Climate Change, Health Outcomes, and Economic Implications: A Case Study of Madurai District

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Abstract

Climate change is among the most pressing global challenges, with measurable consequences for local economies and public health. This study examines Madurai district in Tamil Nadu, focusing on the linkages between rising temperatures, variable rainfall and humidity, and associated health and economic outcomes. Drawing on secondary climate records (2011–12 to 2025–26) and hospital morbidity data for 2025, the analysis identifies heat-related illness, vector-borne diseases, water-borne infections and respiratory conditions as the principal climate-sensitive health risks. These conditions impose substantial household costs through higher medical expenditure, lost workdays and reduced income-earning capacity. Temperature series reveal a clear warming trend, with mean maximum temperature rising from 35.5 °C to 41.1 °C over the study period. A chi-square test of association between gender and disease category yields a statistically significant result ($\chi^2 = 171.68$, $df = 7$, $p < 0.001$), confirming differential disease burdens. The findings underscore the need for locally tailored adaptation measures that strengthen health systems, protect outdoor workers and support climate-resilient livelihoods.

Keywords: climate adaptation; health impact; vector-borne disease; heat stress; Madurai; chi-square analysis

1. Introduction

Climate change alters the frequency, intensity and spatial distribution of weather extremes. In tropical and semi-arid regions such as southern Tamil Nadu, these changes translate into higher daytime temperatures, warmer nights, irregular monsoon rainfall and elevated humidity—conditions that amplify health risks and strain household economies.

Madurai district, characterised by a semi-arid tropical climate with intense summer heat (March–June) and rainfall concentrated in the northeast monsoon (October–December), provides a useful setting in which to examine these linkages.

Rising ambient temperatures increase the incidence of heat exhaustion, heat stroke, dehydration and acute kidney stress, particularly among outdoor labourers, street vendors and residents of dense urban wards subject to the urban heat island effect. Concurrently, temperature and precipitation anomalies influence the breeding and survival of disease vectors, elevating the risk of dengue, chikungunya and other mosquito-borne infections. Water-borne diseases such as typhoid and viral fevers also respond to flooding and contamination events associated with erratic rainfall. Beyond the immediate clinical burden, these illnesses generate economic costs through medical outlays, reduced labour productivity and, in severe cases, permanent impairment of earning capacity.

This paper analyses secondary temperature records for Madurai district spanning 2011–12 to 2025–26 and morbidity data compiled from government hospital and medical college records for the year 2025. The dual objectives are (i) to document climate-sensitive health problems in the district and (ii) to test the statistical association between climate-related illness categories and gender among the sample population. The results are intended to inform local adaptation planning and to highlight the economic dimensions of climate-related morbidity.

2. Objectives

1 To identify climate-sensitive health problems in Madurai district, including heat-related illness, vector-borne disease, water-borne disease and respiratory conditions.

2 To analyse the association between climate-related health illness and gender among the sample population in the study area.

3. Research Methodology

3.1 Study Area

Madurai district, located in southern Tamil Nadu, was selected as the study area. The district experiences a semi-arid tropical climate and contains both urban centres and extensive rural hinterlands. Dense wards such as Simmakkal, Goripalayam and Arapalayam are particularly exposed to urban heat island effects, while outdoor workers and low-income households remain highly vulnerable to temperature extremes and vector-borne disease.

3.2 Data Sources and Period

The analysis relies on secondary data. Temperature series (mean maximum, mean minimum and diurnal temperature range) for the financial years 2011–12 through 2025–26 were compiled from publicly available climate records. Morbidity data for the calendar year 2025 were obtained from government hospital and medical college records, yielding a total of 12,450 recorded cases of climate-sensitive illness. The study therefore covers a 15-year climatic window and a single recent morbidity cross-section.

3.3 Analytical Methods

Descriptive statistics summarise temperature trends and disease composition. The association between gender and disease category is tested with Pearson's chi-square statistic:

$$\chi^2 = \Sigma\,[(O_{ij} - E_{ij})^2 / E_{ij}]$$

where O_{ij} denotes the observed frequency in cell (i, j) and E_{ij} the corresponding expected frequency under the null hypothesis of independence. Degrees of freedom equal $(r - 1)(c - 1)$. The null hypothesis of no association is rejected at the 5 per cent significance level if the calculated χ^2 exceeds the critical value from the chi-square distribution.

4. Climate Trends in Madurai District

Table 1 presents annual mean maximum temperature, mean minimum temperature and diurnal temperature range (DTR) for Madurai district from 2011–12 to 2025–26. Over the 15-year period the mean maximum temperature rose from 35.5 °C to 41.1 °C—an increase of 5.6 °C—while the mean minimum temperature increased from 18.9 °C to 22.6 °C (+3.7 °C). The overall averages for the period are 37.9 °C (maximum), 21.5 °C (minimum) and 16.4 °C (DTR).

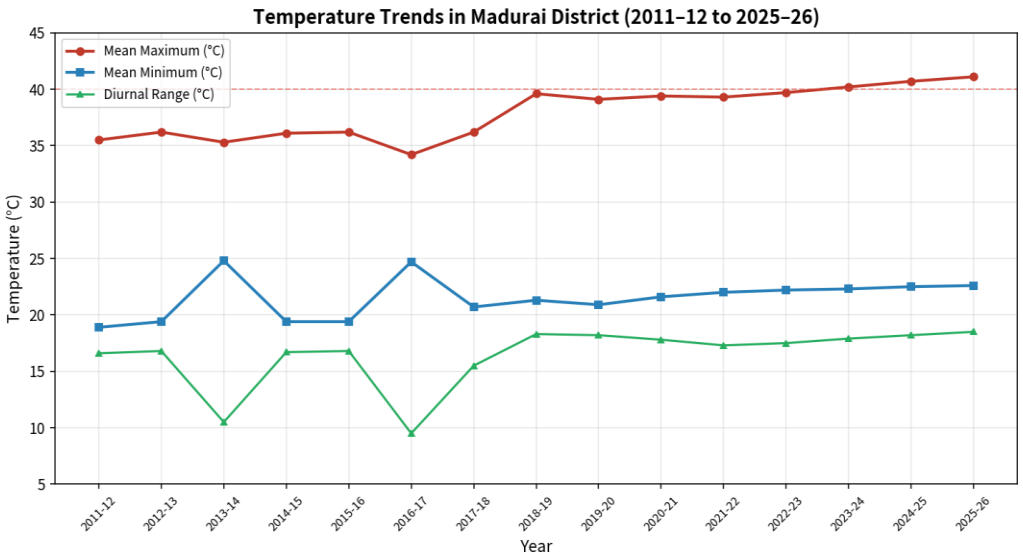
Table 1: Mean Maximum, Mean Minimum and Diurnal Temperature Range (°C), Madurai District, 2011–12 to 2025–26

Year	Mean Maximum (°C)	Mean Minimum (°C)	Variation / DTR (°C)
2011–12	35.5	18.9	16.6
2012–13	36.2	19.4	16.8
2013–14	35.3	24.8	10.5
2014–15	36.1	19.4	16.7
2015–16	36.2	19.4	16.8

2016–17	34.2	24.7	9.5
2017–18	36.2	20.7	15.5
2018–19	39.6	21.3	18.3
2019–20	39.1	20.9	18.2
2020–21	39.4	21.6	17.8
2021–22	39.3	22.0	17.3
2022–23	39.7	22.2	17.5
2023–24	40.2	22.3	17.9
2024–25	40.7	22.5	18.2
2025–26	41.1	22.6	18.5
Average	**37.9**	**21.5**	**16.4**

A marked acceleration in maximum temperatures is visible after 2017–18. From 2018–19 onward, mean maximum temperatures remained above 39 °C, and after 2023–24 they consistently exceeded 40 °C. The lowest DTR values occurred in 2013–14 (10.5 °C) and 2016–17 (9.5 °C), years characterised by unusually high minimum temperatures. High DTR values in later years (peaking at 18.5 °C in 2025–26) indicate large day–night temperature contrasts that can stress both human physiology and agricultural systems.

Figure 1: Temperature Trends in Madurai District, 2011–12 to 2025–26



Analytical inference: The sustained upward trajectory in both maximum and minimum temperatures confirms a progressive warming of the local climate. The crossing of

the 40 °C threshold for mean maximum temperature after 2023–24 is particularly consequential for outdoor workers and for urban populations exposed to heat island effects. Warmer nights reduce the opportunity for physiological recovery, elevating the risk of heat-related morbidity and of chronic conditions such as cardiovascular strain. These climatic shifts form the environmental backdrop against which the health outcomes examined in the next section must be interpreted.

5. Climate-Sensitive Health Problems

5.1 Heat-Related Illnesses

Heat exhaustion, heat stroke, dehydration and acute kidney stress constitute the principal direct thermal risks. Vulnerability is highest among outdoor labourers, street vendors and residents of densely built wards (Simmakkal, Goripalayam, Arapalayam) where the urban heat island effect amplifies ambient temperatures. Prolonged exposure also contributes to cardiovascular events and stroke, conditions that appear with elevated frequency among men in the morbidity data.

5.2 Vector-Borne and Water-Borne Diseases

Dengue and chikungunya are sensitive to temperature and rainfall regimes that govern mosquito breeding. Erratic monsoon rainfall and intermittent flooding create temporary breeding sites, while warmer temperatures accelerate vector development. Typhoid and viral fevers respond to water contamination associated with heavy rainfall events and inadequate sanitation. Together these communicable conditions account for the majority of the recorded morbidity burden.

5.3 Respiratory Conditions

Asthma and related respiratory illnesses are aggravated by heat, dust and air-quality deterioration that often accompany prolonged dry spells and urban pollution. The 1,800 asthma cases recorded in 2025 represent 14.5 per cent of total morbidity, underscoring the importance of non-communicable climate-sensitive conditions alongside infectious disease.

6. Analysis of Health Illness among the Sample Population (2025)

Table 2 presents the gender-wise distribution of 12,450 climate-sensitive illness cases recorded in Madurai district during 2025. Viral fever was the single most frequent condition (2,900 cases; 23.3 %), followed by dengue (2,550; 20.5 %), asthma (1,800; 14.5 %) and

typhoid (1,200; 9.6 %). Men accounted for 51.8 per cent of total cases and women for 48.2 per cent. Heart attack and stroke were markedly more prevalent among men (approximately 65 per cent of cases in each category), whereas viral fever and typhoid showed a modest female predominance. Communicable diseases (dengue, chikungunya, typhoid and viral fever) together comprised 60.2 per cent of the burden, indicating a substantial infectious-disease load.

Table 2. Gender-wise Distribution of Climate-Sensitive Health Illnesses, Madurai District, 2025

Disease / Illness	Women (O)	Men (O)	Row Total
Dengue	1,200	1,350	**2,550**
Chikungunya	450	400	**850**
Typhoid	650	550	**1,200**
Viral Fever	1,500	1,400	**2,900**
Asthma	850	950	**1,800**
Heart Attack	350	650	**1,000**
Stroke	400	650	**1,050**
Other Major Illnesses	600	500	**1,100**
Column Total	**6,000**	**6,450**	**12,450**

Figure 2: Gender-wise Distribution of Climate-Sensitive Health Illnesses (2025)

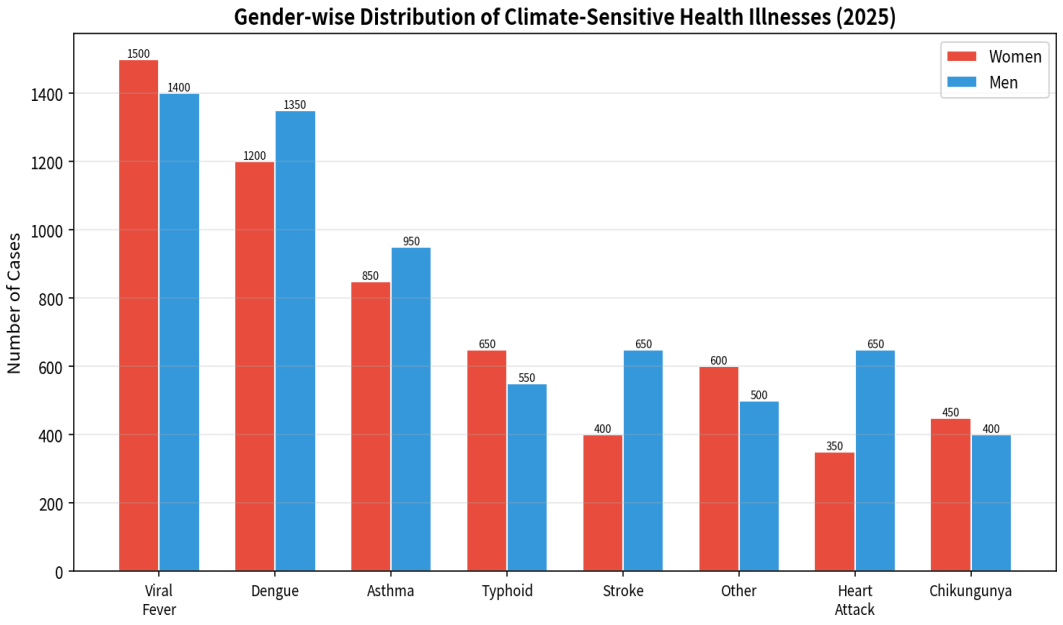
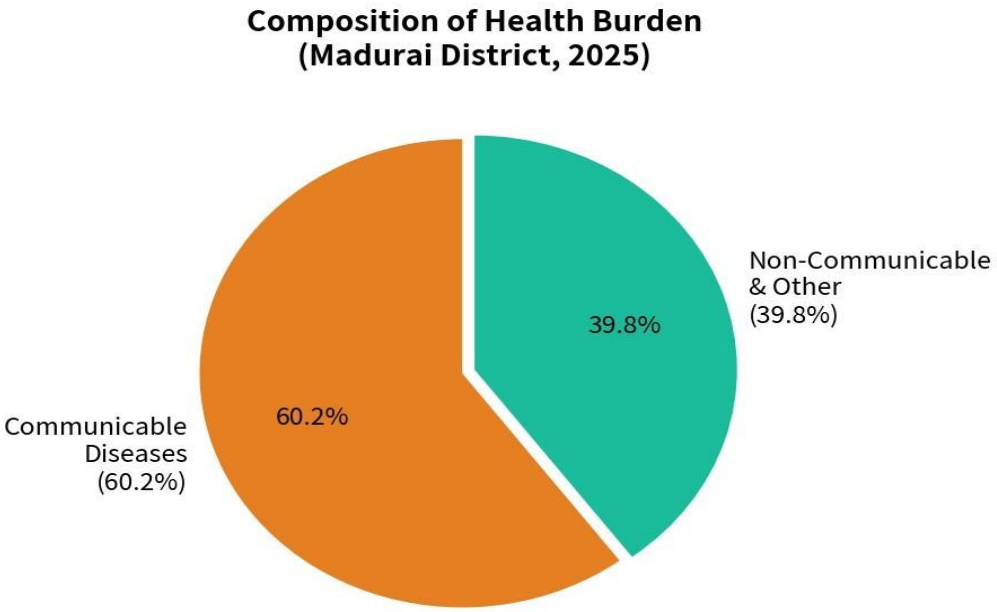


Figure 3: Composition of Health Burden — Communicable versus Non-Communicable (2025)



6.1 Hypothesis Testing

Null hypothesis (H_0)

There is no significant association between gender and type of climate-sensitive health illness among the sample population.

Alternative hypothesis (H_1)

There is a significant association between gender and type of climate-sensitive health illness. Applying the chi-square formula to the observed frequencies in Table 2 yields the following results:

Test statistic (χ^2) = 171.68

Degrees of freedom (df) = 7

Critical value ($\alpha = 0.05$) = 14.07 p-value< 0.001

Because the calculated χ^2 (171.68) greatly exceeds the critical value (14.07) and the p-value is far below 0.05, the null hypothesis is rejected. There is a statistically significant association between gender and disease category. The pattern is driven principally by the excess of heart attack and stroke among men and the relative excess of certain infectious conditions among women. This finding is consistent with occupational exposure differentials (outdoor work among men) and with documented gender differences in healthcare-seeking behaviour and physiological susceptibility.

7. Economic Implications

Climate-sensitive morbidity generates both direct and indirect economic costs. Direct costs comprise out-of-pocket expenditure on consultation, diagnostics, medicines and hospitalisation. Indirect costs arise from lost workdays, reduced productivity during convalescence and, in severe cases, long-term impairment of earning capacity. Households dependent on daily-wage outdoor labour are especially exposed: a single episode of dengue or heat stroke can exhaust savings and force the sale of productive assets. At the aggregate level, elevated disease incidence increases the fiscal burden on public health facilities and reduces labour supply in agriculture, construction and informal services—sectors that together employ a large share of Madurai's workforce.

The warming trend documented in Section 4 implies that these costs are likely to rise in the absence of adaptation. Each additional degree of mean maximum temperature expands the window of heat stress and lengthens the transmission season for vector-borne disease, thereby amplifying both the health and the economic burden.

8. Key Findings

1 Mean maximum temperature in Madurai rose by 5.6 °C between 2011–12 and 2025–26, crossing the 40 °C threshold after 2023–24; mean minimum temperature rose by 3.7 °C over the same period.

2 Viral fever (23.3 %) and dengue (20.5 %) were the leading causes of climate-sensitive morbidity in 2025; communicable diseases accounted for 60.2 % of the total burden of 12,450 cases.

3 A chi-square test confirms a significant association between gender and disease type ($\chi^2 = 171.68$, df = 7, $p < 0.001$). Heart attack and stroke are substantially more common among men; certain infectious conditions show a modest female excess.

4 Climate-related illness imposes measurable economic costs on households through medical expenditure and lost labour income, with outdoor workers and low-income urban residents facing the greatest risk.

9. Conclusion and Policy Implications

The evidence from Madurai district demonstrates a clear warming trend accompanied by a substantial burden of climate-sensitive disease. Heat-related conditions, vector-borne infections and respiratory illness together generate both clinical and economic costs that fall

disproportionately on vulnerable groups. Strengthening primary healthcare capacity for early detection and treatment of dengue, viral fever and heat illness; expanding shade, hydration and rest facilities for outdoor workers; and improving urban heat mitigation in dense wards are immediate priorities. Over the longer term, climate-resilient water management and agricultural practices will be essential to protect livelihoods and reduce the indirect pathways through which climatic stress translates into ill-health and poverty.

Addressing the multifaceted impacts of climate change in Madurai requires integrated strategies that combine environmental management, health-system strengthening and social protection. Only through such coordinated action can the district enhance the resilience of its population and sustain economic well-being under a changing climate.

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