2364	2431	2590
Kamle	2612	2675	2723
Kra Daadi	2416	2456	2490
Kurung Kumey	2323	2564	2578
Lepa Rada	2491	2533	2590
Lohit	2639	2701	2755
Longding	2650	2712	2722
Lower Dibang Valley	2416	2416	2498
Lower Siang	2292	2314	2366
Lower Subansiri	2194	2212	2289
Namsai	2333	2412	2489
Pakke Kessang	2412	2490	2532
Papum Pare	2519	2615	2655
Shi Yomi	2266	2345	2433
Siang	2613	2637	2789
Tawang	2539	2614	2653
Tirap	2670	2714	2763
Upper Siang	2639	2747	2752
Upper Subansiri	2613	2714	2741
West Kameng	1543	1633	1677
West Siang	2187	2234	2276

Appendix 3-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Anjaw	68	75	98	9	45	55	10	10	9
Changlang	71	112	145	8	48	70	9	9	8
Dibang Valley	273	302	332	82	101	112	15	12	11
East Kameng	109	167	188	17	56	79	15	12	11
East Siang	183	201	234	23	65	87	12	11	11
Kamle	249	277	302	21	36	67	8	8	8
Kra Daadi	305	322	378	50	75	89	10	9	8
Kurung Kumey	120	145	180	16	56	76	9	9	8
Lepa Rada	138	167	198	16	45	78	10	9	8
Lohit	254	263	278	32	65	75	6	5	4
Longding	74	112	132	14	56	87	11	10	9
Lower Dibang Valley	197	223	267	36	63	76	11	10	10
Lower Siang	302	324	377	99	124	166	12	11	10
Lower Subansiri	145	196	212	42	64	95	12	12	11
Namsai	125	191	211	13	45	65	10	9	8
Pakke Kessang	191	234	267	18	65	98	12	11	10
Papum Pare	169	197	202	13	55	75	8	8	7
Shi Yomi	136	159	188	31	68	111	10	9	9
Siang	191	223	265	18	65	75	9	8	7
Tawang	185	212	233	20	68	78	10	10	9
Tirap	254	289	297	22	48	66	8	7	6
Upper Siang	254	296	301	32	71	85	9	8	8
Upper Subansiri	191	213	249	18	67	96	9	8	7
West Kameng	74	104	113	18	66	78	11	11	11
West Siang	72	107	127	15	73	87	7	7	7

4. Assam



Assam is the second-largest state in north-eastern India and is situated in the south of the Eastern Himalayas along the Brahmaputra and Barak River valleys. It shares borders with Arunachal Pradesh in the north, West Bengal in the west, and Nagaland and Manipur in the east. The state also shares international borders with Bhutan and Bangladesh. It has a geographical area of 78,438 sq. km and a population of 31.21million according to the 2011 Census. Of the total population, close to 85.90% live in rural areas. Assam has 33 districts, of which 8 are rich in natural resources. The state can be broadly divided into three physiographic domains: Brahmaputra Valley, Central Assam Hills (Mikir Hills in Karbi Anglong and North Cachar Hill districts), and Barak Valley. Assam experiences the predominant influence of the south-west tropical monsoon, which is normally active from April to October with occasional winter showers. Assam is vulnerable to all major natural hazards (drought, flood, cyclone, earthquake, landslides, fires, etc.)

These characteristics make Assam climate sensitive, underpinning the need for climate information. Climate data could serve as a basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

4.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

4.1.1 Trends in temperature

Assam recorded a moderate warming of 0.14°C to 0.28°C in the summer maximum temperature and 0.07°C to 0.23°C in the winter minimum temperature during the historical period. Figure 4-1 presents the mean summer maximum and winter minimum temperatures in Assam during the historical period.

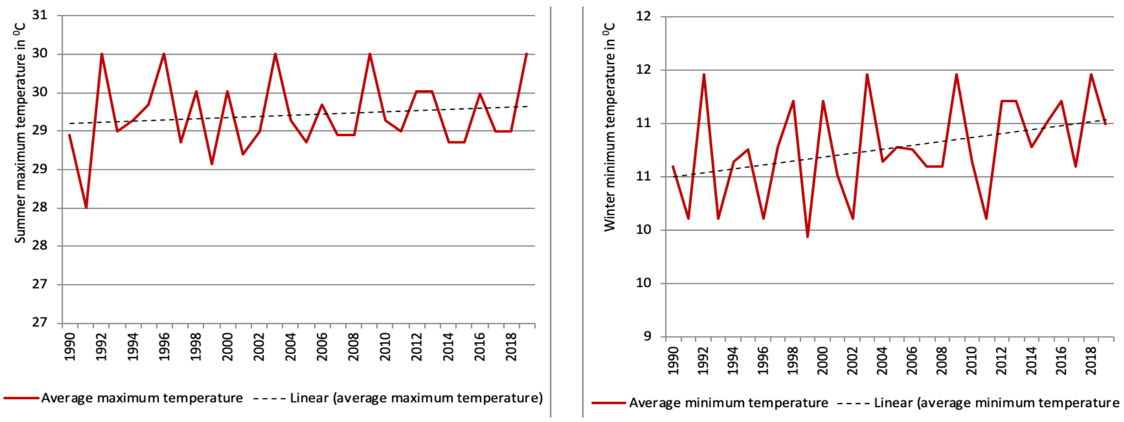


Figure 4-1: Mean summer maximum and winter minimum temperatures in Assam during the historical period (1990–2019)

4.1.2 Trends in rainfall and rainfall variability

An increasing trend in both annual and kharif season rainfall was recorded in all the districts of Assam. The increase in the annual and kharif season rainfall was largely in the western districts, in the range of 10%–15% during the historical period. Figure 4-2 presents the mean annual rainfall in Assam during the historical period.

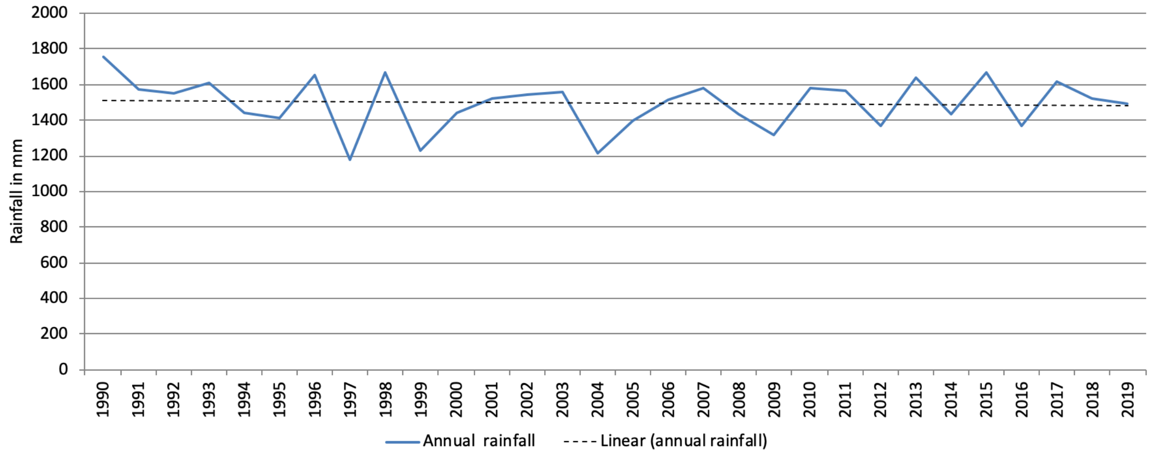


Figure 4-2: Mean annual rainfall in Assam during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 14% in Jorhat to 43% in Hojai (Figure 4-3). The rabi season rainfall variability was in the range of 42% in Tinsukia to 90% in Barpeta, indicating a complete failure of rainfall during the historical period (Figure 4-3).

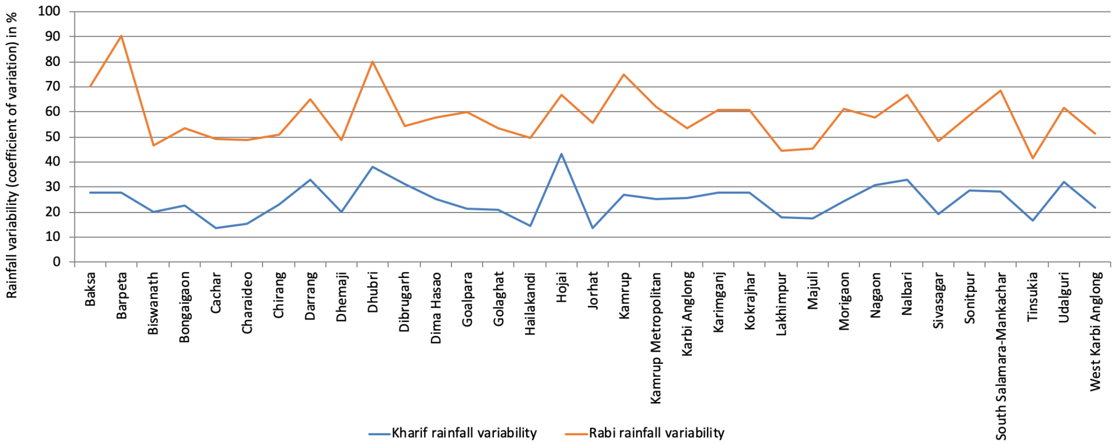


Figure 4-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

4.2 Climate change projections

Temperature and rainfall have been projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

4.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Assam are presented in Figure 4-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases up to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

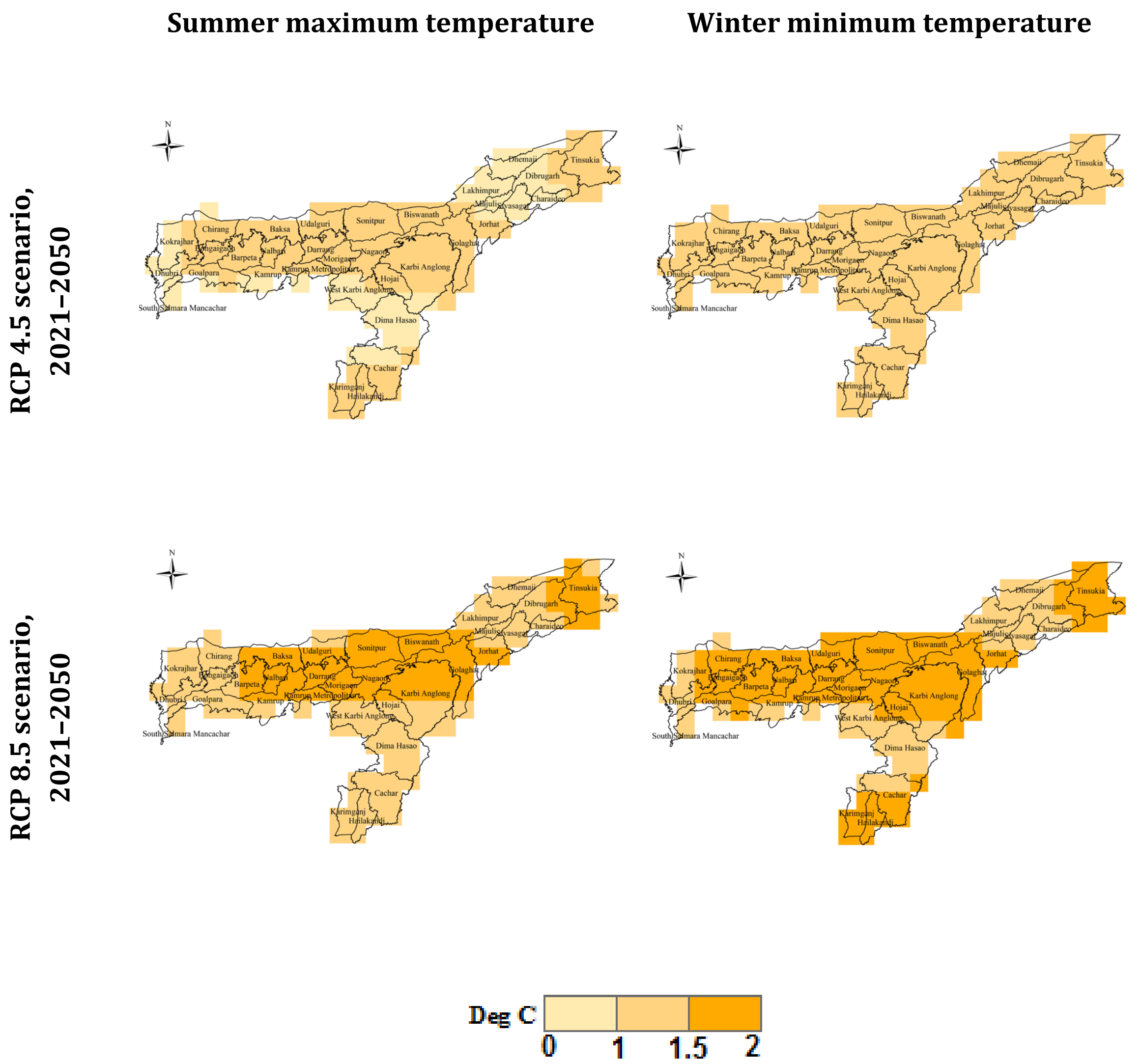


Figure 4-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

4.2.2 Rainfall projections

4.2.2.1 Number of rainy days

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 4-5). The number of rainy days during the historical period and the projected 2030s under RCP 4.5 and 8.5 scenarios is presented in Appendix 4-3. The total number of rainy days that ranged from 1640 to 2644 days over the 30-year historical period increases to 1689 to 2690 days under the RCP 4.5 scenario and 1700 to 2712 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 1 to 3 days annually in all the districts with an increase annually of 3 days in West Karbi Anglong, Chirang, Barpeta, and Charaideo; 2 days in Nalbari, Goalpara, Dibrugarh, Udalguri, Karbi Anglong, Morigaon, Darrang, and Cachar; and 1 day in the remaining districts.

RCP 8.5 scenario: Projected to increase by 1 to 6 days annually across all the districts with an increase of 6 days in Charaideo, Chirang, West Karbi Anglong, and Goalpara; 5 days in Sivasagar; 4 days in Dibrugarh; 3 days in Dhubri, Morigaon, Barpeta, Kamrup, Nagaon, Bongaigaon, Hojai, Nalbari, Biswanath, and Darrang; and 1 to 2 days in the remaining districts.

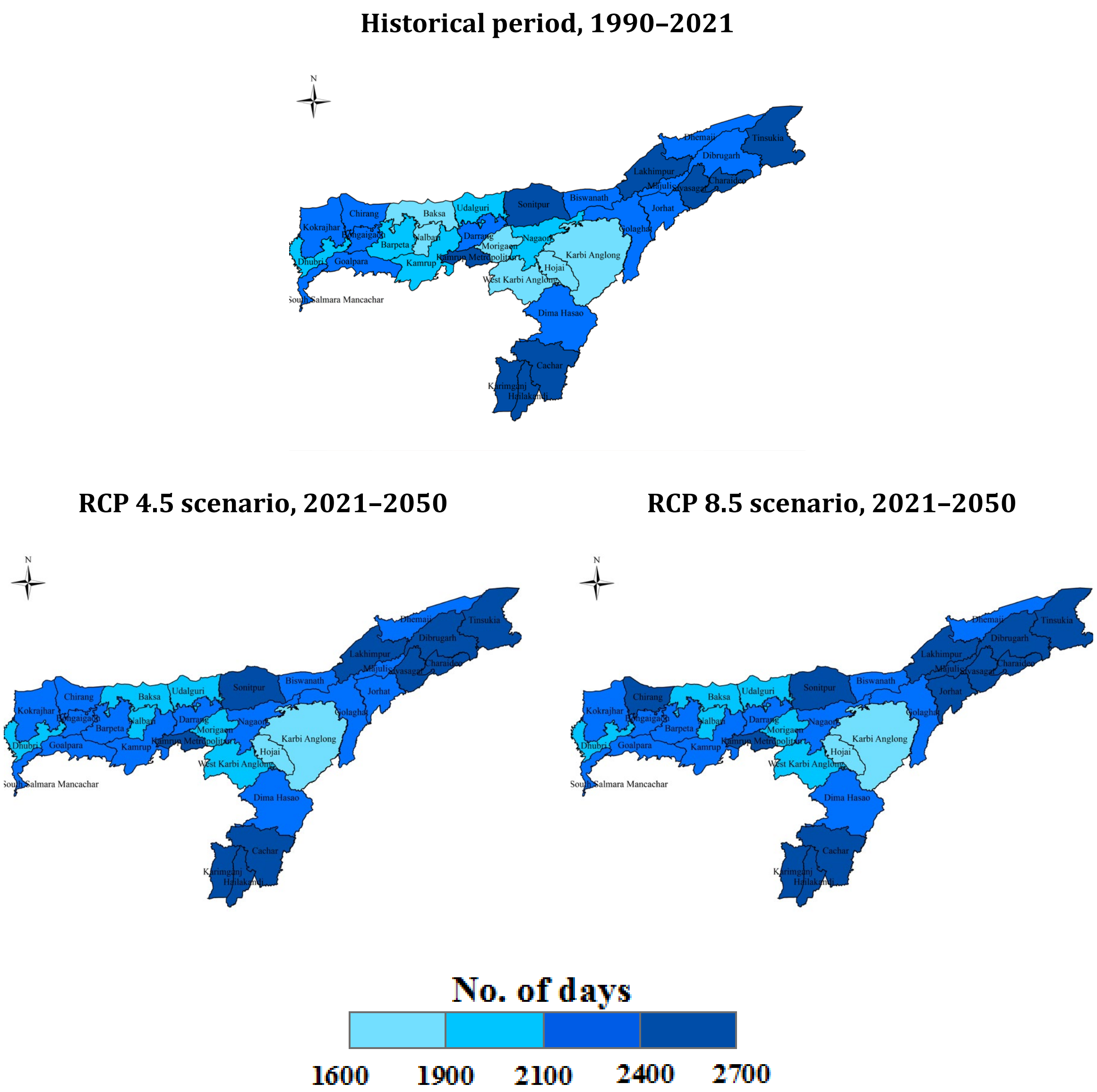


Figure 4-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios Mean rainfall and rainfall variability during the kharif season

4.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 4-6 presents district-wise changes in the kharif season rainfall, and Figure 4-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 6% in Udalguri to 19% in Dima Hasao	Increases in eight districts by 1%–5% and declines in 25 districts by 1%–22%
RCP 8.5	Increases in all the districts, from 11% in Nalbari to 22% in Karbi Anglong	Increases in eight districts by 2%–8% and declines in 25 districts by 3%–20%

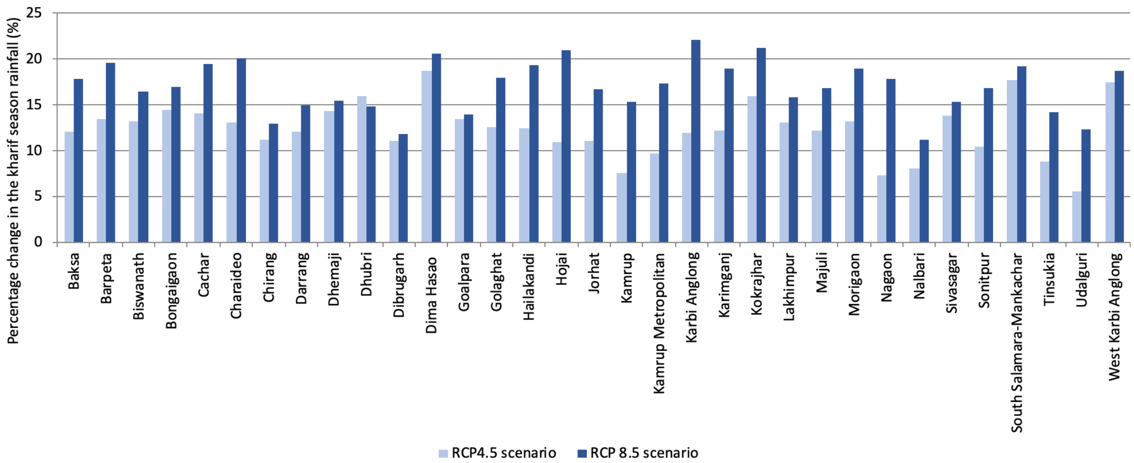


Figure 4-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

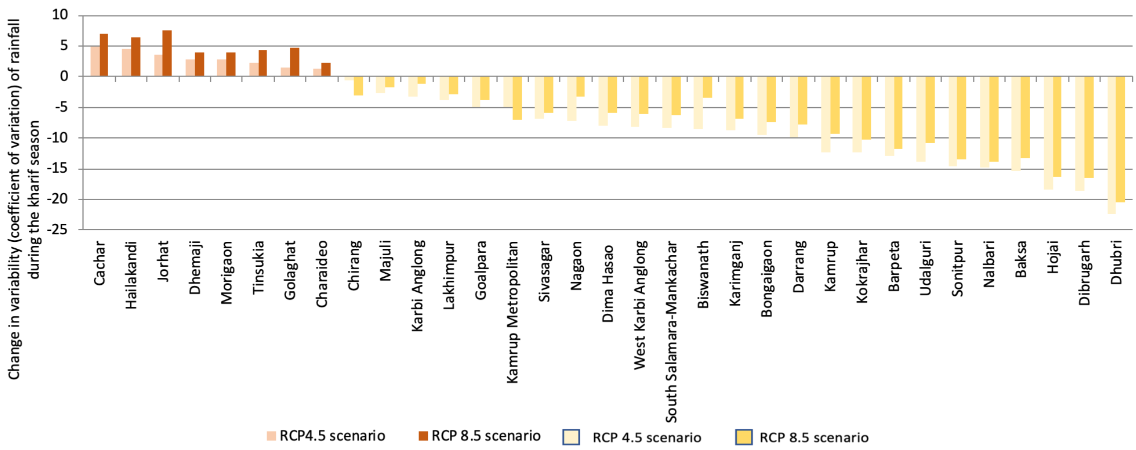


Figure 4-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

4.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 4-8 presents district-wise changes in the rabi season rainfall, and Figure 4-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 6% in Goalpara to 48% in the Dima Hasao	Declines in all the districts by 3%–46%
RCP 8.5	Increases in all the districts, from 12% in Goalpara to 52% in West Karbi Anglong	Declines in all the districts by 3%–28%

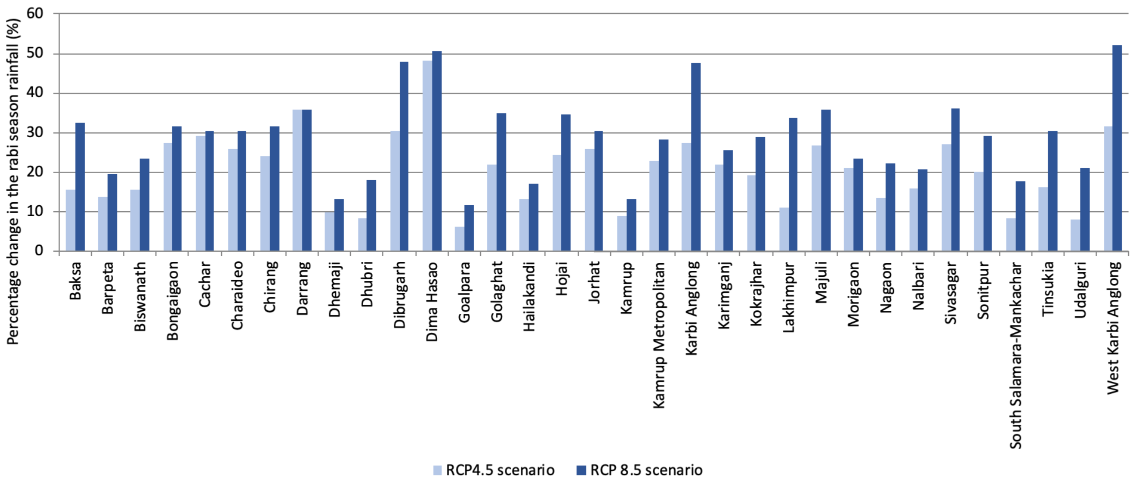


Figure 4-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

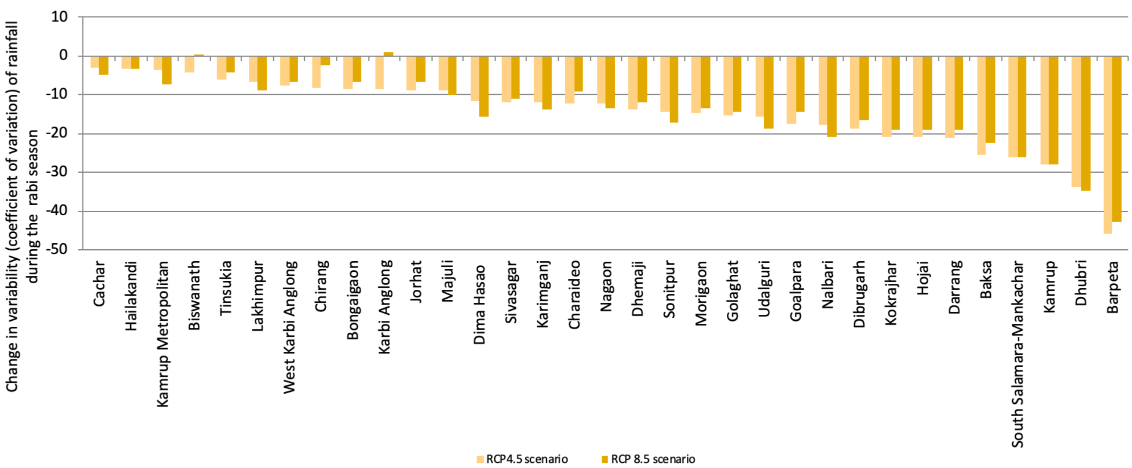


Figure 4-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

4.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and projected 2030s under the two climate scenarios, and the change was computed for all the districts of Assam.

High-intensity rainfall events (Figure 4-10)

The total number of high-intensity rainfall events increases from 35 to 271 days during the historical period (1990–2019) to 89 to 290 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 106 to 292 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to three events in the districts with 18 districts having one event: Cachar, Dhemaji, Charaideo, Kamrup, Karimganj, Hojai, Nalbari, Darrang, Jorhat, Tinsukia, Udalguri, Lakhimpur, Majuli, Barpeta, Morigaon, Kokrajhar, South Salamara-Mankachar, and Chirang. Thirteen districts are projected to have two events: Dibrugarh, Dima Hasao, Goalpara, Golaghat, Hailakandi, Kamrup Metropolitan, Karbi Anglong, Nagaon, Sivasagar, Sonitpur, West Karbi Anglong, Baksa, and Bongaigaon. Three events are projected in Biswanath and Dhubri.

RCP 8.5 scenario: An increase in high-intensity rainfall events is projected in all the districts of Assam. The projected increase per annum is by one to four events with four events projected in Biswanath and Karbi Anglong; three events in Sivasagar, Dhubri, Golaghat, Dima Hasao, Charaideo, Cachar, Kamrup, Baksa, Kamrup Metropolitan, Nagaon, Hailakandi, Goalpara, Lakhimpur, Dhemaji, and Sonitpur; two events in Jorhat, Dibrugarh, Barpeta, Bongaigaon, West Karbi Anglong, Morigaon, Hojai, Nalbari, Karimganj, Majuli, Kokrajhar; and one event in Darrang, Tinsukia, Udalguri, South Salamara-Mankachar, and Chirang.

Very high-intensity rainfall events (Figure 4-11)

The total number of very high-intensity rainfall events increases from 0 to 109 days during the historical period (1990–2019) to 32 to 112 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 45 to 123 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one event in Baksa, Barpeta, Biswanath, Bongaigaon, Darrang, Dhemaji, Dhubri, Dima Hasao, Golghat, Jorhat, Kamrup Metropolitan, Kokrajhar, Morigaon, and Udalguri. Two events are projected in Charaideo, Cachar, Dibrugarh, Hailakandi, Goalpara, Hojai, Kamrup, Karimganj, Karbi Anglong, Lakhimpur, Majuli, Nagaon, Nalbari, Sivasagar, Sonitpur, South Salamara-Mankachar, Tinsukia, and West Karbi Anglong. Very high-intensity rainfall events are not projected to occur in Chirang.

RCP 8.5 scenario: The projected increase per annum is one to three events. Fourteen districts are projected to have three events: Charaideo, Cachar, Goalpara, Hailakandi, Kamrup, Kamrup Metropolitan, Karbi Anglong, Lakhimpur, Majuli, Nagaon, Sivasagar, Sonitpur, Tinsukia, and West Karbi Anglong. Another 14 districts are projected to experience two events: Barpeta, Biswanath, Dhubri, Dibrugarh, Dima Hasao, Golaghat, Hojai, Jorhat, Karimganj, Kokrajhar, Morigaon, Nalbari, South Salamara-Mankachar, and Udalguri. One event is projected for four districts: Baksa, Dhemaji, Darrang, and Bongaigaon. Very high-intensity rainfall events are not projected to occur in Chirang.

Rainfall deficient years (Figure 4-12)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected for a majority of the districts of Assam under both climate scenarios. The number of rainfall deficient years declines from 6 to 14 years during the historical 30-year period to 6 to 13 years under the RCP 4.5 scenario and 4 to 12 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 1 to 3 years. The decline is by 3 years in Baksa, Bongaigaon, Charaideo, and Chirang; 2 years in Barpeta, Biswanath, Darrang, Dhubri, Hojai, Kamrup, Kamrup Metropolitan, Karbi Anglong, Karimganj, Nagaon, Sivasagar, Sonitpur, South Salamara-Mankachar, and West Karbi Anglong; and 1 year in Dhemaji, Dibrugarh, Dima Hasao, Goalpara, Golaghat, Hailakandi, Jorhat, Kokrajhar, Lakhimpur, Morigaon, Nalbari, Tinsukia, and Udalguri. No change is projected in Cachar and Majuli.

RCP 8.5 scenario: The projected decline is by 1 to 5 years. The decline is by 5 years in Baksa and Nalbari; 4 years in Biswanath, Charaideo, Chirang, Karbi Anglong, and South Salamara-Mankachar; 3 years in Barpeta, Darrang, Dhubri, Dima Hasao, Hojai, Jorhat, Kamrup, Kamrup Metropolitan, Sivasagar, Sonitpur, Tinsukia, and West Karbi Anglong; and 1 to 2 years in the remaining districts.

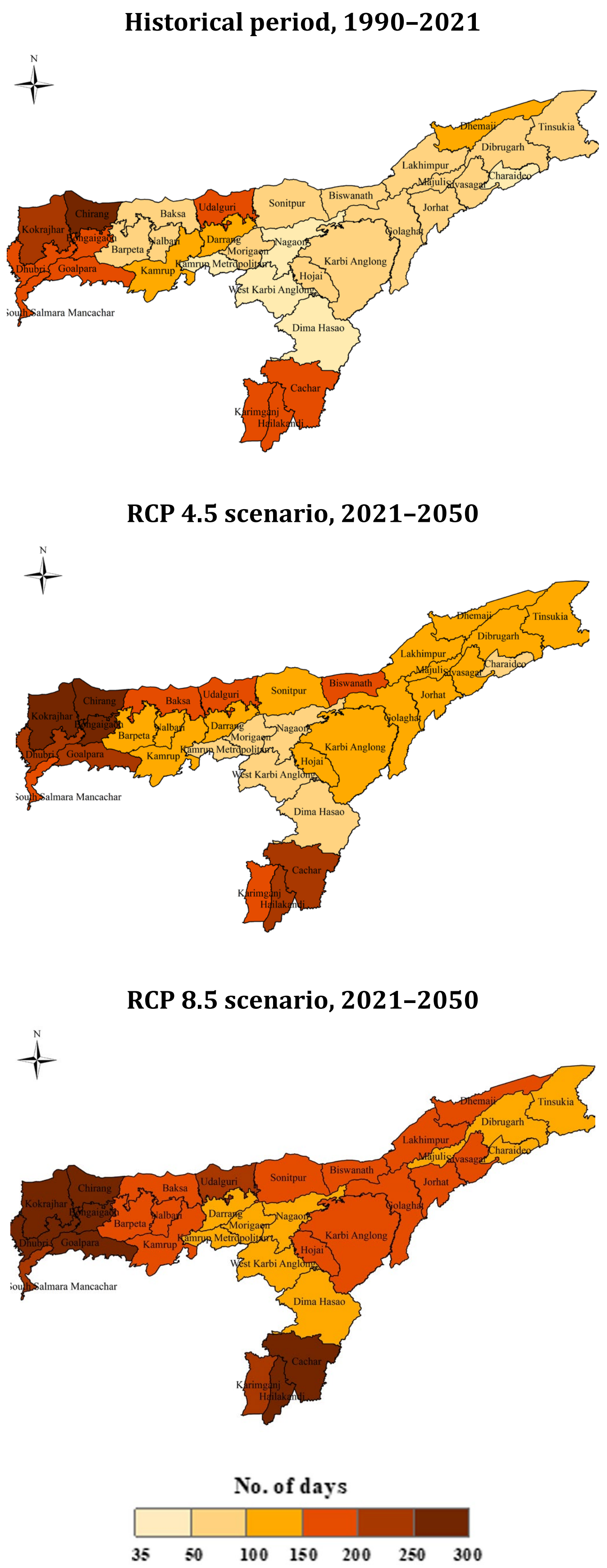


Figure 4-10: The total number of high-intensity events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

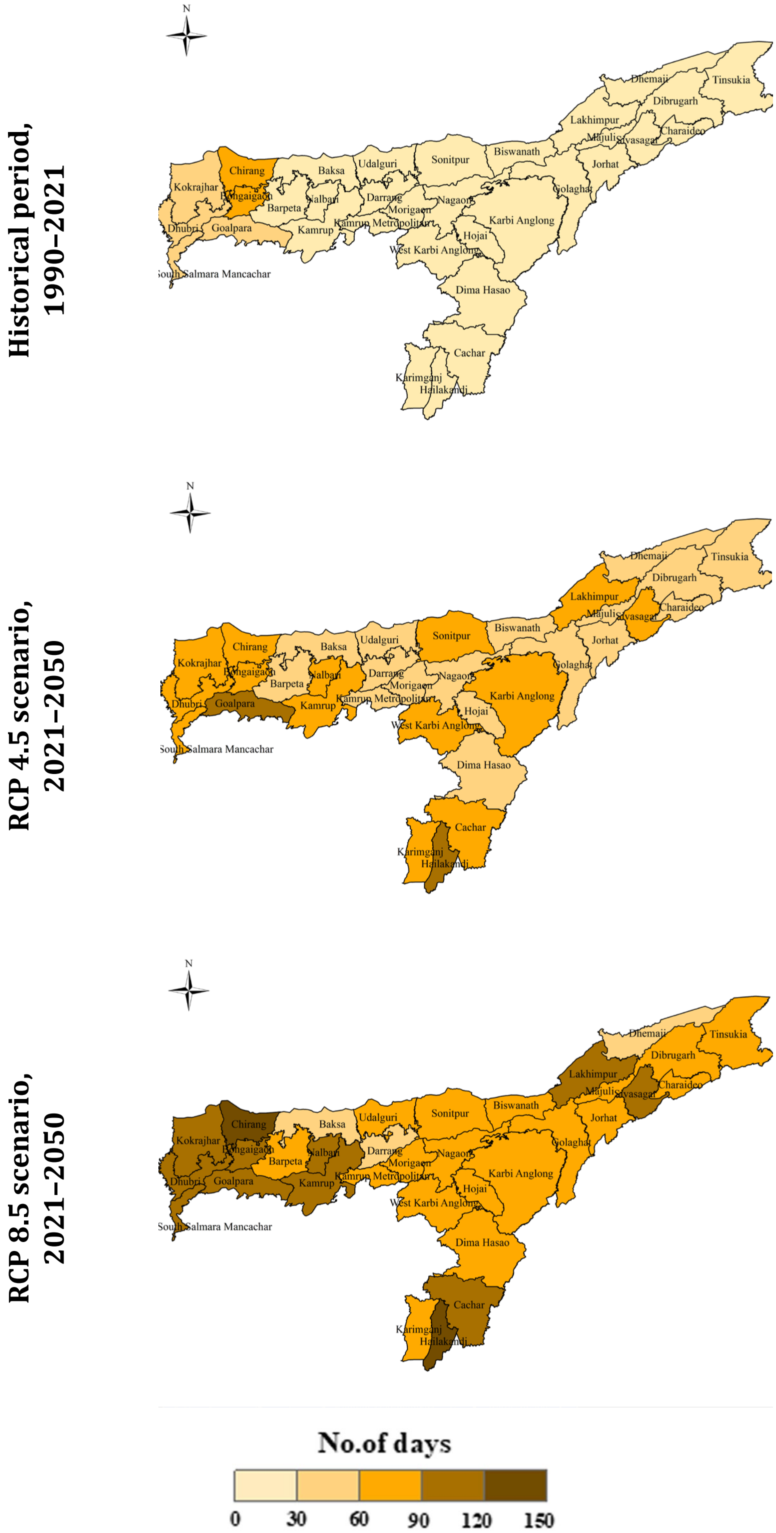


Figure 4-11: The total number of very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

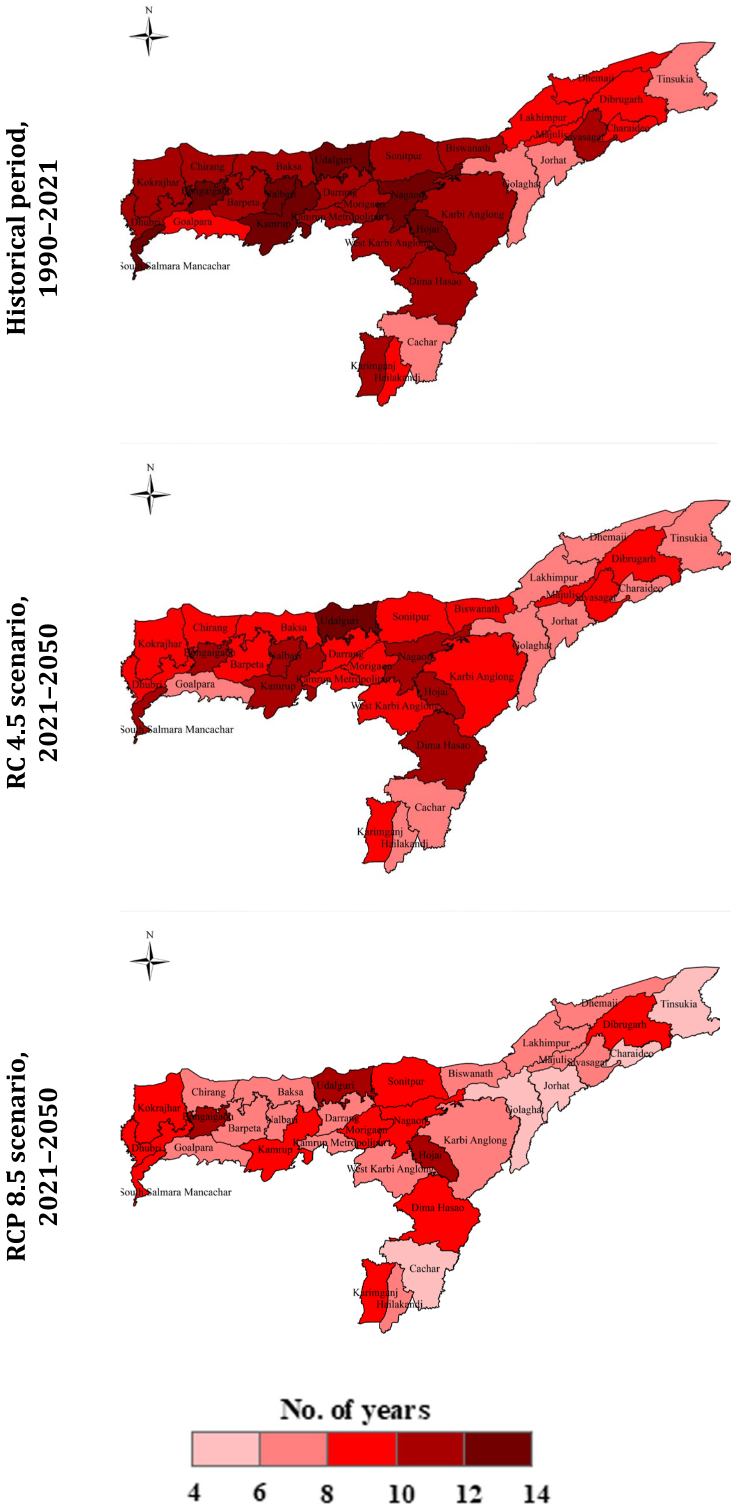


Figure 4-12: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

4.4 The summary of projected changes in the climate for Assam

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 4-1).

- The summer maximum temperature is projected to warm by 1°C to 1.5 °C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.
- The winter minimum temperature is projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1°C to 2°C under the RCP 8.5 scenario.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 4-2).

- There will be a notable increase in rainfall particularly in the western districts under RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios.

- A decline in rainfall variability is projected in a majority of the districts, except eight districts under both climate scenarios.
- A decline in rainfall variability is projected under both climate scenarios in all the districts.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 4-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 3 days under the RCP 4.5 scenario and 1 to 6 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RC 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 4-4).

- A larger increase is expected particularly in the western districts of Assam.

Rainfall deficient years are projected to decline in a majority of the districts under both climate scenarios compared to the historical period (1990–2019; Appendix 4-4).

Appendix

Appendix 4-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Baksa	1.2	1.7	1.1	1.7
Barpeta	1.3	1.8	1.2	1.6
Biswanath	0.7	0.9	1.0	1.4
Bongaigaon	1.4	1.8	1.1	1.7
Cachar	0.7	1.3	1.2	1.6
Charaideo	1.4	1.7	1.2	1.3
Chirang	1.3	1.8	1.3	1.7
Darrang	1.4	1.7	1.3	1.8
Dhemaji	1.3	1.9	1.1	1.4
Dhubri	1.4	1.7	1.2	1.6
Dibrugarh	1.2	1.6	1.3	1.4
Dima Hasao(North Cachar Hills)	0.7	1.2	1.3	1.5
Goalpara	1.6	1.8	1.2	1.3
Golaghat	1.2	1.8	1.3	1.7
Hailakandi	0.6	1.1	1.2	1.5
Hojai	1.1	1.4	1.1	1.4
Jorhat	1.3	1.8	1.2	1.7
Kamrup	1.5	1.6	1.2	1.3
Kamrup Metropolitan	1.5	1.6	1.3	1.4
Karbi Anglong	1.6	1.7	1.2	1.4

Karimganj	0.7	1.3	1.1	1.3
Kokrajhar	1.6	1.9	1.4	1.7
Lakhimpur	1.5	1.8	1.3	1.5
Majuli	1.6	1.8	1.2	1.6
Morigaon	1.4	1.9	1.2	1.4
Nagaon	1.3	1.8	1.3	1.5
Nalbari	1.1	1.6	1.3	1.5
Sivasagar	1.1	1.6	1.1	1.7
Sonitpur	0.9	1.6	1.3	1.5
South Salamara-Mankachar	1.1	1.4	1.4	1.6
Tinsukia	1.1	1.6	1.4	1.6
Udalguri	1.4	1.6	1.2	1.7
West Karbi Anglong	0.8	1.6	1.4	1.5

Appendix 4-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Baksa	13	15	12	18	15	32
Barpeta	11	14	13	20	14	19
Biswanath	8	12	13	16	16	23
Bongaigaon	14	22	14	17	27	32
Cachar	11	18	14	19	29	30
Charaideo	11	15	13	20	26	30
Chirang	11	13	11	13	24	32
Darrang	12	14	12	15	36	36
Dhemaji	11	16	14	15	10	13
Dhubri	11	10	16	15	8	18
Dibrugarh	12	14	11	12	30	48
Dima Hasao (North Cachar Hills)	16	17	19	21	48	51
Goalpara	12	13	14	14	6	12
Golaghat	10	18	13	18	22	35
Hailakandi	12	18	13	19	13	17
Hojai	11	18	11	21	24	34
Jorhat	13	14	11	17	26	30
Kamrup	10	17	8	15	9	13
Kamrup Metropolitan	11	17	10	17	23	28
Karbi Anglong	12	14	12	22	27	48
Karimganj	13	17	12	19	22	25
Kokrajhar	15	17	16	21	19	29
Lakhimpur	14	16	13	16	11	34

Majuli	11	13	12	17	27	36
Morigaon	13	19	13	19	21	23
Nagaon	9	12	7	18	13	22
Nalbari	9	12	8	11	16	21
Sivasagar	12	16	14	15	27	36
Sonitpur	8	14	10	17	20	29
South Salamara-Mankachar	16	18	18	19	8	18
Tinsukia	7	11	9	14	16	30
Udalguri	4	11	6	12	8	21
West Karbi Anglong	16	17	17	19	32	52

Appendix 4-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Baksa	1886	1978	2001
Barpeta	2057	2134	2151
Biswanath	2230	2263	2309
Bongaigaon	2105	2231	2290
Cachar	2644	2690	2712
Charaideo	2466	2543	2654
Chirang	2248	2345	2234
Darrang	2198	2345	2367
Dhemaji	2328	2355	3378
Dhubri	1986	2123	2189
Dibrugarh	2379	2431	2488
Dima Hasao (North Cachar Hills)	2348	2356	2396
Goalpara	2232	2285	2398
Golaghat	2218	2236	2245
Hailakandi	2592	2602	2612
Hojai	1705	1726	1789
Jorhat	2348	2390	2401
Kamrup	2063	2134	2234
Kamrup Metropolitan	2561	2570	2580
Karbi Anglong	1640	1789	1800
Karimganj	2543	2567	2590
Kokrajhar	2224	2267	2289
Lakhimpur	2474	2504	2522
Majuli	2361	2391	2412

Morigaon	1864	1912	1967
Nagaon	2087	2123	2177
Nalbari	1841	1901	1923
Sivasagar	2482	2512	2645
Sonitpur	2560	2576	2587
South Salamara-Mankachar	2248	2289	2300
Tinsukia	2495	2513	2522
Udalguri	1961	2012	2022
West Karbi Anglong	1808	1911	1980

Appendix 4-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Baksa	100	159	185	20	45	60	12	9	7
Barpeta	99	123	167	4	35	62	11	9	8
Biswanath	73	159	180	3	45	67	11	9	7
Bongaigaon	199	254	267	64	90	98	14	11	12
Cachar	179	223	267	21	67	98	6	6	6
Charaideo	48	90	137	0	45	89	9	6	5
Chirang	271	290	292	109	112	110	12	9	8
Darrang	106	137	145	10	39	45	11	9	8
Dhemaji	103	146	178	6	32	45	9	8	8
Dhubri	166	250	267	46	90	108	12	10	9
Dibrugarh	73	120	144	5	56	78	10	9	9
Dima Hasao (North Cachar Hills)	35	97	125	1	45	69	12	11	9
Goalpara	187	235	265	37	96	112	9	8	7
Golaghat	68	126	165	1	45	66	8	7	6
Hailakandi	190	236	269	29	96	123	9	8	7
Hojai	95	133	156	4	55	66	14	12	11
Jorhat	93	124	167	0	44	68	7	6	4
Kamrup	103	145	189	17	67	99	13	11	10
Kamrup Metropolitan	37	97	120	2	45	78	11	9	8
Karbi Anglong	55	109	177	5	68	90	11	9	7
Karimganj	157	197	212	26	75	90	11	9	9
Kokrajhar	244	267	289	50	89	103	11	10	10
Lakhimpur	98	123	176	3	67	99	9	8	7
Majuli	87	112	134	1	56	78	9	9	8
Morigaon	69	93	132	4	45	66	11	10	9
Nagaon	37	89	120	1	48	80	14	12	10
Nalbari	97	134	157	24	78	97	13	12	8
Sivasagar	61	120	165	4	65	93	11	9	8
Sonitpur	82	134	157	4	68	88	12	10	9
South Salamara-Mankachar	175	198	207	35	86	100	13	11	9
Tinsukia	90	120	134	3	56	78	8	7	5
Udalguri	169	197	201	27	60	89	14	13	12
West Karbi Anglong	41	90	106	4	68	84	11	9	8

5. Manipur

Manipur is a hilly state in north-eastern India. It shares borders with Nagaland in the north, Assam in the west, and Mizoram in the south. In the east, Manipur shares its international border with Myanmar. It has a geographical area of 22,327 sq. km and a population of 2.86 million according to the 2011 Census. Of the total population, close to 70.80% live in rural areas. Manipur has 16 districts, and it is drained by Imphal and Bara rivers. It is largely an agrarian state, with the major crops being paddy, maize, and different types of millets.

Manipur is vulnerable to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.), the most common being floods. Flash floods occur almost every year during the rainy season because of poor drainage, heavy run-off, and low infiltration in degraded watersheds. The four valley districts in Manipur—Imphal East, Imphal West, Thoubal, and Bishnupur—are the most exposed to floods.

These characteristics make Manipur climate-sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

5.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

5.1.1 Trends in temperature

Manipur has recorded a moderate warming of 0.2°C to 0.4°C in the summer maximum temperature and a relatively higher warming of 0.25°C to 0.75°C in the winter minimum temperature during the historical period. Figure 5-1 presents the mean summer maximum and winter minimum temperatures in Manipur during the historical period.

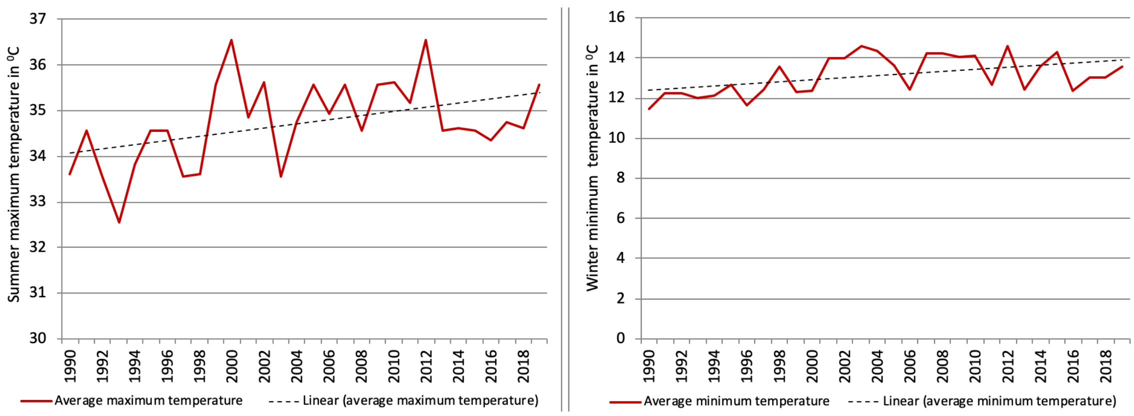


Figure 5-1: Mean summer maximum and winter minimum temperatures in Manipur during the historical period (1990–2019)

5.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual rainfall, in the range of 5%–10%, was recorded in a majority of the districts. For the kharif season, up to a 5% increase in rainfall was recorded in all the districts of Manipur. Figure 5-2 presents the mean annual rainfall in Manipur during the historical period.

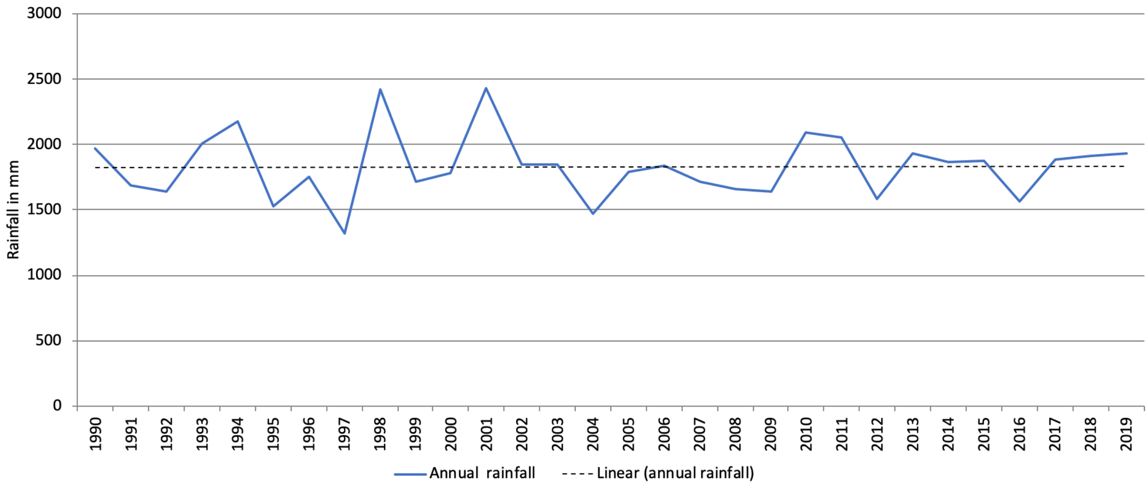


Figure 5-2: Mean annual rainfall in Manipur during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 25% in Churachandpur to 44% in Kamjong and Ukhrul (Figure 5-3). The rabi season rainfall variability was in the range of 50% in Churachandpur and Pherzawl to 62% in Chandel during the historical period (Figure 5-3).

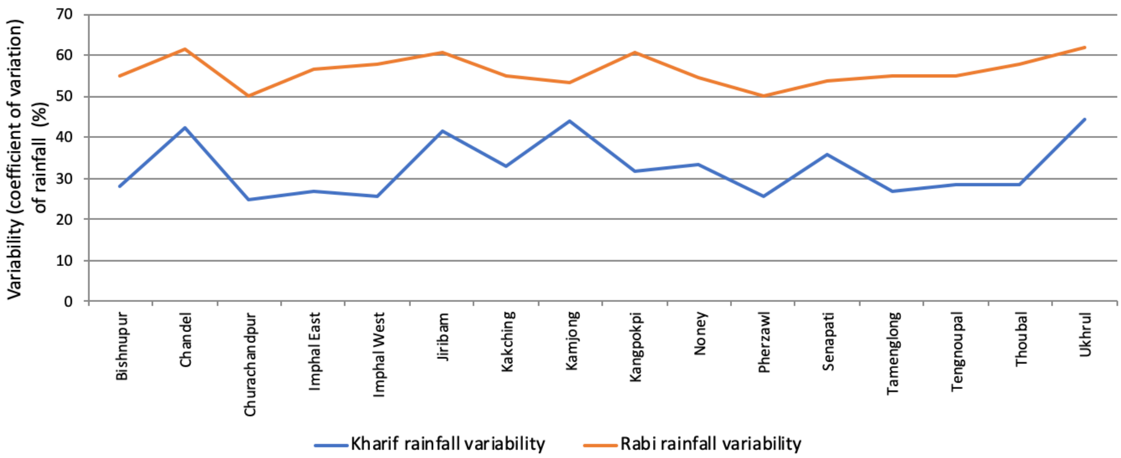


Figure 5-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

5.2 Climate change projections

Temperature and rainfall have been projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

5.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Manipur are presented in Figure 5-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by up to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

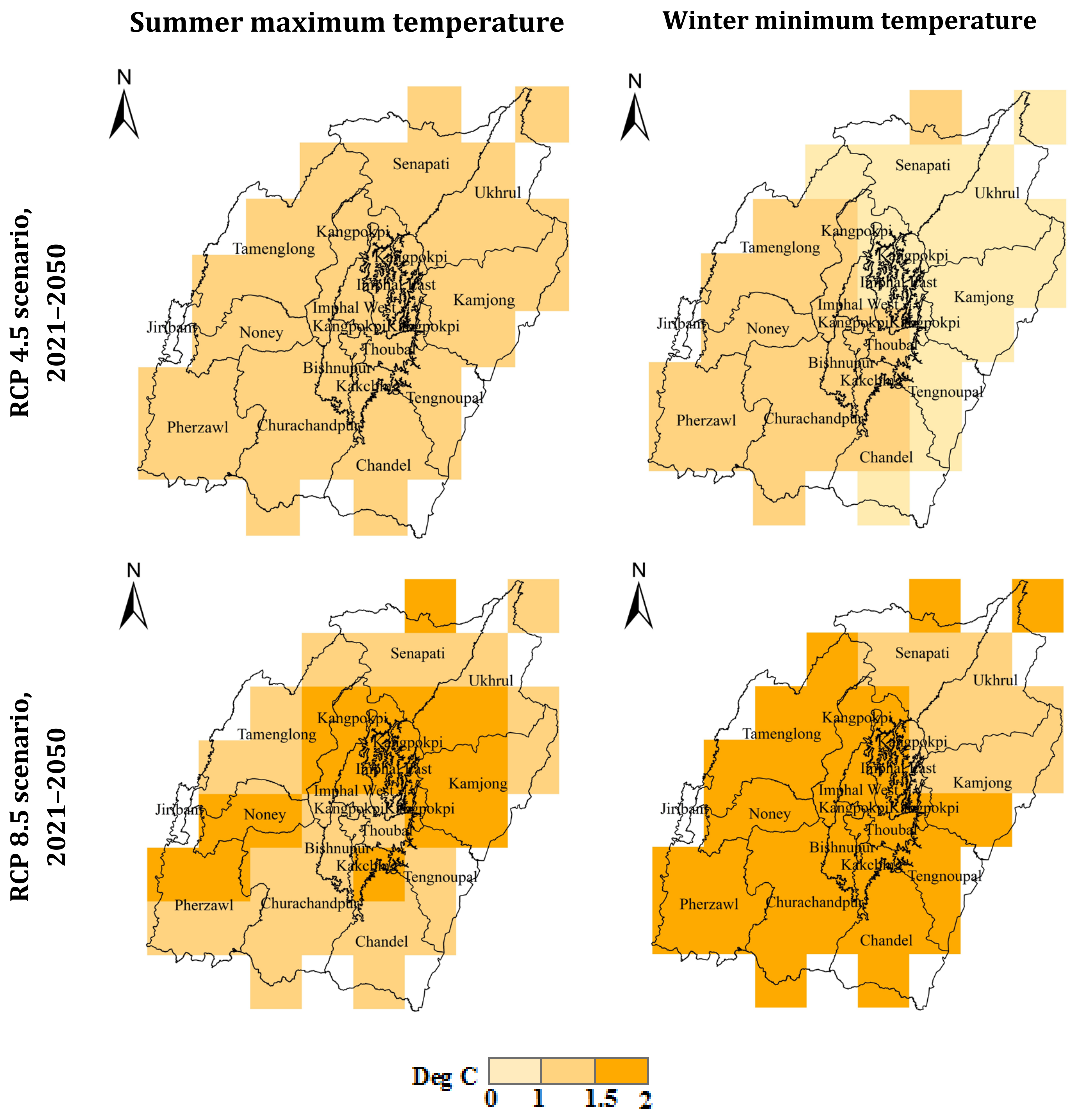


Figure 5-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

5.2.2 Rainfall projections

5.2.2.1 Number of rainy days

According to the India Meteorological Department, a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 5-5). The number of rainy days during the historical period and the projected 2030s under RCP 4.5 and 8.5 scenarios is presented in Appendix 5-3. The total number of rainy days that ranged from 2160 to 2644 days over the 30-year historical period increases to 2234 to 2767 days under the RCP 4.5 scenario and 2284 to 2779 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: The projected increase is by 1 to 5 days annually. The increase is by 5 days in Kangpokpi; 4 days in Imphal East, Imphal West, Jiribam, Kakching, Ukhrul, Thoubal, Noney, and Tengnoupal; 3 days in Bishnupur, Chandel, Churachandpur, and Senapati; and 1 day in Kamjong, Pherzawl, and Tamenglong.

RCP 8.5 scenario: The projected increase is by 1 to 6 days annually in all the districts. The increase is by 6 days in Ukhrul; 5 days in Thoubal, Noney, Kangpokpi, and Tengnoupal; 4 days in Chandel and Kakching; 3 days in Bishnupur, Churachandpur, Imphal East, Imphal West, and Senapati; 2 days in Jiribam and Pherzawl; and 1 day in Kamjong and Tamenglong.

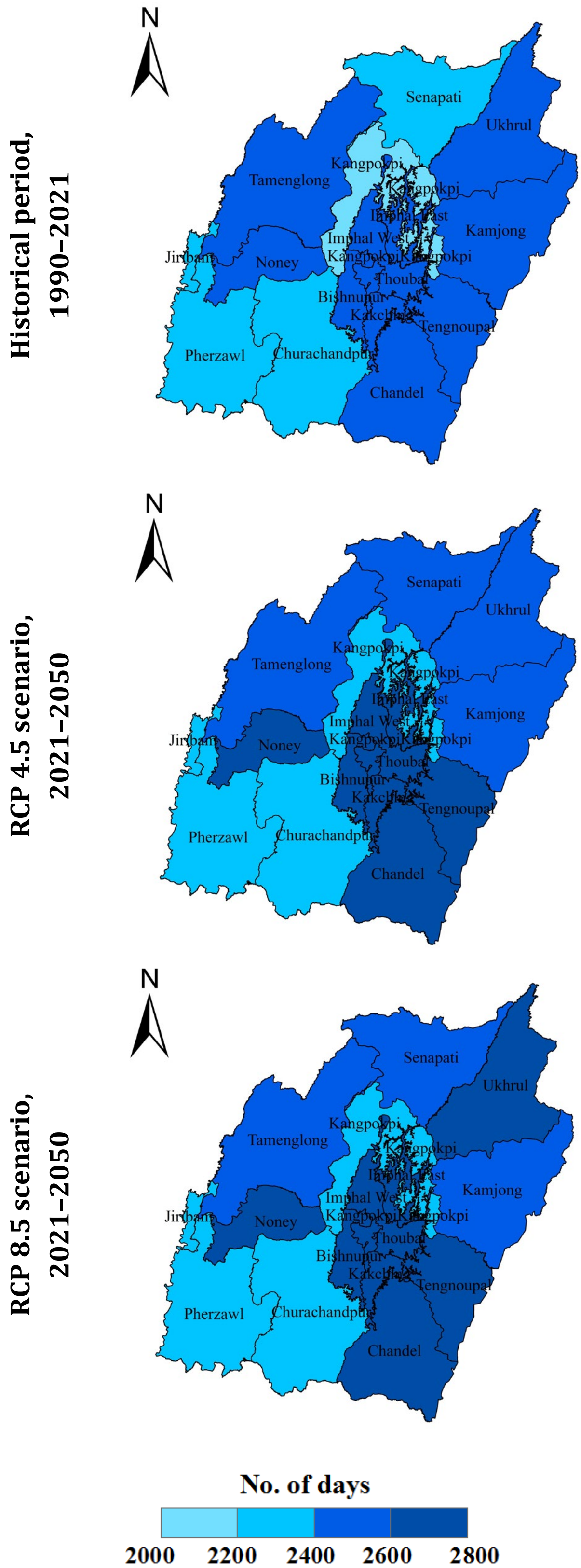


Figure 5-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

5.2.2.2 Mean rainfall and rainfall variability during the kharif season

Manipur receives rainfall from the north-east monsoon. The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 5-6 presents district-wise changes in the kharif season rainfall, and Figure 5-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 11% in Kakching and Kangpokpi to 32% in Imphal West	Increases in six districts by 2%–7% and declines in 10 districts by 7%–22%
RCP 8.5	Increases in all the districts, from 5% in Churachandpur to 24% in West Champaran	Increases in six districts by 2%–5% and declines in 10 districts by 5%–23%

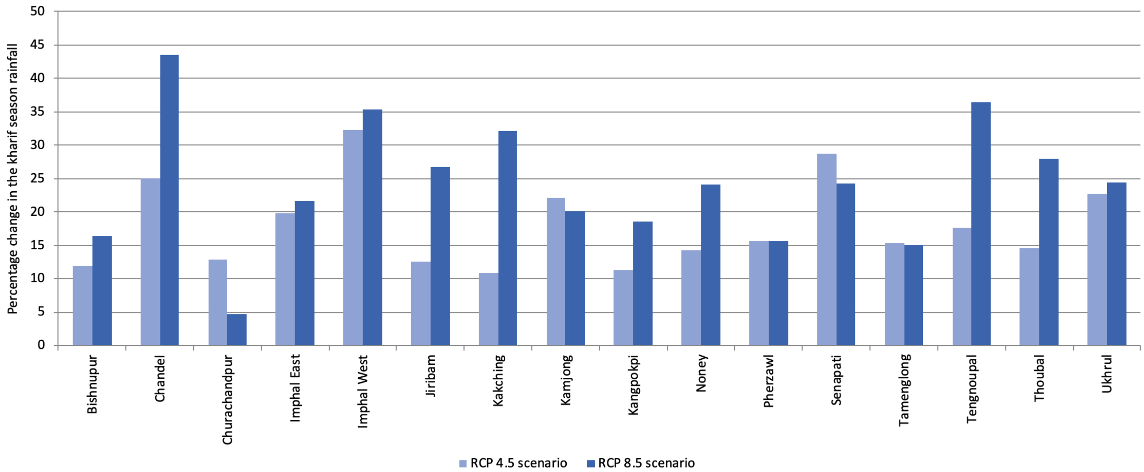


Figure 5-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

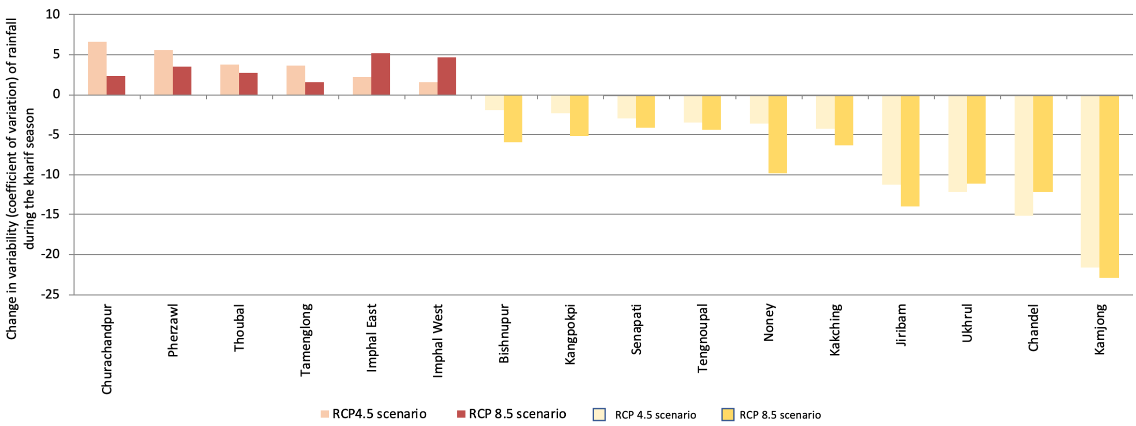


Figure 5-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

5.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 5-8 presents district-wise changes in the rabi season rainfall, and Figure 5-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 2% in Bishnupur to 19% in Kangpokpi	Increases in 10 districts by 2%–8% and declines in six districts by 1%–6%
RCP 8.5	Increases in all the districts, from 3% in Kakching to 30% in Chandel	Increases in 10 districts by 1%–11% and declines in six districts by 2%–6%

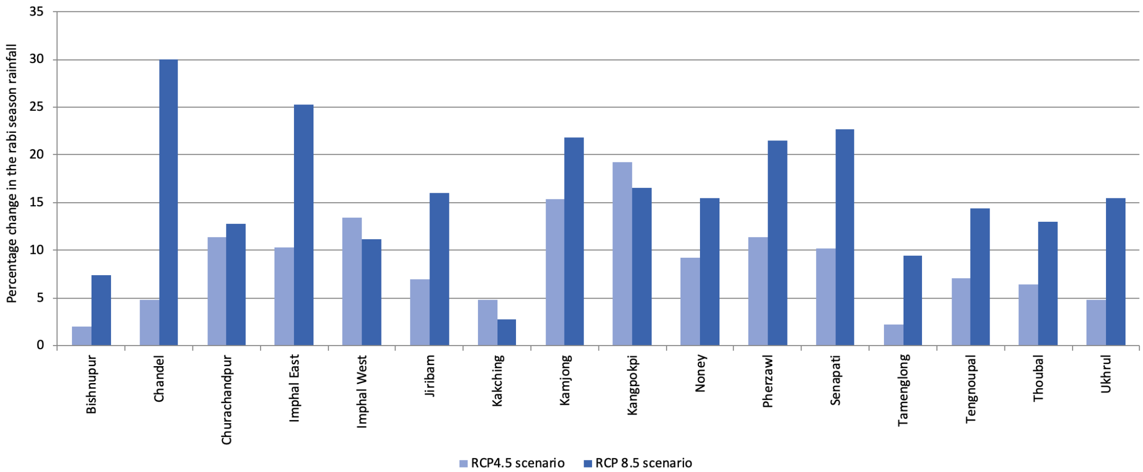


Figure 5-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

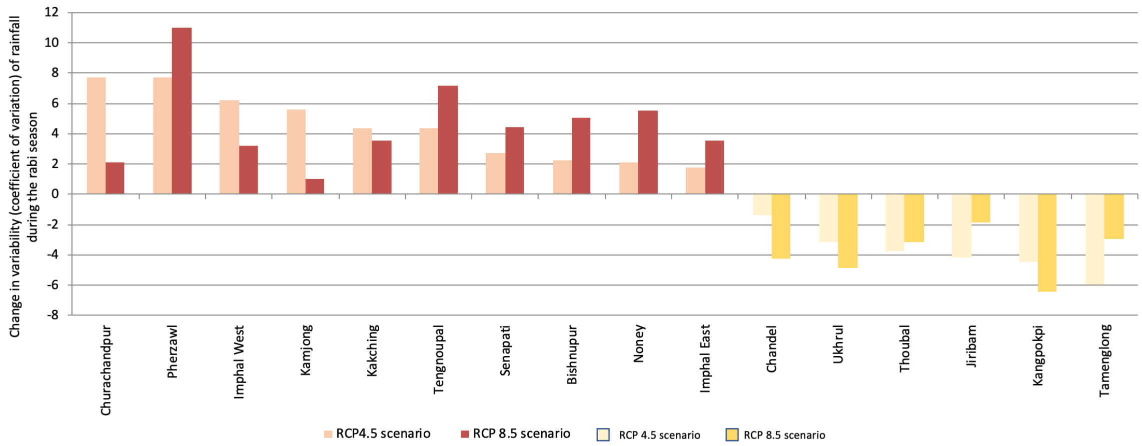


Figure 5-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

5.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and projected 2030s under the two climate scenarios, and the change was computed for all the districts of Manipur.

High-intensity rainfall events (Figure 5-10)

The total number of high-intensity rainfall events increases from 25 to 74 days during the historical period (1990–2019) to 51 to 140 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 70 to 145 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to four events in the districts with four events in Churachandpur and Kamjong districts; two events in Chandel, Imphal East, Imphal West, Jiribam, Noney, Senapati, Tamenglong, and Tengnoupal; and one event in Bishnupur, Kakching, Kangpokpi, Pherzawl, Thoubal, and Ukhrul.

RCP 8.5 scenario: The projected increase per annum is by four events in Churachandpur and Kamjong; three events in Chandel, Imphal East, Imphal West, Noney, Senapati, Tamenglong, Tengnoupal, and Thoubal; two events in Kangpokpi, Kakching, Jiribam, and Ukhrul; and one event in Bishnupur and Pherzawl.

Very high-intensity rainfall events (Figure 5-11)

The total number of very high-intensity rainfall events increases from 1 to 11 days during the historical period (1990–2019) to 10 to 35 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 12 to 55 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one event in Bishnupur, Imphal East, Jiribam, Kakching, Kamjong, Kangpokpi, Noney, Pherzawl, Senapati, and Tamenglong. No change is projected in the remaining six districts of Tengnoupal, Ukhrul, Imphal West, Thoubal, Churachandpur, and Chandel.

RCP 8.5 scenario: The projected increase per annum is by two events in Kakching and Thoubal. One event is projected in 12 districts: Bishnupur, Chandel, Imphal West, Jiribam, Kamjong, Kangpokpi, Noney, Pherzawl, Senapati, Tamenglong, Tengnoupal, and Ukhrul. No change is projected for Churachandpur and Imphal East.

Rainfall deficient years (Figure 5-12)

Rainfall deficient years, computed considering the rainfall during the kharif season, are projected to decline in all the districts of Manipur under both climate scenarios. The number of rainfall deficient years declines from 8 to 13 years during the historical 30-year period to 7 to 12 years under the RCP 4.5 scenario and 7 to 11 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 2 years in Churachandpur, Imphal West, Tamenglong, Bishnupur, and Thoubal; 1 year in Chandel, Imphal East, Jiribam, Kamjong, Kangpokpi, Noney, Pherzawl, Senapati, Tengnoupal, and Ukhrul. No change is projected in Kakching.

RCP 8.5 scenario: The projected decline is by 3 years in Bishnupur, Churachandpur, Tamenglong, Thoubal, and Tengnoupal; 2 years in Chandel, Imphal East, Jiribam, Kamjong, Pherzawl, and Senapati; and one year in Imphal West, Kakching, Kangpokpi, Noney, and Ukhrul.

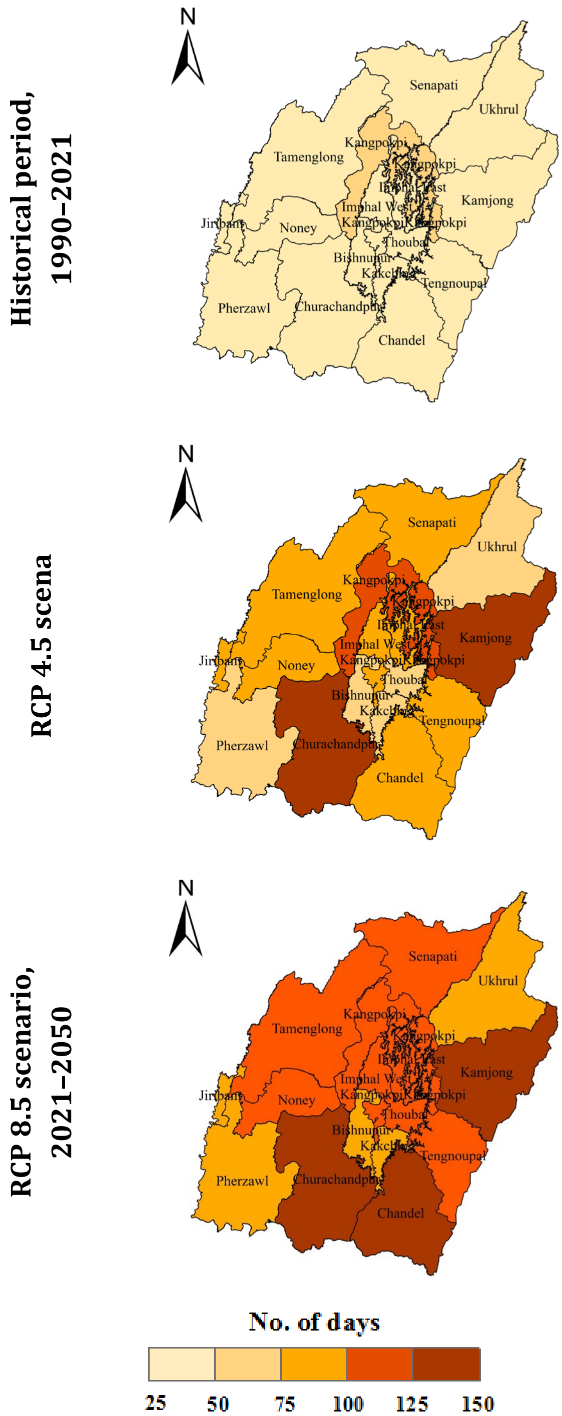


Figure 5-10: The total number of high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

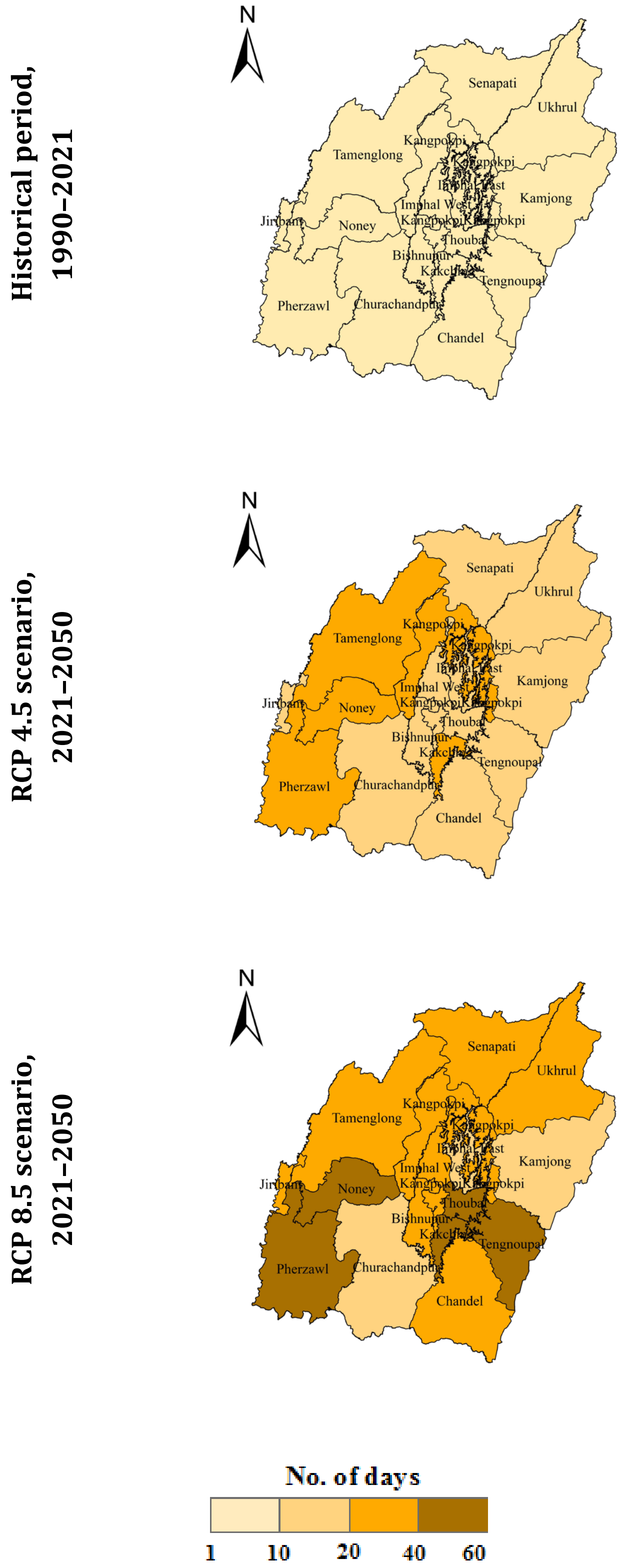


Figure 5-11: The total number of very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

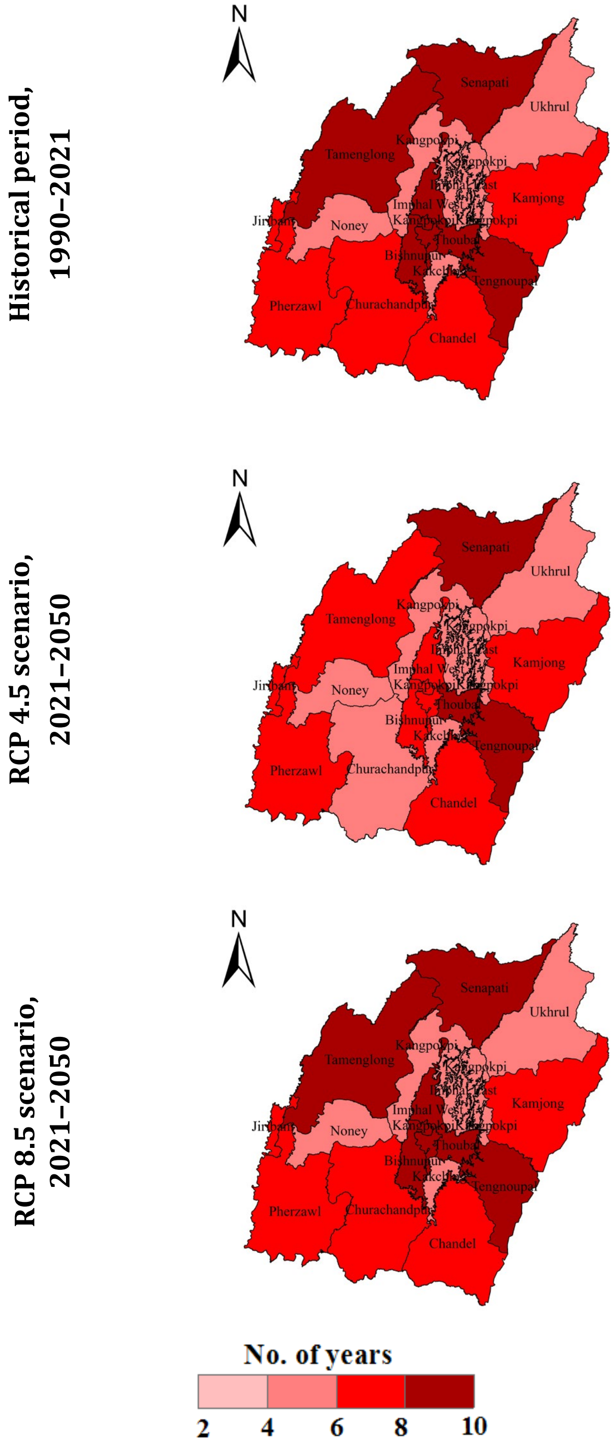


Figure 5-12: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

5.4 The summary of projected changes in the climate for Manipur

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 5-1).

- The summer maximum and winter minimum temperatures are projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 5-2).

- The kharif season rainfall is projected to increase by >25% in Chandel, Senapati, and Imphal West under the RCP 4.5 scenario and Kakching, Thoubal, Chandel, and Imphal West in the RCP 8.5 scenario.

Rainfall variability during the kharif season is projected to increase in some districts and decline in others under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- The projected increase in rainfall variability is in Churachandpur, Pherzawl, Thoubal, Tamenglong, Imphal East, and Imphal West, and the decline in variability is in the remaining districts under both the climate scenarios.

Rainfall variability during the rabi season is projected to increase in some districts and decline in others under RCP 4.5 and RCP 8.5 scenarios compared to the historical period.

- The projected increase in rainfall variability is in Imphal East, Imphal West, Churachandpur, Pherzawl, Kakching, Noney, Senapati, Kamjong, Bishnupur, and Tengnoupal, and the decline in variability is in the remaining districts under both the climate scenarios.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 5-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 5 days under the RCP 4.5 scenario and 2 to 6 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 5-4).

- High-intensity rainfall events are projected to increase by one to four events per annum under both climate scenarios.
- Very-high intensity rainfall events are projected to increase by one event per annum under the RCP 4.5 scenario and one to two events under the RCP 8.5 scenario.

Rainfall deficient years are projected to decline in all the districts under both the climate scenarios compared to the historical period (1990–2019; Appendix 5-4).

- The decline in rainfall deficient years is by 1 to 2 years during the projected period compared to the historical period.

Appendix

Appendix 5-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (oC) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Bishnupur	1.5	1.8	0.6	1.3
Chandel	1.9	3.1	2.0	2.7
Churachandpur	2.4	2.5	1.7	2.8
Imphal East	0.9	1.6	1.5	1.0
Imphal West	2.3	2.9	1.5	2.3
Jiribam	1.7	2.6	1.7	2.1
Kakching	1.4	2.0	2.1	0.7
Kamjong	1.5	1.9	1.5	1.0
Kangpokpi	1.3	1.3	0.8	1.3
Noney	2.2	2.3	1.8	1.4
Pherzawl	2.5	2.8	1.5	2.2
Senapati	0.8	1.0	0.9	1.2
Tamenglong	0.8	2.1	1.5	3.3
Tengnoupal	0.9	2.3	2.0	2.4
Thoubal	1.4	2.7	1.8	1.1
Ukhrul	1.5	1.7	1.0	1.1

Appendix 5-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Bishnupur	9	18	12	16	2	25
Chandel	24	33	25	44	5	30
Churachandpur	20	6	13	5	11	13
Imphal East	23	35	20	22	10	25
Imphal West	14	22	32	35	13	11
Jiribam	9	12	13	27	41	7
Kakching	16	24	11	32	5	3
Kamjong	23	35	22	20	15	22
Kangpokpi	12	17	11	19	19	17
Noney	13	19	14	24	9	15
Pherzawl	49	13	16	16	11	22
Senapati	22	30	29	24	10	23
Tamenglong	13	21	15	15	2	9
Tengnoupal	12	26	18	36	7	14
Thoubal	10	15	15	28	6	13
Ukhrul	13	34	23	66	5	15

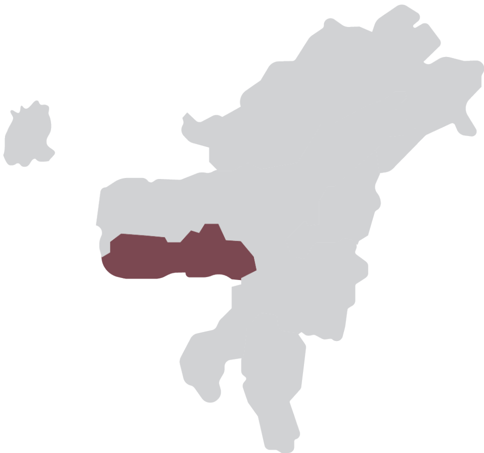
Appendix 5-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Bishnupur	2587	2678	2669
Chandel	2644	2731	2767
Churachandpur	2218	2309	2303
Imphal East	2633	2767	2721
Imphal West	2532	2654	2615
Jiribam	2271	2390	2340
Kakching	2623	2756	2750
Kamjong	2504	2541	2534
Kangpokpi	2160	2322	2321
Noney	2632	2765	2776
Pherzawl	2218	2234	2284
Senapati	2328	2413	2421
Tamenglong	2490	2515	2512
Tengnoupal	2623	2750	2779
Thoubal	2623	2731	2765
Ukhrul	2490	2595	2678

Appendix 5-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Bishnupur	32	55	72	1	20	24	12	10	9
Chandel	34	85	137	2	10	23	10	9	8
Churachandpur	31	138	145	3	12	12	10	8	7
Imphal East	34	92	112	2	20	14	9	8	7
Imphal West	27	92	115	1	11	35	12	10	11
Jiribam	32	92	78	2	19	32	10	9	8
Kakching	32	67	97	2	22	48	8	8	7
Kamjong	27	140	136	1	18	19	10	9	8
Kangpokpi	74	118	120	11	32	36	8	7	7
Noney	34	90	117	2	26	43	9	8	8
Pherzawl	31	63	70	3	35	42	10	9	8
Senapati	28	84	110	2	17	33	12	11	10
Tamenglong	26	85	105	1	24	22	12	10	9
Tengnoupal	32	89	116	2	15	45	13	12	10
Thoubal	32	73	121	2	12	55	13	11	10
Ukhrul	25	51	79	1	15	32	8	7	7

6. Meghalaya



Meghalaya is situated in the north-east of India and shares its domestic border with Assam to the north and north-east and international border with Bangladesh to the south and south-west. It has a geographical area of 22,429 sq. km and a population of 2.96 million according to the 2011 Census. Of the total population, close to 79.93% live in rural areas. Meghalaya has 11 districts rich in natural resources. The state has three distinct regions: Garo Hills, Khasi Hills, and Jaintia Hills. It is drained by a number of rivers including Sanda, Simsang Umngot, and Myntdu. Meghalaya is vulnerable to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.). The plains of Meghalaya adjoining Assam are especially affected by floods because of the backflow of water from the Brahmaputra River during the rainy season between June and October.

These characteristics make Meghalaya climate-sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

6.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

6.1.1 Trends in temperature

Meghalaya recorded a moderate warming of 0.24°C to 0.67°C in the summer maximum temperature and 0.16°C to 0.37°C in the winter minimum temperature during the historical period.

Figure 6-1 presents the mean summer maximum and winter minimum temperatures in Meghalaya during the historical period.

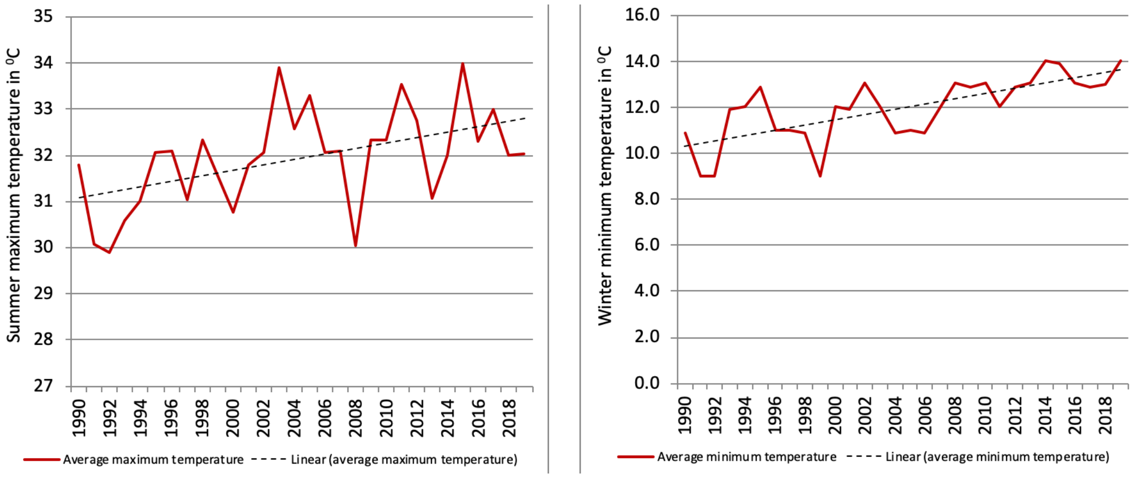


Figure 6-1: Mean summer maximum and winter minimum temperatures in Meghalaya during the historical period (1990–2019)

6.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual and kharif season rainfall was recorded across the districts of Meghalaya. The increase in the annual and kharif season rainfall was largely in the range of 10%–15% in a majority of the districts. Figure 6-2 presents the mean annual rainfall in Meghalaya during the historical period.

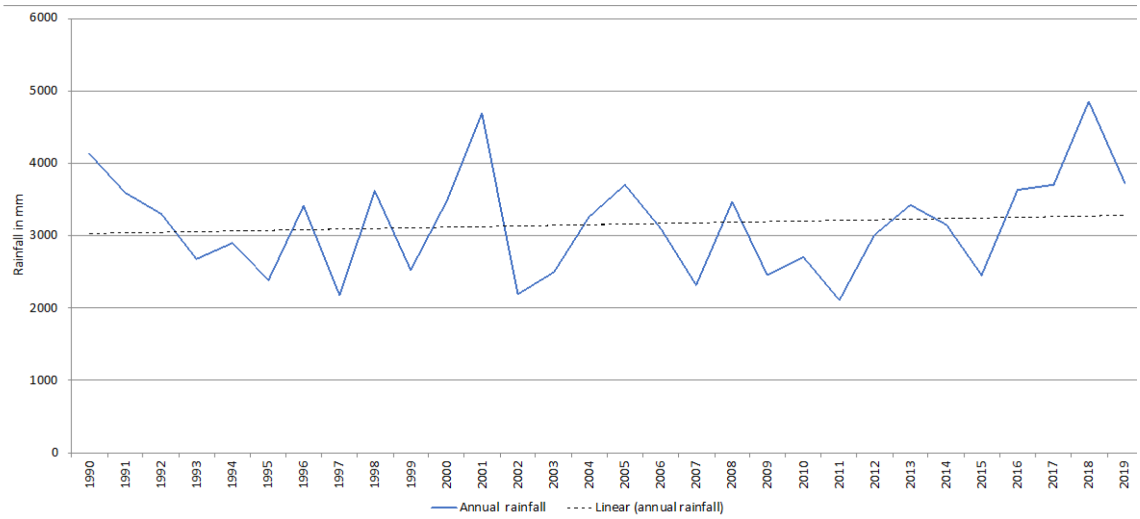


Figure 6-2: Mean annual rainfall in Meghalaya during the historical period (1990–2019)

The kharif season rainfall variability (the coefficient of variation) ranged from 22% in North Garo Hills to 39% in Ri Bhoi (Figure 4-3). The rabi season rainfall variability was in the range of 48% in West Jaintia Hills to 70% in South West Garo Hills during the historical period (Figure 6-3).

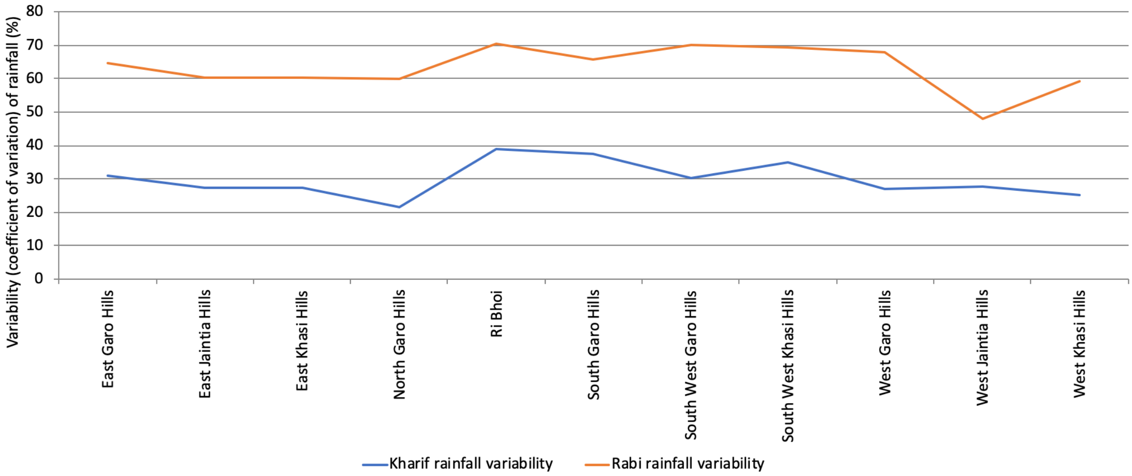


Figure 6-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

6.2 Climate change projections

Temperature and rainfall are projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

6.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Meghalaya are presented in Figure 6-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by 1°C to 2°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

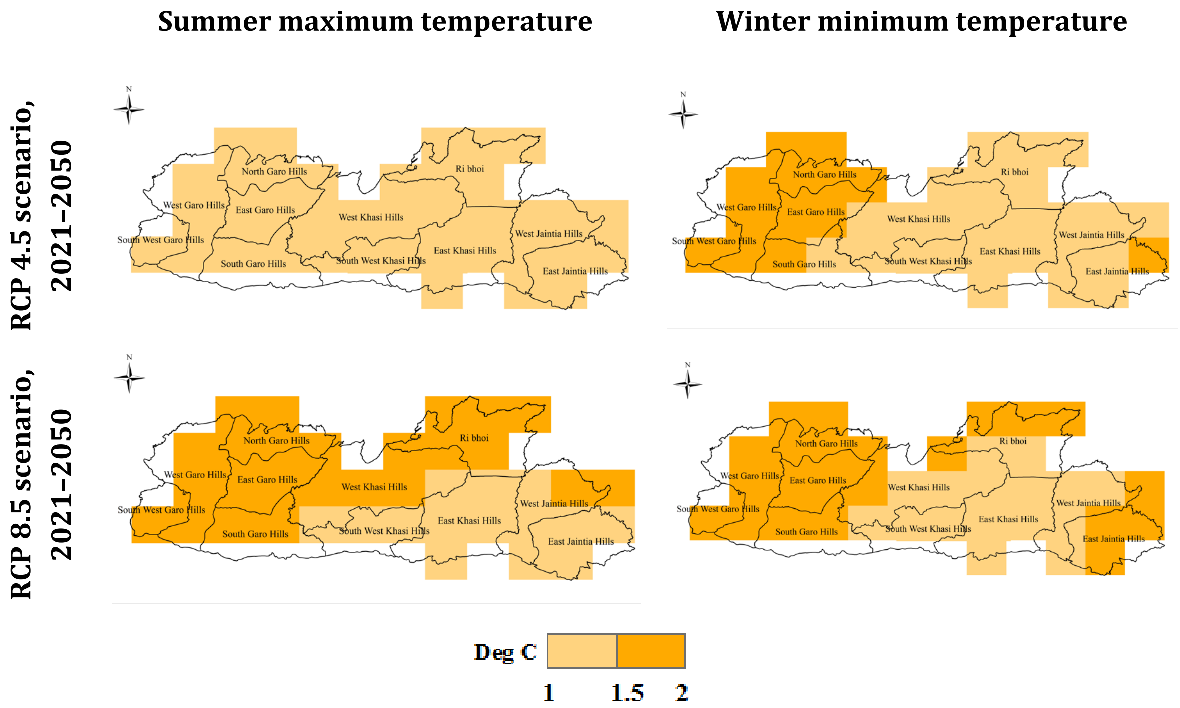


Figure 6-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

6.2.2 Rainfall projections

6.2.2.1 Number of rainy days

According to the India Meteorological Department, a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 6-5). The number of rainy days during the historical period and the projected 2030s under both RCP 4.5 and 8.5 scenarios is presented in Appendix 6-3. The total number of rainy days that ranged from 2009 to 2750 days over the 30-year historical period increases to 2104 to 2780 days under the RCP 4.5 scenario and 2232 to 2946 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 1 to 5 days annually in all the districts. The increase is by 5 days in South West Khasi Hills; 4 days in East Garo Hills, North Garo Hills, Ri Bhoi, South Garo Hills, and West Jaintia Hills; 3 days in East Khasi Hills, South West Garo Hills, and West Garo Hills; 2 days in West Khasi Hills; and 1 day in East Jaintia Hills.

RCP 8.5 scenario: Projected to increase by 1to 12 days annually in all the districts. The increase is by 12 days in Ri Bhoi; 10 days in West Jaintia Hills and South Garo Hills; 8 days in East Garo Hills and South West Garo Hills; 7 days in East Jaintia Hills, North Garo Hills, West Garo Hills, and West Khasi Hills; and 6 days in East Khasi Hills and South West Garo Hills.

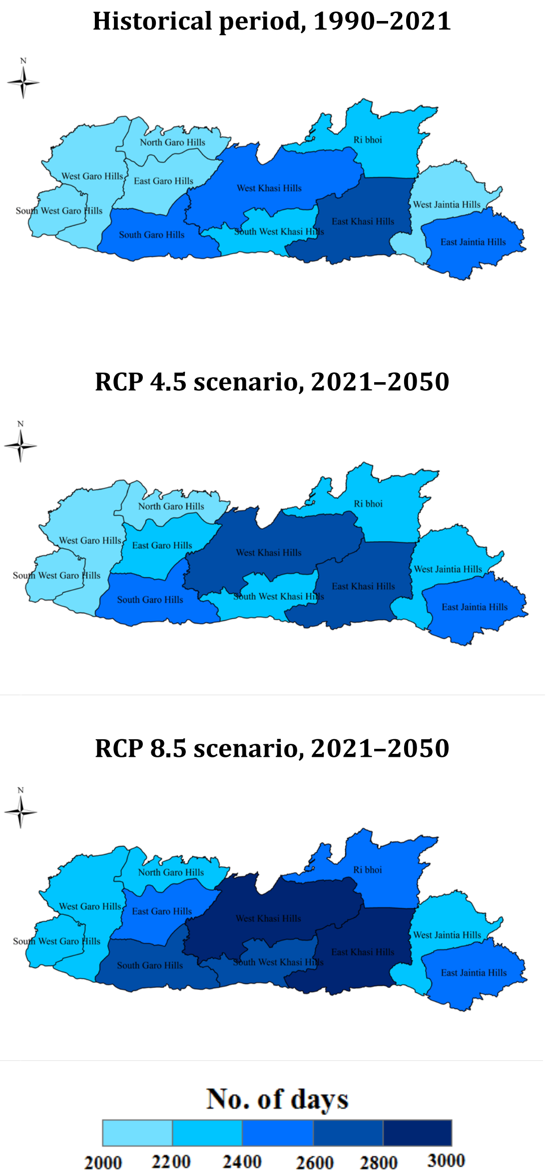


Figure 6-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

6.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 6-6 presents district-wise changes in the kharif season rainfall, and Figure 6-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 7% in East Garo Hills to 19% in West Jaintia Hills	Declines in all the districts by 6%–22%
RCP 8.5	Increases in all the districts, from 12% in East Garo Hills to 20% in Ri Bhoi	Declines in all the districts by 4%–23%

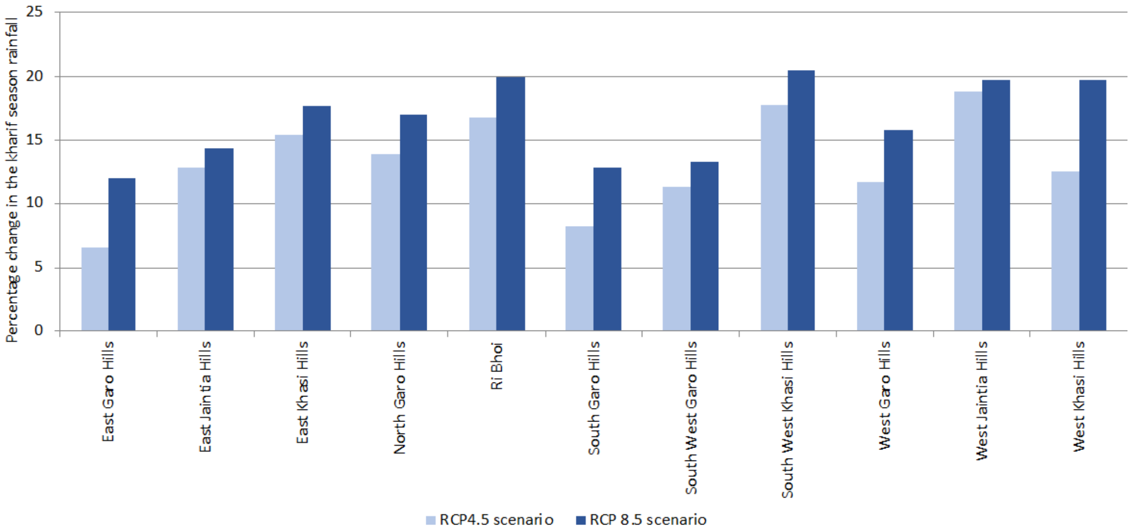


Figure 6-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

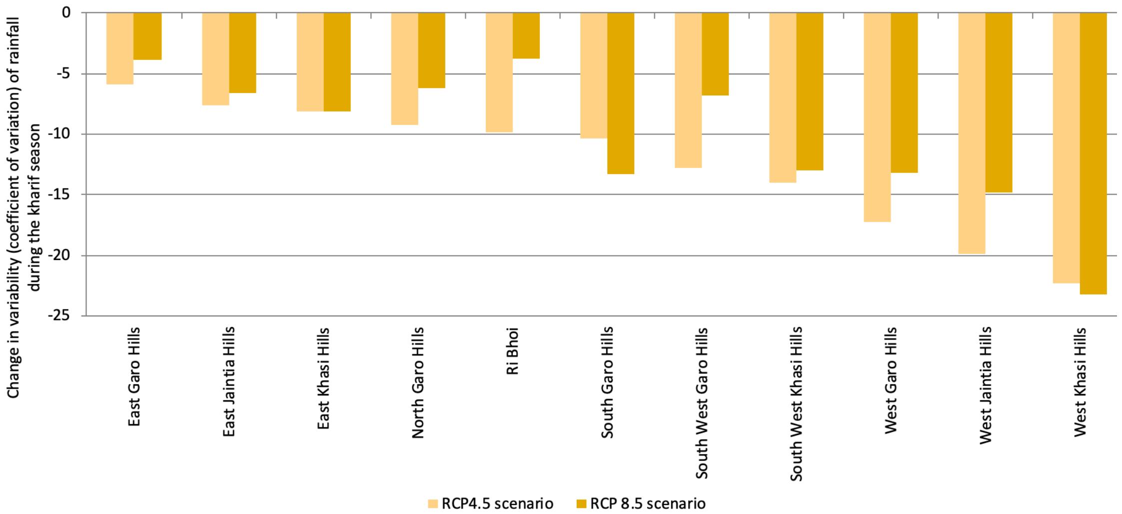


Figure 6-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

6.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 6-8 presents district-wise changes in the rabi season rainfall, and Figure 6-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 5% in East Garo Hills and East Jaintia Hills to 21% in West Jaintia Hills	Declines in all the districts by 6%–22%
RCP 8.5	Increases in all the districts, from 8% in East Jaintia Hills to 34% in West Jaintia Hills	Declines in all the districts by 4%–23%

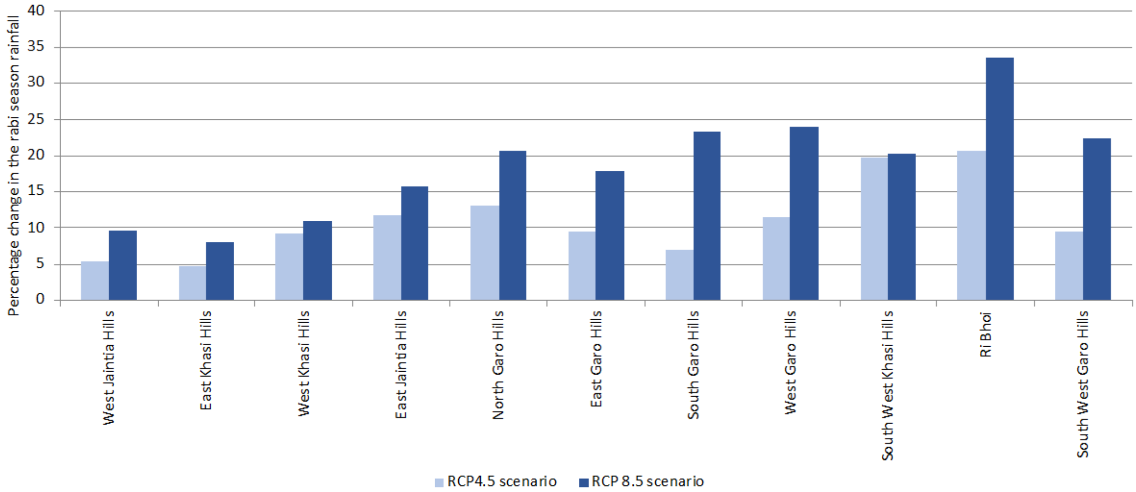


Figure 6-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

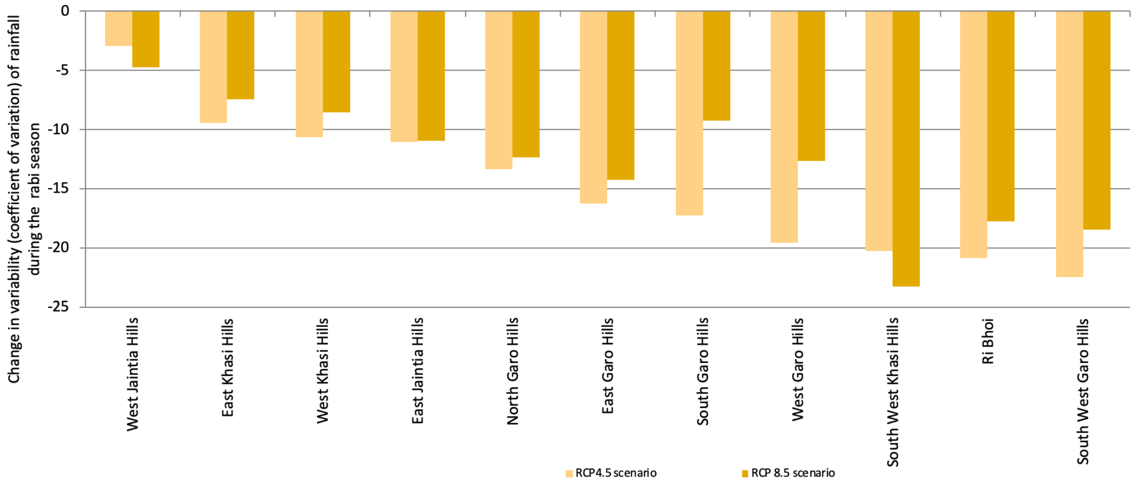


Figure 6-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

6.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and projected 2030s under the two climate scenarios, and the change was computed for all the districts of Meghalaya.

High-intensity rainfall events (Figure 6-10)

The total number of high-intensity rainfall events increases from 97 to 416 days during the historical period (1990–2019) to 124 to 450 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 167 to 476 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: High-intensity rainfall events are projected to increase per annum by one to four events. The increase is by four events in West Jaintia Hills; three events in East Khasi Hills and South West Garo Hills; two events in Ri Bhoi, South Garo Hills, West Garo Hills, and West Khasi Hills; and one event in East Garo Hills, East Jaintia Hills, and North Garo Hills. No change is projected in South West Khasi Hills.

RCP 8.5 scenario: High-intensity rainfall events are projected to increase per annum by one to five events. The increase is by five events in and West Jaintia Hills; four events in East Khasi Hills; three events in North Garo Hills, Ri Bhoi, South Garo Hills, South West Garo Hills, West Garo Hills, and West Khasi Hills; two events in East Garo Hills and East Jaintia Hills; and one event in South West Khasi Hills.

Very high-intensity rainfall events (Figure 6-11)

The total number of very high-intensity rainfall events increases from 12 to 475 days during the historical period (1990–2019) to 78 to 495 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 92 to 480 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: Very high-intensity rainfall events are projected to increase per annum by one to four events. The increase is by four events in West Khasi Hills; two events in East Khasi Hills, East Jaintia Hills, North Garo Hills, West Garo Hills, and West Jaintia Hills; and one event in East Garo Hills, Ri Bhoi, South Garo Hills, South West Garo Hills, and South West Khasi Hills.

RCP 8.5 scenario: Very high-intensity rainfall events are projected to increase per annum by one to five events. The increase is by five events in West Khasi hills; two events in East Garo Hills, East Khasi Hills, North Garo Hills, Ri Bhoi, South West Garo Hills, and West Jaintia Hills; three events in East Jaintia Hills and West Garo Hills; and one event in South Garo Hills and South West Garo Hills.

Rainfall deficient years (Figure 6-12)

Rainfall deficient years, computed considering the rainfall during the kharif season, are projected to decline in all the districts of Meghalaya under both climate scenarios. The number of rainfall deficient years declines from 6 to 14 years during the historical 30-year period to 5 to 11 years under the RCP 4.5 scenario and 4 to 9 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 1 to 4 years with a decline of 4 years in West Khasi Hills; 3 years in East Garo Hills, East Jaintia Hills, Ri Bhoi, and West Garo Hills; 2 years in East Khasi Hills, South Garo Hills, South West Garo Hills, South West Khasi Hills, and West Jaintia Hills; and 1 year in North Garo Hills.

RCP 8.5 scenario: The projected decline is by 1 to 5 years with a decline of 5 years in West Khasi Hills, East Garo Hills, East Jaintia Hills, and Ri Bhoi; 4 years in West Garo Hills, 3 years in East Khasi Hills, South Garo Hills, South West Garo Hills, South West Khasi Hills, and West Jaintia Hills, and 1 year in North Garo Hills.

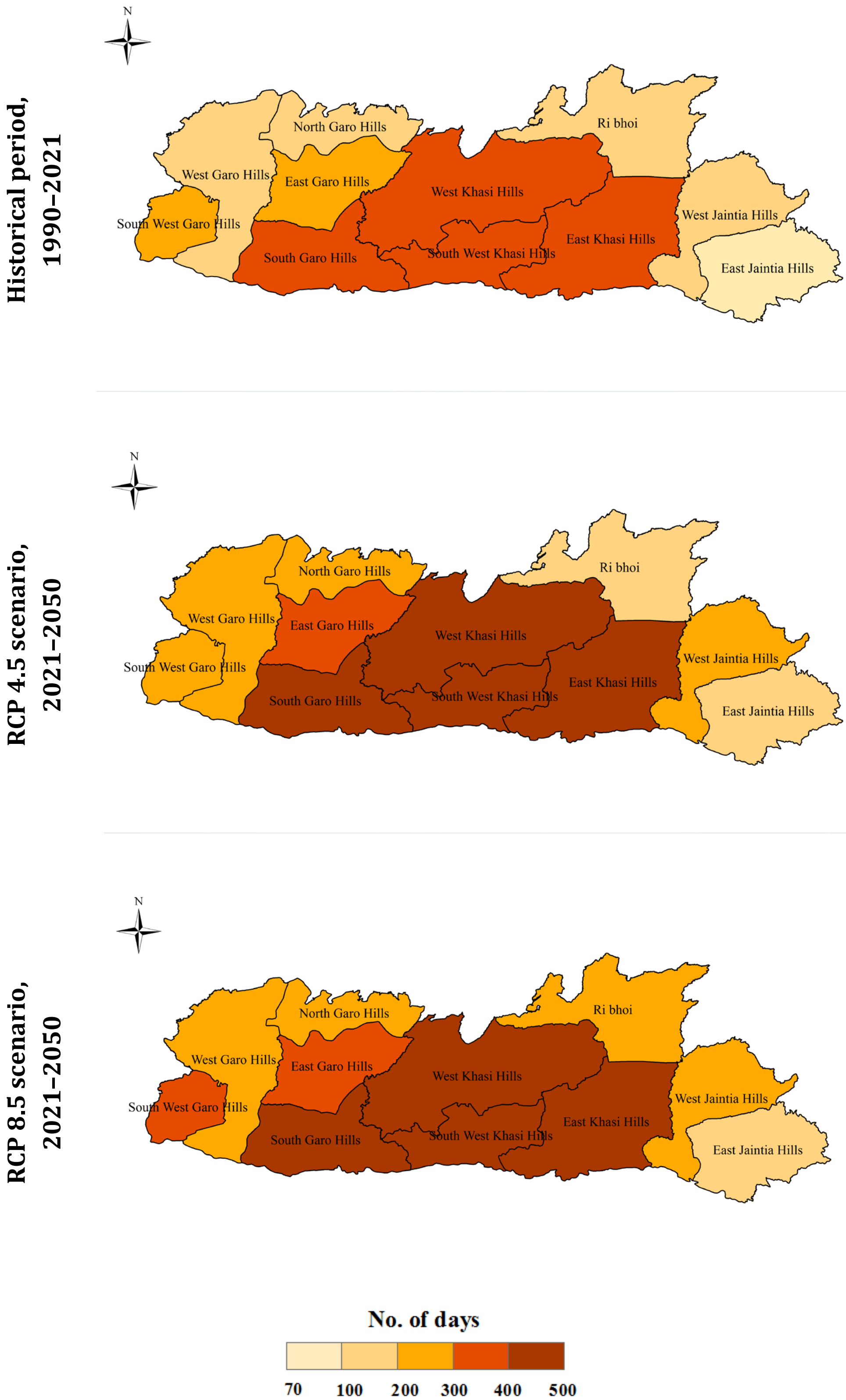


Figure 6-10: The total number of high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

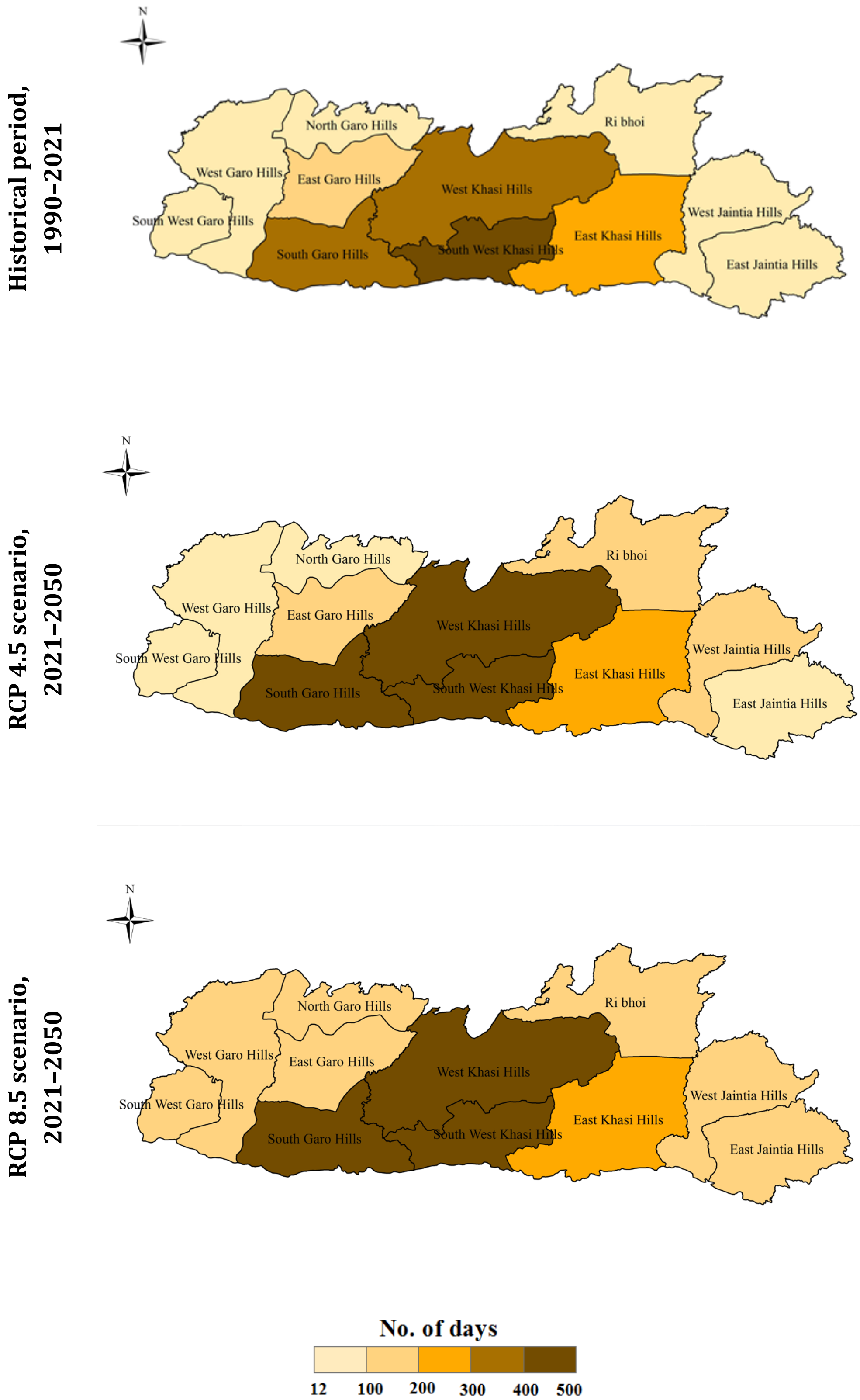


Figure 6-11: The total number of very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

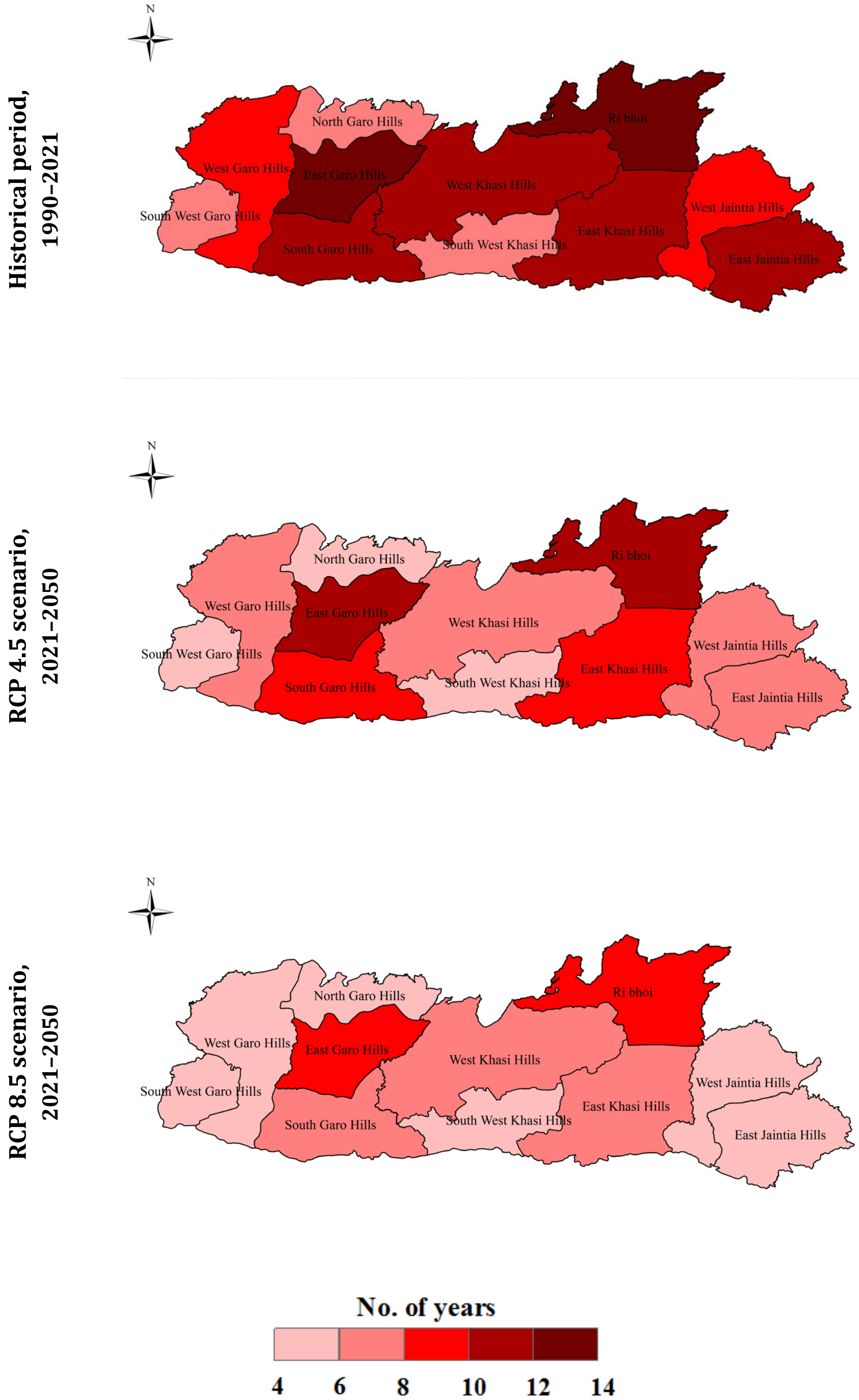


Figure 6-12: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

6.4 The summary of projected changes in the climate for Meghalaya

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 6-1).

- The summer maximum temperature is projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.
- The winter minimum temperature is projected to warm by 1°C to 2 °C under RCP 4.5 and RCP 8.5 scenarios.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 6-2).

- There will be a notable increase in rainfall particularly in the eastern districts of Ri Bhoi, Jaintia Hills, and East Khasi Hills under RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to increase in some districts and decline in others under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the kharif season is projected in the range of 6%–22% under the RCP 4.5 scenario and 4%–23% under the RCP 8.5 scenario. Under both climate scenarios, maximum decline in variability is projected for Ri Bhoi.

Rainfall variability during the rabi season is projected to decline in all the districts under the RCP 8.5 scenario but is projected to increase in a few districts under the RCP 4.5 scenario.

- A decline in rainfall variability during the rabi season is projected in the range of 3%–22% under the RCP 4.5 scenario and 5%–23% under the RCP 8.5 scenario.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 6-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 5 days under the RCP 4.5 scenario and 6 to 12 days under the RCP 8.5 scenario.
- A larger increase is projected particularly in the eastern and southern districts of Meghalaya.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 6-4).

- High-intensity rainfall events are projected to increase by one to four events per annum under the RCP 4.5 scenario and one to five events under the RCP 8.5 scenario.
- Very-high intensity rainfall events are projected to increase by one to four events per annum under both climate scenarios.

Rainfall deficient years are projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 6-4).

- The decline in rainfall deficient years is projected to be 1 to 4 years under the RCP 4.5 scenario and 1 to 5 years under the RCP 8.5 scenario

Appendix

Appendix 6-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
East Garo Hills	1.5	1.7	1.3	1.4
East Jaintia Hills	1.4	1.9	1.7	1.9
East Khasi Hills	1.2	1.8	1.6	1.7
North Garo Hills	1.1	1.8	1.5	1.8
Ri Bhoi	1.2	1.4	1.6	1.8
South Garo Hills	1.3	1.5	1.3	1.7
South West Garo Hills	1.2	1.5	1.7	1.9
South West Khasi Hills	1.1	1.8	1.5	1.8
West Garo Hills	1.2	1.4	1.6	1.8
West Jaintia Hills	1.3	1.5	1.3	1.7
West Khasi Hills	1.2	1.5	1.7	1.9

Appendix 6-2: Changes in rainfall under climate scenarios

Districts	Changes (%) in rainfall during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
East Garo Hills	7	12	4	12	5	10
East Jaintia Hills	13	14	13	16	5	8
East Khasi Hills	15	18	20	23	9	11
North Garo Hills	14	17	14	19	12	16
Ri Bhoi	17	20	11	21	13	21
South Garo Hills	8	13	10	15	9	18
South West Garo Hills	11	13	11	16	7	23
South West Khasi Hills	18	20	12	16	11	24
West Garo Hills	12	16	12	15	20	20
West Jaintia Hills	19	20	14	17	21	34
West Khasi Hills	13	20	23	35	10	22

Appendix 6-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
East Garo Hills	2199	2312	2553
East Jaintia Hills	2411	2512	2598
East Khasi Hills	2750	2780	2946
North Garo Hills	2023	2134	2232
Ri Bhoi	2213	2321	2560
South Garo Hills	2431	2541	2729
South West Garo Hills	2099	2129	2275
South West Khasi Hills	2331	2371	2662
West Garo Hills	2009	2104	2232
West Jaintia Hills	2157	2213	2378
West Khasi Hills	2544	2675	2855

Appendix 6-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
East Garo Hills	272	301	325	123	150	175	14	11	9
East Jaintia Hills	97	124	167	12	78	97	11	8	6
East Khasi Hills	355	450	476	214	260	275	11	9	8
North Garo Hills	187	220	265	37	87	92	6	5	5
Ri Bhoi	148	200	223	70	101	132	14	11	9
South Garo Hills	357	421	450	386	401	412	11	9	8
South West Garo Hills	216	297	312	49	90	103	7	5	4
South West Khasi Hills	416	430	455	475	495	480	8	6	5
West Garo Hills	166	220	267	35	95	132	10	7	6
West Jaintia Hills	133	243	287	45	105	113	9	7	6
West Khasi Hills	380	443	468	331	445	480	12	8	7

7. Mizoram

Mizoram is situated in the south-eastern corner of north-east India. It shares borders with Assam and Manipur to the north and north-east and Tripura in the north-west. Mizoram shares its international borders with Myanmar to the east and Bangladesh to the west. It has a geographical area of 21,081 sq. km and a population of 1.09 million, according to the 2011 Census. Of the total population, close to 47.89% live in rural areas. It rains heavily in Mizoram from May to September. The state has eight districts, which are tribal and hill districts. It is exposed to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.). Floods are common in the state and cause significant damage to croplands lying in the fluvial flood plains of Mat, Chhimtuipui, Tlawng, Tut, Teirei, Khawthlang Tuipui, Tuirial, Tuivawl, and Tuivai rivers.

These characteristics make Mizoram climate sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

7.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

7.1.1 Trends in temperature

Mizoram recorded a moderate warming of 0.24°C to 0.27°C in the summer maximum temperature and 0.20°C to 0.34°C in the winter minimum temperature during the historical period. Figure 7-1 presents the mean summer maximum and winter minimum temperatures in Mizoram during the historical period.

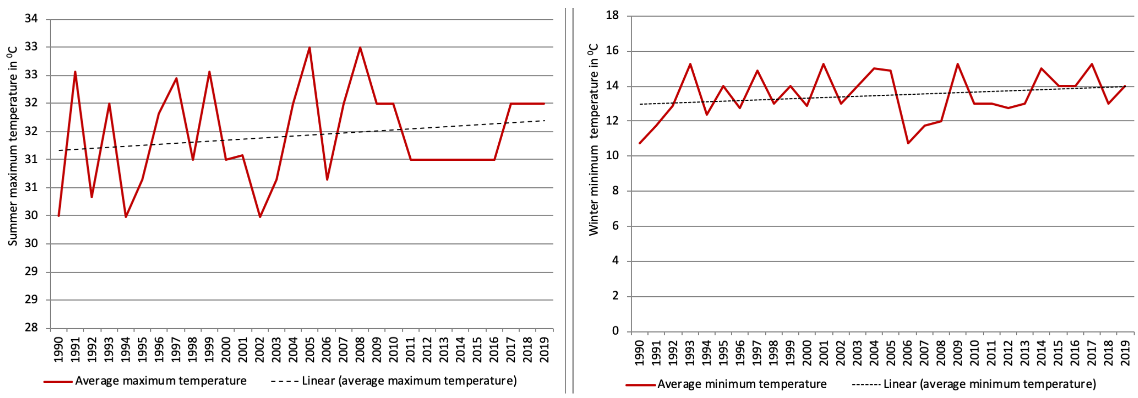


Figure 7-1: Mean summer maximum and winter minimum temperatures in Mizoram during the historical period (1990–2019)

7.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual and kharif season rainfall, the main monsoon season, was recorded across the districts of Mizoram. The increase in the annual and kharif season rainfall was largely in the range of 10%–15% in a majority of the districts. The increase in kharif season rainfall was in the range of 5%–10% in a majority of the districts. Figure 7-2 presents the mean annual rainfall in Mizoram during the historical period.

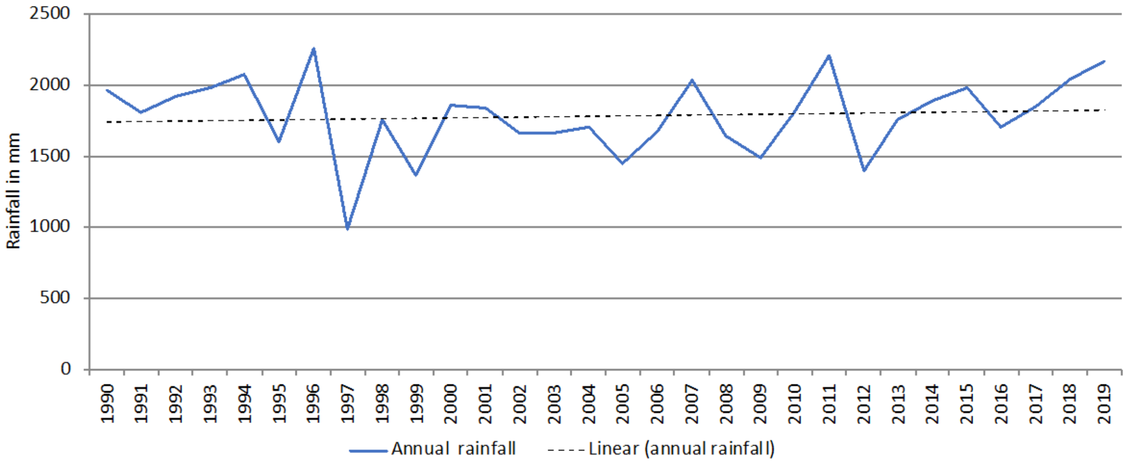


Figure 7-2: Mean annual rainfall in Mizoram during the historical period (1990–2019)

The kharif season rainfall variability (the coefficient of variation) ranged from 17% in Mamit to 42% in Lunglei (Figure 7-3). The rabi season rainfall variability was in the range of 49% in Mamit to 72% in Lawngtlai and Lunglei, indicating a complete failure of rainfall during the historical period (Figure 7-3).

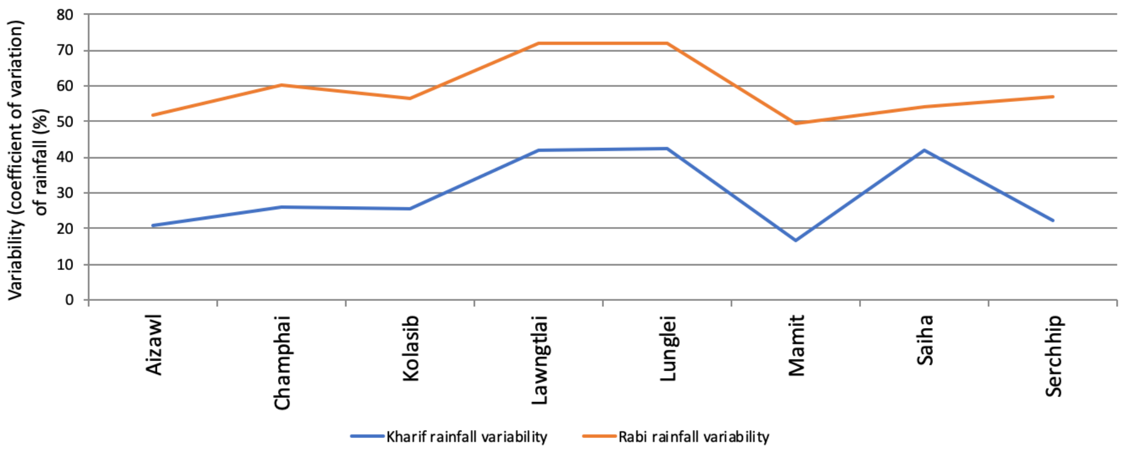


Figure 7-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

7.2 Climate change projections

Temperature and rainfall are projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

7.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Mizoram are presented in Figure 7-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by 1°C to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

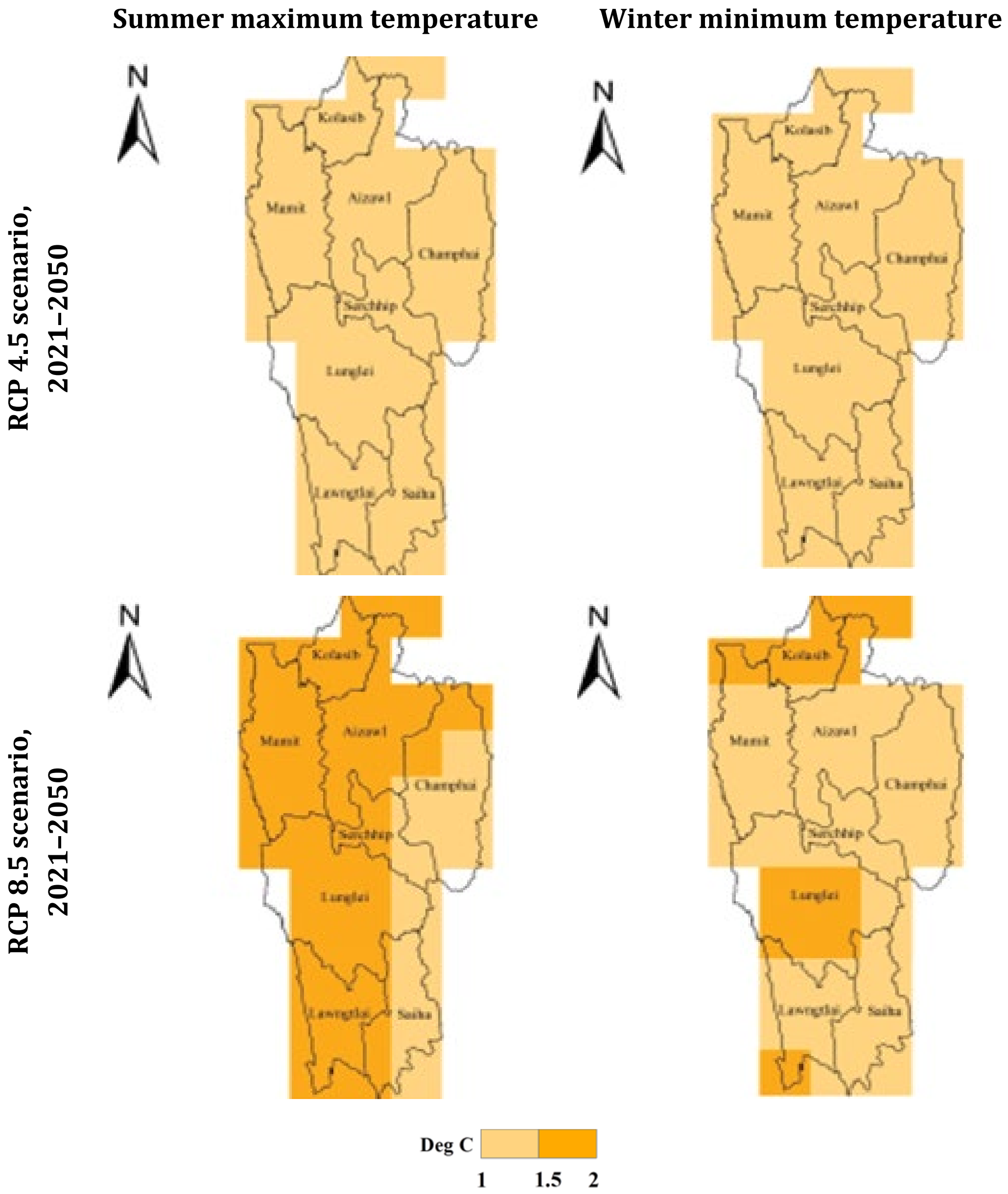


Figure 7-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

7.2.2 Rainfall projections

7.2.2.1 Number of rainy days

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 7-5). The number of rainy days during the historical period and the projected 2030s under RCP 4.5 and 8.5 scenarios is presented in Appendix 7-3. The total number of rainy days that ranged from 1647 to 2606 days over the 30-year historical period increases to 1689 to 2698 days under the RCP 4.5 scenario and 1725 to 2793 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 1 to 5 days annually with an increase of 5 days in Mamit; 3 days in Aizawl, Champhai, Saiha, and Serchhip; 2 days in Kolasib; and one day in Lawngtlai and Lunglei.

RCP 8.5 scenario: Projected to increase by 1 to 10 days annually with an increase of 10 days in Mamit; 9 days in Kolasib; 8 days in Serchhip; 7 days in Champhai; 6 days in Aizawl and Saiha; 3 days in Lawngtlai; and 2 days in Lunglei.

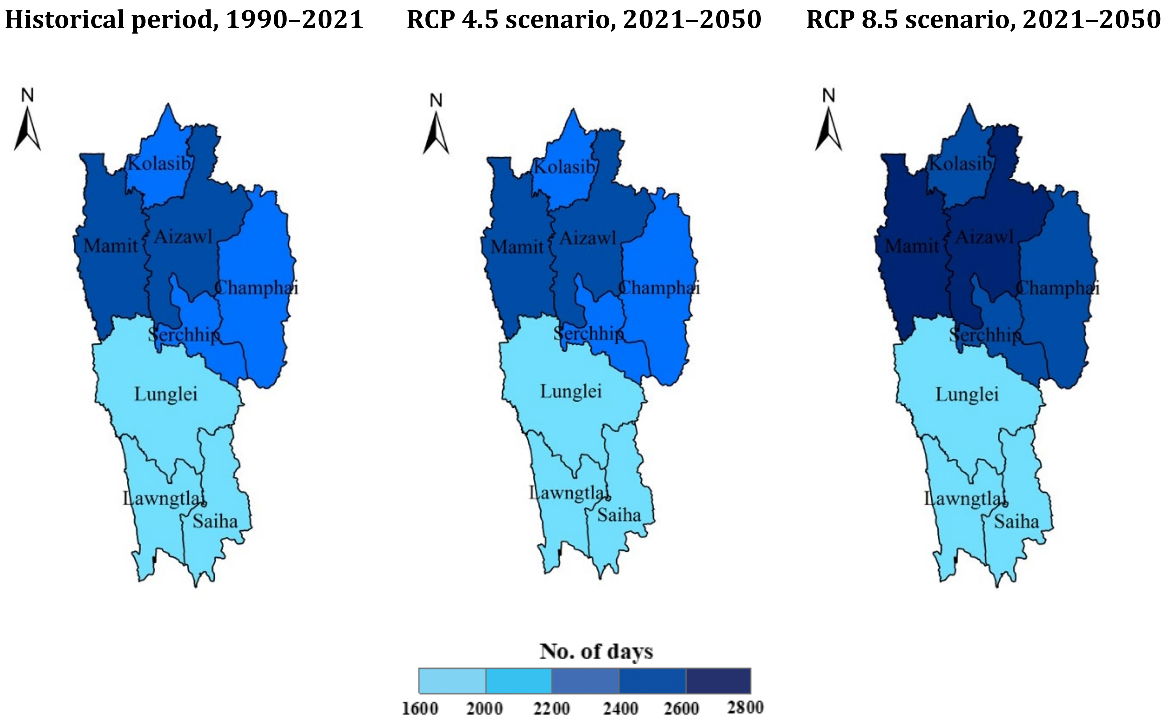


Figure 7-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

7.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 7-6 presents district-wise changes in the kharif season rainfall, and Figure 7-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 3% in Saiha to 20% in Champhai	Declines in all the districts by 1%–24%
RCP 8.5	Increases in all the districts, from 6% in Lawngtlai to 21% in Aizawl	Declines in all the districts by 3%–24%

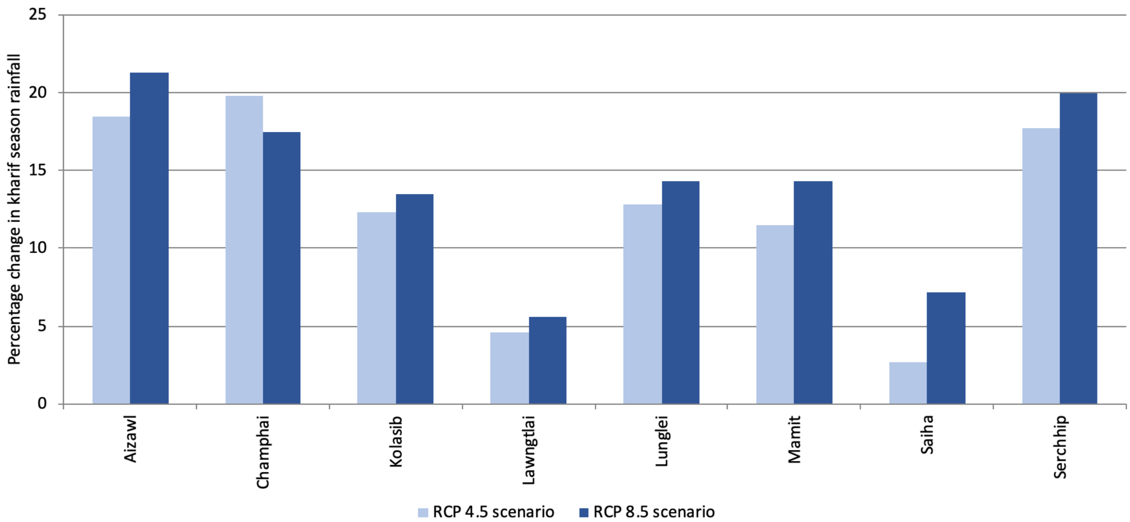


Figure 7-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

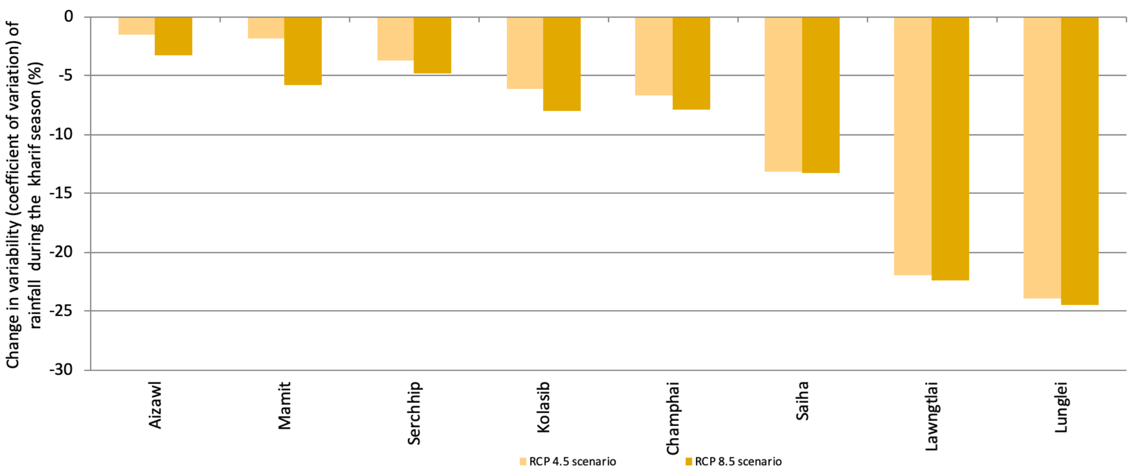


Figure 7-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

7.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 7-8 presents district-wise changes in the rabi season rainfall, and Figure 7-9 presents changes in the variability of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 4% in Lawngtlai to 24% in the Champhai district	Declines in all the districts by 8%–32%.
RCP 8.5	Increases in all the districts, from 6% in Lawngtlai to 27% in Serchhip	Declines in all the districts by 3%–28%.

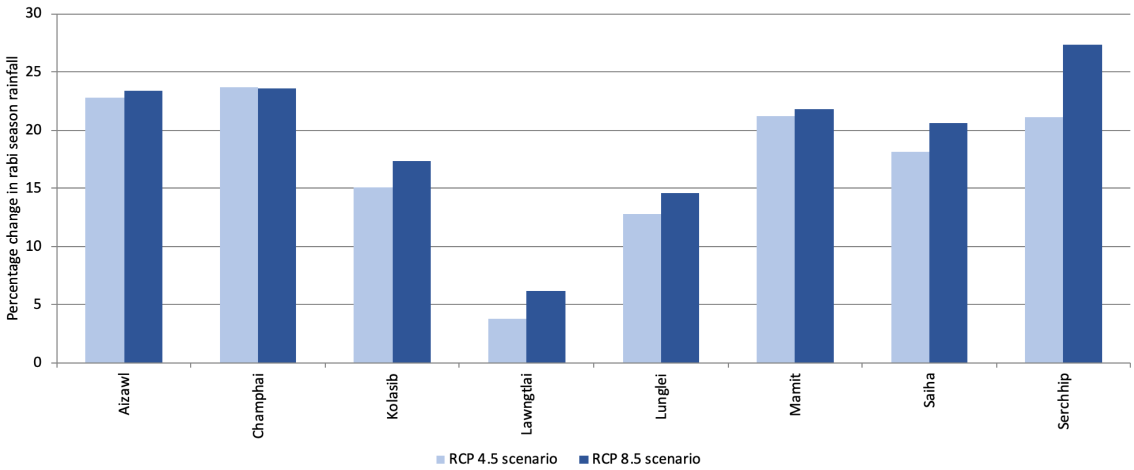


Figure 7-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

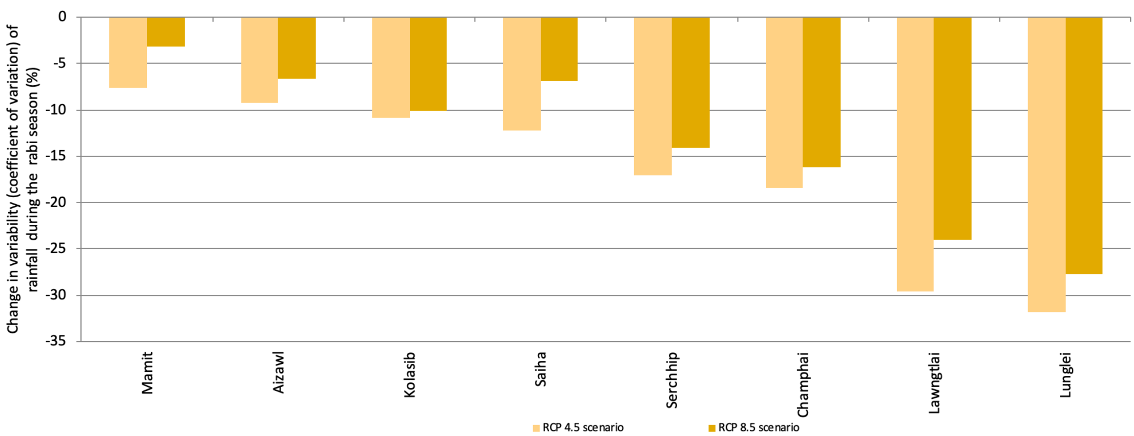


Figure 7-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

7.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and the projected 2030s under the two climate scenarios, and the change was computed for all the districts of Mizoram.

High-intensity rainfall events (Figure 7-10)

The total number of high-intensity rainfall events increases from 88 to 218 days during the historical period (1990–2019) to 123 to 290 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 180 to 305 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to three events in the districts with three events in Saiha and Serchhip; two events in Aizawl, Champhai, Kolasib, and Lawngtlai; one event in Lunglei; and no change in Mamit.

RCP 8.5 scenario: The projected increase per annum is by two to three events in the districts with three events in Lawngtlai, Mamit, Saiha, and Serchhip; two events in Aizawl, Champhai, and Kolasib; and no change in Lunglei.

Very high-intensity rainfall events (Figure 7-11)

The total number of very high-intensity rainfall events increases from 11 to 106 days during the historical period (1990–2019) to 48 to 125 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 79 to 144 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one event in Champhai and Lunglei; two events in Aizawl, Kolasib, Saiha, and Serchipp; and three events in Mamit. There is no change in Lawngtlai.

RCP 8.5 scenario: The projected increase per annum is by one event in Lawngtlai and Lunglei; two events in Aizawl and Kolasib; and three events in Champhai, Mamit, Saiha, and Serchhip.

Rainfall deficient years (Figure 7-12)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected to decline in all the districts of Mizoram under both climate scenarios. The number of rainfall deficient years declines from 5 to 14 years during the historical 30-year period to 4 to 10 years under the RCP 4.5 scenario and 3 to 10 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 1 to 4 years. The decline is by 1 year in Aizawl, Champhai, Mamit, and Serchhip; 2 years in Lunglei; 3 years in Lawngtlai; and 4 years in Saiha. There is no change in Kolasib.

RCP 8.5 scenario: The projected decline is by 1 to 4 years. The decline is by 1 year in Aizawl; 2 years in Champhai, Kolasib, Lunglei, and Mamit; 3 years in Serchhip; and 4 years in Lawngtlai and Saiha.

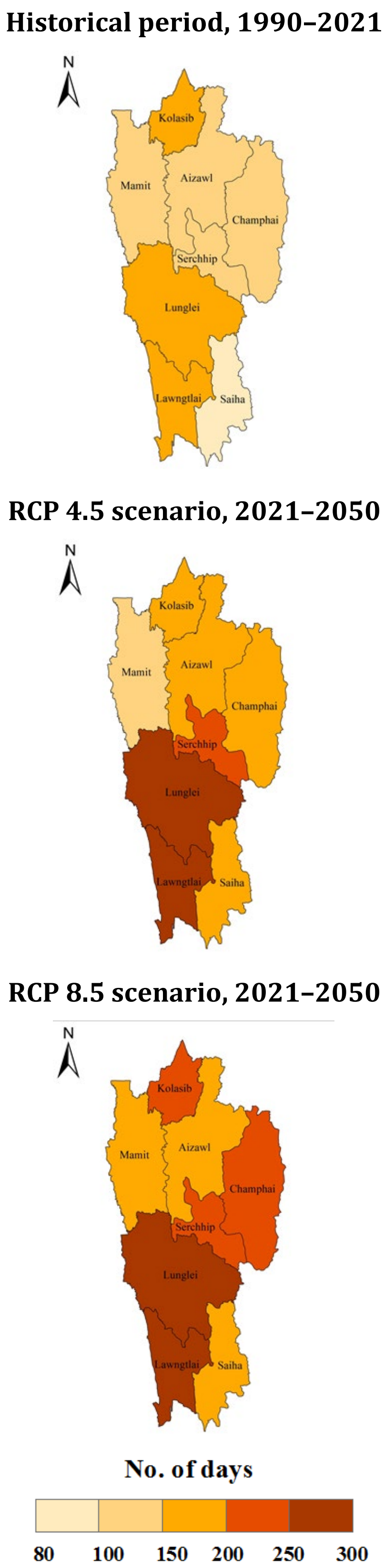


Figure 7-10: Total number of high-intensity events over a 30-year period during historical (1990–2019) and projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

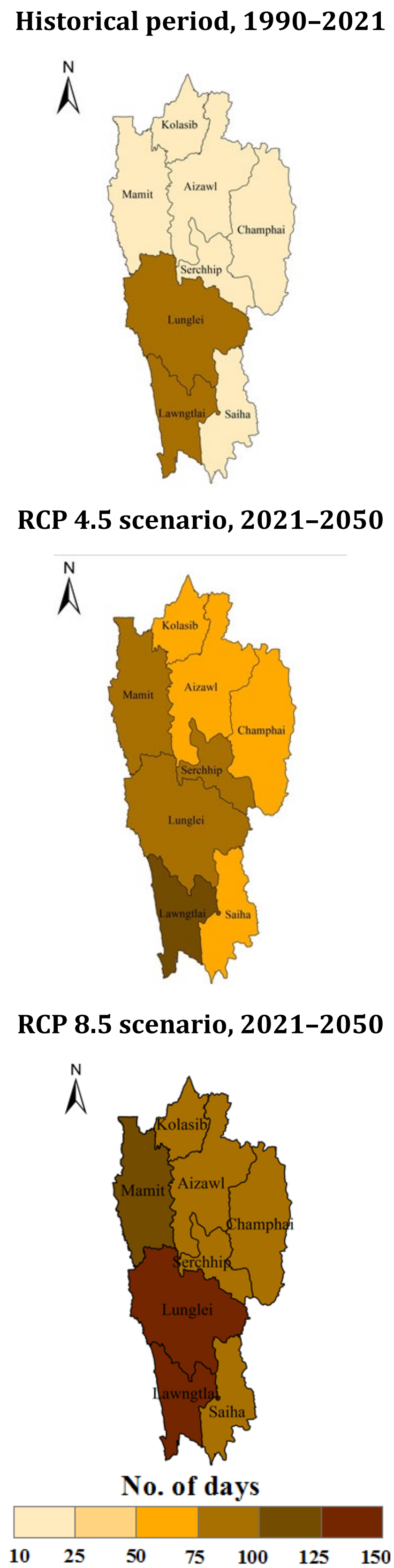


Figure 7-11: The total number of very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

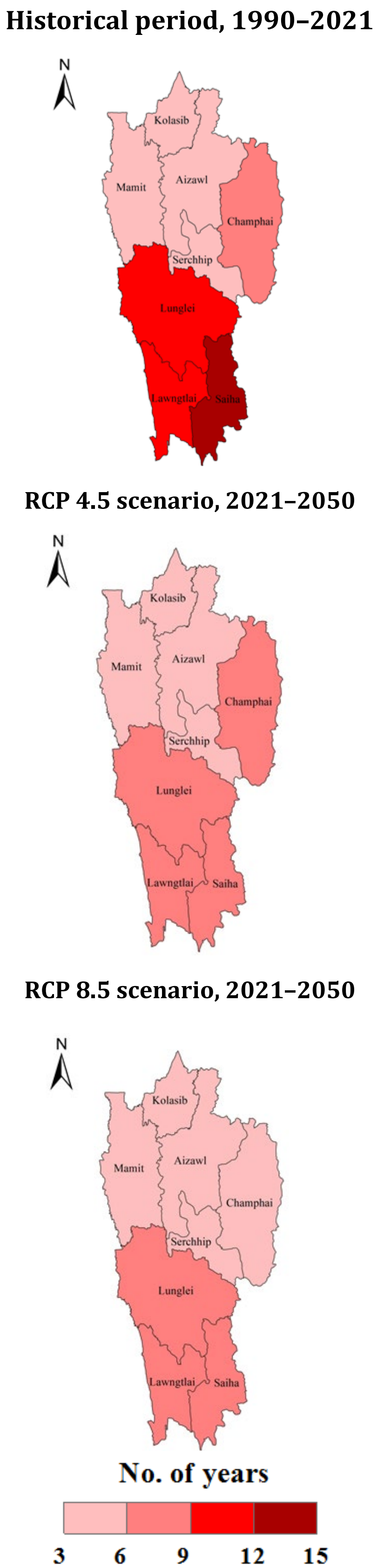


Figure 7-12: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

7.4 The summary of projected changes in the climate for Mizoram

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 7-1).

- The summer maximum and winter minimum temperatures are projected to warm uniformly across all the districts by 1°C to 1.5°C under the RCP 4.5 scenario and 1°C to 2 °C under the RCP 8.5 scenario.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 7-2).

- There will be a notable increase in rainfall particularly in the districts in the north under both RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to increase in some districts and decline in others under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the kharif season is projected under both climate scenarios in all the districts. The least decline is in Aizawl, and the highest decline is in Lunglei.

Rainfall variability during the rabi season is projected to decline in all the districts under the RCP 8.5 scenario but is projected to increase in a few districts under the RCP 4.5 scenario.

- A decline in rainfall variability during the rabi season is projected under both climate scenarios in all the districts. The least decline is in Mamit, and the highest decline is in Lunglei.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 7-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 5 days under the RCP 4.5 scenario and 2 to 10 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 7-4).

- High-intensity rainfall events and very high-intensity rainfall events are projected to increase by one event to three events per annum under the RCP 4.5 scenario and two to three events per annum under the RCP 8.5 scenario.

Rainfall deficient years are projected to decline in seven of the eight districts under the RCP 4.5 scenario and in all the districts under the RCP 8.5 scenario compared to the historical period (1990–2019; Appendix 7-4).

- The decline is by 1 to 4 years under both the climate scenarios. There is no change under the RCP 4.5 scenario in Kolasib district, compared to the historical period.

Appendix

Appendix 7-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Aizawl	1.1	1.3	1.2	1.4
Champhai	1.3	1.5	1.1	1.7
Kolasib	1.2	1.8	1.2	1.8
Lawngtlai	1.4	1.9	1.3	1.4
Lunglei	1.3	1.8	1.4	1.5
Mamit	1.5	1.7	1.4	1.6
Saiha	1.2	1.3	1.2	1.5
Serchhip	1.3	1.6	1.3	1.5

Appendix 7-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Aizawl	19	19	21	18	23	23
Champhai	18	19	17	20	24	24
Kolasib	15	17	12	14	15	17
Lawngtlai	3	4	5	6	4	6
Lunglei	12	14	13	14	13	15
Mamit	13	13	12	14	21	22
Saiha	5	6	3	7	18	21
Serchhip	18	19	18	20	21	27

Appendix 7-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Aizawl	2606	2698	2783
Champhai	2243	2345	2448
Kolasib	2297	2345	2581
Lawngtlai	1647	1689	1725
Lunglei	1766	1789	1821
Mamit	2506	2667	2793
Saiha	1723	1826	1904
Serchhip	2269	2345	2521

Appendix 7-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Aizwal	4	6	6	0	2	3	5	4	4
Champhai	5	6	7	0	2	3	8	7	6
Kolasib	5	7	7	0	2	3	6	6	4
Lawngtlai	7	10	10	4	4	5	12	9	8
Lunglei	7	8	7	4	4	4	12	10	10
Mamit	4	4	6	0	3	4	6	5	4
Saiha	3	6	6	0	2	3	14	10	10
Serchhip	4	7	7	1	3	3	6	5	3

8. Nagaland

Nagaland is situated in the north-eastern part of India. Its shares borders with Arunachal Pradesh to the north, Assam to the west, and Manipur to the south. In the east, Nagaland shares an international boundary with Myanmar. It has a geographical area of 16,579 sq. km and a population of 1.98 million, according to the 2011 Census. Of the total population, close to 71.14% live in rural areas. Nagaland has 11 hill districts rich in natural resources. The climate of Nagaland is typical of a tropical country with heavy rainfall of about 2,000 mm to 2,500 mm, mostly received during the monsoon season between May to September/October. The main rivers that flow through the state are Dhansiri, Doyang, Dikhu, Tizu, and Melak. Nagaland is exposed to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.).

These characteristics make Nagaland climate sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

8.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

8.1.1 Trends in temperature

Nagaland recorded a moderate warming of 0.15°C to 0.35°C in the summer maximum temperature and 0.19°C to 0.45°C in the winter minimum temperature during the historical period. Figure 8-1 presents the mean summer maximum and winter minimum temperatures in Nagaland during the historical period.

Figure 8-1: Mean summer maximum and winter minimum temperatures in Nagaland during the historical period (1990–2019)

8.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual and kharif season rainfall, the main monsoon season, was recorded across the districts of Nagaland. The increase in the annual and kharif season rainfall was largely in the range of 10%–20% in a majority of the districts. Figure 8-2 presents the mean annual rainfall in Nagaland during the historical period.

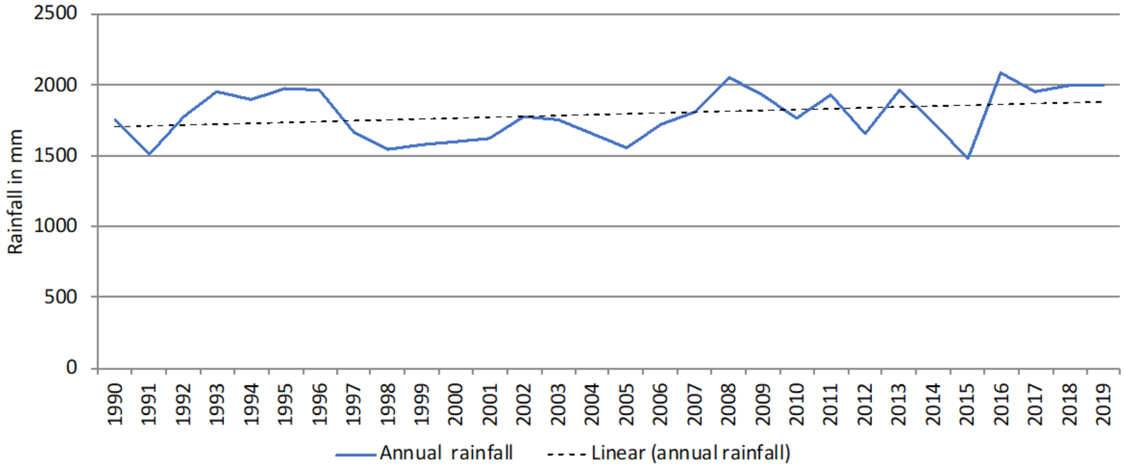


Figure 8-2: Mean annual rainfall in Nagaland during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 15% in Zunheboto to 35% in Peren (Figure 8-3). The rabi season rainfall variability was in the range of 43% in Mon to 57% in Peren, indicating a complete failure of rainfall during the historical period (Figure 8-3).

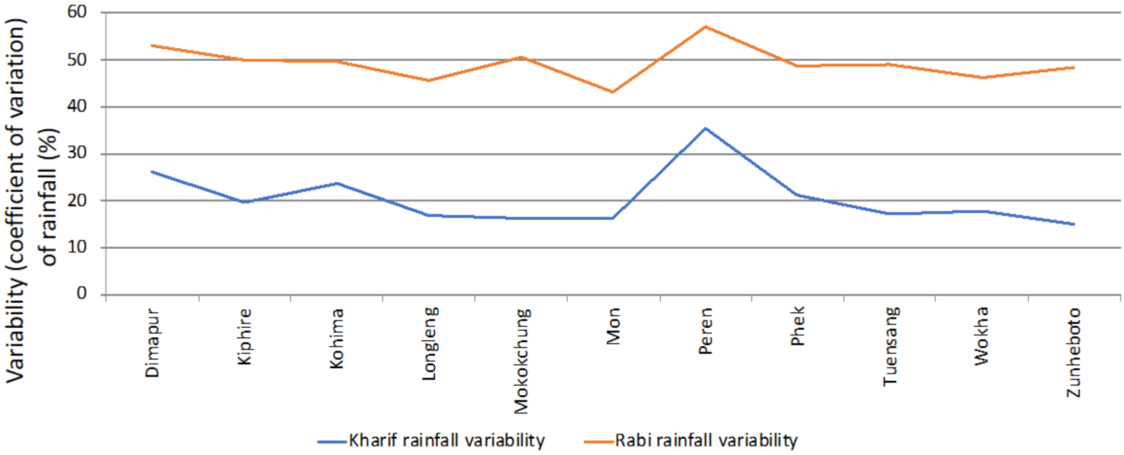


Figure 8-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

8.2 Climate change projections

Temperature and rainfall are projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

8.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Nagaland are presented in Figure 8-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by 1°C to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

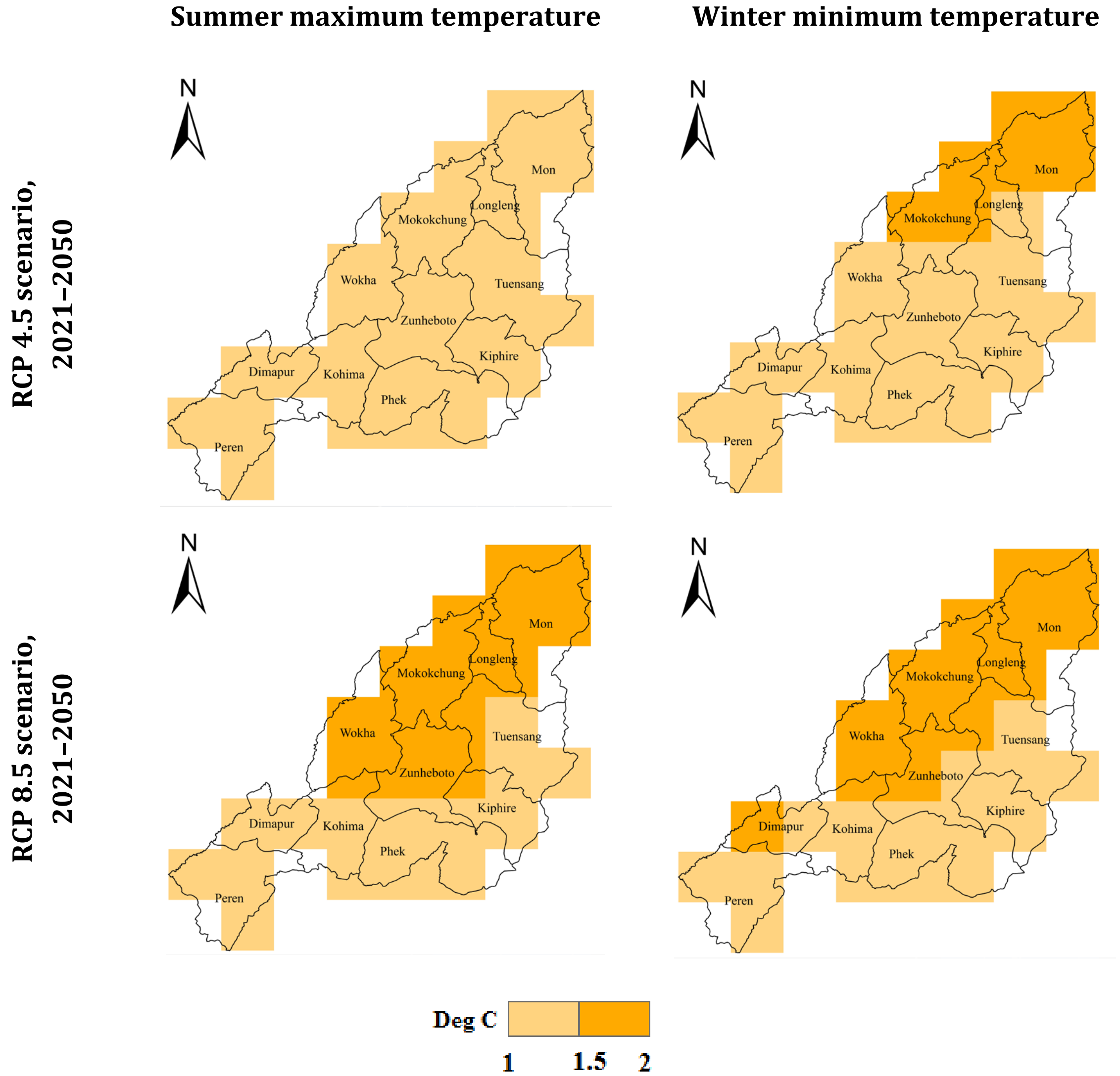


Figure 8-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

8.2.2 Rainfall projections

8.2.2.1 Number of rainy days

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 8-5). The number of rainy days during the historical period and the projected 2030s under both RCP 4.5 and 8.5 scenarios is presented in Appendix 8-3. The total number of rainy days that ranged from 2168 to 2650 days over the 30-year historical period increases to 2298 to 2778 days under the RCP 4.5 scenario and 2398 to 2780 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 1 to 5 days annually with an increase of 5 days in Kohima, Phek, and Zunheboto; 4 days in Mon and Peren; 2 days in Dimapur and Mokokchung; and 1 day in Kiphire, Tuensang, and Wokha. There is no change in Longleng.

RCP 8.5 scenario: Projected to increase by 1 to 8 days annually with an increase of 8 days in Kohima and Peren; 6 days in Phek; 5 days in Dimapur and Kiphire; 4 days in Mon and Zunheboto; 3 days in Mokokchung and Wokha; and 2 days in Tuensang. There is no change in Longleng.

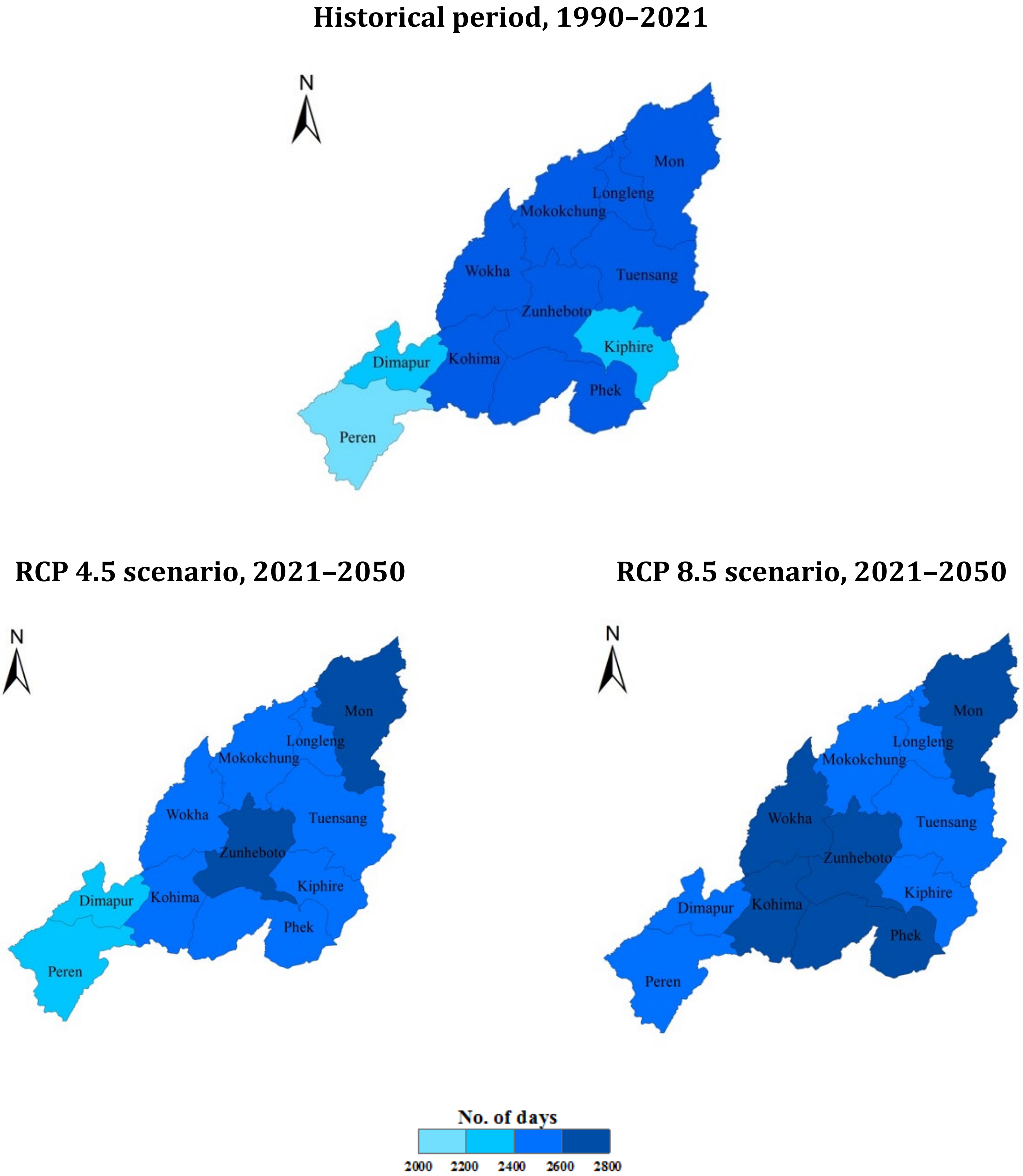


Figure 8-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s)

8.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 8-6 presents district-wise changes in the kharif season rainfall, and Figure 8-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 6% in Kiphire, Mokokchung, and Mon to 16% in Wokha	Increases in Mokokchung and Zunheboto by 1%–2% and declines in nine districts by 2%–13%
RCP 8.5	Increases in all the districts, from 9% in Mokokchung to 28% in Kohima	Increases in Mokokchung and Zunheboto by 4%–5% and declines in nine districts by 4%–15%

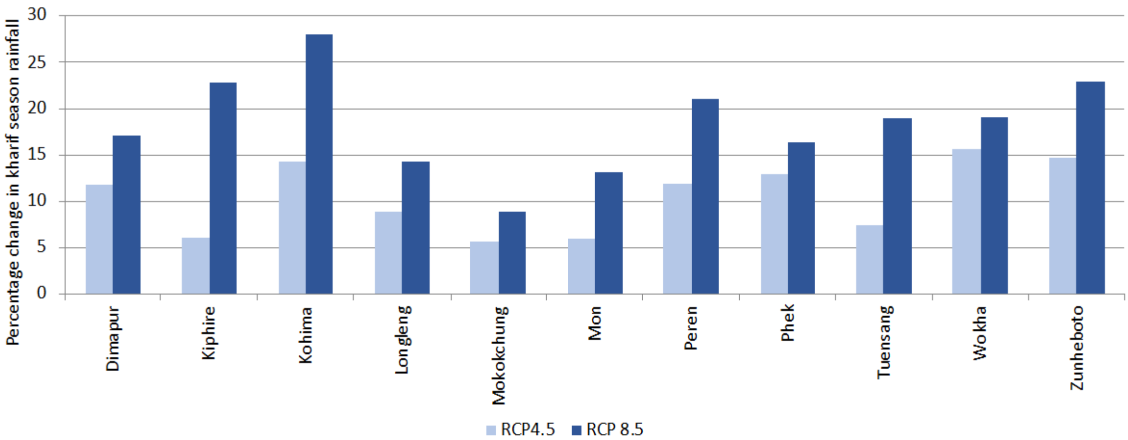


Figure 8-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

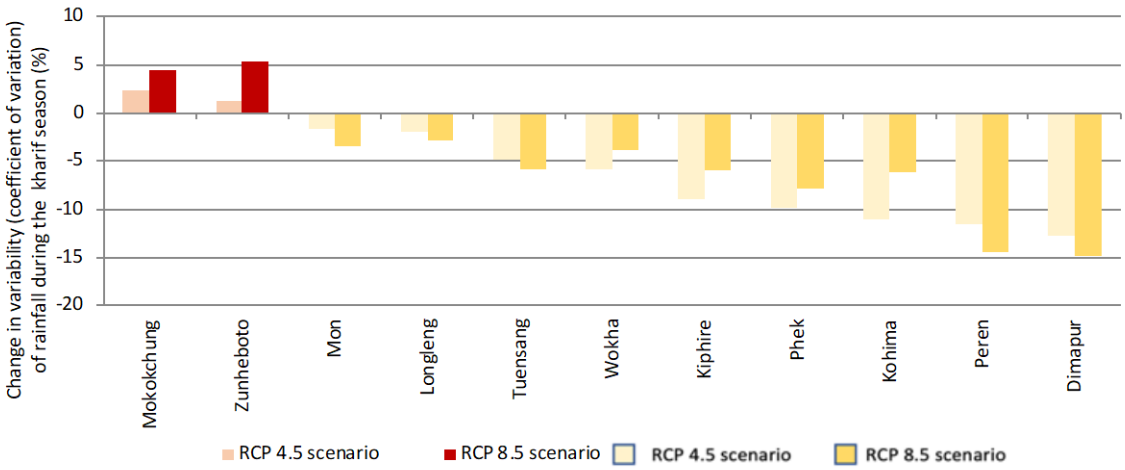


Figure 8-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

8.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 8-8 presents district-wise changes in the rabi season rainfall, and Figure 8-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 6% in Kiphire to 30% in Peren district	Declines in all the districts by 4%–16%.
RCP 8.5	Increases in all the districts, from 17% in Wokha to 43% in Tuensang district	Declines in all the districts by 5%–16%.

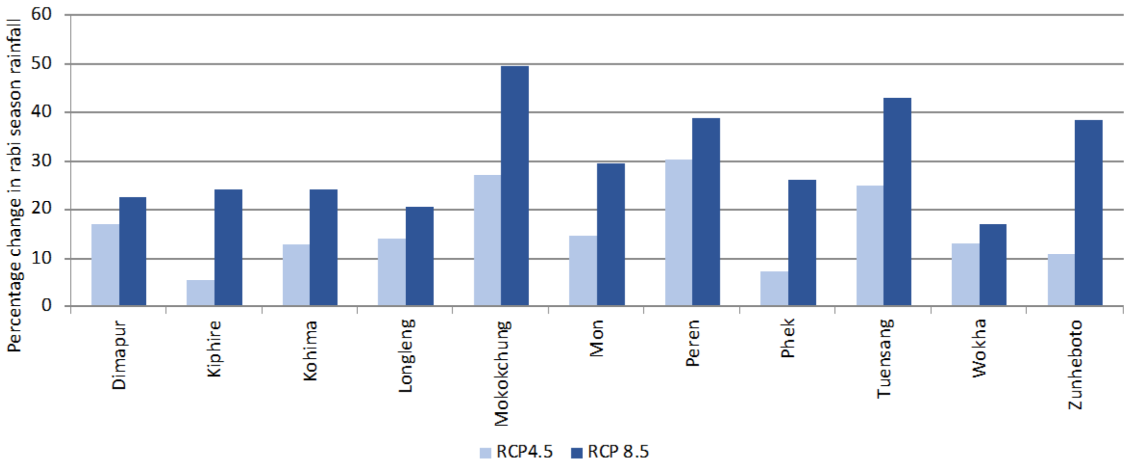


Figure 8-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

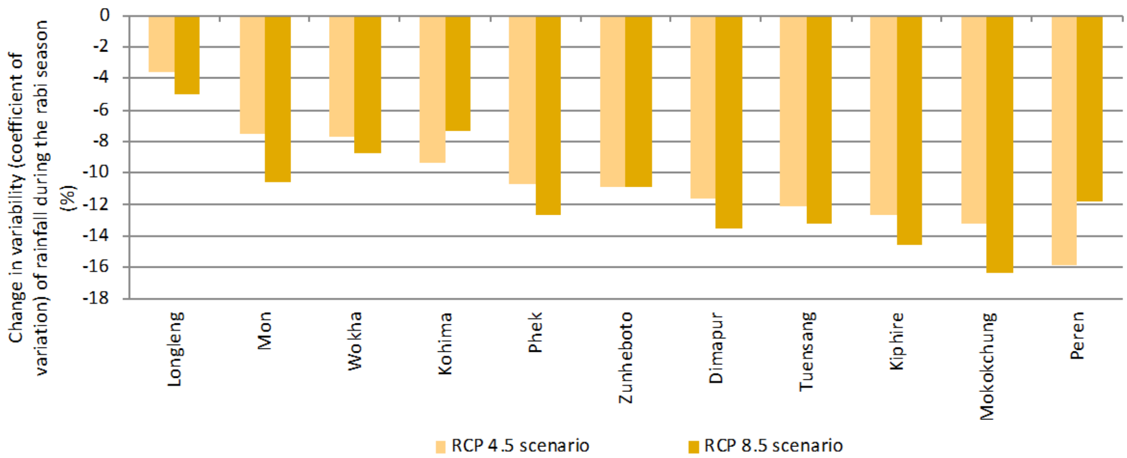


Figure 8-9: Projected changes in the variability of the rabi season rainfall compared to the historical period (1990–2019) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios

8.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day, termed 'Low' intensity; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and the 2030s under the two climate scenarios, and the change was computed for all the districts of Nagaland.

High-intensity rainfall events (Figure 8-10)

The total number of high-intensity rainfall events increases from 30 to 58 days during the historical period (1990–2019) to 63 to 103 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 81 to 134 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by two events in Kiphire, Kohima, Mokokchung, Phek, Tuensang, Wokha, and Zunheboto and by one event in Dimapur, Longleng, Mon, and Peren.

RCP 8.5 scenario: The projected increase per annum is by two events in Dimapur, Kiphire, Kohima, Mokokchung, and Phek; three events in Peren, Tuensang, Wokha, and Zunheboto; and one event in Longleng and Mon.

Very high-intensity rainfall events (Figure 8-10)

The total number of very high-intensity rainfall events increases from 5 to 17 days during the historical period (1990–2019) to 11 to 30 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 12 to 27 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one event in Dimapur, Kohima, Longleng, Mon, Peren, and Wokha and two events in Kiphire, Mokokchung, Phek, Tuensang, and Zunheboto.

RCP 8.5 scenario: The projected increase per annum is by one event in Mokokchung, Mon, and Peren; two events in Dimapur, Kiphire, Kohima, Longleng, Phek, Tuensang, and Wokha; and three events in Zunheboto.

Rainfall deficient years (Figure 8-11)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected to decline in all the districts of Nagaland under both climate scenarios. The number of rainfall deficient years declines from 7 to 14 years during the historical 30-year period to 4 to 11 years under the RCP 4.5 scenario and 4 to 10 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline in all the districts is by 2 to 4 years. The projected decline is by 2 years in Longleng and Phek; 3 years in Dimapur, Kiphire, Kohima, Mokokchung, Peren, and Zunheboto; and 4 years in Mon, Tuensang, and Wokha.

RCP 8.5 scenario: The projected decline in all the districts is by 1 to 6 years. The projected decline is by 1 year in Longleng; 3 years in Kiphire, Kohima, Phek, and Zunhebeto; 4 years in Peren, Dimapur, Mokokchung, and Mon. Tuensang and Wokha have a decline of 5 and 6 years, respectively.

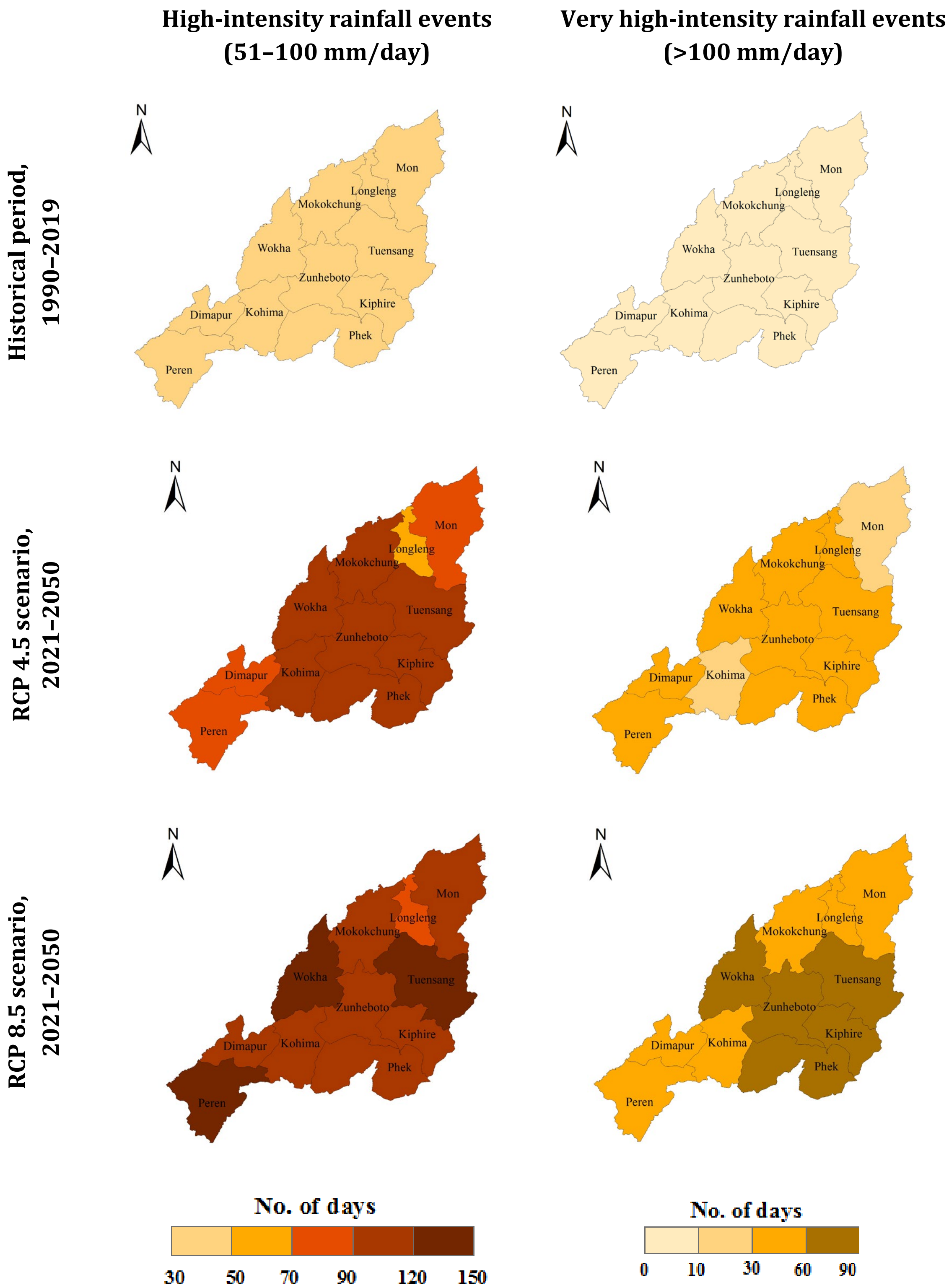


Figure 8-10: The total number of high-intensity and very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

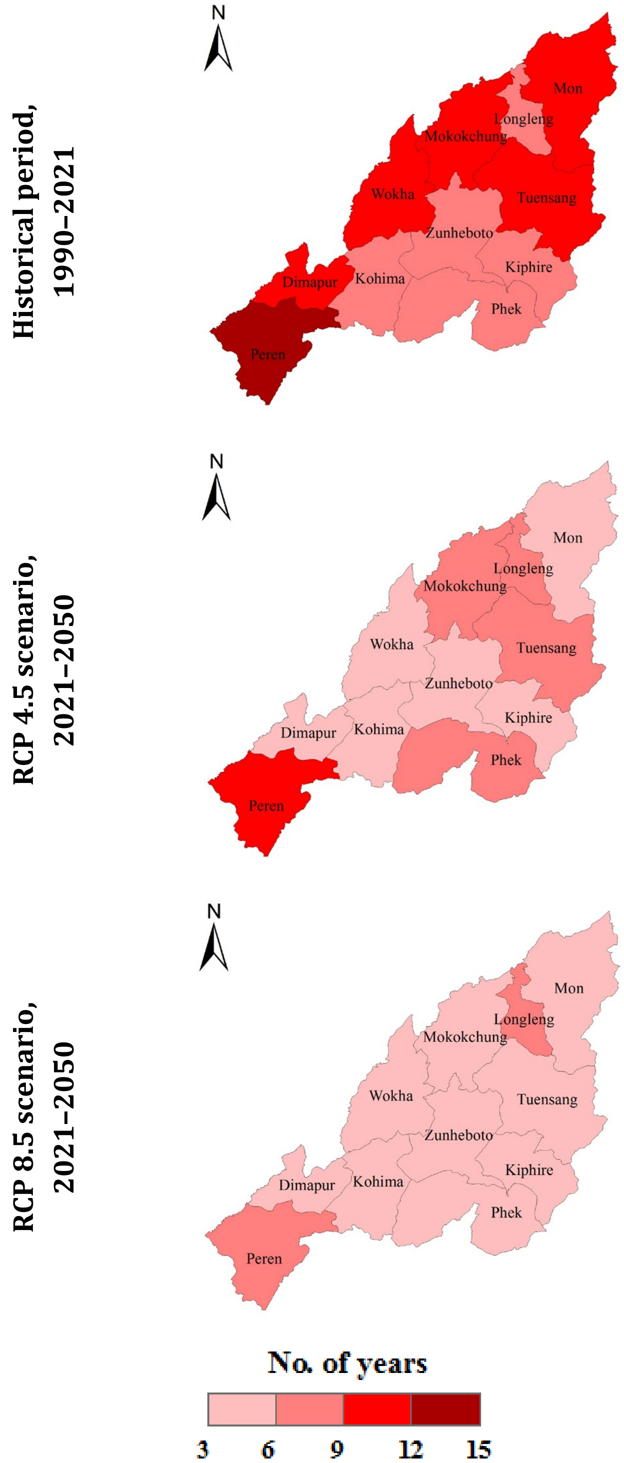


Figure 8-11: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

8.4 The summary of projected changes in the climate for Nagaland

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 8-1).

- The summer maximum temperature is projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.
- The winter minimum temperature is projected to warm by 1.5°C to 2°C under both RCP 4.5 and RCP 8.5 scenarios.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 8-2).

- There will be a notable increase in rainfall particularly in the northern districts under both RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to increase in some districts and decline in others under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- The projected decline in rainfall variability is expected in most of the districts.
- The projected increase in variability is expected in two districts: Mokokchung and Zunheboto.

Rainfall variability during the rabi season is projected to decline in all the districts under the RCP 4.5 and the RCP 8.5 scenarios.

- The projected decline in the rainfall variability is between 4%–16% under the RCP 4.5 scenario and 5%–16% under RCP 8.5 scenario.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 8-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 1 to 5 days under the RCP 4.5 scenario and 2 to 8 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 8-4).

- High-intensity rainfall events are projected to increase by two events per annum in seven districts and one event per annum in four districts under the RCP 4.5 scenario. Under the RCP 8.5 scenario, high-intensity rainfall events are projected to increase by three events per annum in four districts, two events per annum in five districts, and one event per annum in two districts.
- Very-high intensity rainfall events are projected to increase by one to two events per annum under the RCP 4.5 scenario and by one to three events under the RCP 8.5 scenario.

Rainfall deficient years are projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 8-4).

- The decline in rainfall deficient years is by two to four years under the RCP 4.5 scenario and one to six years under the RCP 8.5 scenario.

Appendix

Appendix 8-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Dimapur	1.1	1.5	1.6	1.7
Kiphire	1.3	1.5	1.2	1.4
Kohima	1.3	1.7	1.5	1.2
Longleng	1.4	1.8	1.6	1.8
Mokokchung	1.2	1.9	1.7	1.9
Mon	1.1	1.8	1.6	1.9
Peren	1.2	1.4	1.6	1.7
Phek	1.4	1.5	1.2	1.4
Tuensang	1.3	1.5	1.1	1.5
Wokha	1.3	1.8	1.6	1.9
Zunheboto	1.4	1.7	1.7	1.9

Appendix 8-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Dimapur	14	18	12	17	17	23
Kiphire	7	23	6	23	6	24
Kohima	14	22	14	28	13	24
Longleng	9	10	9	14	14	20
Mokokchung	5	11	6	9	27	50
Mon	6	13	6	13	15	29
Peren	14	29	12	21	30	39
Phek	17	27	13	16	7	26
Tuensang	13	22	7	19	25	43
Wokha	15	17	16	19	13	17
Zunheboto	14	21	15	23	11	38

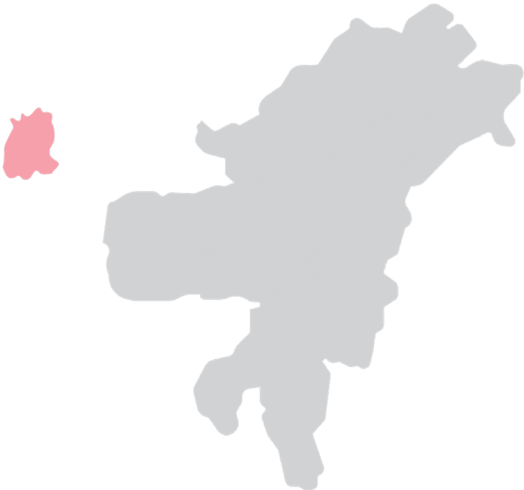
Appendix 8-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Dimapur	2291	2337	2443
Kiphire	2398	2439	2543
Kohima	2406	2556	2658
Longleng	2531	2545	2542
Mokokchung	2495	2564	2590
Mon	2650	2764	2780
Peren	2168	2298	2398
Phek	2438	2596	2628
Tuensang	2495	2527	2554
Wokha	2567	2590	2665
Zunheboto	2626	2778	2754

Appendix 8-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Dimapur	55	83	101	4	37	49	11	8	7
Kiphire	54	102	114	6	57	77	7	4	4
Kohima	46	92	104	2	24	56	9	6	6
Longleng	45	63	81	1	45	50	9	7	8
Mokokchung	43	99	109	0	46	42	10	7	6
Mon	58	80	92	3	30	42	10	6	6
Peren	54	86	130	5	40	47	14	11	10
Phek	53	99	104	2	60	62	9	7	6
Tuensang	51	103	126	0	53	66	12	8	6
Wokha	30	93	134	1	44	67	10	6	5
Zunheboto	33	95	116	0	68	84	8	5	5

9. Sikkim



Sikkim is situated in the north-eastern part of India. It borders Tibet in the north and north-east, Bhutan in the east, Nepal in the west, and West Bengal in the south. It has a geographical area of 7,096 sq. km and a population of 0.61 million, according to the 2011 Census. Of the total population, close to 74.85% live in rural areas. It is a mountainous state with wide variation in altitudes ranging from 300 to 8,586 meters. Kanchenjunga, the highest Indian peak and the third highest mountain in the world, is located in the state. The state is divided into four districts, all of which are tribal and hill districts.

The major rivers in Sikkim are Teesta and Rangit, and the minor rivers are Rani Khola, Busuk Khola, Rishi Khola, and Ratey Chu. Crops are cultivated using springs and surface water the above-mentioned rivers. Sikkim is vulnerable to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.)

These characteristics make Sikkim climate sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

9.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

9.1.1 Trends in temperature

Sikkim recorded a moderate warming of 0.23°C to 0.47°C in the summer maximum temperature and 0.12°C to 0.25°C in the winter minimum temperature during the historical period. Figure 9-1 presents the mean summer maximum and winter minimum temperatures in Sikkim during the historical period.

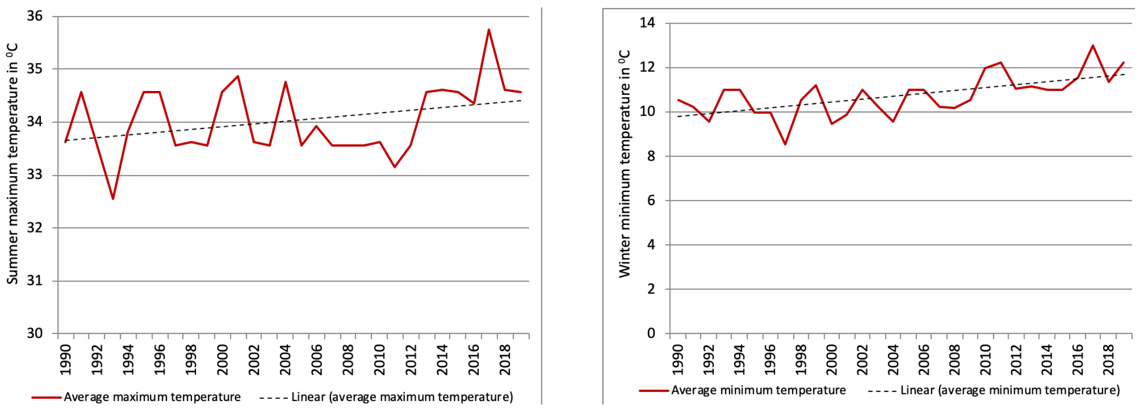


Figure 9-1: Mean summer maximum and winter minimum temperatures in Sikkim during the historical period (1990–2019)

9.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual and kharif season rainfall, the main monsoon season, was recorded across the districts of Sikkim. The increase in the annual rainfall was largely in the range of 15%–20% during the historical period. Figure 9-2 presents the mean annual rainfall in Sikkim during the historical period.

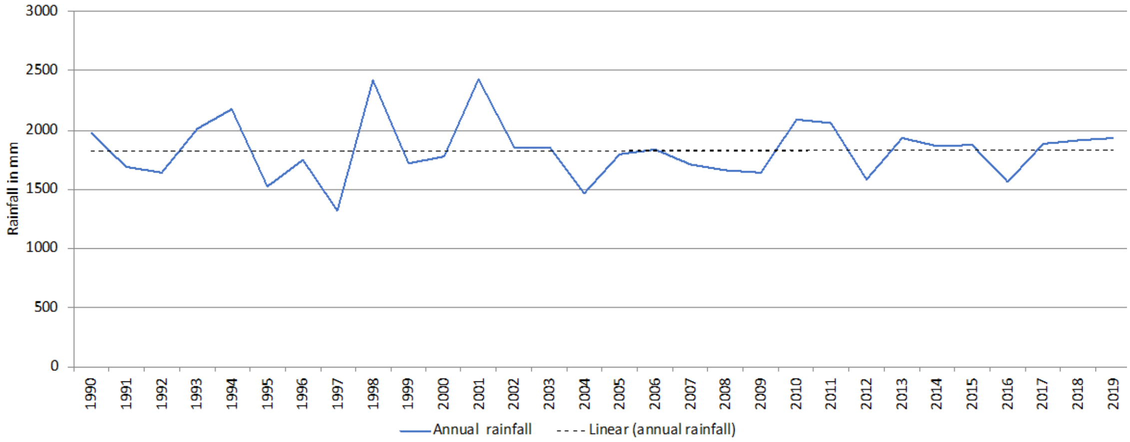


Figure 9-2: Mean annual rainfall in Sikkim during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 25% in North Sikkim to 16% in South Sikkim (Figure 9-3). The rabi season rainfall variability was in the range of 57% in South Sikkim to 69% in East Sikkim, indicating a complete failure of rainfall during the historical period (Figure 9-3).

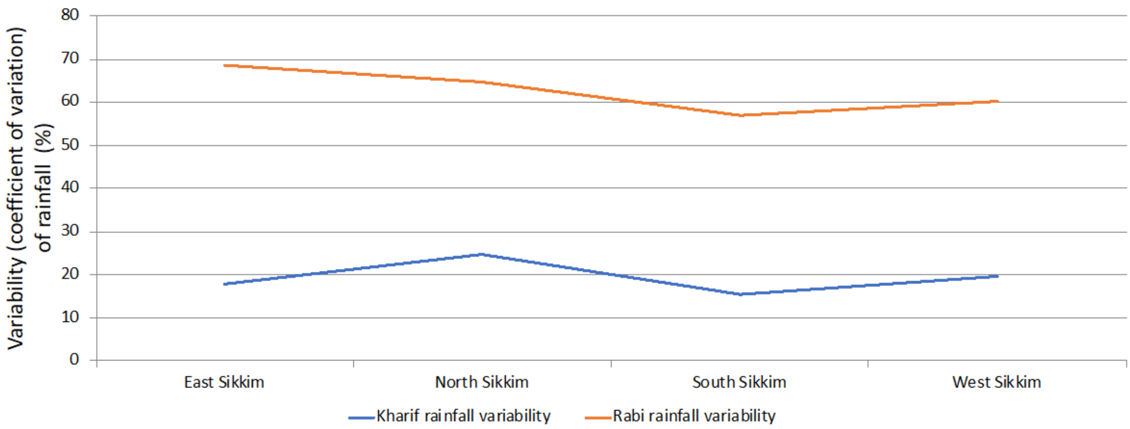


Figure 9-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

9.2 Climate change projections

Temperature and rainfall are projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

9.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Sikkim are presented in Figure 9-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases up to 1°C	Increases up to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

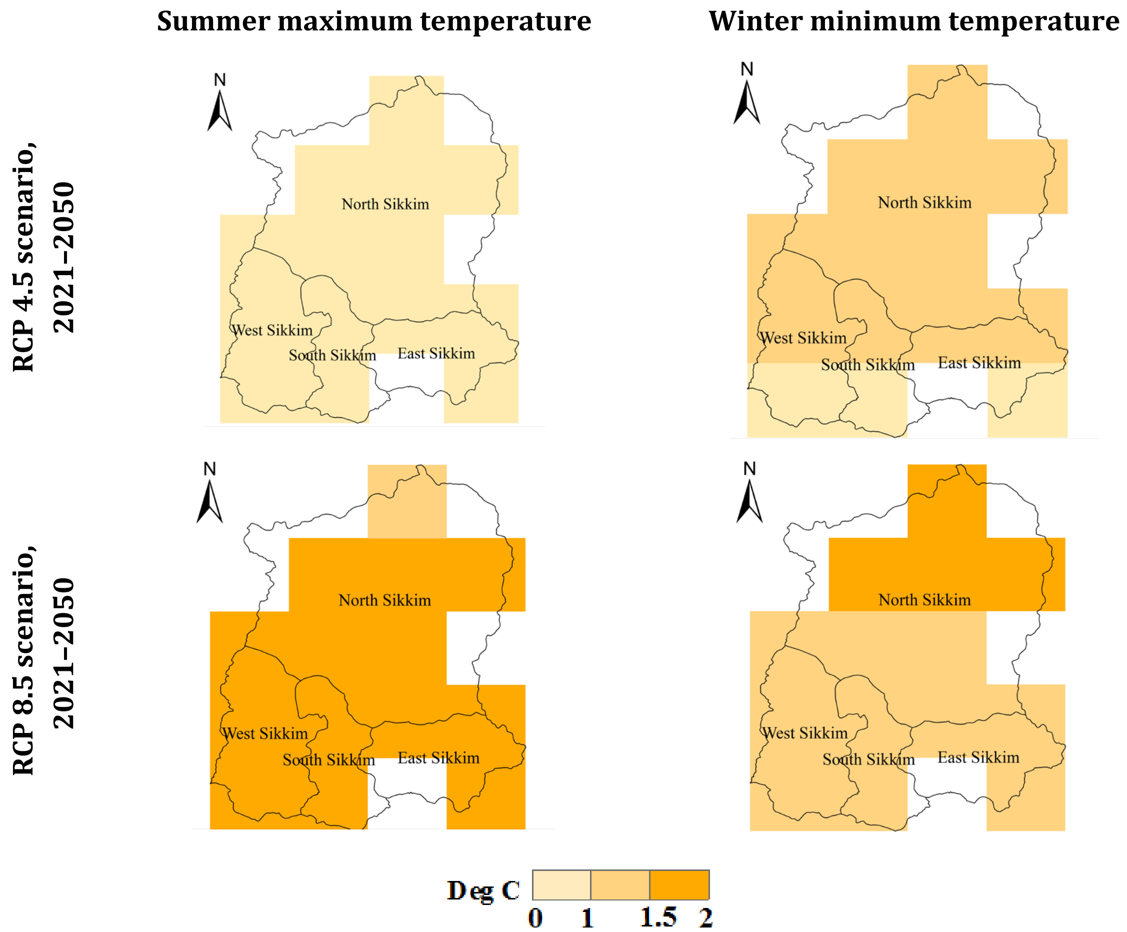


Figure 9-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

9.2.2 Rainfall projections

9.2.2.1 Number of rainy days

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 9-5). The number of rainy days during the historical period and the projected 2030s under RCP 4.5 and RCP 8.5 scenarios is presented in Appendix 9-3. The total number of rainy days that ranged from 2487 to 3133 days over the 30-year historical period increases to 2877 to 3446 days under the RCP 4.5 scenario and 2973 to 3463 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 7 to 24 days annually, with an increase of 24 days in South Sikkim, 13 days in North Sikkim, 11 days in West Sikkim, and 7 days in East Sikkim.

RCP 8.5 scenario: Projected to increase by 10 to 22 days annually, with an increase of 22 days in South Sikkim, 19 days in West Sikkim, 16 days in North Sikkim, and 10 days in East Sikkim.

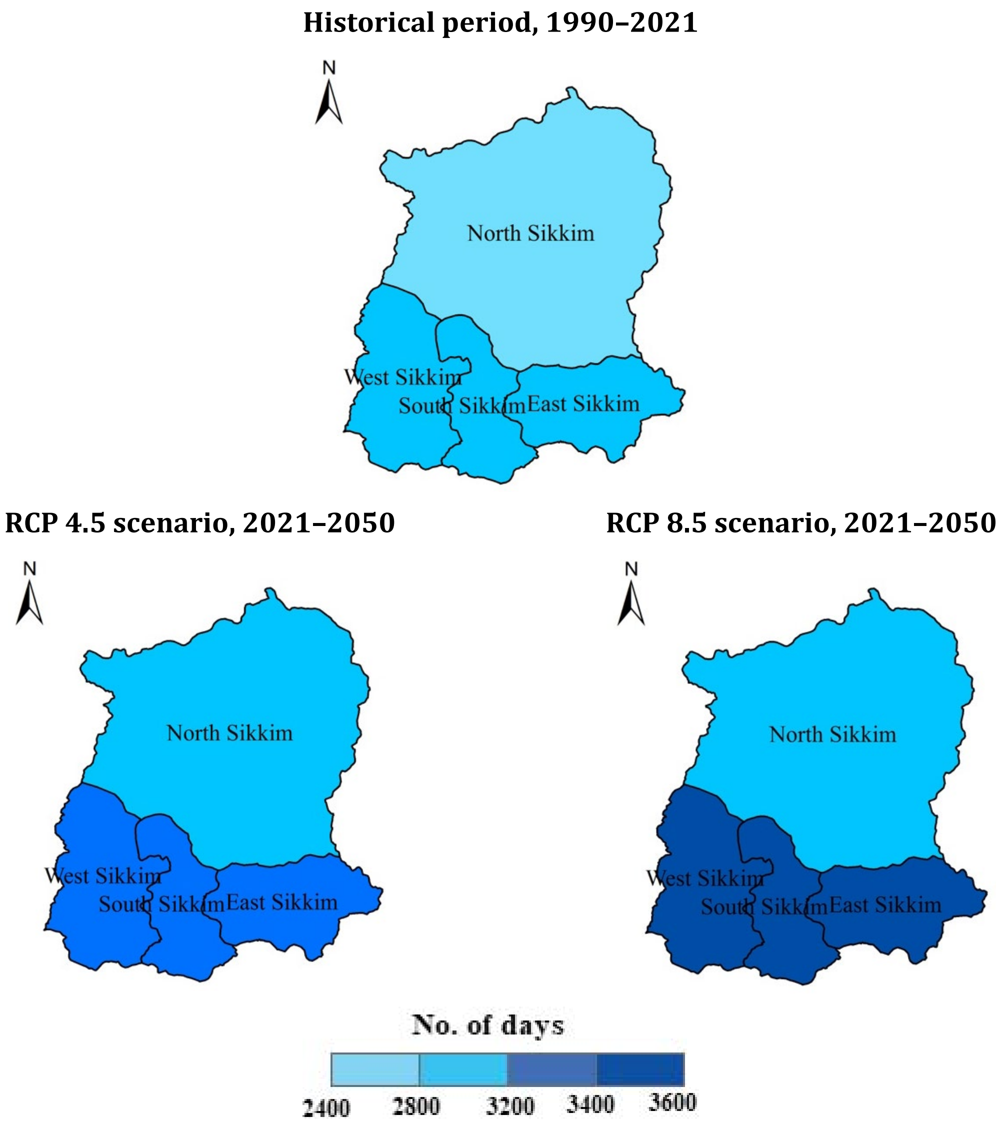


Figure 9-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

9.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 9-6 presents district-wise changes in the kharif season rainfall, and Figure 9-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 3% in East Sikkim to 10% in South Sikkim	Declines in all the districts by 2%–4 %
RCP 8.5	Increases in all the districts, from 9% in East Sikkim to 19% in North Sikkim and West Sikkim	Declines in all the districts by 3%–5%

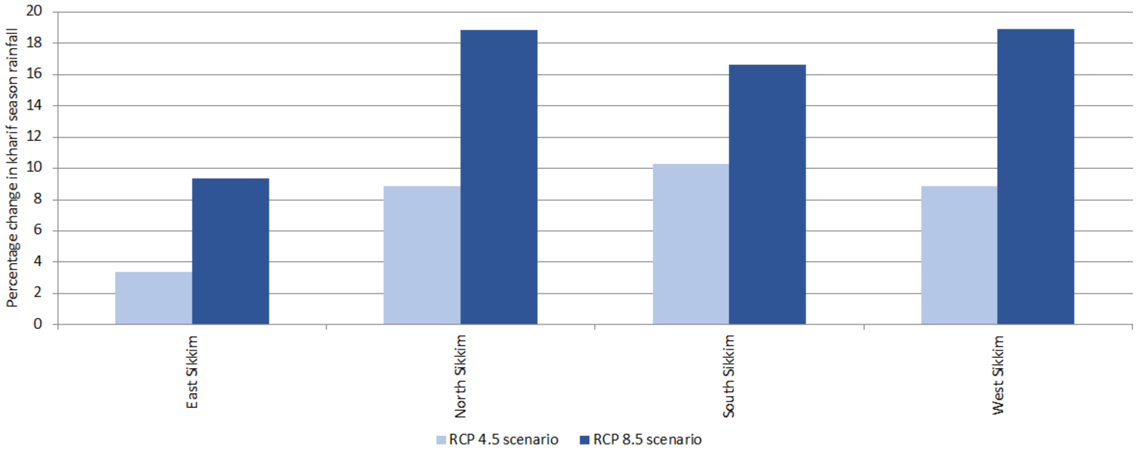


Figure 9-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

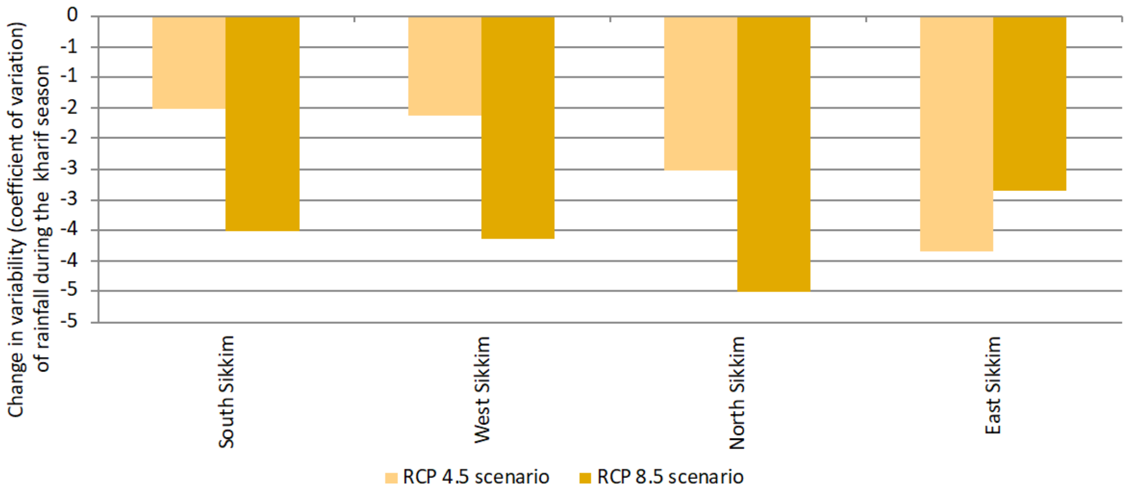


Figure 9-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

9.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 9-8 presents district-wise changes in the rabi season rainfall, and Figure 9-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 13% in East Sikkim to 23% in West Sikkim	Declines in all the districts by 5%–12%.
RCP 8.5	Increases in all the districts, from 18% in South Sikkim to 25% in North Sikkim	Declines in all the districts by 8%–11%.

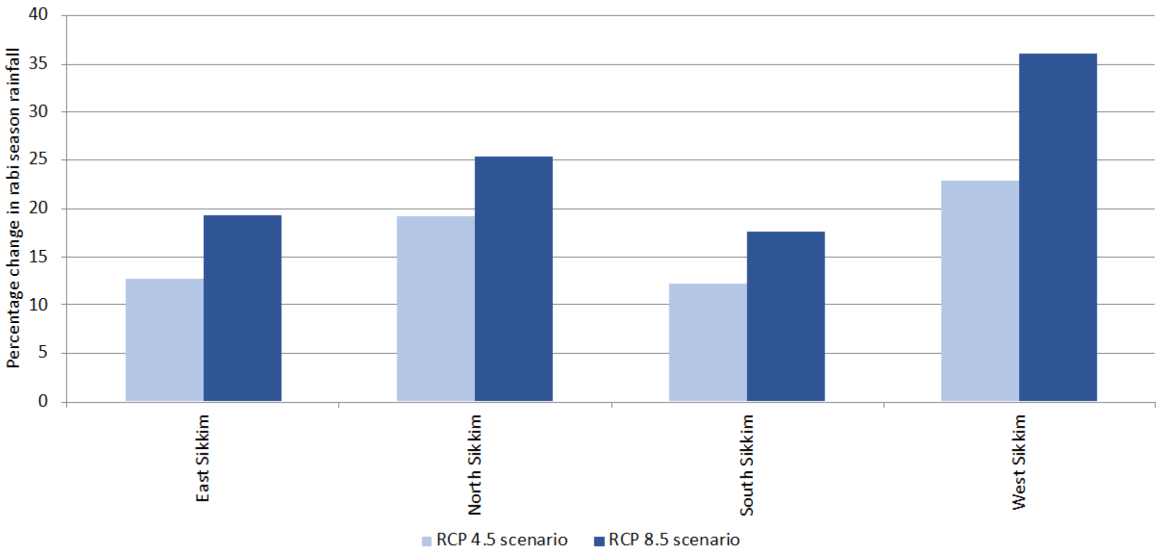


Figure 9-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

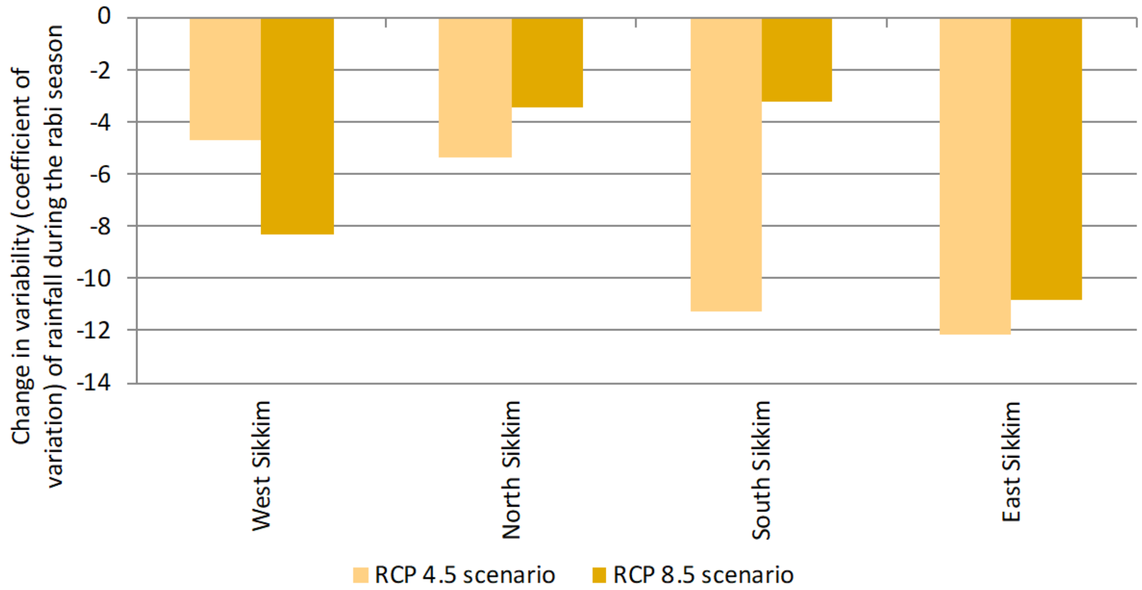


Figure 9-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

9.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and the projected 2030s under the two climate scenarios, and the change was computed for all the districts of Sikkim.

High-intensity rainfall events (Figure 9-10)

The total number of high-intensity rainfall events increases from 81 to 195 days during the historical period (1990–2019) to 129 to 278 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 145 to 321 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by two to three events with three events in East Sikkim and South Sikkim and two events in North Sikkim and West Sikkim.

RCP 8.5 scenario: The projected increase per annum is by two to four events with four events in East Sikkim and South Sikkim, three events in West Sikkim, and two events in North Sikkim.

Very high-intensity rainfall events (Figure 9-10)

The total number of very high-intensity rainfall events increases from 6 to 36 days during the historical period (1990–2019) to 49 to 105 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 61 to 120 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by two events in East Sikkim, South Sikkim and West Sikkim and one event in North Sikkim.

RCP 8.5 scenario: The projected increase per annum is by three events in East Sikkim, South Sikkim and West Sikkim and two events in North Sikkim

Rainfall deficient years (Figure 9-11)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected to decline in all the districts of Sikkim under both climate scenarios. The number of rainfall deficient years declines from 8 to 12 years during the historical 30-year period to 7 to 11 years under the RCP 4.5 scenario and 7 to 9 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 1 year in all the districts of Sikkim.

RCP 8.5 scenario: The projected decline is by 3 years in West Sikkim, 2 years in South Sikkim, and 1 year in North Sikkim and East Sikkim.

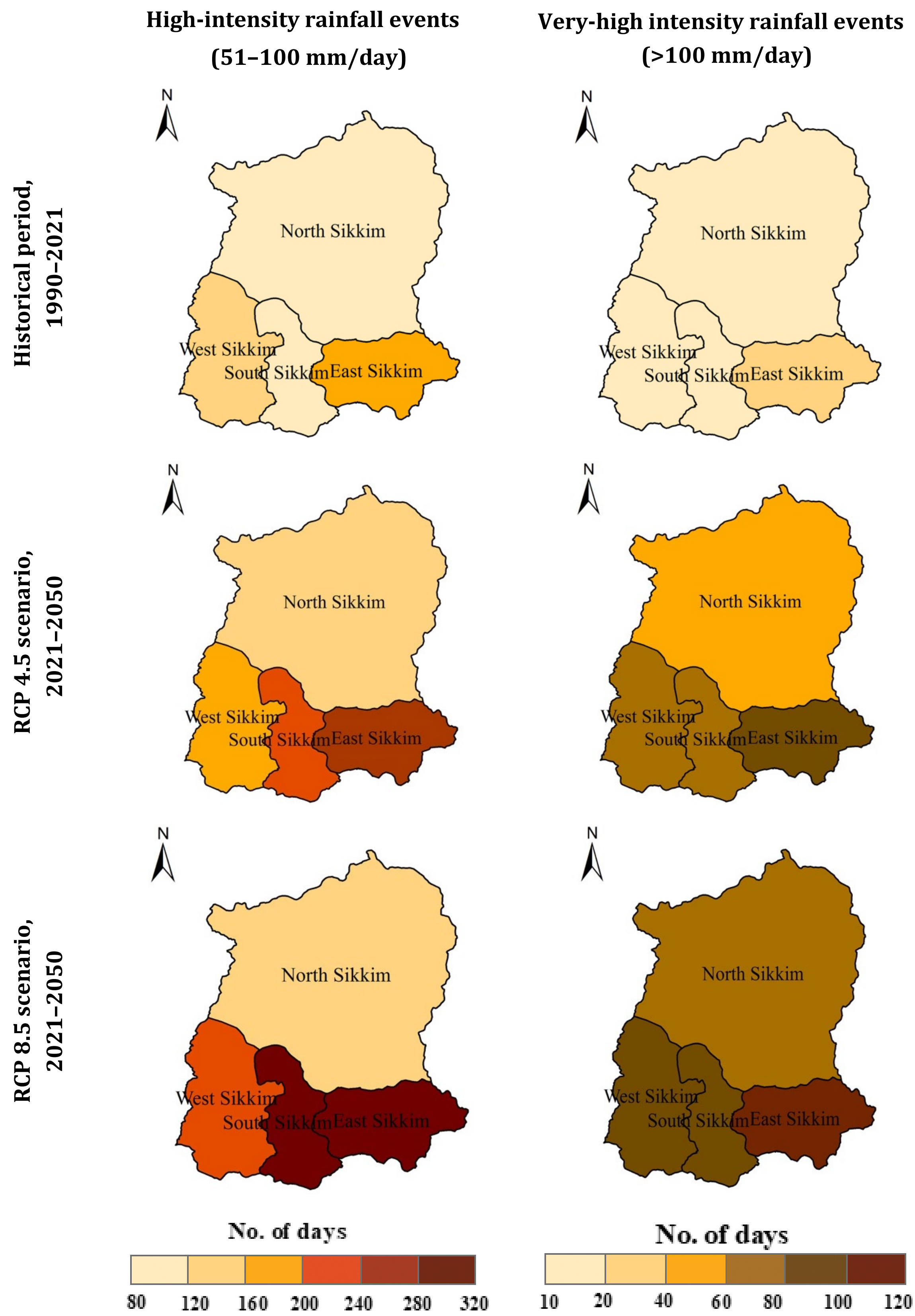


Figure 9-10: The total number of high-intensity and very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

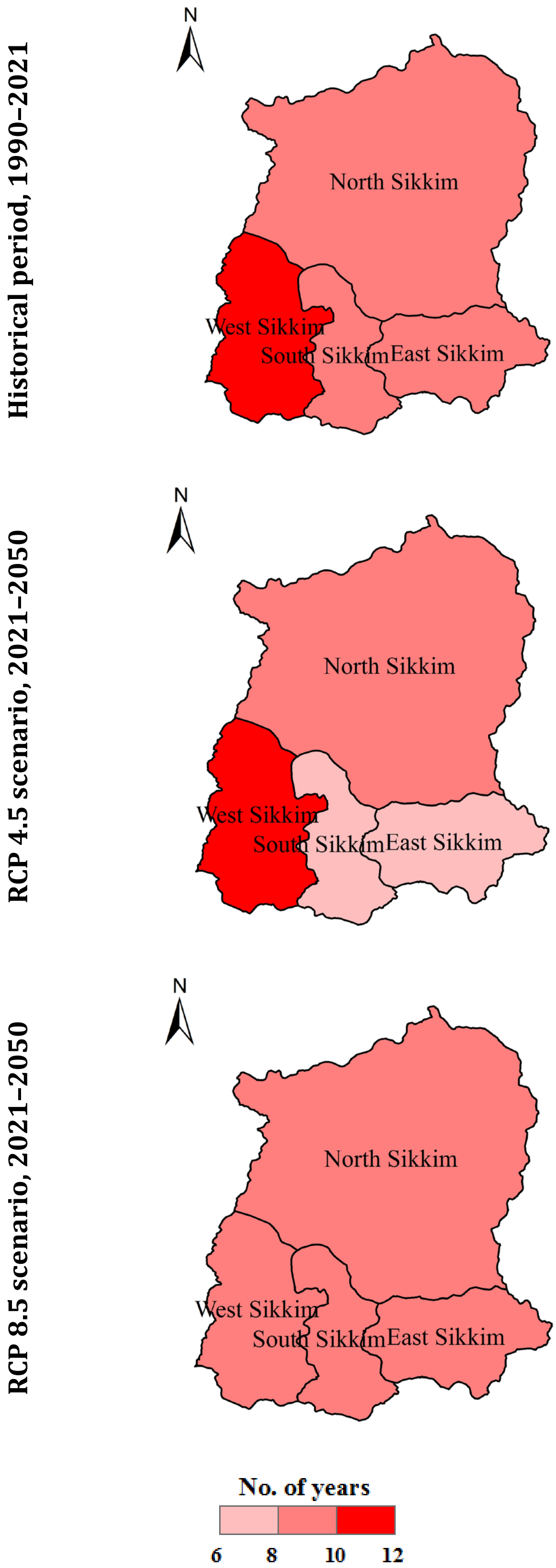


Figure 9-11: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

9.4 The summary of projected changes in the climate for Sikkim

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 9-1).

- The summer maximum temperature is projected to increase by up to 1°C under the RCP 4.5 scenario and 1.5°C to 2 °C under the RCP 8.5 scenario.
- The winter minimum temperatures are projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1°C to 2 °C under the RCP 8.5 scenario across all the districts.

Rainfall is projected to increase during the kharif and rabi seasons in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 9-2).

- The increase in rainfall is higher during the rabi season than during the kharif season under both the climate scenarios.

Rainfall variability during the kharif season is projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability in the range of 2%–4% is projected under the RCP 4.5 scenario.
- A decline in rainfall variability in the range of 3%–5% is projected under the RCP 8.5 scenario.

Rainfall variability during the rabi season is projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability in the range of 5%–12% is projected under the RCP 4.5 scenario.
- A decline in rainfall variability in the range of 8%–11% is projected under the RCP 8.5 scenario.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 9-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 7 to 24 days under the RCP 4.5 scenario and 10 to 22 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 9-4).

- High-intensity rainfall events are projected to increase by four to nine events under the RCP 4.5 scenario and five to 11 events under the RCP 8.5 scenario.
- Very-high intensity rainfall events are projected to increase by two to four events per annum under both the climate scenarios.

Rainfall deficient years are projected to decline in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 9-4)

Appendix

Appendix 9-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
East Sikkim	0.9	1.6	1.2	1.7
North Sikkim	0.7	1.8	0.7	0.9
South Sikkim	0.9	1.7	1.2	1.4
West Sikkim	0.7	1.6	1.1	1.4

Appendix 9-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
East Sikkim	8	16	3	9	13	19
North Sikkim	11	17	9	19	19	25
South Sikkim	17	22	10	17	12	18
West Sikkim	18	22	9	19	23	36

Appendix 9-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
East Sikkim	3133	3335	3435
North Sikkim	2487	2877	2973
South Sikkim	2818	3446	3463
West Sikkim	2905	3246	3463

Appendix 9-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
East Sikkim	195	278	321	36	105	120	8	7	7
North Sikkim	81	129	145	9	49	61	10	9	9
South Sikkim	119	203	241	6	69	88	9	8	7
West Sikkim	123	193	212	10	72	98	12	11	9

10. Tripura

Tripura is situated in the north-eastern part of India. It shares borders with Assam and Mizoram to the east and Bangladesh to the north, south, and west. It has a geographical area of 10,489 sq. km and a population of 3.67 million, according to the 2011 Census. Of the total population, 73.83% live in rural areas. Tripura has eight districts, of which four are tribal hill districts rich in natural resources. It has a humid climate and is drained by ten major rivers including Burima, Gomati, Khowai, Haora, Longai, Dhalai, Muhuri, Feni, Juri, and Manu. The state is exposed to all major natural hazards (droughts, floods, cyclones, earthquakes, landslides, fires, etc.).

These characteristics make Tripura climate sensitive, underpinning the need for climate information. Climate data could serve as the basis for climate hazard mapping and risk assessment of various regions, sectors, and communities to ensure climate-proof development.

10.1 Historical climate

Temperature and seasonal rainfall—kharif and rabi—at the district level for the historical period spanning 1990–2019 are presented in the subsequent sections.

10.1.1 Trends in temperature

Tripura recorded a moderate warming of 0.27°C to 0.42°C in the summer maximum temperature and 0.23°C to 0.29°C in the winter minimum temperature during the historical period. Figure 10-1 presents the mean summer maximum and winter minimum temperatures in Tripura during the historical period.

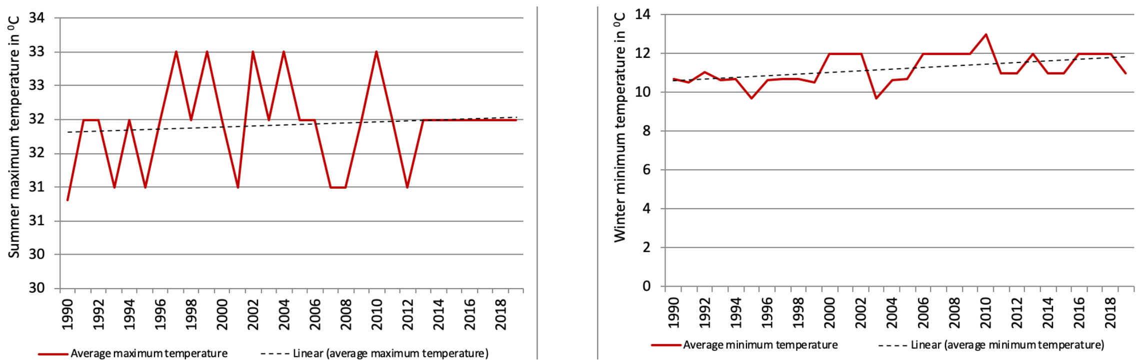


Figure 10-1: Mean summer maximum and winter minimum temperatures in Tripura during the historical period (1990–2019)

10.1.2 Trends in rainfall and rainfall variability

An increasing trend in the annual rainfall, in the range of 5%–15%, was recorded in a majority of the districts. In the kharif season, a 10%–15% increase in rainfall was recorded in all the districts. Figure 10-2 presents the mean annual rainfall in Tripura during the historical period.

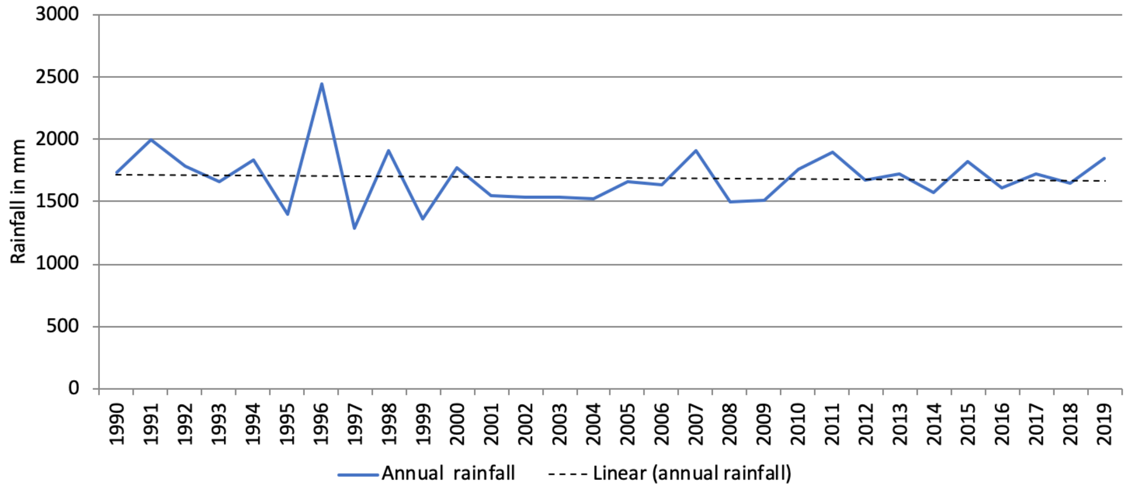


Figure 10-2: Mean annual rainfall in Tripura during the historical period (1990–2019)

The kharif season rainfall variability (coefficient of variation) ranged from 17% in North Tripura to 26% in South Tripura (Figure 10-3). The rabi season rainfall variability was in the range of 43% in North Tripura to 59% in South Tripura, indicating a complete failure of rainfall during the historical period (Figure 10-3).

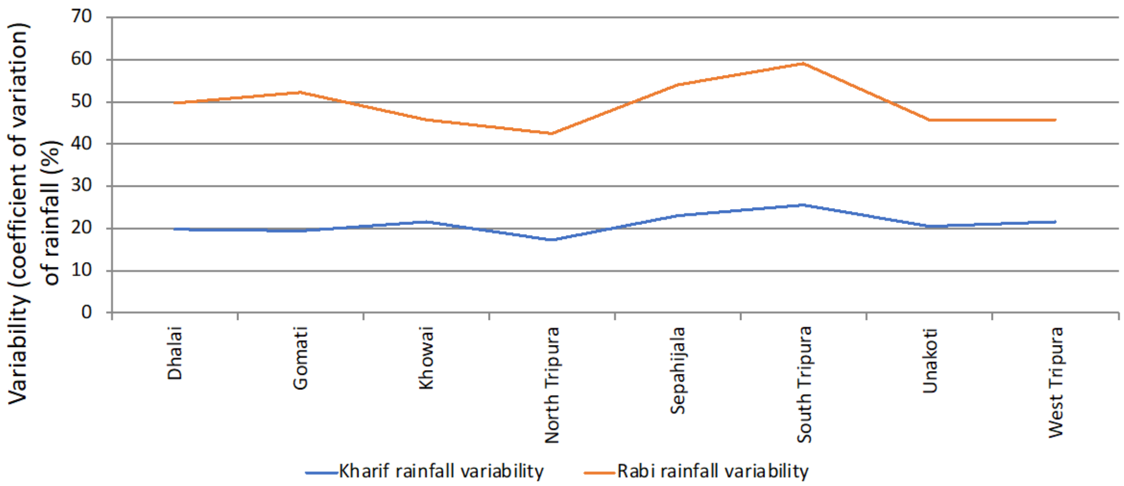


Figure 10-3: The kharif and rabi season rainfall variability (coefficient of variation) in the districts during the historical period (1990–2019)

10.2 Climate change projections

Temperature and rainfall are projected for the 2030s under two representative concentration pathways (RCP)—RCP 4.5 (medium emission) and RCP 8.5 (high emission) scenarios. For details on the scenarios and models, refer to Section 2.2.

10.2.1 Temperature projections

The projected changes in the summer maximum and winter minimum temperatures for all the districts of Tripura are presented in Figure 10-4.

The summary of projected changes between 2021–2050 and 1990–2019 is as follows:

Climate scenarios	Summer maximum	Winter minimum
RCP 4.5	Increases by 1°C to 1.5°C	Increases by 1°C to 1.5°C
RCP 8.5	Increases by 1°C to 2°C	Increases by 1°C to 2°C

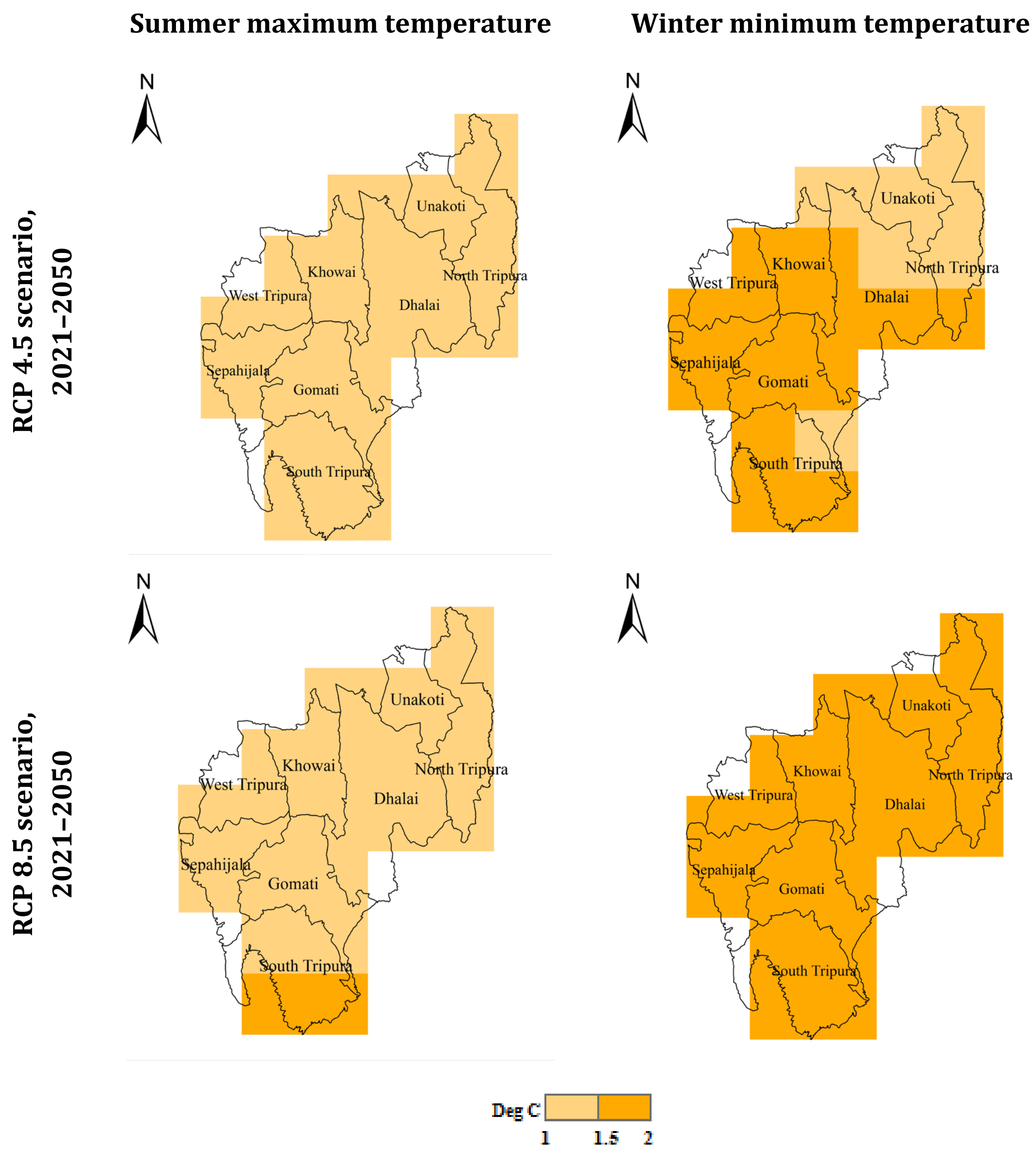


Figure 10-4: Projected changes in the summer maximum and winter minimum temperatures (°C) during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios. The changes are calculated by subtracting the mean over 1990–2019 from the mean over 2021–2050.

10.2.2 Rainfall projections

10.2.2.1 Number of rainy days

According to the India Meteorological Department (IMD), a *rainy day* is defined as a day with rainfall of 2.5 mm or more. The analysis of rainy days under historical and projected periods shows that there will be an increase in the number of rainy days during the projected period in all the districts (Figure 10-5). The number of rainy days during the historical period and the projected 2030s under both RCP 4.5 and 8.5 scenarios is presented in Appendix 10-3. The total number of rainy days that ranged from 2023 to 2719 days over the 30-year historical period increases to 2229 to 2807 days under the RCP 4.5 scenario and 2326 to 2819 days under the RCP 8.5 scenario during the projected 2030s. The increase per annum is as follows:

RCP 4.5 scenario: Projected to increase by 3 to 7 days annually with an increase of 7 days in Sepahijala; 6 days in Gomati; 5 days in Dhalai, South Tripura, and Unakoti; 4 days in Khowai; and 3 days in North Tripura and West Tripura.

RCP 8.5 scenario: Projected to increase by 3 to 10 days annually with an increase of 10 days in Sepahijala, 9 days in South Tripura, 8 days in Gomati, 7 days in Khowai and Unakoti, 6 days in West Tripura, 5 days in Dhalai, and 3 days in North Tripura.

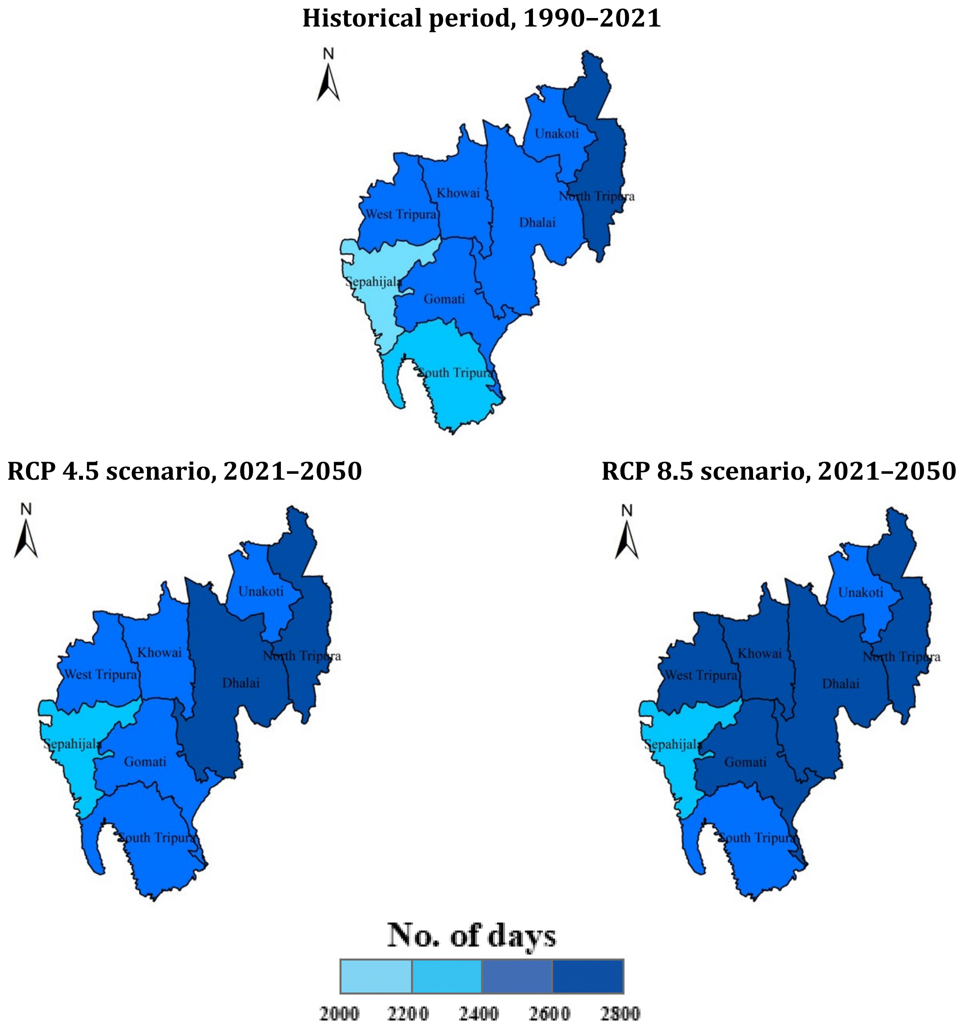


Figure 10-5: The total number of rainy days during the 30-year historical (1990–2019) and projected (the 2030s) periods under RCP 4.5 and RCP 8.5 scenarios

10.2.2.2 Mean rainfall and rainfall variability during the kharif season

The kharif season rainfall is projected to increase in all the districts under both climate scenarios. Figure 10-6 presents district-wise changes in the kharif season rainfall, and Figure 10-7 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability (coefficient of variation)
RCP 4.5	Increases in all the districts, from 7% in Sepahijala to 19% in North Tripura.	Declines in all districts by 2%–9%
RCP 8.5	Increases in all the districts, from 11% in South Tripura to 27% in West Tripura.	Declines in all districts by 2%–9%

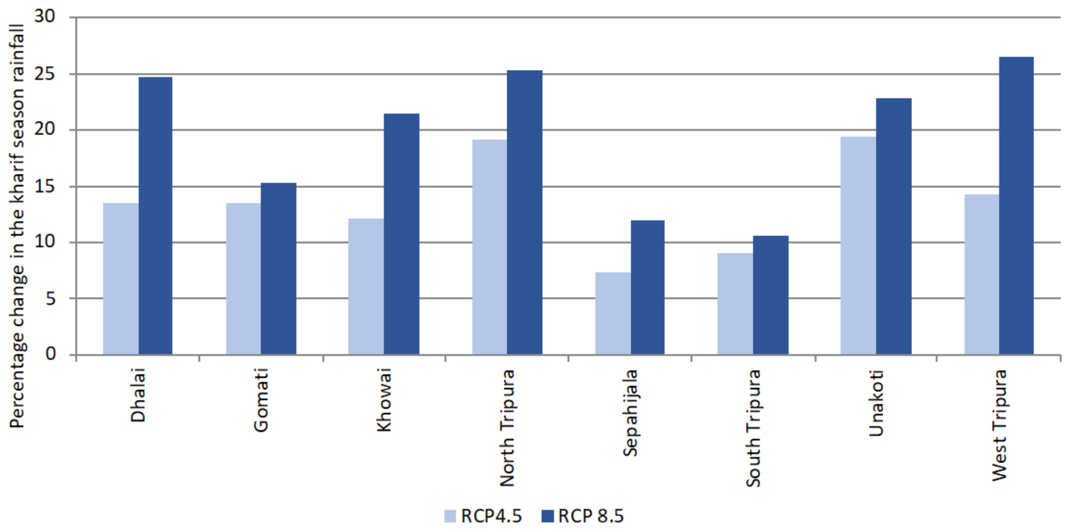


Figure 10-6: Projected percentage change in the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

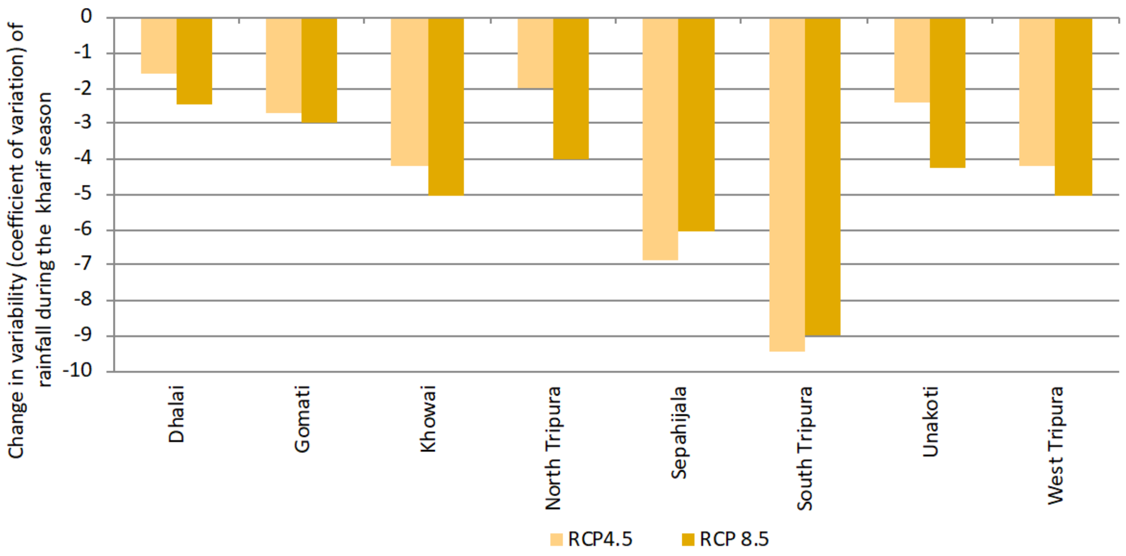


Figure 10-7: Projected changes in the variability (coefficient of variation) of the kharif season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

10.2.2.3 Mean rainfall and rainfall variability during the rabi season

The rabi season rainfall is projected to increase in all the districts under both climate scenarios. Figure 10-8 presents district-wise changes in the rabi season rainfall, and Figure 10-9 presents changes in the variability (coefficient of variation) of rainfall under both climate scenarios.

Climate scenarios	Mean seasonal rainfall	Rainfall variability
RCP 4.5	Increases in all the districts, from 6% in Gomati to 22% in Dhalai.	Declines in all districts by 2%–7%.
RCP 8.5	Increases in all the districts, from 8% in Khowai to 40% in Dhalai.	Declines in all districts by 2%–10%.

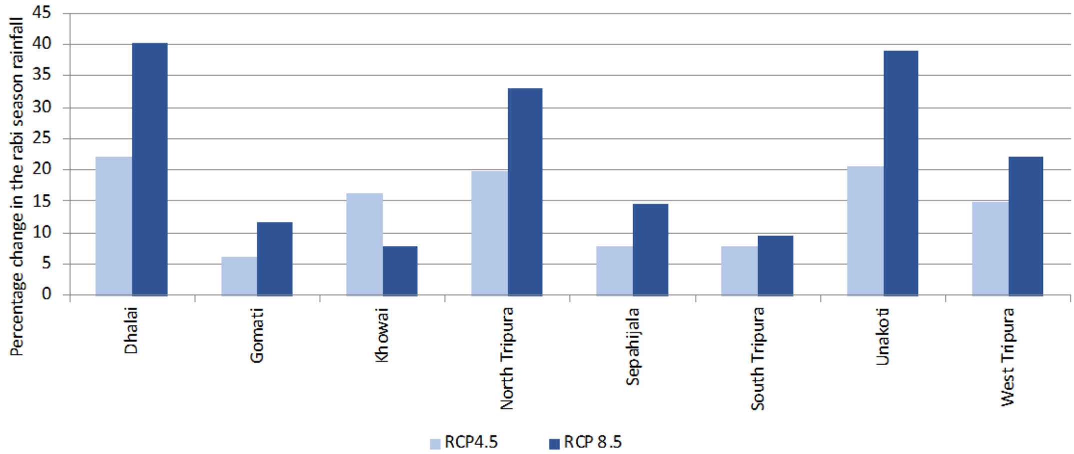


Figure 10-8: Projected percentage change in the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

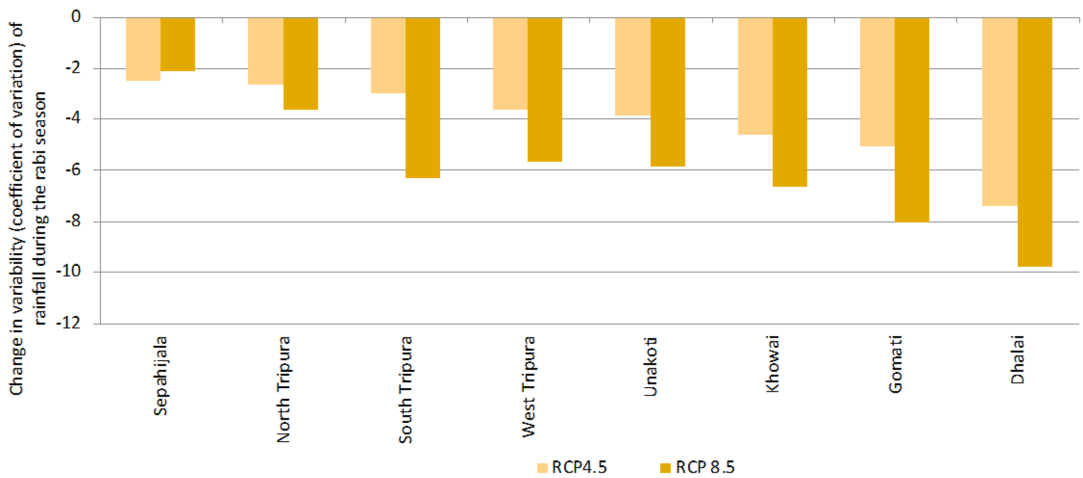


Figure 10-9: Projected changes in the variability of the rabi season rainfall during the short-term period (the 2030s) under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019)

10.3 Heavy rainfall events and rainfall deficient years

Rainfall during the kharif season was analysed by considering the intensity of rainfall under three categories: <50 mm/day, termed 'Low' intensity; 51–100 mm/day, termed 'High' intensity; and >100 mm/day, termed 'Very High' intensity. The number of such events was computed for the historical period and for the 2030s under the two climate scenarios, and the change was computed for all the districts of Tripura.

High-intensity rainfall events (Figure 10-10)

The total number of high-intensity rainfall events increases from 88 to 219 days during the historical period (1990–2019) to 135 to 312 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 165 to 348 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one to three events in the districts with an increase of three events in Sepahijala, Unakoti, and West Tripura; two events in Gomati and North Tripura; and one event in Dhalai, Khowai, and South Tripura.

RCP 8.5 scenario: The projected increase per annum is by two to four events in the districts with an increase of four events in North Tripura, Sepahijala, and Unakoti; three events in Gomati, South Tripura, and West Tripura; and two events in Dhalai and Khowai.

Very high-intensity rainfall events (Figure 10-10)

The total number of very high-intensity rainfall events increases from 15 to 94 days during the historical period (1990–2019) to 40 to 112 days in the 2030s (2021–2050) under the RCP 4.5 scenario and 65 to 132 days under the RCP 8.5 scenario. On a per annum basis, the increase under the two climate scenarios is as follows:

RCP 4.5 scenario: The projected increase per annum is by one event in Dhalai, Gomati, Khowai, North Tripura, Sepahijala, and West Tripura; two events in Unakoti; and zero events in South Tripura.

RCP 8.5 scenario: The projected increase per annum is by one event in Gomati, Sepahijala, and South Tripura and two events in Dhalai, Khowai, North Tripura, Unakoti, and West Tripura.

Rainfall deficient years (Figure 10-11)

Rainfall deficient years, computed by considering the rainfall during the kharif season, are projected to decline in all the districts of Tripura under both climate scenarios. The number of rainfall deficient years declines from 9 to 14 years during the historical 30-year period to 9 to 12 years under the RCP 4.5 scenario and 8 to 11 years under the RCP 8.5 scenario during the projected period.

RCP 4.5 scenario: The projected decline is by 2 years in Khowai, Sepahijala, South Tripura, and West Tripura. There is no decline in Dhalai, Gomati, North Tripura, and Unakoti.

RCP 8.5 scenario: The projected decline in all the districts, except Gomati and North Tripura, is by 1 to 3 years. The projected decline is by 3 years in Khowai, Sepahijala, South Tripura, and West Tripura; 2 years in Unakoti; and 1 year in Dhalai. There is no change in Gomati and North Tripura.

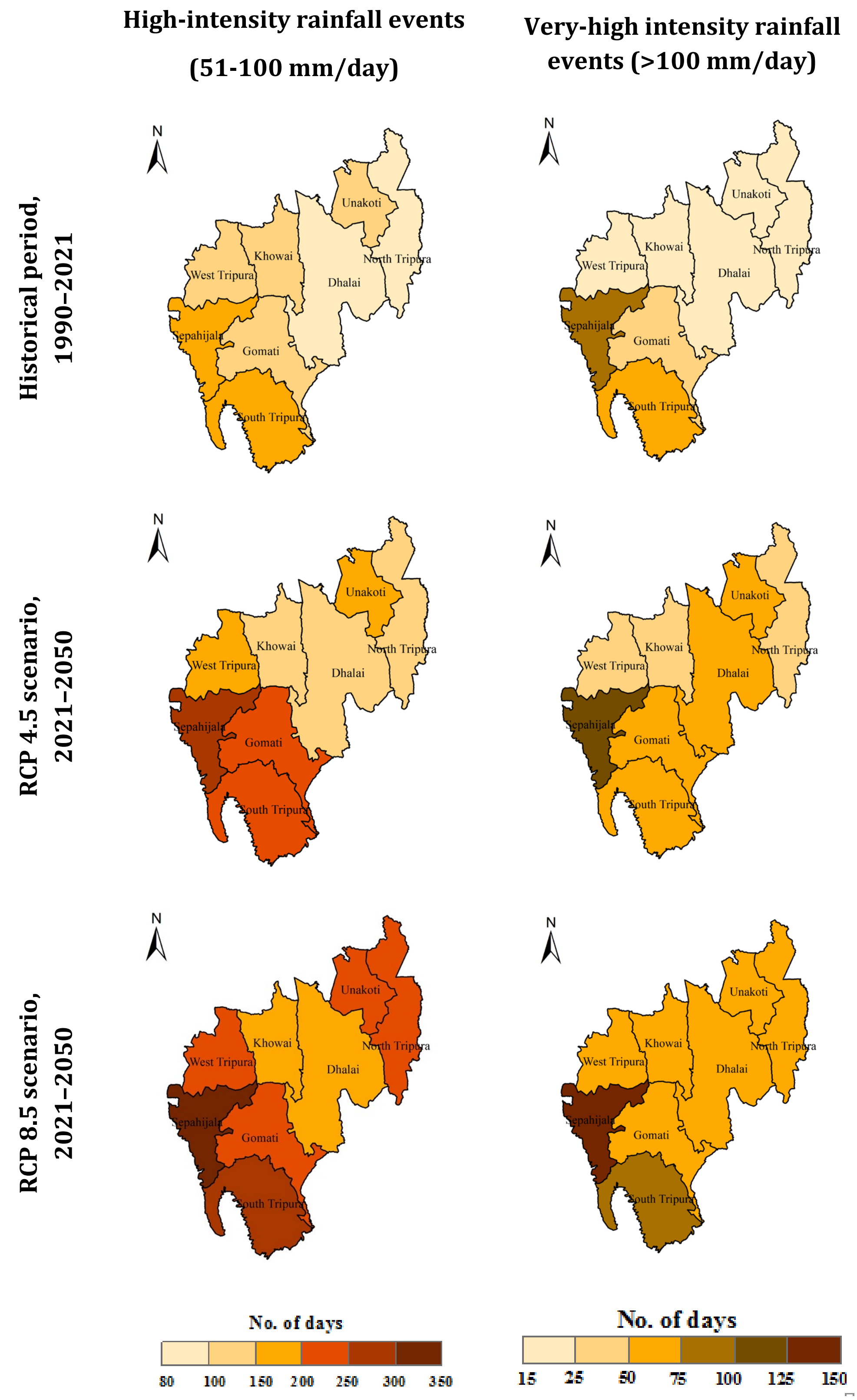


Figure 10-10: The total number of high-intensity and very high-intensity rainfall events over a 30-year period during historical (1990–2019) and the projected short-term (2021–2050) periods under RCP 4.5 and RCP 8.5 scenarios

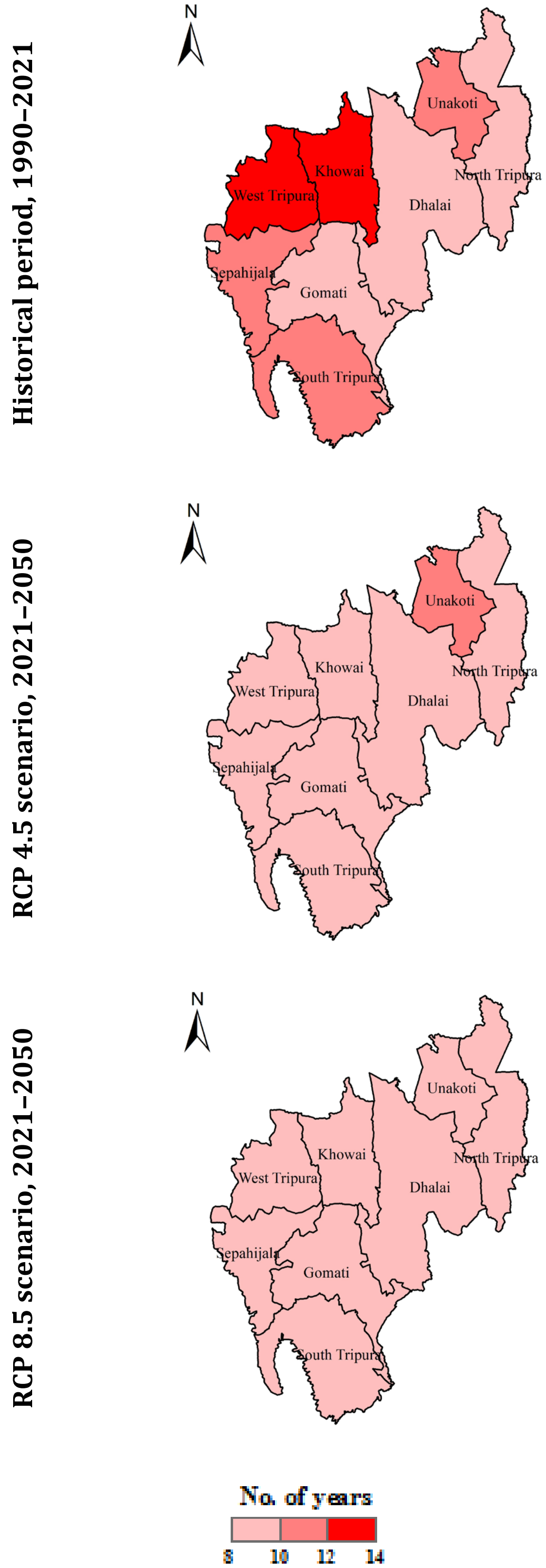


Figure 10-11: The number of rainfall deficient years over a 30-year period during the historical period (1990–2019) and the projected short-term (2021–2050) period under RCP 4.5 and RCP 8.5 scenarios

10.4 The summary of projected changes in the climate for Tripura

The temperature is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 10-1).

- The summer maximum temperature is projected to warm by up to 1°C to 1.5 °C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.
- The winter minimum temperature is projected to warm by 1°C to 1.5°C under the RCP 4.5 scenario and 1.5°C to 2°C under the RCP 8.5 scenario.

Rainfall is projected to increase in the short term (2021–2050) in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 10-2)

- There will be a notable increase in rainfall particularly in the northern districts under RCP 4.5 and RCP 8.5 scenarios.

Rainfall variability during the kharif season is projected to decline under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the kharif season is projected to be in the range of 2%–9% under both climate scenarios in all the districts.

Rainfall variability during the rabi season is projected to decline under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019).

- A decline in rainfall variability during the rabi season is projected to be in the range of 2%–7% under the RCP 4.5 scenario and 2%–10% under RCP 8.5 scenario.

The number of rainy days is projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990–2019; Appendix 10-3).

- The increase annually during the projected 2030s (2021–2050) is in the range of 3 to 7 days under the RCP 4.5 scenario and 3 to 10 days under the RCP 8.5 scenario.

Heavy rainfall events are projected to increase in all the districts under RCP 4.5 and RCP 8.5 scenarios compared to the historical period (1990-2019; Appendix 10-4).

- High-intensity rainfall events are projected to increase in the range of 1 to 3 days under the RCP 4.5 scenario and 2 to 4 days under the RCP 8.5 scenario.
- Very-high intensity rainfall events are projected to increase by one to two events per annum under both climate scenarios.

Rainfall deficient years are projected to decline in four of the eight districts under the RCP 4.5 scenario and six of the eight districts under the RCP 8.5 scenario compared to the historical period (1990–2019; Appendix 10-4).

- Rainfall deficient years are projected to decrease by 2 years in four districts under the RCP 4.5 scenario and 1 to 3 years in six districts under the RCP 8.5 scenario.

Appendix

Appendix 10-1: Changes in temperature under climate scenarios

Districts	Changes in temperature (°C) during the 2030s (2021–2050) compared to the historical period (1990–2019)			
	Summer maximum temperature		Winter minimum temperature	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Dhalai	1.1	1.7	1.2	1.6
Gomati	1.1	1.8	1.6	2.1
Khowai	1.3	1.9	1.6	1.7
North Tripura	1.2	1.6	1.2	1.5
Sepahijala	1.3	1.8	1.6	1.8
South Tripura	1.5	1.9	2.4	2.8
Unakoti	1.4	1.6	1.2	1.3
West Tripura	1.3	1.8	1.6	1.7

Appendix 10-2: Changes in rainfall under climate scenarios

Districts	Changes in rainfall (%) during the 2030s (2021–2050) compared to the historical period (1990–2019)					
	Annual rainfall		Kharif season rainfall		Rabi season rainfall	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Dhalai	14	23	13	25	22	40
Gomati	11	11	13	15	6	12
Khowai	14	21	12	22	16	8
North Tripura	16	24	19	25	20	33
Sepahijala	8	16	7	12	8	15
South Tripura	9	11	9	11	8	10
Unakoti	17	19	19	23	20	39
West Tripura	11	23	14	27	15	22

Appendix 10-3: The total number of rainy days (>2.5 cm/day) during the historical period (1990–2019) and the projected 2030s (2021–2050)

Districts	Historical	RCP 4.5 scenario	RCP 8.5 scenario
Dhalai	2533	2675	2690
Gomati	2447	2625	2680
Khowai	2477	2584	2676
North Tripura	2719	2807	2819
Sepahijala	2023	2229	2326
South Tripura	2279	2422	2550
Unakoti	2416	2569	2612
West Tripura	2477	2560	2646

Appendix 10-4: Extreme events under historical (1990–2019) and projected short-term (2021–2050) periods. The numbers indicate the total number of days with either high- or very high-intensity rainfall over a 30-year period and the number of rainfall deficient years over a 30-year period.

Districts	High-intensity rainfall events			Very high-intensity rainfall events			Rainfall deficient years		
	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5	Historical	RCP 4.5	RCP 8.5
Dhalai	98	140	165	15	58	75	10	10	9
Gomati	143	210	236	33	53	75	9	9	9
Khowai	109	149	175	19	40	70	14	12	11
North Tripura	88	135	220	17	46	67	9	9	9
Sepahijala	219	312	348	94	112	132	11	9	8
South Tripura	180	209	272	53	61	90	11	9	8
Unakoti	110	195	223	18	66	75	11	11	9
West Tripura	109	199	203	19	47	65	14	12	11

11. Conclusion

A moderate warming of summer maximum and winter minimum temperatures and an increase in rainfall were recorded during the historical period spanning 1990–2019 in the north-eastern states.

Climate projections for the north-eastern states at the district level for the period 2021–2050 (the 2030s) indicate a warmer and wetter future with an increase in extreme events, particularly heavy rainfall events. The heavy rainfall events are projected to be more frequent and more intense, and the projections are largely in agreement with the literature available at the global, South Asia, and national levels. The findings are particularly consistent with national-level projections of climate by the Ministry of Earth Sciences.

The projected changes in climate in the various districts of the north-eastern states of India could have the following implications:

Water: Climate change is affecting and could affect where, when, and how much water is available. Rising temperatures, changing precipitation patterns, and increasing heavy rainfall events could affect the amount of water in rivers, lakes, springs, and streams and the amount of water replenished into the ground. This has implications for water management for irrigation and drinking purposes. In the north-east, according to a NITI Aayog report, 'With the climate change manifested in the form of rising temperatures, rise in rainfall intensity, reduction in its temporal spread and a marked decline in winter rain, the problem of dying springs is being increasingly felt across the Indian Himalayan region'. This spells doom to the north-eastern states as the water needs are predominantly met from springs—about 37% in Arunachal Pradesh; 45% in Nagaland; 55% in Manipur, Meghalaya, and Mizoram; and 94% in Sikkim[4]. The climate projections clearly indicate the need for improved flood management strategies for effective adaptation.

Agriculture: Agriculture crops require specific conditions to thrive and have specific temperature and water requirements. Higher temperatures projected in the various districts of the north-eastern states can adversely impact crop growth and production. When coupled with increasing rainfall, this could promote the growth of invasive species and pests and their spread to newer areas. Projected heavy rainfall events could damage crops, leading to crop loss and adverse impacts on farm incomes and livelihoods. Climate change could thus increase the strain on agriculture systems through changes in the distribution and magnitude of rainfall, warming of temperature, and the frequency of heavy rainfall events.

Forest and wildlife: Changes in climate could affect both forests and wildlife, as well as the entire ecosystem. The projected increase in heavy rainfall events could lead to a higher incidence of pests and diseases. On the other hand, higher summer temperatures could increase the biomass fuel load in forests, leading to forest fires. The north-east region of India supports more than one-third of India's biodiversity and represents the Indo–Burma global biodiversity hotspot. According to Kanwal (2017), the forest and biodiversity in the region are already facing numerous anthropogenic threats, further aggravated by climate change. This situation underlines the need

[4]https://www.downtoearth.org.in/news/climate-change/climate-crisis-in-north-east-india-what-is-behind-water-scarcity-in-the-region-78910

for policy actions to promote conservation and sustainable use of resources and formulating and implementing adaptation strategies to reduce the vulnerability of forests and biodiversity.

Health: Projections of a warmer and wetter future in the districts of the north-eastern states have health implications. These implications could be both direct (thermal stress due to high summer temperatures and death, injury, or mental stress caused by forced migration due to climate- or weather-related disasters such as floods, droughts, and storms) as well as indirect (through changes in the ranges of disease vectors such as mosquitoes and rodents and changes in the availability and quality of water, air quality, and food availability and quality). The riverine islands of the Brahmaputra, for example, have been identified to be most vulnerable to health impacts of climate change—largely owing to frequent floods caused by heavy rainfall in the region[4].

Infrastructure: Projected high summer temperatures and an increase in heavy rainfall events have implications for energy supply and management. The performance of power infrastructure assets and the assets themselves are likely to be adversely impacted under high temperature and heavy rainfall conditions. While the increase in the summer maximum temperature, extended dry spells, and water shortage is a key risk to thermal power plants, heavy rainfall events could cause material damage to solar and wind power plants. Other infrastructure such as communication networks, transport, bridges, roads, and railways could also be damaged because of high temperature and heavy rainfall events.

According to a climate vulnerability assessment done by the Indian Institute of Technology Mandi, the Indian Institute of Technology Guwahati, and the Indian Institute of Science, Bangalore—considering the socio-economic, demographic, and health status; sensitivity of agricultural production; forest-dependent livelihoods; and access to information services and infrastructure—four of the top five states in the Indian Himalayan Region ranked highly vulnerable are from north-east India. Therefore, to cope with the changes in climate and their multiplying effects on social and economic inequities, it is vital that we build capacities that ensure the use of climate information and the flow of critical climate data to planners and decision makers. This work is an effort in that direction. Further analysis considering specific sectors and their exposure and vulnerabilities at a state level can help states identify climate risks and integrate them into the planning and implementation of future projects and programmes and formulate adaptation or resilience-building strategies for existing infrastructure. Building climate resilience—the ability to anticipate, absorb, accommodate, and recover from the effects of a potentially hazardous event—has several benefits. Delaying actions needed for resilience even by 10 years could almost double the costs.

References

Census. (2011). Primary census abstracts. https://censusindia.gov.in/2011-Common/Archive.html

Srivastava, A. K., Rajeevan, M., & Kshirsagar, S. R. (2009). Development of a high resolution daily gridded temperature data set (1969–2005) for the Indian region. *Atmospheric Science Letters, 10*(4), 249–254. https://doi.org/10.1002/asl.232

IPCC. (2014). Summary for policymakers. In: *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group ii to the fifth assessment report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32. https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf

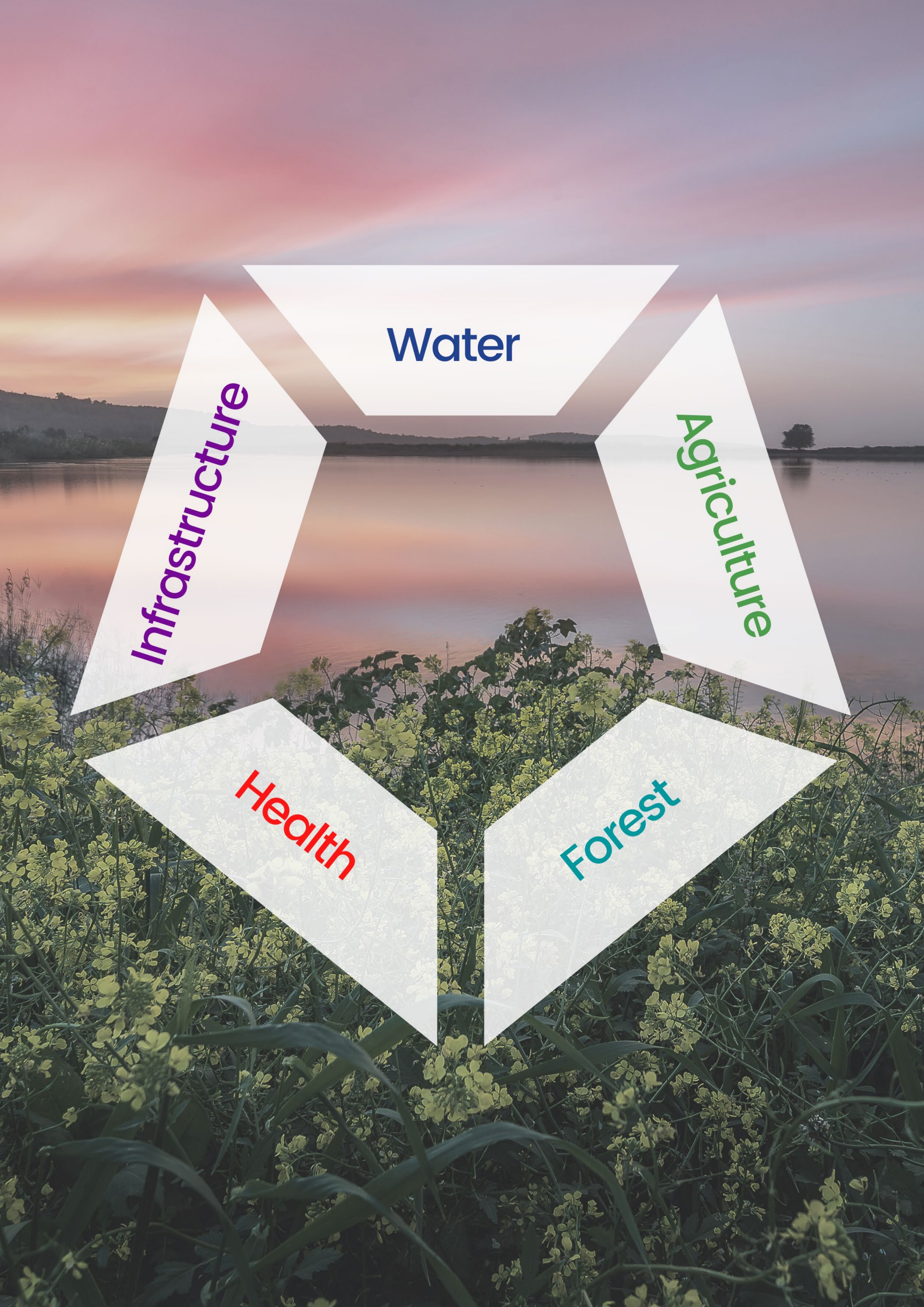
IPCC. (2021). Summary for policymakers. In: *Climate Change 2021: The physical science basis. Contribution of working group i to the sixth assessment report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Pai, D. S., Rajeevan, M., Sreejith, O. P., Mukhopadhyay, B., & Satbha, N. S. (2021). Development of a new high spatial resolution (0.25° × 0.25°) long period (1901–2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region. *MAUSAM, 65*(1), 1–18. https://doi.org/10.54302/mausam.v65i1.851

Taylor, K. E., Stouffer, R. J., & Meehl, G. A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, *93*(4), 485–498. https://journals.ametsoc.org/view/journals/bams/93/4/bams-d-11-00094.1.xml

20th livestock census. (2019). https://ruralindiaonline.org/en/library/resource/20th-livestock-census-2019-all-india-report/

Vulnerability atlas of India. (2019). *Earthquake, wind, flood, landslide, thunderstorm maps and damage risk to housing* (3rd ed.). https://bmtpc.org/topics.aspx?mid=56&Mid1=180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