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Recent climate change in the Imphal Valley, Manipur, India: A historical baseline and contemporary assessment

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ABSTRACT

The Imphal Valley is a geographically distinctive intermontane basin in Northeast India where climate, topography, drainage, agriculture, wetlands and settlement are closely interconnected. This study establishes a historical climatic baseline for Imphal using the India Meteorological Department (IMD) Climatological Tables of Observatories in India, 1951–1980, and compares it with the IMD 1991–2020 climatological normal. The analysis also contextualizes three supplied annual observations (1981, 1982 and 2025) with published long-term station and regional rainfall studies. The 1951–1980 baseline indicates a mean dry-bulb temperature of 20.2 °C, mean daily maximum temperature of 26.6 °C, mean daily minimum temperature of 14.2 °C, and mean annual rainfall of 1353.1 mm. July was the wettest month, receiving 283.8 mm with 16.4 rainy days. The historical absolute temperature range extended from –2.7 °C to 35.6 °C. The 1991–2020 normal gives mean daily maximum and minimum temperatures of 27.7 °C and 15.5 °C, respectively, annual rainfall of 1381.0 mm, and 93.8 rainy days. Thus, the contemporary normal is 1.1 °C warmer in mean daily maximum temperature and 1.3 °C warmer in mean daily minimum temperature, whereas annual rainfall differs by only 27.9 mm (+2.1%). July rainfall is 53.9 mm lower (–19.0%) in the contemporary normal. The three selected annual observations show higher temperatures and lower rainfall in 2025 than in 1981, but these endpoint observations cannot substitute for a continuous trend analysis. Published analysis of the 1969–2018 Imphal/Tuliha record reports significant warming and strong rainfall variability, while a 1901–2022 gridded analysis across Manipur documents spatially heterogeneous changes in rainfall seasonality and multiple change points. The evidence therefore supports interpreting recent climate change in the valley through temperature rise, seasonal redistribution and variability of rainfall, and interactions with hydrological and land-use processes rather than annual rainfall totals alone.

Keywords: Imphal Valley, Manipur, Climate change, Temperature, Rainfall, Climatological normal, Rainfall variability, Rainfall seasonality, Northeast India, Hydro-meteorological hazards

1. Introduction

Climate is a fundamental component of the physical environment and strongly influences hydrology, geomorphological processes, vegetation, agriculture and human settlement. Temperature and precipitation are particularly important because changes in their magnitude, timing and variability affect evapotranspiration, soil moisture, river discharge, groundwater recharge and hydro-meteorological hazards. The IPCC identifies continued warming and changes in the global water cycle as important components of contemporary climate change (IPCC, 2021) [1].

These interactions are especially relevant to intermontane basins such as the Imphal Valley. The valley contains agricultural land, wetlands, rivers and a rapidly expanding built-up area, while the surrounding hills influence runoff generation and local hydro-meteorological conditions. Long-term station observations are therefore essential for distinguishing persistent climate signals from short-term variability.

For Imphal, the IMD climatological tables provide two useful reference periods: 1951–1980 and 1991–2020. The latter is the current standard 30-year climatological normal published by IMD (IMD, 2022) [2]. Regional studies also show that Northeast India has spatially heterogeneous rainfall and temperature trends (Jain *et al.*, 2013) [3], while station-level analysis for Imphal/Tuliha reports significant warming and high rainfall variability (Singh, 2021) [4]. More recently, Singh *et al.* (2025) [5] documented spatially heterogeneous changes in rainfall seasonality across Manipur.

The objectives are to: (i) establish a historical climatic baseline for Imphal; (ii) summarize historical temperature, rainfall and selected weather characteristics; (iii) compare the historical baseline with the 1991–2020 normal; (iv) place the supplied recent annual observations in the context of published long-term analyses; and (v) discuss environmental implications without overstating what the available data can demonstrate.

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2. Study area

The Imphal Valley forms the central lowland portion of Manipur and is a fluvio-lacustrine intermontane basin surrounded by hill ranges. Major drainage systems include the Imphal, Nambul and Iril rivers and their tributaries. The IMD Imphal/Tulihal observatory is identified in the 1991–2020 climatological tables as Station Index 42623, at approximately 24°46'N, 93°54'E and 781 m above mean sea level.

3. Geological setting of the study area

The Imphal River has its origin from the northern hills of Karong in Senapati District and runs through the Alluvium plain of the valley. The valley is virtually a flat valley filled with Alluvium of fluvio-lacustrine origin. It occurs as an intermontane basin having distinct geomorphic and geologist features.

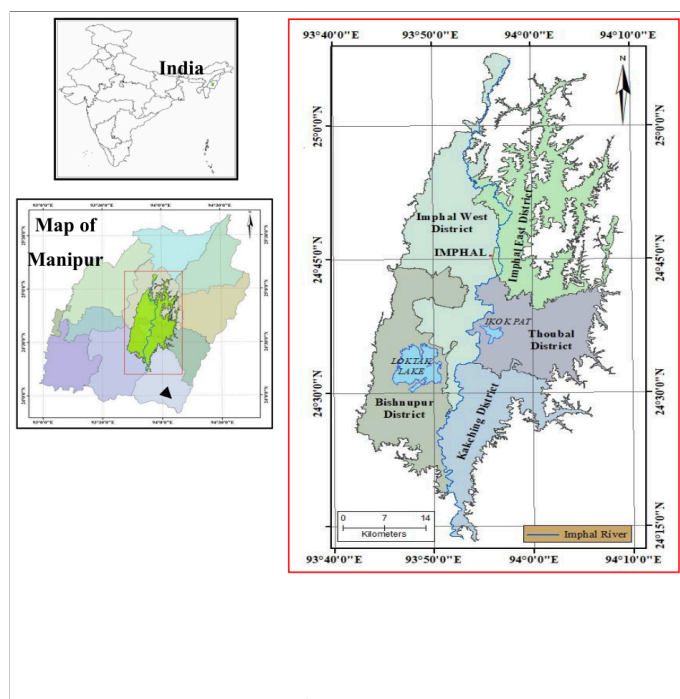


Figure 1. Location map of the study area

The valley is surrounded by the hilly terrain of Indo-Myanmar Range of North East. Most closely to the southern and western part of the valley lies the Loktak lake within few small hillocks such as Thanga, Karang and Ithing hills do occur in the form of isles. Occurrence of these hillocks within the lake suggests that lowest elevation is just at the foothills, not far away from the foothill region. Such a situation is possible only when the low-lying depression is created by tectonic stretching of the crust, not normally by erosional processes. A number of isolated, small to considerably large, hillocks also do occur within the valley protruding above the flat alluviums somewhat like monad-nocks or inselbergs. These hillocks look like to be denudational remnants but found to have some structural control on close examination.

3. Materials and methods

3.1 Historical and contemporary climatology

The historical baseline was compiled from IMD's Climatological Tables of Observatories in India, 1951–1980 (5th ed., 1999) [7]. Variables include temperature, rainfall, rainy days and selected weather phenomena. The contemporary reference period is the IMD 1991–2020 climatological normal for Imphal, Station Index 42623.

IMD describes these normals as 30-year climatological (Figure 2) averages prepared for comparison of current and recent climate conditions (IMD, 2022) [2].

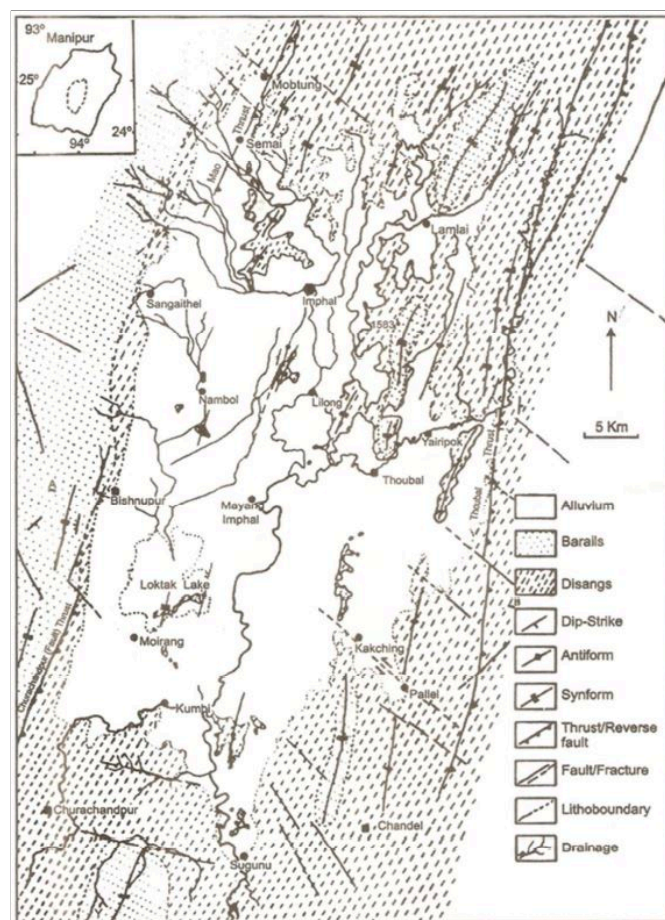


Figure 2. Geological and structural map of the Imphal valley (after Ibotombi Soibam *et al.* (2008) [6]).

3.2 Comparative calculation

For each directly comparable variable, the difference between periods was calculated as $\Delta X = X_{1991-2020} - X_{1951-1980}$, and percentage difference as $100 \times (X_{1991-2020} - X_{1951-1980}) / X_{1951-1980}$.

3.3 Selected annual observations

Only three annual observations—1981, 1982 and 2025—are available in the supplied manuscript dataset. They are therefore treated as selected observations rather than as a continuous time series. No Mann–Kendall statistic or Sen slope is calculated from these three points.

3.4 Trend-statistical framework

The Mann–Kendall (MK) test is a non-parametric method for detecting monotonic trends, and Sen's slope estimates the median rate of change. For a complete series $x_1 \dots x_n$, $S = \sum \sum \text{sgn}(x_j - x_i)$, where sgn is +1, 0 or −1 according to the sign of the difference. In practical climate-series applications, ties and serial correlation should be considered when estimating the variance of S ; modified MK procedures may be required where serial dependence is material. Sen's slope is the median of all pairwise slopes $(x_j - x_i) / (j - i)$. In this paper, these methods are used only to describe results already reported in the cited literature; no new MK/Sen statistics are claimed from the incomplete annual observations supplied here.

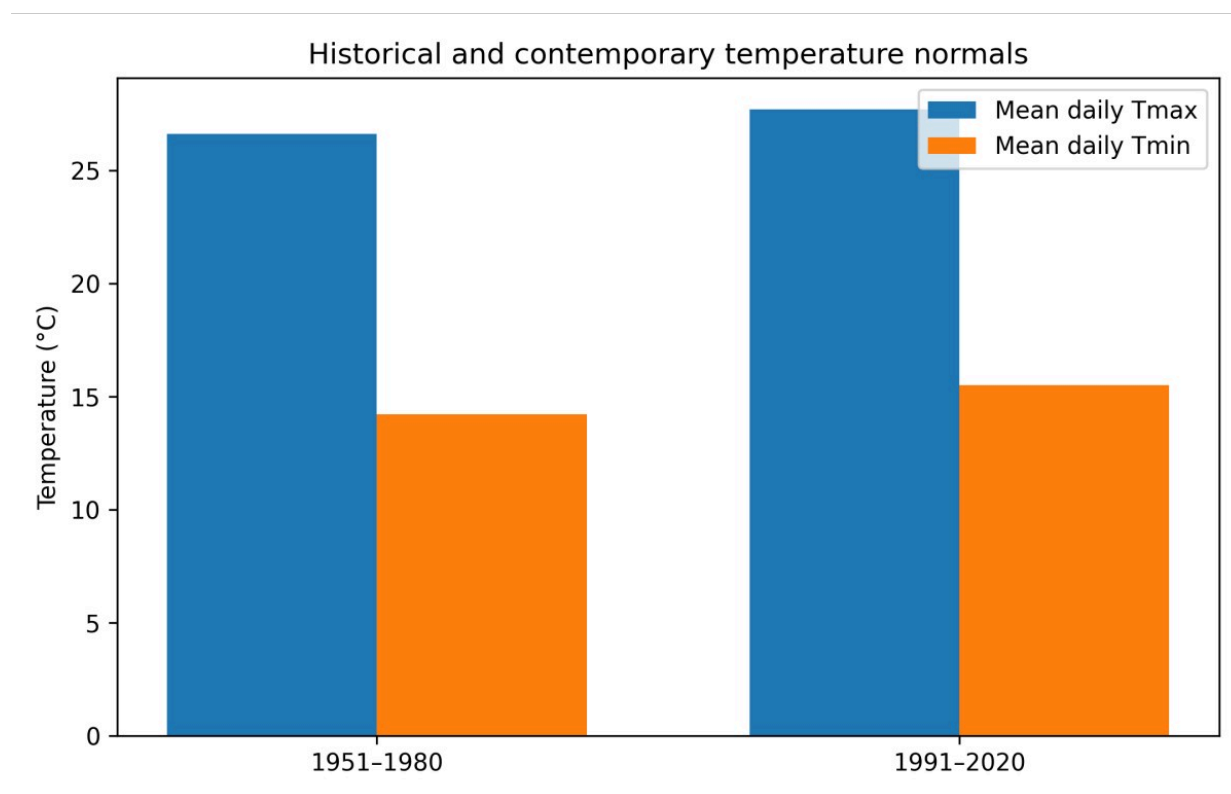


Figure 3. Historical versus contemporary mean daily maximum and minimum temperature.

Table 1. Selected annual observations available in the supplied dataset.

Year	Tmax (°C)	Tmin (°C)	Tmean (°C)	Rainfall (mm)
1981	28.2	14.1	21.15	1420.5
1982	28.5	14.0	21.25	1380.2
2025	29.8	15.3	22.55	1290.0

4. Results

4.1 Historical temperature characteristics

The 1951–1980 baseline indicates a mean dry-bulb temperature of 20.2 °C, mean wet-bulb temperature of 17.5 °C, mean daily maximum temperature of 26.6 °C and mean daily minimum temperature of

14.2 °C. The absolute maximum was 35.6 °C in 1979 and the absolute minimum was −2.7 °C in 1970.

4.2 Historical rainfall characteristics

Mean annual rainfall during 1951–1980 was 1353.1 mm with 94.0 rainy days. July was the wettest month, with 283.8 mm and 16.4 rainy days. Annual rainfall ranged from 1764.8 mm in 1966 to 903.9 mm in 1979, a difference of 860.9 mm. The maximum 24-hour rainfall was 122.4 mm on 27 May 1956.

Table 2. Historical temperature characteristics of Imphal.

Parameter	1951–1980 baseline
Mean dry-bulb temperature	20.2 °C
Mean wet-bulb temperature	17.5 °C
Mean daily $T_{\max}$	26.6 °C
Mean daily $T_{\min}$	14.2 °C
Highest monthly temperature	33.7 °C
Absolute maximum	35.6 °C (1979)
Absolute minimum	−2.7 °C (1970)

4.3 Historical weather phenomena

The historical record indicates approximately 44 days per year with 0 oktas of total cloud, 124 days with 6–7 oktas and 69 days with 8 oktas. Visibility was predominantly within the 4–10 km category, aver-

aging about 217.2 days per year. Thunderstorms occurred on approximately 54 days per year and fog on approximately 35.5 days per year.

Table 3. Historical rainfall characteristics of Imphal.

Parameter	Historical value
Mean annual rainfall	1353.1 mm
Mean annual rainy days	94.0 days
Wettest month	July: 283.8 mm; 16.4 rainy days
Wettest year	1966: 1764.8 mm
Driest year	1979: 903.9 mm
Wettest–driest difference	860.9 mm
Maximum 24-h rainfall	122.4 mm (27 May 1956)

5. Contemporary IMD climate normal (1991–2020)

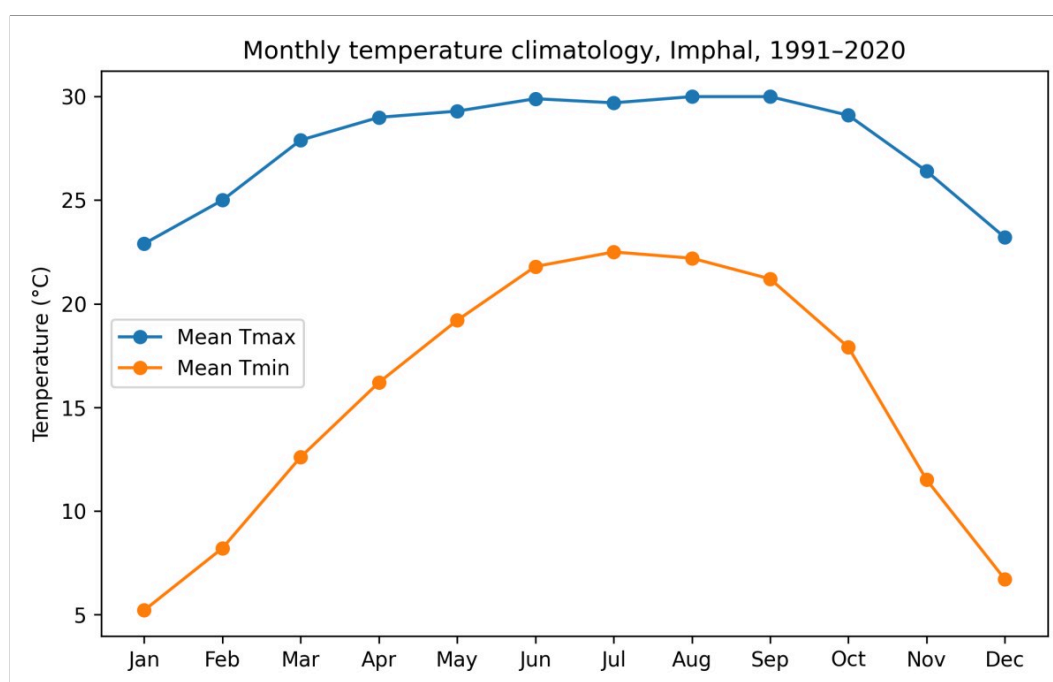
The IMD 1991–2020 normal provides the contemporary reference climate. Mean annual $T_{\max}$ is 27.7 °C, mean annual $T_{\min}$ is 15.5 °C, annual rainfall is 1381.0 mm and the annual number of rainy days is 93.8.

Table 4. Monthly and annual IMD climatological normal for Imphal, 1991–2020 (Station Index 42623).

Month	$T_{\min}$ (°C)	$T_{\max}$ (°C)	Rainfall (mm)	Rainy days
January	5.2	22.9	22.9	1.0
February	8.2	25.0	21.6	2.7
March	12.6	27.9	70.8	5.0
April	16.2	29.0	124.1	9.2
May	19.2	29.3	191.6	12.4
June	21.8	29.9	218.1	14.7
July	22.5	29.7	229.9	16.1
August	22.2	30.0	194.8	13.0
September	21.2	30.0	163.3	9.7
October	17.9	29.1	112.5	7.2
November	11.5	26.4	26.2	1.8
December	6.7	23.2	17.7	0.9
Annual	15.5	27.7	1381.0	93.8

Rainfall increases rapidly from March to June, reaches a maximum in July (229.9 mm), remains high through August and September, and declines during October–December. Mean monthly $T_{\max}$ reaches

about 30 °C in August and September, while $T_{\min}$ is lowest in January (Figure. 3 and 4)

**Figure 4.** Monthly temperature climatology of Imphal, 1991–2020.

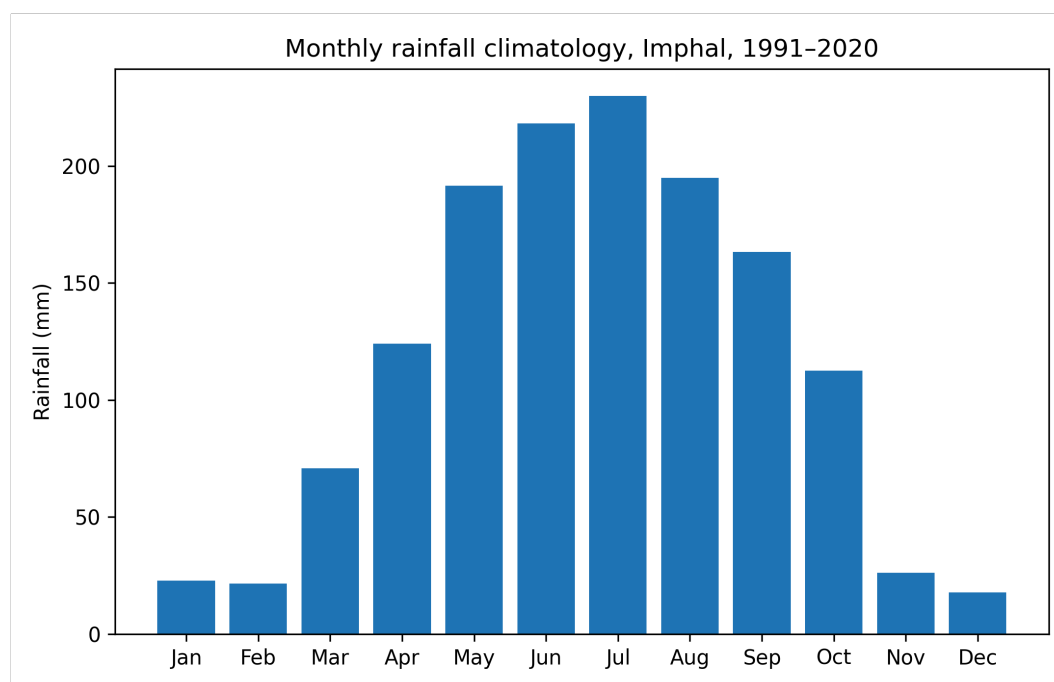


Figure 5. Monthly rainfall climatology of Imphal, 1991–2020.

6. Historical–contemporary comparison

The comparison indicates a pronounced shift in temperature relative to the historical baseline, while the annual rainfall total differs only modestly. The July decrease is substantially larger than the annual

percentage difference, illustrating why annual totals alone can obscure seasonal changes.

Table 5. Direct comparison between the historical baseline and contemporary IMD normal.

Parameter	1951–1980	1991–2020	ΔX	% difference
Mean daily $T_{\max}$	26.6 °C	27.7 °C	+1.1 °C	+4.1%
Mean daily $T_{\min}$	14.2 °C	15.5 °C	+1.3 °C	+9.2%
Annual rainfall	1353.1 mm	1381.0 mm	+27.9 mm	+2.1%
Annual rainy days	94.0	93.8	−0.2 days	−0.2%
July rainfall	283.8 mm	229.9 mm	−53.9 mm	−19.0%
July rainy days	16.4	16.1	−0.3 days	−1.8%

7. Long-term station trends and regional rainfall seasonality

7.1 Imphal/Tulihal station evidence

Singh (2021) [4] analysed monthly, seasonal and annual rainfall and temperature for Imphal/Tulihal for 1969–2018 using coefficient of variation, Mann–Kendall testing and Sen’s slope. The published study reports significant positive trends in temperature variables at annual and seasonal scales, with an annual 1969–2018 Sen slope of 0.039 °C/year for maximum temperature, 0.030 °C/year for minimum temperature and 0.039 °C/year for mean temperature. The study also identifies two broad phases, with slower warming before 1993 and a much faster rise after 1993; the latter is reported in the paper as approximately 0.45 °C/year for annual mean temperature. This phase-specific value is reproduced here as a published result, not as a recalculation from the present dataset.

For rainfall, Singh (2021) [4] reports a coefficient of variation of 20.88% and comparatively weak annual/seasonal patterning. The pub-

lished Sen slope for the 1969–2018 pre-monsoon season is 1.931 mm/year, while May shows +2.17 mm/year; the paper identifies May and November as statistically significant monthly rainfall trends. These results indicate that rainfall variability is more spatially and seasonally complex than the temperature signal.

7.2 Regional Manipur rainfall seasonality

Singh et al. (2025) [5] analysed 1901–2022 gridded rainfall at 0.25° × 0.25° resolution across 33 grid points in Manipur using the Seasonality Index, Individual Seasonality Index, Replicability Index, Mann–Kendall test, Sen’s slope and sequential Mann–Kendall test. They found a seasonal rainfall regime with SI values of 0.60–0.79. Increasing SI_i trends occurred at 57.57% (19/33) of grid points and decreasing trends at 30.3%, with Sen slopes from −0.00003 to 0.00089 year^{−1}. Multiple change points occurred, particularly after 1973, with increased evidence after 2000. Importantly, the study reports spatially heterogeneous changes; it does not justify treating increased seasonality as equivalent to a universal increase in rainfall intensity at Imphal.

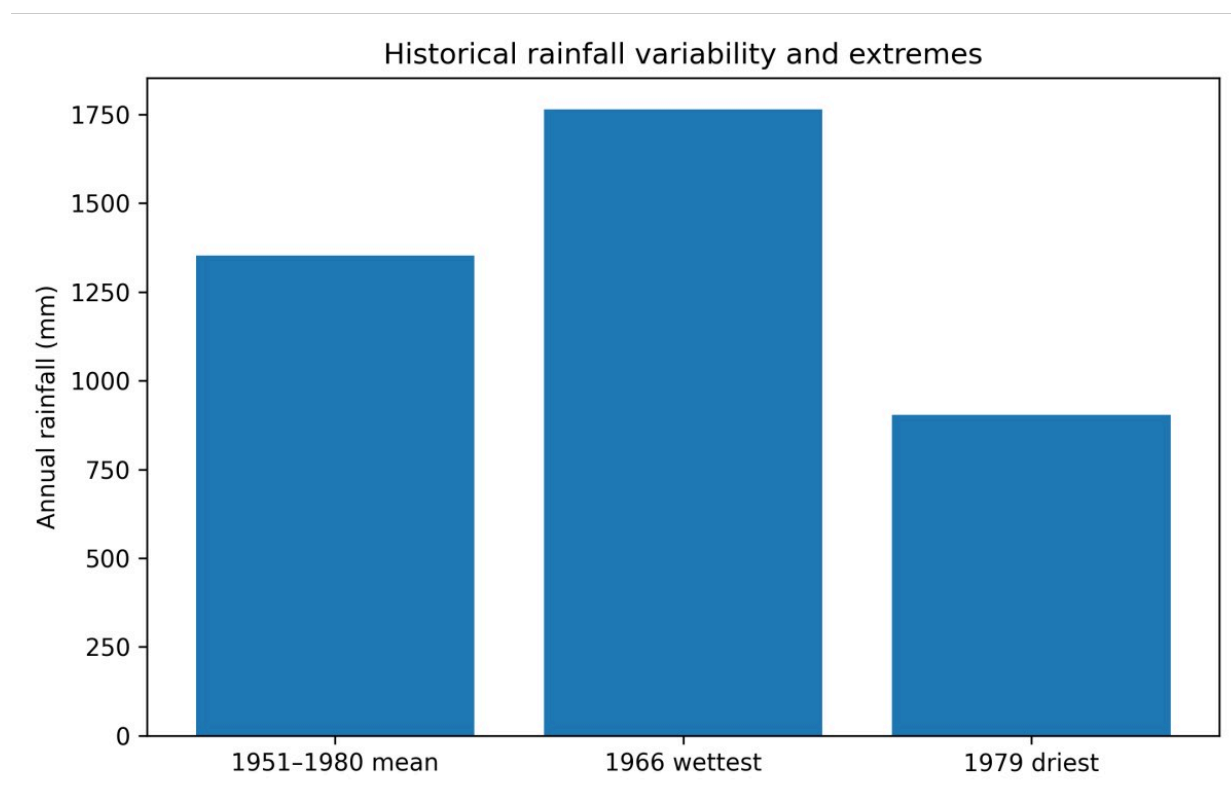


Figure 6. Historical annual rainfall mean and documented wettest/driest years.

8. Environmental implications

Temperature increase can raise atmospheric evaporative demand and crop water requirements. The contemporary normal is warmer than the historical baseline, while rainfall remains strongly seasonal. The combination can affect soil moisture, irrigation requirements and agricultural scheduling, particularly where irrigation capacity is limited. For urban hydrology, the relevant issue is not simply whether annual rainfall is higher or lower. Rainfall timing, storm duration, antecedent wetness, catchment response and the proportion of impervious surfaces can alter runoff and flood response. The present study does not quantify the separate contribution of urbanisation to flooding; that relationship should be tested using rainfall intensity, discharge, land-use and drainage data.

A useful conceptual formulation is: Climate-related environmental risk = climatic forcing × hydrological response × exposure × vulnerability. This is a conceptual framework rather than a calibrated risk equation. Future work should combine high-resolution rainfall intensity, river stage/discharge, wetland storage, land-use change, drainage capacity and exposure data.

The evidence supports practical priorities including continued high-quality meteorological observations, preservation of natural wetland and retention areas, improved urban drainage planning, integration of seasonal climate information into agricultural planning, and systematic monitoring of rainfall intensity and hydrological response.

9. Limitations

The historical and contemporary values are climatological reference periods rather than a homogeneous annual time series. The supplied recent annual dataset contains only three years and therefore cannot independently establish a statistically significant trend. Published MK and Sen results are cited as secondary evidence and were not recomputed here. In addition, the present study does not quantify rainfall intensity distributions, streamflow trends, land-use change or exposure/vulnerability indices. These limitations should be stated explicitly in any interpretation of climate-related hazards.

10. Conclusions

The Imphal Valley shows a clear difference between the historical 1951–1980 climate baseline and the contemporary 1991–2020 normal. Mean daily $T_{\max}$ increased by 1.1 °C and mean daily $T_{\min}$ by 1.3 °C, whereas annual rainfall changed by only +27.9 mm (+2.1%). July rainfall decreased by 53.9 mm (−19.0%). Historical rainfall also showed substantial interannual variability, from 903.9 mm in 1979 to 1764.8 mm in 1966. The three selected annual observations indicate warmer and drier conditions in 2025 than in 1981, but they are not sufficient to define a trend.

Published long-term station analysis independently documents significant warming at Imphal/Tuliha and strong rainfall variability, while regional Manipur analysis identifies heterogeneous changes in rainfall seasonality and multiple change points. Taken together, the evidence indicates that assessment of recent climate change in the valley should focus on temperature change, seasonal rainfall structure and variability, and their interaction with hydrology and land use. Long-term integrated monitoring is required for robust attribution and for climate-resilient planning.

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