Current Scenario of Climate Change in Madurai District: Trends in Temperature, Rainfall and Urban Heat Stress

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Abstract

Climate change is increasingly affecting the environmental and socio-economic conditions of Madurai District in Tamil Nadu. Madurai has a warm semi-arid climate, with high temperatures during the pre-monsoon and summer months and substantial dependence on the northeast monsoon for rainfall. Recent evidence indicates that rising urbanisation, expansion of built-up areas, declining vegetation and changes in surface-water availability are intensifying local heat stress. This paper examines the current scenario of climate change in Madurai District by considering temperature characteristics, rainfall variability, urban heat-island effects and associated environmental impacts. The study uses secondary data from the India Meteorological Department (IMD), Government of Tamil Nadu publications and recent peer-reviewed research on the Madurai region. The IMD climatological normal for Madurai during 1981–2010 shows an annual mean maximum temperature of 34.5°C and an annual mean minimum temperature of 23.9°C, with mean annual rainfall of 869.4 mm. Seasonal rainfall concentration is particularly important, with October and November contributing a large share of annual rainfall. Recent research for 2015–2024 reports persistent urban-rural temperature differences and increasing heat accumulation in the Madurai region. The study argues that climate change in Madurai is expressed not only through warming but also through rainfall variability, water stress, changing land use and urban thermal stress. Strengthening water-body conservation, urban greening, climate-resilient agriculture, heat-action planning and sustainable land-use management is essential for improving the district's climate resilience.

Keywords: Climate Change, Madurai District, Temperature, Rainfall Variability, Urban Heat Island, Water Resources, Urbanisation, Climate Resilience

Introduction

Climate change has become one of the major environmental and developmental challenges of the twenty-first century. Changes in temperature, precipitation, extreme weather events, water availability and ecosystems have direct implications for agriculture, public health, livelihoods and urban development. District-level assessment is especially important because climate impacts differ considerably from one region to another. Madurai District is an important urban, agricultural and commercial centre in southern Tamil Nadu. The district experiences high temperatures for much of the year and receives rainfall from both the southwest and northeast monsoon systems, with the northeast monsoon playing a particularly important role in the annual rainfall regime. According to the India Meteorological Department, the 1981–2010 climatological normal for Madurai is 34.5°C for annual mean maximum temperature, 23.9°C for annual mean minimum temperature and 869.4 mm for annual rainfall. October has the highest climatological mean rainfall at 185.8 mm, followed by November at 147.2 mm.

The climate problem in Madurai is closely connected with rapid urbanisation. Expansion of roads, concrete surfaces, buildings and other impervious areas modifies the local surface-energy balance and can increase heat retention. A recent 2026 study of the Madurai region, using land-use/land-cover changes, water-spread information and temperature observations, found a persistent urban-rural temperature gradient and identified built-up expansion, declining vegetation and shrinking water spread as important factors contributing to urban heat vulnerability. Therefore, the present study focuses on the current climate-change scenario in Madurai by examining temperature conditions, rainfall characteristics, urban heat stress and environmental implications.

Climate Change Pathway in Madurai

Urbanisation

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Increase in Built-up / Impervious Surfaces

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Reduction in Vegetation and Water Bodies

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Greater Heat Absorption and Heat Retention

↓

Higher Urban Surface Temperature

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Urban Heat-Island Stress

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Higher Water Demand + Health Stress + Energy Demand

Statement of the Problem

Madurai is increasingly exposed to climate-related pressures, including high summer temperatures, rainfall variability, water-resource stress and the local urban heat-island effect. At the same time, urban expansion is reducing natural and semi-natural land surfaces. The resulting increase in thermal stress may affect water demand, agriculture, human comfort, energy use and public health. The major problem is therefore not simply a change in average climate, but the interaction between climatic variability and human-induced land-use change. Understanding this interaction is necessary for developing district-level climate adaptation and mitigation strategies.

Objectives of the Study

The study has the following objectives:

1. To examine the temperature and rainfall characteristics of Madurai District.
2. To analyse the seasonal pattern and variability of rainfall.
3. To examine recent evidence of urban heat stress in the Madurai region.
4. To identify the major environmental and socio-economic impacts of climate change.
5. To suggest suitable adaptation and mitigation measures for climate-resilient development.

Review of Literature

Recent literature on Madurai highlights the growing importance of urban heat and land-use change. A 2025 study examining rapid urbanisation and land-surface temperature in Madurai during 2013–2023 reported a relationship between urban expansion, environmental degradation and increasing surface temperatures. More recent research published in 2026 provides an integrated assessment of urban heat-island vulnerability in the Madurai region. The study combined land-use/land-cover dynamics, major water-body water-spread variations and

urban-rural temperature observations. It reported that daily temperature observations from 2015–2024 showed a persistent urban-rural temperature difference, while built-up areas experienced greater thermal stress than areas with vegetation or water. The study also highlighted the role of water bodies as local cooling elements. Official climatological information from the IMD provides an important baseline for understanding present-day variations. The Madurai climatological table for 1981–2010 shows substantial seasonal variation in rainfall, with the highest normal rainfall occurring in October and November. Government of Tamil Nadu statistical publications also show that Madurai can experience considerable departures from normal rainfall. For 2021–22, the district recorded 1,118.5 mm against a normal of 836.3 mm, indicating a surplus of 282.2 mm or approximately 33.7% relative to the normal. These studies and official datasets indicate that climate change in Madurai should be evaluated using both long-term climatological baselines and recent observations.

Research Methodology

The study is based mainly on secondary data.

- India Meteorological Department (IMD), Madurai climatological and extreme-weather records.
- Government of Tamil Nadu, Statistical Hand Book and climate/rainfall publications.
- Recent peer-reviewed studies on Madurai's land surface temperature, urbanisation and urban heat-island vulnerability.
- Relevant government climate-action information.

Period of Analysis

The study uses:

- **1981–2020** as the IMD climatological baseline.
- **2013–2023** for selected urbanisation and land-surface-temperature evidence.
- **2015–2024** for recent urban-rural temperature and thermal-stress evidence reported in the 2026 Madurai study.
- **2012–2025** for water-spread-area evidence reported in the same recent study.

Temperature Scenario of Madurai

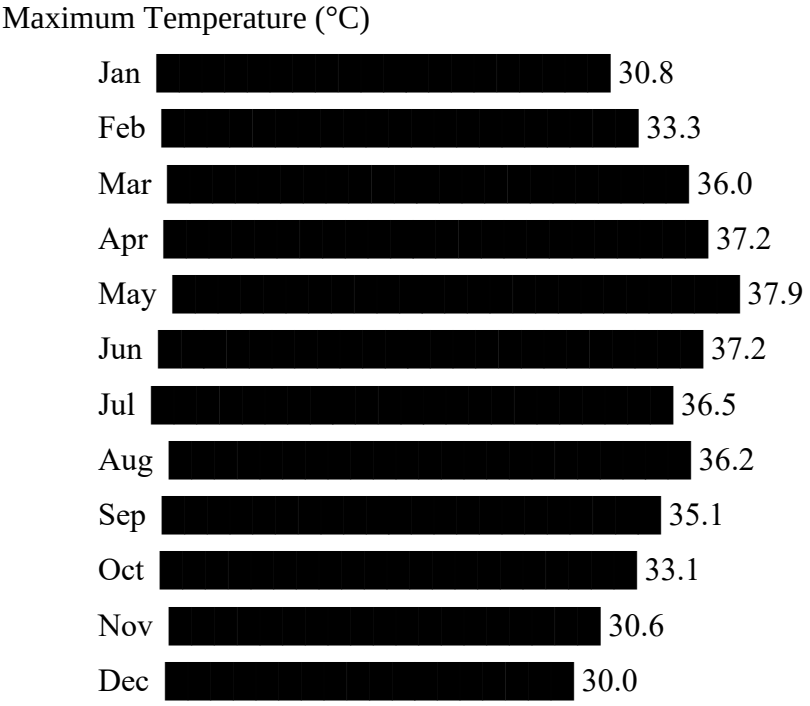
Table 1: IMD Climatological Temperature Profile of Madurai, 1981–2020

Month	Mean Minimum Temp. (°C)	Mean Maximum Temp. (°C)
January	20.6	30.8
February	21.5	33.3
March	23.4	36.0
April	25.6	37.2
May	26.3	37.9
June	26.2	37.2
July	25.9	36.5
August	25.5	36.2
September	24.6	35.1
October	23.7	33.1
November	22.7	30.6
December	21.3	30.0
Annual Mean	**23.9**	**34.5**

Source: India Meteorological Department, Madurai climatological table, 1981–2020.

The table shows a clear seasonal temperature cycle. Mean maximum temperature rises from 30.8°C in January to 37.9°C in May, the hottest month in the climatological normal. April, May and June are particularly warm months. The mean monthly maximum temperature across the 12 months is approximately 34.5°C, while the mean monthly minimum temperature is approximately 23. 9°C.The standard deviation of monthly maximum temperatures is approximately 2.83°C, while the standard deviation for monthly minimum temperatures is approximately 2.05°C. This shows moderate seasonal variability in temperature. Recent IMD records also demonstrate that extreme heat events occur in Madurai. For example, the IMD extreme-weather record reports a September maximum temperature of 41.6°C on 26 September 2024, which is the all-time September record in the cited Madurai station series.

Seasonal Temperature Pattern



The diagram clearly indicates that temperature rises sharply from February to May and remains high through July. May records the highest climatological normal maximum temperature of **37.9°C**.

Rainfall Scenario of Madurai

Table 2: Monthly Rainfall Normal of Madurai, 1981–2020

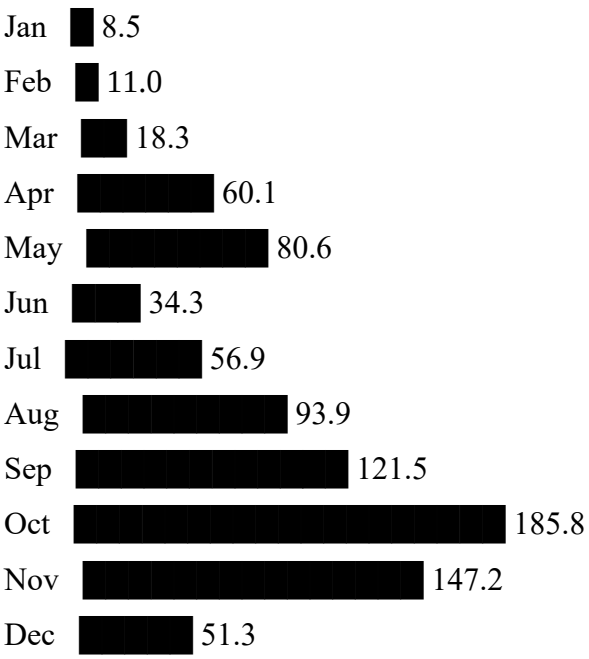
Month	Mean Rainfall (mm)
January	8.5
February	11.0
March	18.3
April	60.1
May	80.6
June	34.3
July	56.9
August	93.9
September	121.5
October	185.8
November	147.2

December	51.3
Annual Total	**869.4**

Source: India Meteorological Department, Madurai climatological table, 1981–2020.

Madurai receives rainfall unevenly across the year. October has the highest normal rainfall of 185.8 mm, followed by November with 147.2 mm and September with 121.5 mm. In contrast, January and February are relatively dry months. The monthly rainfall series has a standard deviation of approximately 55.97 mm and a coefficient of variation of about 77.26%. This high coefficient of variation reflects the strong seasonal concentration and variability of rainfall. Thus, rainfall availability is strongly dependent on a limited number of wet months. Any shift in the timing, intensity or duration of rainfall can have important implications for agriculture, tanks, groundwater recharge and urban drainage.

Seasonal Rainfall Pattern



Rainfall is highly concentrated during the latter part of the year. October and November together form a critical rainfall period. This pattern increases the importance of efficient rainwater harvesting, tank storage and groundwater recharge.

Rainfall Variability: Recent Evidence

Table 3: Madurai District Rainfall: 2021–22

Indicator	Rainfall (mm)
Actual annual rainfall	1,118.5
Normal annual rainfall	836.3
Departure	+282.2
Percentage departure	+33.7%

Source: Government of Tamil Nadu, Statistical Hand Book, 2021–22.

Madurai received 1,118.5 mm of annual rainfall during June 2021–May 2022 against a normal of 836.3 mm. The excess was 282.2 mm, equivalent to approximately 33.7% above normal. This example demonstrates an important feature of climate variability: a district can receive substantially above-normal annual rainfall while still experiencing water stress during dry periods. Therefore, climate resilience requires attention not only to annual rainfall totals but also to rainfall timing, intensity, spatial distribution and storage capacity.

Urban Heat-Island Scenario in Madurai

Recent evidence indicates that the urban climate of Madurai is becoming increasingly important in understanding climate change. The 2026 study of the Madurai region used daily temperature observations from 2015–2024, land-use data and water-spread observations from 2012–2025. It found that urban areas consistently experienced higher temperatures than surrounding rural areas and that heat vulnerability was associated with increasing built-up density, declining vegetation and shrinking water bodies.

Table 4: Selected Indicators Reported in the Recent Madurai UHI Study

Indicator	Reported value
Study period for temperature observations	2015–2024
Study period for water-spread observations	2012–2025
Surface-temperature range	27.14°C–39.82°C
Mean surface temperature	34.48°C
Urban heat-island differential increase	+1.42°C

Reported average annual temperature increase	0.11°C/year
Heat accumulation index, 2015	1,124°C
Heat accumulation index, 2024	1,406°C
Increase in heat accumulation	25.1%

Source: Ramesh et al. (2026), *Discover Cities*.

The recent evidence shows that Madurai's climate challenge is strongly linked with urban land transformation. The reported increase in heat accumulation from 1,124°C in 2015 to 1,406°C in 2024 represents an increase of approximately **25.1%**. The study also identified a persistent urban-rural temperature gradient and greater thermal stress in densely built-up locations.

Major Impacts of Climate Change in Madurai

Agriculture

Changes in rainfall timing and increasing heat can affect crop growth, soil moisture and irrigation requirements. Irregular rainfall can create both drought conditions and short-duration intense rainfall events.

Water Resources

Madurai depends heavily on tanks, reservoirs, groundwater and seasonal rainfall. Recent research indicates declining water-spread conditions in parts of the Madurai region and highlights the cooling and hydrological importance of surface-water bodies.

Urban Heat Stress

Dense built-up areas absorb and retain heat. Reduced vegetation and surface-water availability can increase local thermal stress, especially during the pre-monsoon and summer seasons.

Public Health

Higher temperatures can increase heat stress and discomfort, especially among vulnerable groups. Urban climate planning should therefore include shade, cooling spaces, vegetation and heat-awareness measures.

Biodiversity and Ecosystems

Loss of vegetation and transformation of agricultural and natural surfaces reduce ecosystem resilience. Green spaces and water bodies are important for maintaining local ecological balance and moderating urban temperatures.

Findings of the Study

The major findings are as follows:

1. Madurai has a naturally warm climate, with an IMD climatological annual mean maximum temperature of **34.5°C** and minimum temperature of **23.9°C**.
2. May is the hottest month in the climatological normal, with a mean maximum temperature of **37.9°C**.
3. Average annual rainfall is **869.4 mm**, but rainfall is highly concentrated in the latter part of the year.
4. October receives the highest climatological monthly rainfall, at **185.8 mm**.
5. The high coefficient of variation of monthly rainfall indicates strong seasonal variability.
6. Madurai can experience large departures from normal rainfall; during 2021–22, rainfall was approximately **33.7% above normal**.
7. Extreme heat is becoming an important local climate concern, with the IMD station recording **41.6°C on 26 September 2024**, an all-time September record in the cited series.
8. Recent research identifies urbanisation, declining vegetation and shrinking surface-water areas as important drivers of urban heat vulnerability in the Madurai region.
9. The recent 2015–2024 evidence shows a persistent urban-rural temperature difference.
10. Climate change in Madurai should therefore be addressed through an integrated approach covering **temperature, rainfall, water management, urban planning and ecosystem conservation**.

Suggestions

1. **Increase urban green cover:** Expand roadside trees, parks, institutional green spaces and neighbourhood vegetation.
2. **Protect water bodies:** Restore tanks, ponds and urban wetlands to improve water storage and local cooling.

3. **Promote rainwater harvesting:** Capture intense monsoon rainfall and improve groundwater recharge.
4. **Climate-resilient agriculture:** Encourage efficient irrigation, crop diversification and water-saving practices.
5. **Heat-resilient urban planning:** Promote shaded public spaces, appropriate building design and reduction of unnecessary impervious surfaces.
6. **Develop district-level heat action measures:** Strengthen public awareness, early warning and heat-response planning.
7. **Improve climate monitoring:** Maintain long-term district-level temperature and rainfall datasets for local planning.
8. **Use GIS and remote sensing:** Regularly monitor land-use change, vegetation and water-spread conditions.
9. **Strengthen community participation:** Involve local communities in tank restoration, water conservation and tree-planting programmes.
10. **Integrate climate change into development planning:** Urban growth should be aligned with water availability, ecological carrying capacity and climate resilience.

Conclusion

The current scenario of climate change in Madurai District is characterised by the interaction of high temperatures, seasonal rainfall variability, urbanisation, changing land use and increasing local heat stress. The IMD climatological baseline demonstrates that Madurai already experiences a warm climate, with very high temperatures during April–June and rainfall concentrated strongly in the northeast monsoon period. Recent research provides evidence that these climatic conditions are being modified by urban expansion.

The 2026 integrated assessment of the Madurai region reports a persistent urban-rural temperature gradient and identifies built-up expansion, vegetation decline and water-body reduction as major contributors to urban heat vulnerability. Therefore, climate change adaptation in Madurai should move beyond emergency responses and adopt long-term climate-resilient planning. Conservation of water bodies, expansion of green infrastructure, improved rainfall management, climate-resilient agriculture and systematic heat monitoring can substantially strengthen the district's capacity to respond to future climate risks. A coordinated approach involving government institutions, local bodies, researchers, farmers and communities is essential for building a sustainable and climate-resilient Madurai.

References

India Meteorological Department (IMD). Madurai: Climatological Table, 1981–2010. India Meteorological Department, Government of India.

India Meteorological Department (IMD). Madurai Extreme Weather Events – September. Government of India, station 43360.

Government of Tamil Nadu. Statistical Hand Book of Tamil Nadu 2021–22: Climate and Rainfall. Department of Economics and Statistics, Government of Tamil Nadu.

Ramesh, B. K., Arivoli, E., Saravanan, S., Joshi, S., et al. (2026). "Integrated assessment of urban heat island vulnerability in the Madurai region, India." Discover Cities, 3, Article 145. Published 26 July 2026.

"Impacts of rapid urbanization on land surface temperature and environmental degradation in Madurai, India: A decadal analysis (2013–2023)." Published 25 March 2025.



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