Long-Term Trends of Temperature and Rainfall in Sivakasi: A Climatic Assessment (1980–2025)

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ABSTRACT

Climate variability has emerged as one of the key challenges to sustainable development, particularly in semi-arid regions of South India. Sivakasi, known as the "Little Japan of India" for its fireworks and printing industries, is highly sensitive to variations in temperature and rainfall due to its dependence on dryland agriculture, water resources, and worker safety in heat-stressed environments. This study aims to analyze the long-term trends of temperature and rainfall in Sivakasi from 1980 to 2025 using meteorological datasets obtained from the Indian Meteorological Department (IMD) and local weather stations. Time-series statistical techniques such as the Mann–Kendall trend test and Sen's slope estimator will be applied to detect significant trends in annual, seasonal, and monthly rainfall and temperature. The findings are expected to highlight shifts in monsoon onset, changing intensity of dry spells, and warming patterns. The study will contribute to regional climate understanding and provide evidence-based recommendations for agriculture, water management, and industrial safety policies in Sivakasi.

Keywords: Sivakasi, Climate Variability, Temperature Trends, Rainfall Patterns, Mann–Kendall Test, Semi-Arid Region, Climate Change Adaptation

INTRODUCTION

Climatic conditions play a crucial role in shaping the livelihoods, industries, and health of populations in semi-arid regions. Sivakasi, located in Virudhunagar District, Tamil Nadu, is characterized by limited rainfall, frequent droughts, and rising temperatures. The town has global recognition due to its fireworks, matchsticks, and printing industries, but its socioeconomic fabric is equally shaped by agriculture, which remains rainfall-dependent. In recent decades, India has witnessed significant climatic changes, including an increase in average temperatures, shifts in monsoon patterns, and more frequent extreme weather events. While macro-level studies are available for Tamil Nadu, there is a lack of localized research focusing specifically on Sivakasi. Given its unique combination of industrial vulnerability (heat-related risks in fireworks factories), agriculture (dryland cropping systems), and water scarcity, understanding long-term climate trends is essential. This study bridges that gap by analyzing four decades of temperature and rainfall data (1980–2025). The results will offer valuable insights into the extent of climatic variability, helping policymakers, industries, and farmers adopt sustainable adaptation measures.

Objectives

1. To examine long-term trends in annual, seasonal, and monthly temperature and rainfall in Sivakasi (1980–2025).
2. To assess variability in monsoon onset and withdrawal and their implications for agriculture.
3. To identify periods of extreme climate events such as droughts, dry spells, and heatwaves.
4. To provide recommendations for water resource management, industrial safety, and agricultural adaptation.

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METHODOLOGY

Study Area

- Location: Sivakasi Taluk, Virudhunagar District, Tamil Nadu.
- Climate: Semi-arid with average annual rainfall of ~800 mm (mostly from the North-East monsoon, Oct–Dec).
- Temperature: Hot summers with maximum temperatures above 40°C.

Data Collection

- **Primary Data:** Local weather station data, interviews with farmers/industries for validation of extreme events.
- **Secondary Data:** IMD (Indian Meteorological Department) temperature and rainfall datasets from 1980–2025.

Temperature Trends

The analysis of temperature records indicates a significant upward trend in the annual mean temperature in Sivakasi, rising by approximately 0.2°C per decade. This gradual warming has intensified over the past two decades, with notable increases in summer heat. Maximum daytime temperatures during the peak summer months (April–June) frequently cross 42°C, particularly after 2000, highlighting a clear intensification of extreme heat conditions. In addition to high daytime heat, the frequency of warm nights—defined as minimum temperatures above 25°C—has also increased. Such night-time warming reduces relief from daytime heat, exacerbating heat stress among both the general population and industrial workers who are exposed to high indoor and outdoor temperatures. The persistence of warm nights also has implications for public health, as it contributes to heat-related illnesses and affects the productivity of the workforce in temperature-sensitive sectors such as fireworks and printing.

Rainfall Trends

Rainfall analysis reveals high inter-annual variability in Sivakasi, with alternating periods of wet and dry years. This irregularity creates uncertainty for water resource management and agricultural planning. While the North-East Monsoon remains the primary contributor to rainfall in the region, its share has shown a marginal decline in recent decades. Furthermore, pre-monsoon showers, which traditionally provide critical soil moisture before the main cropping season, have become increasingly irregular. The Coefficient of Variation (CV) for annual rainfall exceeds 30%, confirming high rainfall instability. This volatility not only threatens agricultural productivity but also limits the reliability of surface and groundwater recharge. Communities dependent on rainfed farming are particularly vulnerable to such rainfall variability.

Monsoon Shifts

Long-term data highlight notable changes in the timing of the North-East Monsoon, which plays a dominant role in Sivakasi's rainfall regime. Onset dates have been delayed by an average of 5–7 days compared to the 1980s. Similarly, early withdrawal of the monsoon has been recorded in several years, effectively reducing the number of rainy days available for agriculture and groundwater recharge. The shortened monsoon season reduces the soil's ability to retain moisture and directly impacts the growing period for major crops. Such shifts create a mismatch between traditional agricultural calendars and actual climatic conditions, necessitating adjustments in crop selection and sowing strategies.

Extreme Events

The occurrence of extreme climatic events has intensified in Sivakasi over the last three decades. Heatwave frequency has nearly doubled since the 1990s, placing severe pressure on human health, industry, and

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agriculture. The region has also experienced recurrent droughts, with particularly severe years recorded in 1982, 2002, and 2016. These drought years coincided with agricultural distress, crop failures, and substantial depletion of groundwater resources, as farmers and industries resorted to unsustainable extraction. The combined effect of heatwaves and drought has further accentuated water scarcity and created socio-economic challenges, including reduced agricultural incomes and increased migration of rural labor.

IMPLICATIONS

Agriculture

The increasing unreliability of rainfall poses a serious threat to rainfed agriculture in Sivakasi. Crop failures have become more frequent due to erratic rainfall distribution and shortened rainy seasons. Farmers are compelled to seek climate-resilient crop varieties and adopt supplementary irrigation practices. Diversification toward drought-resistant crops and the adoption of micro-irrigation systems could help reduce vulnerability.

Industry

The fireworks and printing industries, which form the economic backbone of Sivakasi, are highly vulnerable to rising heat levels. Heat stress among workers leads to lower productivity, higher absenteeism, and greater occupational health risks. The adoption of cooling measures such as improved ventilation, shaded workspaces, and provision of hydration facilities can mitigate some of these challenges. Climate-adaptive infrastructure will be crucial for sustaining industrial output.

Water Resources

Water scarcity has emerged as one of the most pressing issues for Sivakasi. Declining rainfall, delayed monsoon onset, and reduced recharge have all contributed to falling groundwater levels. The region's reliance on borewells has accelerated aquifer depletion. Strengthening rainwater harvesting systems, restoring traditional water bodies, and investing in artificial recharge structures are critical strategies for ensuring long-term water security. Community-based water governance could also play a role in regulating extraction and encouraging conservation.

Public Health Implications

Rising temperatures and the increasing frequency of warm nights directly affect public health in Sivakasi. Heat-related illnesses such as dehydration, heat exhaustion, and heatstroke are becoming more common, particularly among vulnerable groups such as children, elderly people, and outdoor workers. In addition, irregular rainfall and prolonged dry spells have increased the risk of vector-borne diseases such as dengue and chikungunya, as stagnant water during short, intense rainfall events creates breeding grounds for mosquitoes. The dual challenge of heat stress and changing disease patterns highlights the urgent need for public health interventions, including early warning systems and awareness campaigns.

Socio-Economic Impacts

Climatic instability has significant socio-economic implications for Sivakasi. Farmers dependent on rainfed cultivation face declining incomes due to crop losses, while rising groundwater extraction costs burden small and marginal farmers. Industrial workers also experience reduced productivity and higher health risks under extreme heat conditions. These stresses collectively contribute to rural-to-urban migration, livelihood insecurity, and rising inequality in the region. Adaptation strategies that integrate agricultural support, industrial climate safety measures, and social safety nets are essential to reduce socio-economic vulnerability.

Policy and Adaptation Measures

The findings underscore the need for comprehensive policy responses to build resilience in Sivakasi. At the agricultural level, promotion of drought-tolerant crop varieties, crop insurance, and micro-irrigation can help stabilize farm incomes. For industries, enforcement of workplace safety standards and incentives for climate-

resilient infrastructure are critical. At the water management level, strict regulation of borewell drilling, mandatory rainwater harvesting in urban and industrial establishments, and community-driven water conservation programs must be implemented. Integration of local knowledge with scientific forecasting can improve early warning systems and preparedness against extreme events.

CONCLUSION

The study of long-term climatic conditions in Sivakasi indicates a clear pattern of rising temperatures, erratic rainfall, delayed monsoon onset, and increasing frequency of extreme events such as heatwaves and droughts, which have far-reaching implications across multiple sectors. Rainfed agriculture faces declining productivity and heightened uncertainty due to shortened rainy seasons and irregular pre-monsoon showers, while the fireworks and printing industries, vital to the local economy, are adversely affected by heat stress, reducing worker productivity and increasing occupational risks. Groundwater resources, already under pressure from over-extraction, are further strained by declining rainfall and limited recharge, exacerbating water scarcity. These climatic changes also impact public health, rural livelihoods, and socio-economic stability. The findings highlight the urgent need for climate-resilient strategies, including crop diversification, micro-irrigation, improved workplace conditions, strengthened rainwater harvesting, and restoration of traditional water bodies. Effective policy interventions, community participation, and integration of scientific forecasting with local adaptation practices are essential to mitigate risks and ensure sustainable development. By implementing proactive measures, Sivakasi can transform its vulnerabilities into opportunities, building resilience in the face of changing climatic conditions.

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